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ARTISANAL FISHING UNDER THE INFLUENCE OF THE HYDROLOGICAL REGIME IN NEOTROPICAL RIVER

Carlos Eduardo Zacarkim
Universidade Federal do Paraná, Programa de Pós-graduação em Engenharia e Tecnologia Ambiental, Laboratório de Engenharia e Tecnologia em Aquicultura – LETA
Palotina, PR, Brasil
https://orcid.org/0000-0001-8642-0556

Pitágora Augusto Piana
Programa de Pós-graduação em Recursos Pesqueiros e Engenharia de Pesca – PREP, Grupo de Pesquisas em Recursos Pesqueiros e Limnologia – GERPEL, Instituto Neotropical de Pesquisas Ambientais – INEO
Toledo, PR, Brasil
https://orcid.org/0000-0002-4666-6663

Abstract: Seasonal changes in the hydrological regime in neotropical rivers may affect the composition, distribution and the abundance of freshwater fish species. The effects on fish communities have been linked to factors such as duration, frequency and periodicity of the hydrological regime, leading to changes in small-scale commercial fishing, within the flood and drought regime, that may affect the recruitment, size and distribution of the fishing effort. The present work has tested the hypothesis that the flood pulse of the Araguaia River influences the small-scale commercial fishing, evaluating the predictions that either in the temporal series, or in the flood, ebb and drought regime, influences the fishing income of the region. In the fishery landing analysis, between 2008 and 2011, it is seen a steep drop in capture volume from 2009. The identification of an overfishing context in the region has become evident with the decrease of yield, the increase of the number of fishermen, and the inversion of CPUEs (kg/fishermen) by daily yield (kg/day), with the catches exceeding the maximum sustainable yield (MSY) of 50 tons.
Keywords: Overfishing; Araguaia River; Amazon River basin; fishery yields

INTRODUCTION

Seasonal changes in the hydrological regime in neotropical rivers may affects the composition, distribution and the abundance of freshwater species. In this sense, flood pulses are considered the main regulators of aquatic communities, once changes are promoted in the biogeochemical cycles, make available a direct interchange of nutrients from the floodplain vegetation and contribute to the life cycle of many fish and invertebrate species (Agostinho *et al.*, 2004; Jowett *et al.*, 2005; Baptista *et al.*, 2010; Gillson & Suthers, 2012). The effect on fish communities has been related to factors as duration, frequency and periodicity of each hydrological regime, promoting changes in the small-scale commercial fishing patterns, between the flood and drought regimes, affecting the recruitment, size and fishing effort distribution (Salas & Gaertner, 2004; Jowett *et al.*, 2005; Suzuki *et al.*, 2009; Snelder & Lamouroux, 2010).

In Brazil, the small-scale commercial fishing corresponds to more than 60% of continental landings, being the Northern region responsible for 55.7% of the Brazilian freshwater fishery production, in a total of 248,911 tons in 2010, coming from the Amazon and Araguaia-Tocantins basins (MPA, 2012). According to the same author, this region concentrates around 38% of all artisanal fishermen of the country, being 223,501 from Pará state and 6,263 in Tocantins State. Considering the importance of the artisanal fishing, the present work has tested the hypothesis that the flood pulse of Araguaia River influences the small-scale commercial fishing in Xambioá, Tocantins state, evaluating the predictions that either in the temporal series, or in the flood, ebb and drought regime, influences the fishing income of the region.

MATERIALS AND METHODS

AREA OF STUDY

Araguaia River rises in Serra Caiapo, next to the Emas National Park, in Mineiros city (GO), and flows into Tocantins river, forming a large river system that links the Center-West to the Northern region of Brazil. This river naturally divides Mato Grosso and Goias states, Mato Grosso and Tocantins, and finally Pará and Tocantins states. It is over 2000 km length and may be divided into High (450 km), Medium (1505 km) and Low (160 km), being largely navigable (ANA, 2012).

For this work, fishery landings from 2008 to 2011 were evaluated, in colony Z-2, in Xambioá city, Tocantins state, Central

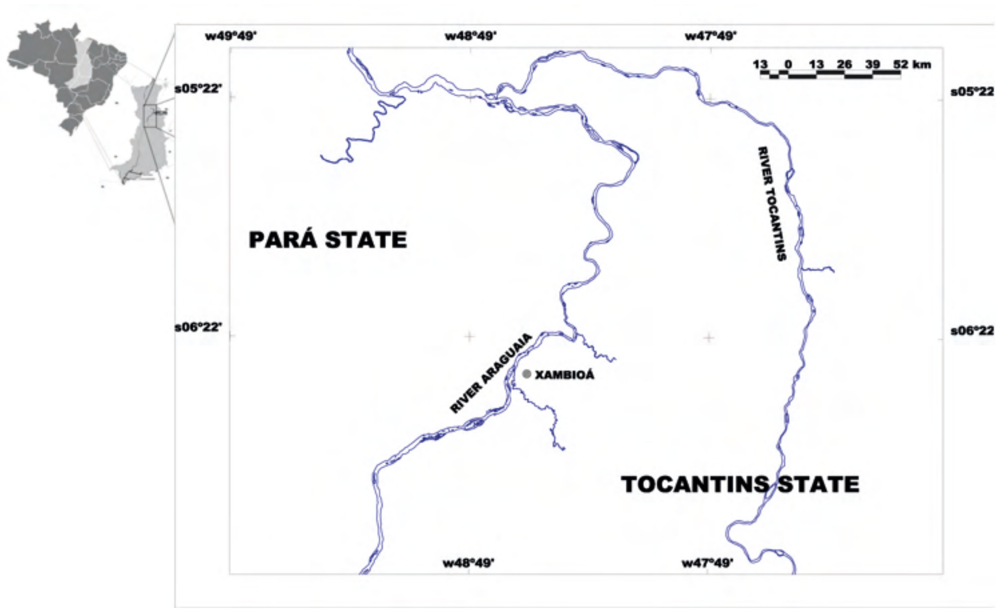

Figure 1. Region surrounding the lower Araguaia River, which acts as a natural division between the states of Pará and Tocantins showing the Xambioá city where the fishery landing data were evaluated

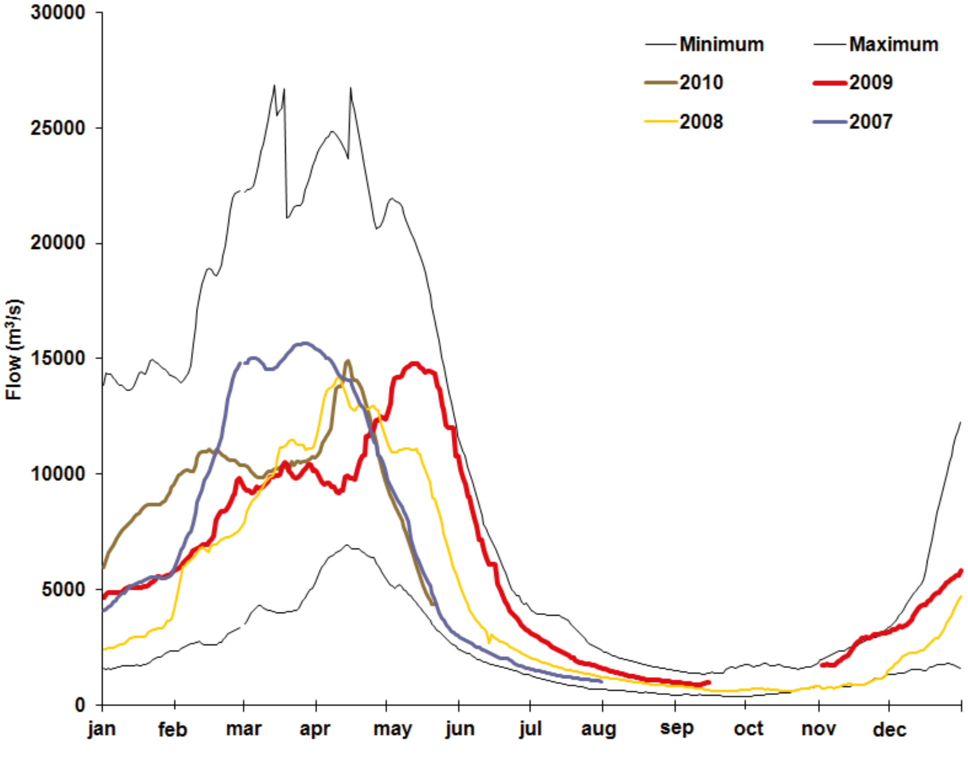

Figure 2. Time-series of the water level of the Araguaia River between 2007 and 2010 series. Source: modified from Agência Nacional de Águas [ANA] (National Agency of Waters).

Coordinates 6°8'14.62"S and 48°19'52.86"W (Figure 1).

HYDROLOGICAL REGIME

According to ANA (2012), the hydrological regime of Araguaia river may be divided into four periods: I) Rising period water, from November to January, when the rains begin, the river level rise and the fishing activities is forbidden due to the reproductive period; II) Flood period, from February to April, when the Araguaia River overflows into the floodplain; III) Ebb period, between May and July, when the waters start to down, and IV) Drought period, within August and October, when islands arise through the central channel (Figure 2).

DATA SURVEY AND PROCESSING

The research was made using the fishery landing data of Z-2 colony, Xambioá city, Tocantins state, between 2008 and 2011. The analyzed information were: captured species, total landing, number of fishermen responsible for landing and average price per kg of fish landed on the fishermen colony and the local market. Fish from artisanal fishing were identified according Santos *et al.* (2004) and Melo *et al.* (2005).

The capture data were analyzed through the bifactorial variance analysis, followed by the Tukey test, considering the period (temporal series) and the hydrological regime (Flood, Ebb, Drought) as source of variances, considering 5% significance (StatSoft Inc., 2004). The spatial and temporal distribution patterns were given through abundance, expressed in terms of Catch per Unit of Effort (CPUE), in numbers of individuals and biomass (King, 1995; McCluskey & Lewison, 2008) and the Maximum Sustainable Yield (MSY) it was analyzed according to Schaefer model (Ricker, 1975; Quinn & Deriso, 1999).

RESULTS

Whitin the fish species landed by the artisanal fishing in colony Z-2, stands out the order Characiforms, family Characidae with *Myleus* sp., and Prochilodontidae with *Prochilodus nigricans*. In the order Perciformes, stands out *Ciclha* spp., while for Siluriformes, *Ageneiosus inermis* stands out. The list of species landed in colony Z-2, in Xambioá city – TO, low Araguaia river region is seen in Table 1.

The fish landed in the Fishermen Colony Z-2 of Xambioá has presented seasonal pattern related to the hydrological cycle of Araguaia River, the fishing effort, the diversity and richness of captured species. When evaluating the fishing landing through the bifactorial analysis of variance, no significative integration was observed within the hydrological cycle (Figure 3A), however, the main significative effect was observed for the interstice 2008-2011 (Figure 3B; $F(3,6) = 12$; $P < 0.005$).

The total fishing yield was significative superior in 2009, exceeding the maximum sustainable yield of 50 tons, being landed 70.3 tons of fish. This capture, however, has declined in subsequent years, in where 2011 was seen as the worst yield in the evaluated temporal series, in a total of 27.9 tons of fish. Between 2008 and 2009, the expressive increase of fishing yield, supported also by the increase of fishermen working in landing. Despite the decrease in captures in the subsequent years, the number of fishermen raised in 2010, with a minor reduction in 2011 (Figure 4).

Species	Common name
Order Characiformes	
Family Anostomidae	
Leporinus friderici /Leporinus spp.	Piau
Family Characidae	
Brycon falcatus	*Matrinxã, Piabanha*
Myleus sp	Pacu Branco
Serrasalmus maculatus/ Serrasalmus spp.	Piranha
Family Curimatidae	
Psectrogaster amazonica	Branquinha
Family Ctenoluciidae	
Boulengerella lucius	Bicuda
Family Cynodontidae	
Hydrolycus arnatus	Cachorra
Family Erythrinidae	
Hoplias sp	Traíra
Family Hemiodontidae	
Anodus orinocoensis	Ubarana
Family Prochilodontidae	
Prochilodus nigricans	Curimatá
Semaprochilodus brama	Jaraqui
Order Clupeiformes	
Family Pristigasteridae	
Pellona castelnaeana	Apapa/sardinhão
Order Perciformes	
Family Cichlidae	
Cichla kelberi/ Cichla piquiti	Tucunaré
Geophagus sp	Cará
Family Sciaenidae	
Plagioscion squamosissimus	Curvina
Order Siluriformes	
Family Auchenipteridae	
Ageneiosus inermis/ Ageneiosus ucayalensis	Fidaldo
Family Doradidae	
Oxydoras niger	Cuiú-Cuiú
Family Loricariidae	
Baryancistrus sp	Cari
Family Pimelodidae	
Pseudoplatystoma reticulatum	Pintado/Surubin
Hypophthalmus marginatus	Mapara
Zungaro zungaro	Jaú
Phractocephalus hemioliopterus	Pirarara
Pinirampus pirinampu	Barbado

Table 1 – List of species landed by the artisanal fishing in colony Z-2, Ximbioá city, TO.

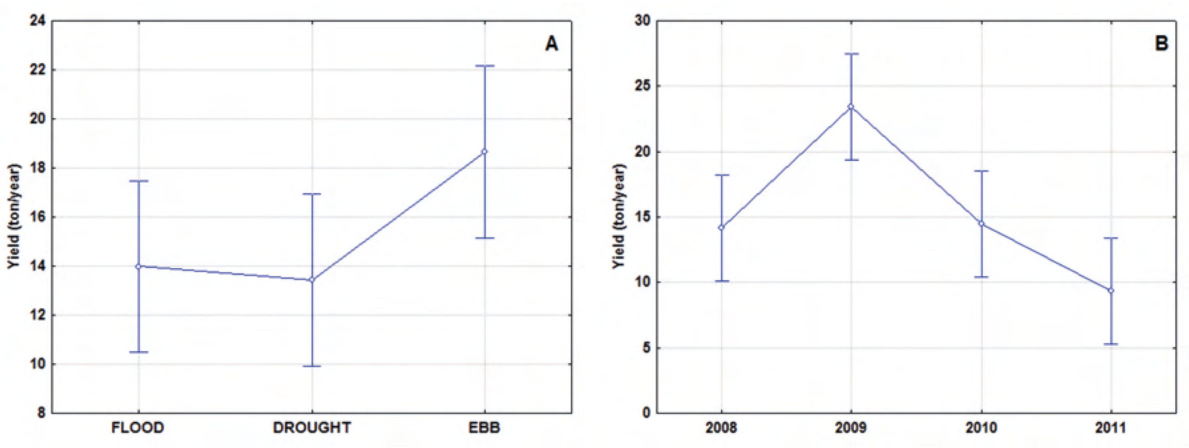

Figure 3. Mean values ± 95% of confidence interval for vertical bars. A) Hydrological cycle (Flood, Ebb, and Drought); B) Temporal series (2008-2011). Non-overlapping bars indicate significant differences through Tukey test.

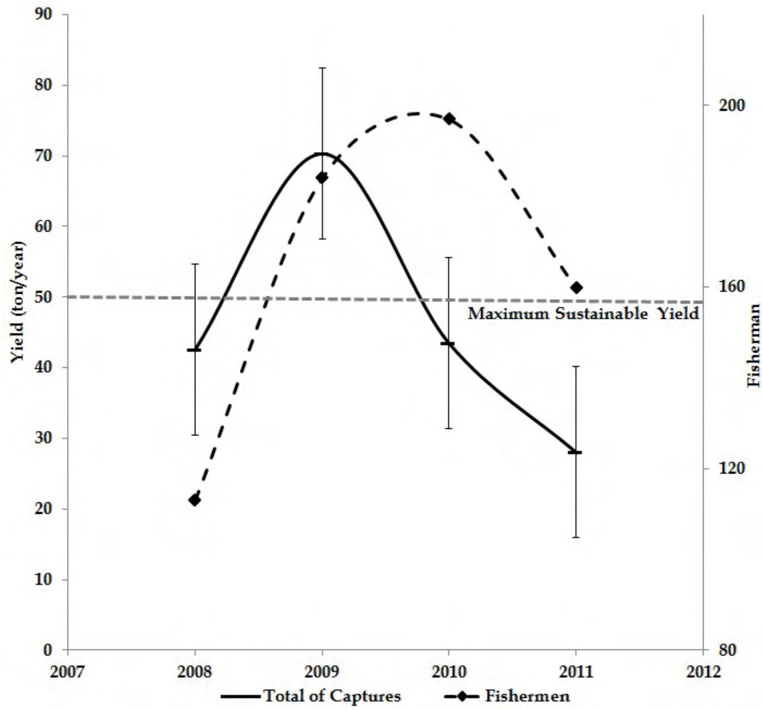

Figure 4. Landing of fish made on Xambioá city, TO, between 2008-2011. Mean values of ± 95% of confidence interval for vertical bars. Maximum Sustainable Yield (MSY) according to Schaefer model (Ricker, 1975; Quinn & Deriso, 1999). Non-overlapping bars indicate significant differences through Tukey test.

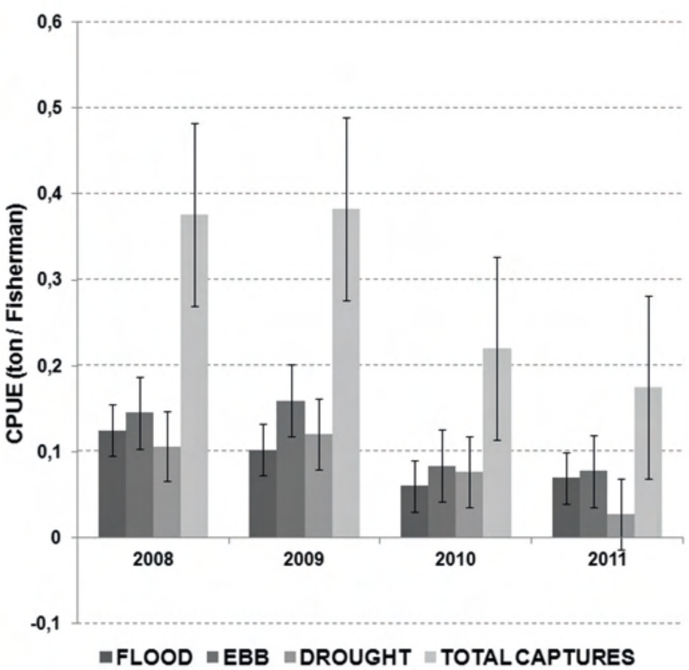

Figure 5. Catch per unit effort (CPUE ton/fisherman) between 2008-2011. Mean values of ± 95% of confidence interval for vertical bars. Non-overlapping bars indicate significant differences through Tukey test.

SPECIES	2008 TOTAL kg	2008 CPUE kg/fisherman	2008 CPUE kg/day	2009 TOTAL kg	2009 CPUE kg/fisherman	2009 CPUE kg/day	2010 TOTAL kg	2010 CPUE kg/fisherman	2010 CPUE kg/day	2011 TOTAL kg	2011 CPUE kg/fisherman	2011 CPUE kg/day
Pellona castelnaeana	207.0	25.9	23.0	1320.0	11.1	14.3	313.0	5.2	13.0	95.0	3.8	7.3
Pinirampus pirinampu	1532.5	37.4	31.9	3385.7	22.1	23.7	1155.5	9.8	18.9	655.5	7.4	12.4
Boulengerella lucius	2.0	2.0	2.0	---	---	---	6.0	6.0	6.0	---	---	---
Psectrogaster amazonica	650.0	72.2	59.1	1619.0	17.2	23.1	398.0	8.3	13.7	144.0	6.3	8.5
Hydrolycus arnatus	2694.0	41.5	37.4	4862.54	31.6	29.5	2570.0	17.51	30.2	2053.52	16.4	18.8
Geophagus sp	54.0	27.0	18.0	107.0	7.6	7.1	663.5	10.1	13.8	107.0	8.2	8.2
Prochilodus nigricans	8399.5	113.5	95.4	12849.3	73.0	72.6	6412.3	37.9	48.9	3408.5	27.1	27.1
Plagioscion squamosissimus	2611.0	42.1	39.0	3137.5	22.9	22.4	1940.5	13.0	21.8	786.2	7.9	11.9
Semaprochilodus brama	2481.0	60.5	59.1	1314.0	10.3	13.7	1169.7	9.1	19.8	478.8	8.4	10.6
Zungaro zungaro	4270.0	92.8	72.4	6374.5	55.0	51.4	3395.0	33.0	44.1	2102.0	27.3	33.9
Ageneiosus inermis/ Ageneiosus ucayalensis	3705.5	54.5	86.2	6413.3	26.9	30.4	2638.3	12.5	21.6	1602.9	11.1	14.7
Hypophthalmus marginatus	615.0	32.4	30.8	393.0	6.3	8.4	331.0	7.5	12.7	519.0	12.7	21.6
Myleus sp	7757.5	115.8	85.2	13500.6	81.3	68.2	11770.2	63.6	62.6	8482.2	56.2	52.0
Brycon falcatus	40.0	10.0	8.0	36.0	36.0	18.0	---	---	---!	---	---	---
Leporinus friderici / Leporinus spp.	1703.5	71.0	48.7	4982.8	33.4	30.6	4593.5	27.5	28.4	3384.0	26.2	26.0
Serrasalmus maculatus/ Serrasalmus spp.	1264.0	28.1	23.4	3203.0	22.4	22.4	2003.0	13.4	22.0	1206.0	10.8	13.3
Hoplias sp	409.0	24.1	20.5	1000.0	8.4	11.0	122.0	5.1	5.3	1.0	1.0	1.0
Cichla kelberi/ Cichla piquiti	4131.0	55.1	51.6	5806.7	35.6	33.2	3957.8	23.0	28.1	2770.5	19.4	20.5
Baryancistrus sp	---	---	---	---	---	---	---	---	---	199.0	6.9	7.7

Table 2 – Relation of species landed by the artisanal fishing in Xambioá city, TO. Data referrers to the Catch Per Unit Effort (CPUE kg/fisherman) and CPUE (kg/day) between 2008-2011.

In terms of capture by effort unit, fishing in the low Araguaia River has declined, where the maximum capture was in 2009, being supported by the improvement of fishing efforts. In the subsequent years, the CPUE (ton/fisherman) has presented a considerable fall, when the effort raised in terms of number of fishermen and, consequently, number of gear; while the yield has kept decreasing in the following years (Figure. 5). The fishing effort in the low Araguaia River is made mainly by gillnets, longlines, cast nets and hand lines. The captures are made throughout the week, in an average of five days per week, where landings happen daily as the fish is catched.

Despite fishing not having a defined target species, the landing is focused specially in *Prochilodus nigricans*, *Myleus* sp., *Semaprochilodus brama* e *Cichla* sp. species. In 2008, the capture of *Prochilodus nigricans* was of 8.39 tons, while for *Myleus* sp. was 7.75 tons, with a change in this relation from 2009, when *Myleus* sp. represented 13.5 tons, while *Prochilodus nigricans* got the second place in yield, with 12.8 tons of fish (Table 2).

The catch per unit of effort, in species terms, has presented similar variation to fishing yield, with maximum catch in 2009 and decline in subsequent years. Either CPUE (kg/fisherman), as CPUE (kg/day) have presented significative fall from 2010. Comparing both CPUEs, however, it is seen that CPUE (kg/fisherman) was higher than CPUE (kg/day) within 2008 and 2009, alternating in the following years.

The variability in catches per unit effort, related to individually species, was given either to the daily yield (kg/day), or to the yield by fisherman (kg/fisherman). The most focused species or with a higher participation in landings would present higher CPUE (kg/fisherman) until the maximum yield was achieved in 2009. From that point, the CPUE (kg/day) has exceeded the amount of fish caught by fisherman. Another fact observed was that some species with lower participation on landings, and that presented relatively low CPUEs in 2008 and 2009 had increased in the subsequent years, contrary to the negative tendency of the other species. It can be observed for *Hypophthalmus marginatus* e *Baryancistrus* sp. (Table 2).

In the evaluation of captures, it is also observed a mean reduction of 60% in landings within 2009 and 2011. This reduction was expressive for some species with higher participation in fish landings, such as *Ageneiosus inermis* (75%), *Prochilodus nigricans* (73%), *Zungaro zungaro* (67%) e *Semaprochilodus brama* (64%). Consequently, the decline in captures may be seen for the catch per unit effort, with mean reduction of around 74% for CPUE (kg/fisherman) and 66% for CPUE (kg/day). Considering the CPUE for species, the reduction was of 86% for CPUE (kg/fisherman) and 82% in CPUE (kg/day) in the capture of *Ageneiosus inermis*, 80% for CPUE (kg/fisherman) and 83% for CPUE (kg/day) in the capture of *Semaprochilodus brama* and 76% for CPUE (kg/fisherman) and 72% for CPUE (kg/day) in the capture of *Prochilodus nigricans* within 2008 and 2011 (Table 2).

The commercial value of fish landed in Xambioá has presented variations between the period evaluated and the commercialization centers. The species seen as noble and that, consequently, has a higher market value throughout the local market are *Pseudoplatystoma reticulatum* (U$ 4.20), *Cichla* sp. (U$ 4.0) and *Zungaro zungaro* (U$ 3.8). The fish landed in the fishermen colony, however, did not undergo through significative variations within the commercialized species, following the table and prices stipulated by it (Figure 6).

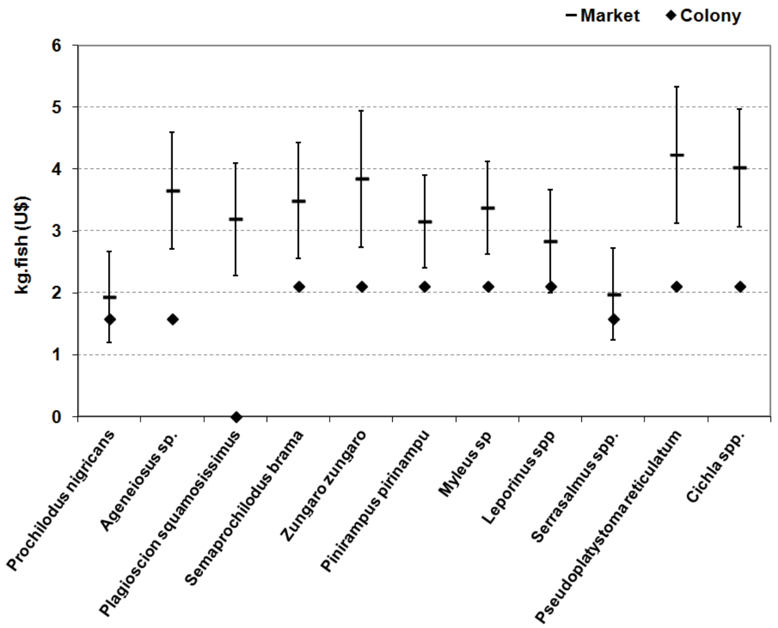

Figure 6. Market value of species landed within 2008-2011. In hairline, the value received in local market; in black points, the value received for the fish landed in the fishermen colony. Bars indicate standard deviation.

DISCUSSION

The fishing landing in Xambioá city is characterized by the lack of a target species of artisanal fishing, being 26 species commercialized within 2008 to 2011. The results demonstrate that 87% of landing from this period are focused in 10 species, corresponding to five species of order Characiformes (*Leporinus* spp., *Myleus* sp., *Hydrolycus arnatus*, *Prochilodus nigricans* and *Semaprochilodus brama*), three species of order Siluriformes (*Hypophthalmus marginatus*, *Phractocephalus hemioliopterus* and *Zungaro zungaro*), and two species of order Perciformes (*Cichla* sp. and *Plagioscion squamosissimus*). The diversification in fishing landings done by the artisanal fishing has been observed in several works for different regions (Mcclanahan & Mangi, 2004; Isaac *et al.*, 2009; Cowx & Van Anrooy, 2010; Cavole *et al.*, 2015; Gallardo-Fernández & Saunders, 2018). In studies made by Zacarkim *et al.* (2015), it was observed the prevalence of *Prochilodus nigricans* and *Semaprochilodus brama* in fishing landings of artisanal fishing in Araguaia-Tocantins basin. These species, together with the *Psectrogaster amazonica* correspond to 70% of landings made in the municipal market of Imperatriz-MA (Cetra & Petrere Jr., 2001).

In the fishing landing analysis between 2008 and 2011, a seasonal variation was observed, with a significative fall in the volume of captures from 2009. According to various authors, rivers with floodplain, as Araguaia River, present seasonal variations in the capture volume throughout the years (temporal series), as in the hydrological cycle (flood, ebb, drought, and raising water) throughout the year (Jowett *et al.*, 2005; Gubiani *et al.*, 2007; Fernandes *et al.*, 2009a; Isaac *et al.*, 2009; Lamberth *et al.*, 2009; Matono *et al.*, 2014), once the flood pulse promotes the enlargement of the physical space available for the species, decreasing the fragmentation between habitats and increasing the availability of resources such as food and shelter. Furthermore, various species are dependent of these seasonal variations for their cycle of life, working as a dispersion mechanism in rivers of such nature (Agostinho *et al.*, 2004; Wolter & Sukhodolov, 2008; Jonsson & Jonsson, 2009; Suzuki *et al.*, 2009).

In years of expressive flood events, studies have shown an increase in colonization rates of fish, caused by the floods in coastal areas in rivers with floodplain. The extended drought of such events may lead to environmental stress situations (abiotic and biotic), reducing the richness and abundance of species (Arellano-Torres *et al.*, 2006; Gubiani *et al.*, 2007; Fernandes *et al.*, 2009b; Isaac *et al.*, 2009). In the temporal analysis, the flood pulse of Araguaia River seems not have influenced or not have been a limiting factor in the recruitment of species. Thus, river flow, amplitude and duration of flood regime registered in 2008 and 2010 were alike, contrary to the captures, which presented linear fall.

The hypothesis that the seasonal variation in the hydrological regime of Araguaia River affects the fishing yield may not be proven. However, the annual flood pulse alterations are true, but are not being decisive for the landing reduction, since, as observed, the number of active fishermen has increased between 2008 and 2011, not reflecting in yield.

The maximum capture obtained in 2009, exceeding the maximum sustainable yield of 50 tons, with posterior fall in CPUE (kg/fisherman and kg/day), reflects the clear condition of overfishing. Another argument that supports such statement is the inversion of CPUEs, where the yield per fisherman (kg/fisherman) is inverted by the yield per day (kg/day), that is, the individual captures were reduced, while the total captures increased due to the raise in the number of fishermen, without resulting in yield raise. The collapse of fishing activities in the subsequent years is reflected also in the effort reduction, in 2011, where some fishermen abdicate the fishing activity. However it is important to recognize that the analysis showed in this paper is just one among several approaches and models possible (Walters *et al.*, 2005; Andrade, 2015, Naranjo-Madrigal *et al.*, 2019).

With the selective pressure on the stock of some species of fishing landings in Xambioá, there was an alteration in the amount correspondent to each species, in the global capture of the evaluated period. This context may be observed in the participation of *Myleus* sp., *Leporinus* spp. and *Hydrolycus arnatus*, where these species represented, in 2008, 18.2%, 4.0% and 6.2%, respectively, while in 2011 the participation of these species raised up to 30.3% for *Myleus* sp., 12.0% for *Leporinus* spp. and 7.3% for *Hydrolycus arnatus*, if compared to the others. Within the species that had a reduction in the participation of landings are: *Prochilodus nigricans*, *Zungaro zungaro, Semaprochilodus brama* and *Ageneiosus inermis*. These species were in 2008 present in 19.7%, 10.0%, 87.0% and 5.8%, being reduced to 12.1%, 7.5%, 5.8% and 1.7%, respectively. The observed overfishing context, associated to the possible seasonal disruptions, inherent to the hydrological regime of Araguaia river, illegal fishing or the poor resource management may result in a fishing activity crisis in the region (McCluskey & Lewison, 2008; Barletta *et al.*, 2010; Poff *et al.*, 2010; Zorn *et al.*, 2012; Cavole *et al.*, 2015; Dowling *et al.*, 2015; B. Leroy *et al.*, 2016).

In this sense, the lack of evaluation of landing data in fishing colonies has been compromising the correct management of fishing in the region. Collecting such information would however demand improvement of resources and personal for this activity. Nevertheless, sample records for key regions could subsidize decision making for the closing period, capture quotas, and restriction of fishing licenses.

When evaluating the revenues of fish landings, results point out a discrepancy between fish commercialized in the colony (lower price) and the fish sold in the local market (higher price). This incongruence in market values of the fish may and have been the foundation of this poor management of fisheries. According to MTE (2012), the artisanal fisherman profession is only regulated if the fisherman is registered in a fishing colony for a continuous period of one year. Thus, in many cases the fisherman is obligated to present what he caught in the colony where he is registered, and consequently pays a lower price for the fish.

As the fish price sold in a local market has a higher value for noble species, the fisherman does not land those in the colony, presenting only the species of lower value as *Myleus* sp and *Prochilodus nigricans*. Then, species as *Zungaro zungaro* and *Ciclha* sp. have its yields underestimated, while others, such as *Pseudoplatystoma reticulatum* and *Phractocephalus hemioliopterus* don't even appear in landings. Hence, the fishing statistics becomes fragile, once it is made of inconsistent data and without the real management conditions.

CONCLUSION

Data related to the flood pulse of the low Araguaia River have rejected the hypothesis that the fishery yield in artisanal fishery of Xambioá region – TO is influenced by the river flow. The identification of an overfishing context in the region has become evident with the catches exceeding the maximum sustainable yield of 50 tons and the inversion of CPUEs (kg/fishermen) by daily yield (kg/day). Landings are underestimated in the region, once some species are catch but not registered due to the higher price at the local market gives, in comparison to what is paid by the fishermen colonies.

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