Fisheries Research 221 (2020) 105354

Contents lists available at ScienceDirect

Fisheries Research

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

Is there sustainability for "satellite" ornamental fishing regions? A case study of Guamá River basin- Pará -Brasil

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ARTICLE INFO

Handled by: A.E. Punt

Keywords:
Auxiliary fishing site
Socio-economic
Management

ABSTRACT

Ornamental fisheries and socio-economic aspects of fishermen in the major fishing regions in Brazil such as the Xingu River have been well studied. However, there is lack of information about the sustainability of "satellites" (auxiliary) fishing areas, which contribute towards supplying fish for exportation centers as Belém, the Capital of Pará state-Brazil. The ornamental fishery in the Guamá River basin is an example of an important activity that supports the families along the river, but it has low social returns and its sustainability is consequently in jeopardy without government aid. We collected fish samples and environmental data to evaluate the market chain aspects, fishery tools and techniques, fish handling and environmental issues of the region. We observed a reduction in numbers of families involved in the ornamental fishery over time. The intensification of anthropogenic impacts reduced the environmental integrity degree of fishing sites have resulted in lower fish diversity. The fishery was characterized by capture of a limited number of loricariids fish where the small ones are preferred. Thus the fishing is more selective and consequently an environmental issue. Economically, income is directly associated to the exportation market, consequently the US dollars value influences the species and quantity of the traded fish. Most of the fishermen work on an informal basis and have no intention to continue in this activity due to the low profits reflected by presence of middlemen which concentrates the profit. Therefore, without a management plan for improvement of fishing, environmental and fish quality, the activity presents risks of unsustainability. Suggestions to ensure the perpetuation of this activity are discussed.

1. Introduction

Ornamental fish trade began in Brazil in 1955 with the trading of Cardinal tetra *Paracheirodon axelrodi* from the Rio Negro in Amazon basin. During this time, the cardinal tetra trade increased, stimulating the inclusion of riverine families, as an alternative activity to agriculture to ensure their income. From the beginning of the 1970s, ornamental fishing expanded to include different species, reaching almost 20 million fish exported by the end of the decade. In the 1990s, export values exceeded 2 million US Dollars (USD), making the northern Brazil region one of the most important regions for ornamental fishery in the world (Chao et al., 2001; Olivier, 2001; Souza, 2001).

Currently, the northern Brazil region remains one of the largest ornamental fish catching areas, contributing to the improvement of its regional economy and international trade. Pará state is the most important state for artisanal ornamental fishing in Brazil, as it is performed in three main different drainage basins (Amazonas, Tapajós, Xingu) (dos Anjos et al., 2009; Ribeiro et al., 2010; Secex, 2010; Ladisa et al., 2017).

However, this export-only trade causes a dependence on the dollar value, which consequently affects incomes across the production chain, mainly affecting the fishermen and the environment through adverse

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https://doi.org/10.1016/j.fishres.2019.105354
Received 13 January 2019; Received in revised form 31 August 2019; Accepted 3 September 2019

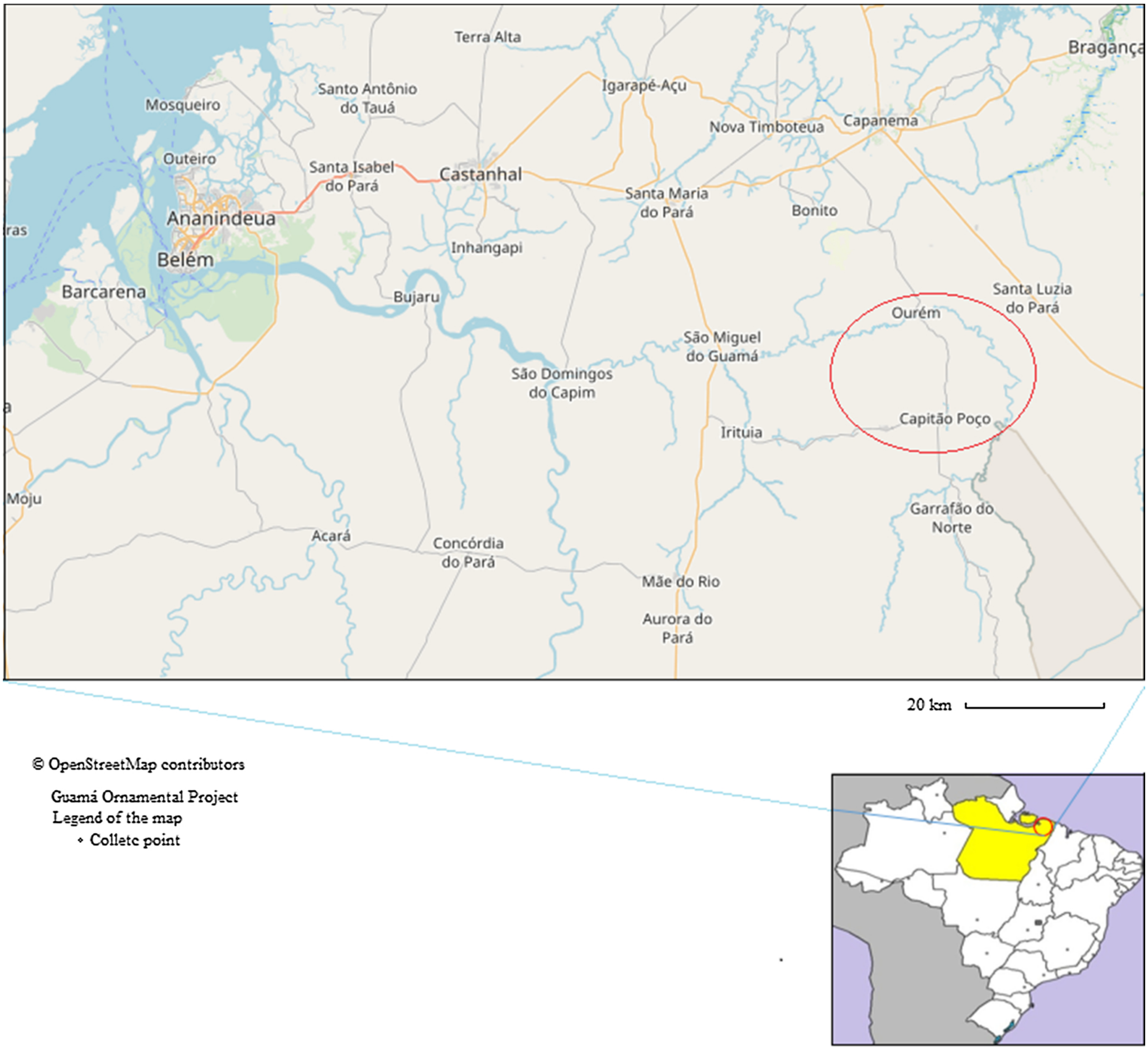

Fig. 1. Localization of study area in the hydrographic system of Guamá River.

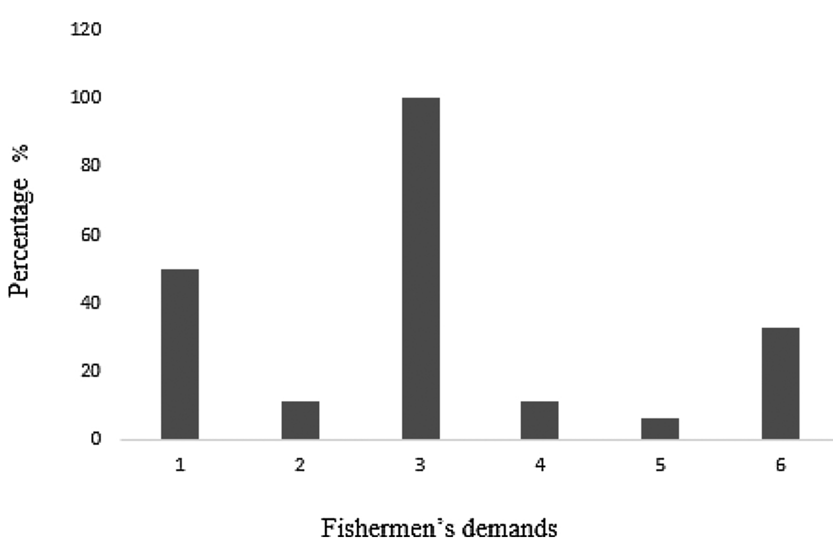

Fig. 2. Fishermen's demands for improve and remain in the activity; (1) Increase the fish values, (2) Easier professional registration, (3) Governmental support, (4) Sell directly to exporters, (5) Increasing fish stocking time and (6) Improve the boats.

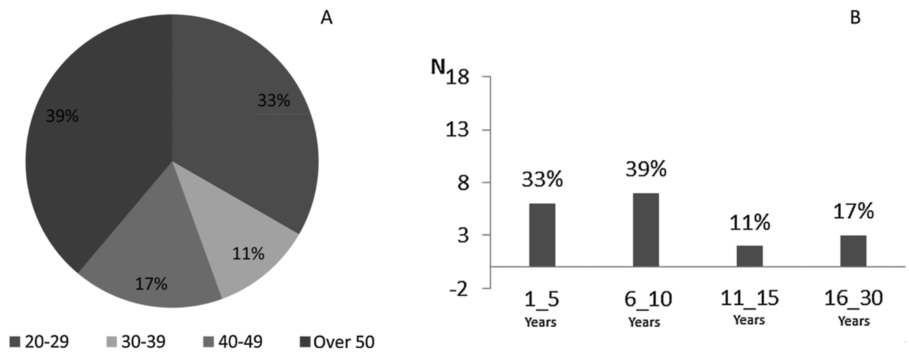

Fig. 3. A. Fisherman's age from Guamá River basin. B. Time on activity from ornamental fishermen of Ourém and Capitão Poço municipality (N18: Number of interviewed).

economic scenarios. In these scenarios, exporters wanting to provide the quantity of fish demanded for export usually use satellite-fishing areas to reduce costs. The Guamá River basin, located in Pará state, is used as a satellite-fishing site. (Anjos et al., 2018).

The main characteristic of the Guamá fishing site is its easy access to the export center in Belém county (Pará, Brazil), working as an auxiliary fishing area for the most productive areas, such as the Xingu river basin, Pará, Brazil. According to Torres (2007a, 2007b), approximately 128 riverine families were involved in this activity.

Although it is a promising activity, there have been minimal studies about its regional sustainability. Overfishing, environmental quality, the socioeconomic index and the international market influence the sustainability of this fishing activity (Cinner and Mcclanahan, 2006). Thus, the rational use of these natural resources is necessary to maintain sustainability, and it is important to understand the ornamental fishing chain, as well as the magnitude of the demands and concerns about the environment, the socioeconomics and the culture of the fishermen, which are important to the sustainability of this activity.

For these reasons, this study aims to characterize ornamental fishing from the middle of the Guamá River basin, PA, Brazil. This study describes the fishery, the fishing tools used and the target fish. It also discusses the environmental and socioeconomic aspects for future possible actions on fishery management and public policies in regional ornamental fishing to subsidize its sustainability.

2. Materials and methods

The present study was carried out in the Guamá River region, in the Ourém (fishing area: São José, Tupinambá, Puraquequara) and the Capitão Poço cities (fishing area: Igarapé Açu) in Pará state (Fig. 1). A semi-structured questionnaire for all fishermen and their families was applied. The questionnaire consisted of five components: personal data, ornamental fishery data, fish commercialization, demands, concerns and perspectives for the regional ornamental fishery. These procedures followed the recommendations of Godoy (1995), and a content analysis method to interpret the data was followed according to Triviños (1994).

Sixteen trips were conducted to collect data from the fishery and environment. The trips were performed only in the dry season (December to March) due to the lower water depth and higher transparency that enabled the fishing. The fishing spots were identified and the coordinates were registered by a GPS device.

Fishery data (fish species caught, locations, tools) were noted and tabbed on an Excel program. The Catch-Per-Unit-Effort (CPUE) index was determined following CPUE = Fish quantity (n) / Fishing Time (s). After catching the fish, the morphological characteristics and presence of ectoparasites were observed. Parasite infection was characterized by the parasitological indices of mean intensity, prevalence and abundance (Bush et al., 1997).

The physical and chemical characteristics of the water were examined using a multisensor analyzer Horiba U-10, which determined temperature, dissolved oxygen, salinity, pH, electric conductivity and turbidity rates. Total ammonia was measured with a HANNA HI93715 equipment.

The environmental integrity degree (EID) was determined by evaluation of seven physical environmental indicators as reported in Vieira and Shibatta (2007) and adapted to Guamá River conditions. The aspects evaluated were related to the river channel morphology, substrate, sedimentation, river shading, riparian vegetation, and then scored as 0 (poor), 1 (medium), 2 (good) and 3 (excellent). The fishing spots were classified as good, regular and poor based on scores ranging from 0 to 9 (poor), 10 to 18 (regular) and 19 to 27 (good), determined by the sum of the scores.

The ecological data were analyzed with a vectorial representation according to Burrough (1986). Furthermore, thematic maps were produced to represent the fishing sites, ecological data, spatial distributions and environmental integrity. As such, cluster and principal components analyses were conducted (Manly and Olson, 1999).

3. Results

The ornamental fishery is the main activity for 22% of fishermen, while for most of them (78%) ornamental fishery is not the main

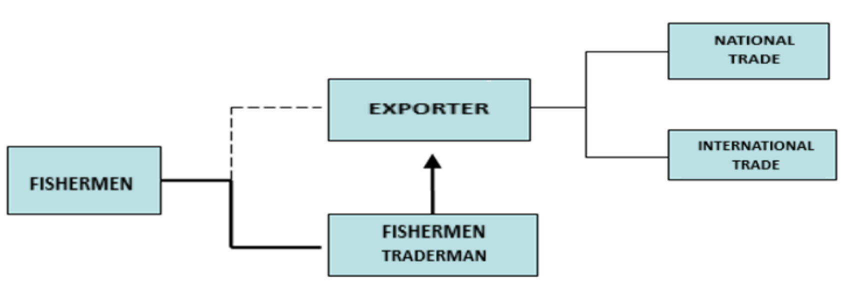

Fig. 4. Guamá river ornamental fish marketing chain.

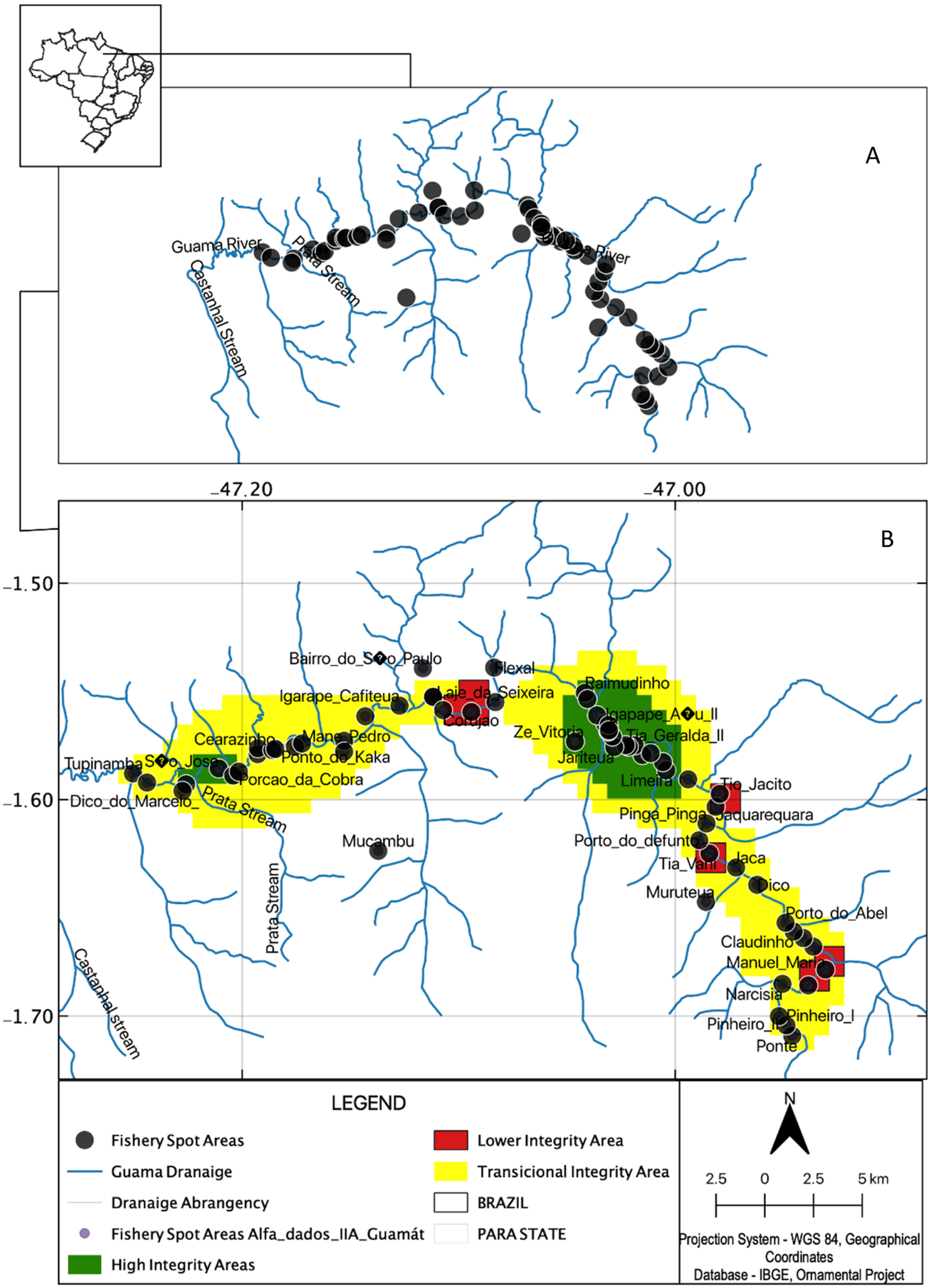

Fig. 5. A- Spatial distribution of fishing spots evaluated on middle Guamá River region; B- Classification of fishing spots related to environmental integrity (EID); green: good EID, yellow: regular EID and red: poor EID (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

activity, and in many cases agriculture (31%) is their primary activity. It was noteworthy that many of the fishermen (78%) considered ornamental fishery as a non-profit activity. Also, the lack of governmental support (100%) and reduced fish values (50%) were the most common problems reported by fisherman who decided not to continue the activity (Fig. 2).

All active fishermen (94% men and 6% woman) from Ourém and Capitão Poço cities (N = 18) were interviewed. Two major groups were differentiated by age: 20–29 years old (33%) and over 50 years old (39%) (Fig. 3A). Most of the younger fishermen have been active between six and 10 years (39%) while the older ones have been active since the 1980s (17%) (Fig. 3B). None of the fishermen have an elementary school education.

Furthermore, the presence of middlemen in the production chain was observed, selling the fish to exporters. Only in a few cases (28%), some fishermen were able to trade directly with exporters (Fig. 4), but this trade occurs mainly because some of these fishermen (17%) possess a professional card and/or registration in the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), reflecting the lack of governmental support.

However, the interviewed fishermen declared that they did not have any knowledge of fish trading or market aspects, which made them dependent on the middlemen. Also they had never tried breeding ornamental fish as an alternative option, instead preferring agriculture to aquaculture.

3.1. Characterization of fishing areas

Thirty-three upstream and 34 downstream fishing spots from Guamá River were sampled (Fig. 5A), of which 67.3% were classified as regular (Fig. 5B), characterized by a few branches in the rivers, deforestation in some areas, erosion that changed the river channel and the presence of human activity. Another 11.9% of the locations were classified as poor sites, presenting intensive environmental degradation that was characterized by significant deforestation, intense anthropogenic impact (due to the agricultural activity) and frequent river silting (Fig. 5B). Only 20.8% of the locations studied were classified as good; these were characterized by little erosion, vegetation cover with minimal evidence of deforestation, no signs of alteration in the river channel and a few branches used by several fish species for shelter (Fig. 5B).

Allied to the difference in the EID, the water's physical–chemical values in the fishing spots showed variation along the river. The dissolved oxygen concentration had a mean value of 6.39 ± 0.26 mg/L; the mean temperature was 27.88 ± 0.36 °C and the pH had a mean value of 5.98 ± 0.36, with just one point presetting value of 4.0. The mean values of turbidity, conductivity and ammonia were 28.54 ± 5.83 UNT, 0.30 ± 0.02 mS/cm and 0.18 ± 0.22 mg/L, respectively. The loads factor of the water parameters quantified by PCA showed turbidity (Factor 1) as the most significant parameter to classify the fishing spots, followed by pH and temperature (Factor 2) (Fig. 6).

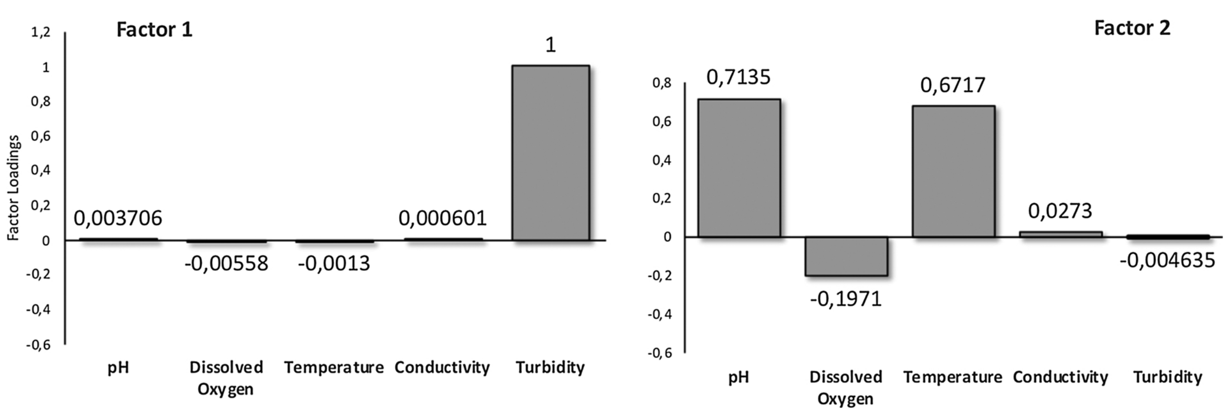

Fig. 6. Results of principal components analysis for water quality parameters, standing out factor loads and their components. – A) Factor 1; B) Factor 2.

Table 1
The habitat for the eight species captured in Guama River.

Scientific name	Common name*	Habitat
Ancistrus sp. 1	Ancistrus barbudo	Trunk and Tree
Lasiancistrus saetiger (Armbruster, 2005)	Acari canoa velha	Trunk and Tree
Hypostomus sp.1	Acari cobra (Pleco)	Trunk and Tree
Hypostomus sp.2	Picoto	Rocks
Leporacanthicus galaxias (Isbrücker & Nijssen, 1989)	Pinima	Trunk and Tree
Peckoltia oligospila (Günther, 1864)	Bola	Trunks, pebble, beaches
Rineloricaria cf. lanceolata (Günther, 1868)	Loricaia	Trunks, pebble, beaches
Pseudacanthicus spinosus (Castelnau, 1855)	Assacu	Big rocks

* Common name used in the Brazil.

3.2. Fishery characterization

Fishing for ornamental fish is primarily carried out in the dry season (December to March). The most caught and traded species are siluriforms from the Loricariidae family. These plecos species generate income for fishermen (Table 1), but their importance varies among the fishing communities. The eight traded pleco species and their habitats are presented in Table 1 and Fig. 7.

Three types of fishing were identified: hand fishing (fishermen dive in holding their breath), using a cast net, or trawling. There is a noticeable difference between the catch per unit of effort (CPUE) with the methods used (Fig. 8).

Trawling was the most common method used to catch the Acari Bola *Peckoltia oligospila* (an endemic fish in Guamá River), but also to catch

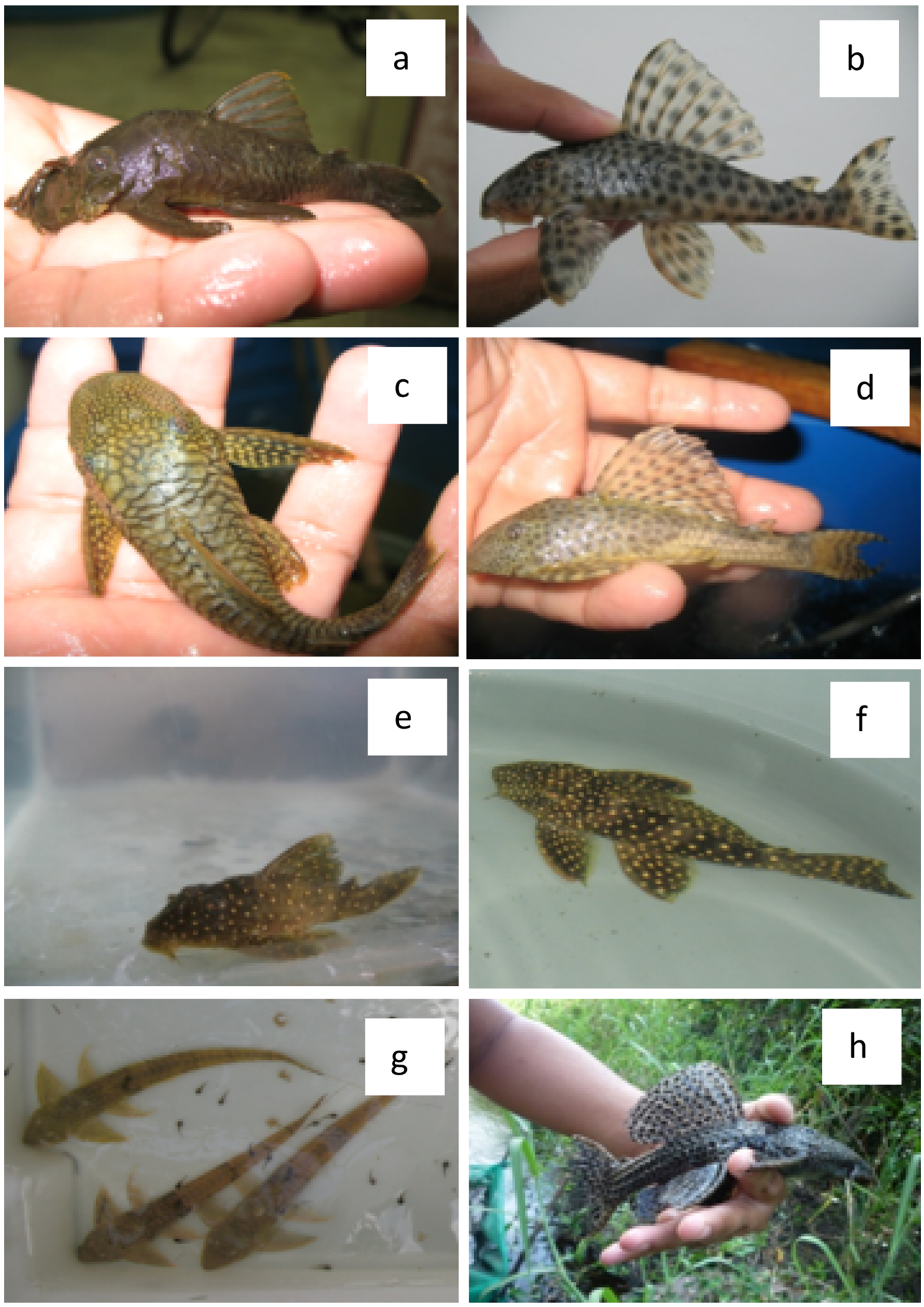

Fig. 7. Fish captured in Guama River basin: Ancistrus barbudo, (*Ancistrus* sp.) (a); Bola, (*Peckoltia Oligospila*) (b); acari canoa velha, (*Lasiancistrus saetiger*) (c); Cobra/ pleco, (*Hypostomus* sp.1) (d); picoto (*Hypostomus* sp 2) (e); Pinima, (*Leoporacanthicus galáxias*) (f); Loricaia branca, (*Rineloricaia cf. lanceolata*) (g), Assacu, (*Pseudocanthicus spinosos*) (h). These are the most common names used in the Brazil.

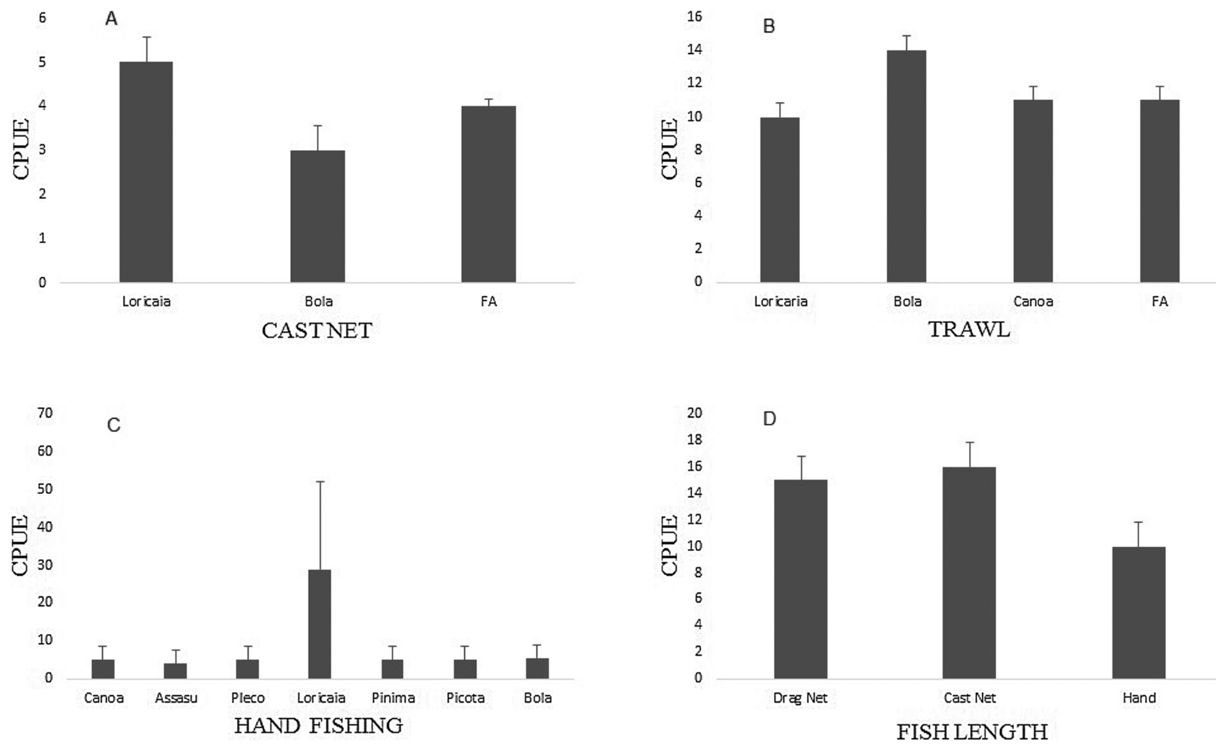

Fig. 8. CPUE of fishery tool: A cast net; B trawl; C hand fishing; and D fish length (cm), of plecos fish captured by fishery tools. FA: fish not target.

Fig. 9. Fisherman prepared to hand fishing.

loricaia and canoa plecos. The cast net method captures more fish per unit of effort (CPUE). These two methods (trawling and cast net) caught many other species that were non-target species (Fig. 8A and B, FA). The hand fishing technique was used to catch the largest number of species and the smallest sized fish (Fig. 8C and Fig. 9)

After being caught, the fish were kept in net pens until being traded. The fish presented satisfactory physical aspects, but in some cases lesions were observed, such as physical trauma, bleeding on the fin base and discoloration of the dorsal region. In some species, leech infestation (*Bratacobdella* sp.) was observed after being caught. The highest parasite prevalence was observed in Bola pleco *P. oligospila,* Loricaia *Rineloricaiacf.Lanceolata*, and pleco *Hypostomus* sp.1, with the highest leech prevalence values in the bola pleco (Fig. 10A). However, the pleco *Hypostomus* sp. 1 showed the highest mean intensity values of leech infestation (Fig. 10B).

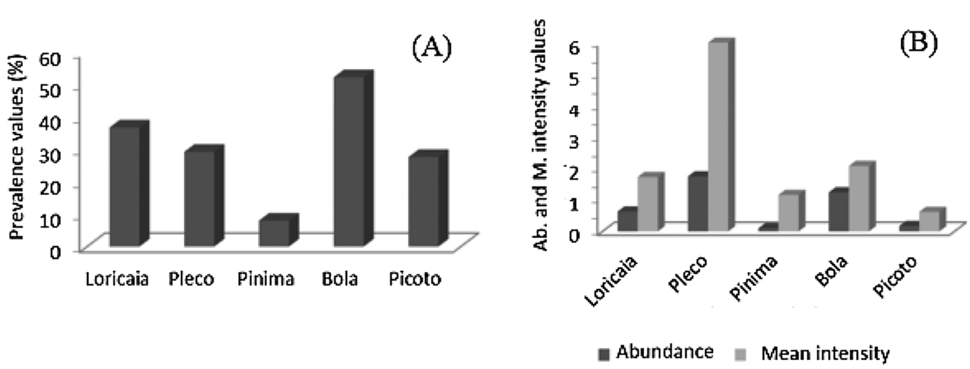

Fig. 10. Prevalence (A), abundance and mean intensity (B) of parasite infestation on each species from Guamá River.

4. Discussion

Ornamental fishing is an important activity in the Amazon region, generating income for riverine families, so understanding the socio-economic aspects as well as the fish caught, allied with an analysis of the environmental and anthropic impacts, is important to ensure the sustainability of this activity (Souza and de Mendonça, 2009; Inomata and de Carvalho Freitas, 2018; de Araújo et al., 2018).

A reduction of the number of families in the activity in the region was observed. According to Torres (2007b), there were 124 families involved with ornamental fishing, but in the present study, only 18 families remain. The fishermen do not consider ornamental fishing to be a lucrative activity, so they have switched to agriculture, which is now considered their main activity. However, many of these families depend on middlemen and the unknown negotiation of fish prices. Specialized training and fishermen's associations could be an option to reduce the dependence on middlemen and allow the fishermen to negotiate directly with the ornamental fish industry.

In the present study, few areas were classified as good by EID and that was reflected in the fishing areas. The expansion of the agriculture sector could be a cause of further degradation of the riparian forest (dos Santos and de Aquino, 2015). These anthropogenic actions have altered fish habitats, with some species ultimately disappearing. These alterations have reduced the essential resources for fish survival (Dudgeon et al., 2006; Vörösmarty et al., 2010), as reflected by the poor environmental integrity and the low diversity at the fishing locations.

The artisanal ornamental fishing carried out in the Guamá River basin provides a catch of several species, and the hand fishing technique is a highly selective method for capturing ornamental species with a high economic potential. However, the selection of small fish is an environmental concern, and catching young fish can reduce breeding. The fishermen have no access to information regarding eco-friendly fishing techniques or correct technical management (Torres, 2007a, 2007b; Torres et al., 2008). Furthermore, there is no consideration of transportation and stocking density in captivity. The presence of leeches and injured plecos fish stands out as one of the most frequent problems of commercialization. Fish with these problems are rejected by middlemen due to their poor prices on the market, which raises an additional environmental concern about where the rejected specimens are released. These leeches act as a vector of the trypanosome parasite (D'Agosto and Serra-Freire, 1993), threatening sustainability due to the transmission of disease.

Thus, knowledge about suitable captivity techniques and aquaculture methods could be an important means for improving fish quality and quantity, and ultimately raise the commercial value (Marques, 1991; Neto, 2001; Begossi and da Silva, 2004; Castello, 2007; Silveira, 2009). In addition, these practices could reduce the impact of the off-season aspect and US dollar variations throughout the years.

Another factor that threatens the production and sustainability of fishing is the lack of governmental aid in this region. A successful fishing system has governmental control, providing welfare to the fishermen, as well as encouraging environmental preservation (Hilborn et al., 2005). A sustainable activity must satisfy the needs of a specific population and leave new generations in the same or better conditions. According to the United Nations (1983), in order to reach a sustainable situation, improved interactions between social, economic and environmental factors are necessary.

However, governmental incentives alone are not sufficient to guarantee sustainability, and shared management is necessary (Gutiérrez et al., 2011). Shared management between fishermen, the federal institutions, research organizations and financial institutes could bring benefits for all partners. This system has been shown to be an efficient sustainability tool in Zambia, Indonesia, the Philippines, Thailand, Vietnam and some parts of the Amazon region (Jentoft, 2005; Pomeroy et al., 2007; Ruddle and Hickey, 2008; Madzudzo, 2014). In addition, international aquarium and ornamental aquatic organism institutions could be aggregated to improve the shared management.

Thus, through this study, it was possible to observe several problems reported by fishermen, including the necessity of increasing technical knowledge, as well as applying management strategies to improve the sustainability of the activity and ensure new generations of ornamental fishermen. Therefore, increasing knowledge of fishing capture techniques, fishing management, aquaculture production and green labeling are suggestions to avoid seasonal influences in fishing and trade, as well as to maintain fish quality and improve fish prices.

5. Conclusion

Ornamental fishing in Guamá River is an important activity to riverine families however, the activity is in decline due to the several problems pushing fishermen to quit of ornamental fishing. Thus, a management plan that provides better conditions for both fishermen and captured fish is essential to grant the sustainability of the activity, and to avoid the increase of deforestation to replacement for agriculture.

Acknowledgement

The authors thank to National Council for Scientific and Technological Development and by financial support to Rodrigo Yudi Fujimoto (305195/2016-6).

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