BOLETIM DO INSTITUTO DE PESCA
ISSN 1678-2305 online version
Scientific Article

HYDROELECTRIC DAMS FROM MADEIRA RIVER SEASONALLY IMPACTS THE FISHERIES PRODUCTION IN THE GUAPORÉ BASIN (RONDÔNIA, BRAZIL)*

Helen Cristina PARAZZI de Freitas[1]
Carolina Rodrigues da Costa DORIA[2]
Raniere Garcez Costa SOUSA[3]*

[1] Universidade Federal de Rondônia - UNIR, Programa de Pós-Graduação em Ciências Ambientais – PGCA. Rua da Paz, 4376, Lino Alves Teixeira, CEP: 76.916-000, Presidente Médici, RO, Brazil.

[2] Universidade Federal de Rondônia - UNIR, Departamento de Ciências Biológicas, Programa de Pós-Graduação em Biodiversidade e Biotecnologia - PPG Bionorte. Campus – BR 364, km 9,5, CEP: 76.801-059, Porto Velho, RO, Brazil.

[3] Universidade Federal de Rondônia - UNIR, Departamento de Engenharia de Pesca, Programa de Pós-Graduação em Ciências Ambientais - PGCA. Rua da Paz, 4376, Lino Alves Teixeira, CEP: 76916-000, Caixa Postal 32, Presidente Médici, RO, Brazil. ranieregarcez@unir.br (*corresponding author)

Financial support: This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

Received: July 29, 2020
Approved: January 21, 2021

ABSTRACT

In the Amazon region, fisheries play an important role in the socioeconomic and cultural context and are directly affected by changes in the hydrological cycle, which can interfere with the numbers and frequency of fish species landed. This study analyzed the variation of fishery production against the seasonality of the water level of the Guaporé River (a tributary of the Madeira River) using information contained in the records of fishery landings in the area under study. In addition, two periods pre (2000 to 2008) and post (2009 to 2019) installation of the Jirau and Santo Antônio dams in the Madeira River were considered. Fish production in the period prior to damming indicated linearity ($r^2 = 0.41$) which was inversely proportional to the water levels of the Guaporé River, with low fish production in the flood and high production during the low water phases. However, for the period after damming, these variables showed low correlation ($r^2 = 0.14$). Among the fish species exploited, 35.13% presented significant differences (p <0.05) between the production values for the periods before and after installation of the dams. Therefore, the results showed significant differences between the values of fishery production by species and phases of the hydrological cycle of the Guaporé River, which occurred in the periods pre and post damming of the Madeira River, which indicates that the hydroelectric dams have negatively impacted the fish stocks of this region. The information contained in this study is useful and serves as a basis for coherent decision-making, since it aids in the sustainable management and monitoring of fish stocks in the Madeira River Basin.

Keywords: Amazon Basin; dams; hydrological cycle; inland fishing.

HIDRELÉTRICAS DO RIO MADEIRA IMPACTAM SAZONALMENTE A PRODUÇÃO PESQUEIRA DA BACIA DO GUAPORÉ (RONDÔNIA, BRASIL)

RESUMO

Na região Amazônica, a atividade pesqueira desempenha papel importante no contexto socioeconômico e cultural, sendo influenciada diretamente pela variação do ciclo hidrológico, que interfere na abundância e na frequência das espécies de peixes desembarcadas. O presente estudo analisou a variação da produção pesqueira frente a sazonalidade do nível do rio Guaporé, utilizando informações contidas nos registros dos desembarques pesqueiros das colônias de pescadores da área em estudo, considerando dois períodos: *Pré*-barramento (2000 a 2008) e *Pós*-barramento (2009 a 2019) do rio Madeira pelos empreendimentos hidrelétricos de Jirau e Santo Antônio. A produção pesqueira no período *Pré* indicou linearidade ($r^2 = 0,41$) inversamente proporcional ao nível do rio, com baixa produção na cheia e alta na seca, enquanto que no período *Pós* essas variáveis apresentaram baixa correlação ($r^2 = 0,14$). Dentre as espécies de peixes explotadas, 35,13% apresentaram diferenças significativas (p <0,05) entre os valores de produção dos períodos *Pré* e *Pós*-barramento. Os resultados exibiram diferenças significativas entre os valores da produção pesqueira por espécies e fases do ciclo hidrológico do rio Guaporé, ocorridas nos períodos *Pré* e *Pós*-barramento do rio Madeira, indicando que os barramentos hidrelétricos estejam influenciando negativamente os estoques pesqueiros dessa região. As informações descritas neste estudo são úteis e necessárias para tomadas de decisões mais acertadas que visem o monitoramento e o manejo sustentável dos estoques pesqueiros na bacia do rio Madeira.

Palavras-chave: Bacia Amazônica; barragens; ciclo hidrológico; pesca interior.

INTRODUCTION

The geographical space, the physico-chemical characteristics and the seasonal variation of the Amazon Basin influence the hydrological behavior of its tributaries (Bernardi et al., 2012). These factors, added to anthropogenic actions, can cause imbalances in fish stocks

(Torrente-Vilara and Doria, 2012) and therefore cause environmental and economic losses throughout the fish production chain, whether for subsistence or commercialization (Batista and Miranda, 2019).

The Amazonian aquatic environments form a complex mixture of habitats that are governed by the hydrological regime (Sousa et al., 2017). The degree of connections established between these ecosystems (Rodrigues et al., 2015) contribute to the abundance and richness of fish populations (Vasconcelos et al., 2011; Prado et al., 2016). This is because the dynamics enabled between rivers and floodplains favor not only the dispersal of fish species, but also serve as the trophic and reproductive migratory routes of certain fish species (Thomaz et al., 2007; Sousa et al., 2017).

In the rising and flood phases of the river, there is a heterogeneity of the biota due to the enlargement of the flooded areas. However, the opposite occurs between the receding and the low water phases because much of the microhabitats are disconnected, which causes the isolation of the environments and fish populations. As a result, there is an increase in interspecific competition (Bozelli et al., 2015). In this process, precipitation also plays an important role in providing seasonality, which serves as a stimulus for fish reproduction and increase of aquatic biomass (Inomata et al., 2018).

However, there are many factors that negatively affect the Amazon region, such as deforestation, which affects up to 20% of the entire forest area. As a result, climate change (Espinoza et al., 2009), mining (Val et al., 2016), the unrestrained installation of dams for fish farming (Almeida, 2006) and the implementation of hydroelectric plants, all affect the river corridors of the Amazon River (Doria et al., 2018; Batista and Miranda, 2019) and seasonal dynamics (Timpe and Kaplan, 2017), thus inhibiting nutrient cycling and rheophilic fish routes (Andrade et al., 2012; Harris et al., 2016; Torrente-Vilara et al., 2018).

These factors are also currently perceived in the region of the Madeira River Basin. As a result, many of these actions have been followed by a decline in fish diversity and fishery production (Agostinho et al., 2007; Lima et al., 2020). Therefore, to understand part of this problem, a main "bottleneck" was identified in this region. When considering a stretch of one of its tributaries, the Guaporé River was analyzed using seasonal records of local fishery production to see if there was a pattern that indicates possible changes in fisheries between the periods of pre- and post-hydroelectric dam construction in the Madeira River Basin.

In order to meet the growing demand for electricity, the Brazilian Federal Government implemented two large hydroelectric plants in the Madeira River basin (Santo Antônio and Jirau dams, that began operating in 2011 and 2012, respectively) with installed capacity of 7,000 Megawatts (Brasil, 2011). Therefore, these barriers brought impacts on the aquatic environment, changing the hydrological regimes and the fish migration routes (Fearnside, 2014; Hauser, 2018; Santos et al., 2018), causing a reduction in the fisheries landings during the construction and after the closure of these dams (2009–2014). Also reflecting in a large of socio-environmental impacts on the traditional riverside communities, whose depends heavily on natural resources such as fish (Doria et al., 2017).

In order to test the hypothesis that there are no changes in the fisheries production in the Guaporé River basin, which can be perceived between the periods pre- and post-damming of the Madeira River. Thus, this study aimed to verify whether the damming has caused changes in the fishery production, analyzing the variations in fishery production from the riverine communities located in the main stretch of the Guaporé River, while at the same time taking into consideration the influence of seasonal phases of the river water level. Thus, we contemplated the pre-damming period (2000 to 2008) and post-damming period (2009 to 2019) after the installation of the Jirau and Santo Antonio hydroelectric dams in the Madeira River Basin, in order to generate information for the management of fishery resources in the state of Rondônia (RO).

MATERIALS AND METHODS

Study location

This study was conducted in the Guaporé River Basin, which is approximately 59,339.38 km^2 (ANA, 2015; Rondônia, 2018), and has its headwaters in Chapada dos Parecis, in the state of Mato Grosso. Its tributaries are of low depth (between 2 and 8 meters) and, because of this, it forms floodplains known locally as pantanal do Guaporé (Doria and Brasil de Souza, 2012) (Figure 1).

Data collection

The information regarding the fishery production and the frequency of fish species landed in the study region were acquired in the period from November 2018 to November 2019, from the fishing colonies of the Guaporé River Basin. Concomitantly, the daily hydrometric measurements were collected from station No. 15150000, which is located in the community of Pedras Negras, in the city of São Francisco do Guaporé, RO (ANA, 2019). This information was authorized for use by ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade) under license No. 0650590120190107 and the research was approved by the Ethics Committee of the Universidade Federal de Rondônia, under registration No. 9619.8518.0.0000.5300.

Fishery statistics

The measurements of the hydrological level of the Guaporé River were submitted to descriptive statistics for the quantification of the duration of the phases of the hydrological cycle (rising, flood, receding and low water phases), according to the methodology described by Torrente-Vilara and Doria (2012). Subsequently, the values of fishery production and the hydrological level of the Guaporé River (pre- and post-damming) were used in Pearson's correlation analysis to verify possible linearity between these variables (Triola, 1998).

Fishery production data, when meeting the assumptions of homoscedasticity, were submitted to the Student's t test to ascertain significant differences between the averages of fishery production related to the distribution of fish species according to the seasonal phases and, or pre- and post-damming.

A correspondence analysis (CA) was used to evaluate the force of similarity of the coordinates between the variables employed (phases of the hydrological cycle, fish species and the pre-and post-damming fishery production), since it is a multivariate statistics technique that aims to simplify the structure of data variability (categorical variables) that are generally correlated with each other, without losing the original information of the data sets. Thus, these data were represented through a graphic model that facilitates the interpretation of the relationship between such groups of information (Greenacre,

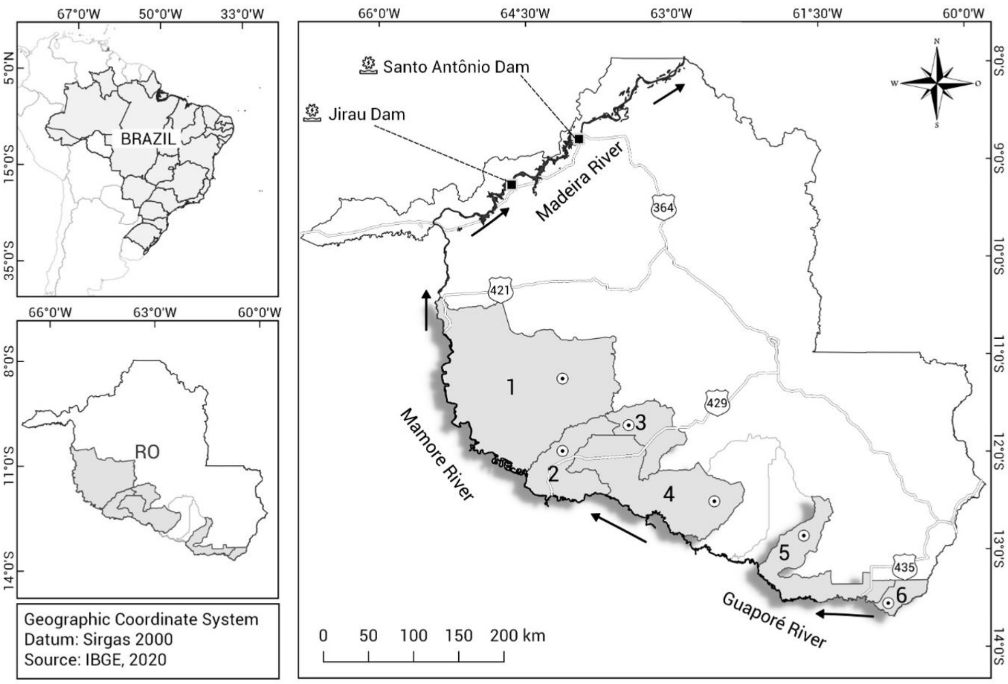

Figure 1. Location of the study area with emphasis on the Madeira River Dams and micro-regions of the Guaporé River Basin. Key to micro-regions: 1 = Guajará-Mirim, 2 = Costa Marques, 3 = Seringueiras, 4 = São Francisco do Guaporé, 5 = Pimenteiras do Oeste, 6 = Cabixi. Dotted lines represent the access roads. Dot spot are the fishing data collection point (fishermen colonies).

2017). All statistical analyses were performed using the Statistic 9.0 software (StatSoft Inc., 2009) considering a *p*-value of ≤ 0.05.

RESULTS

Hydrological parameters and evaluation of fishery production

The hydrological periods of the study region were defined as: rising (December to February), where the river level rises from 262 to 574 cm; Flood (March to May) from 574 to 616 cm; receding (June and July) the river level drops from 616 to 283 cm; and low water phase (August to November) 283 to 262 cm (Torrente-Vilara and Doria, 2012) (Figure 2).

Regarding the data of fish landings, these were grouped by the two periods of pre- and post-damming of the Madeira River and showed different patterns, which were directly related to the phases of the hydrological cycle. In the pre-damming period, the fishery production was inversely proportional to the phases of the hydrological cycle, showing the lowest values of fish landings in the rising water phase (January and February; 22.15 t) and in the flood (March and April; 45.23 t), followed by an increase in production values in the receding water phase (May, June and July; 166.84 t) with its highest peak in the low water phase; 255.46 t) (Figure 2).

On the other hand, in the post-damming period, low fishery production can be observed at the beginning of the rising water phase (January; 14.07 t), which is followed by continuous growth during the whole of this phase (January and February; 116.08 t) up to the end of the flood phase (May; 145.67 t), which continued and reached its highest peak during the receding water phase (July; 235.86 t). This was followed by a slight decrease in the fish landing values at the beginning of the low water phase (August; 211.81 t), though it reached a second peak in landings at the end of this phase (October; 218.90 t), which is followed by a sudden drop in the landings at the beginning of the rising water phase (December; 6.09 t) (Figure 2).

The distribution of the daily averages of the hydrometric levels of the Guaporé River showed an annual flood pulse, which defined a single-mode pattern for the data series throughout the sampling period. Alterations in the hydrological levels were observed for only two years, which were both in the post-damming period and in the rising water phase; one in 2015 (990 cm) and the other in 2017 (928 cm). In the other floods of the study period, the averages of the seasonal phases ranged between 675 and 736 cm. In the pre-damming period, it was evident that the indices of higher fishery production were between the receding and low water phases, with increasing peaks over the years. In the post-damming period, fishery production showed oscillations between the phases of flood, receding and low water, and showed a decrease in the production of landed fish (Figure 3).

The mean values of the monthly fishery landings (FL) when correlated with the flood pulse of the Guaporé River (HL) presented distinct linearity in the Pearson test. The results for the pre-damming period showed a significant difference in the dispersion of the production values (FL= 255.0521-0.181*HL, $p = 0.026$), with a coefficient of determination $r^2 = 41\%$, indicating that as the level of the Guaporé River rose, fishery production in the region decreased. However, the landing data related to the post-damming period (FL = 207.219-0.0954 * HL, $p = 0.217$) showed a low linear correlation with the seasonality of the river level, which was confirmed with the value of $r^2 = 14\%$ (Figure 4).

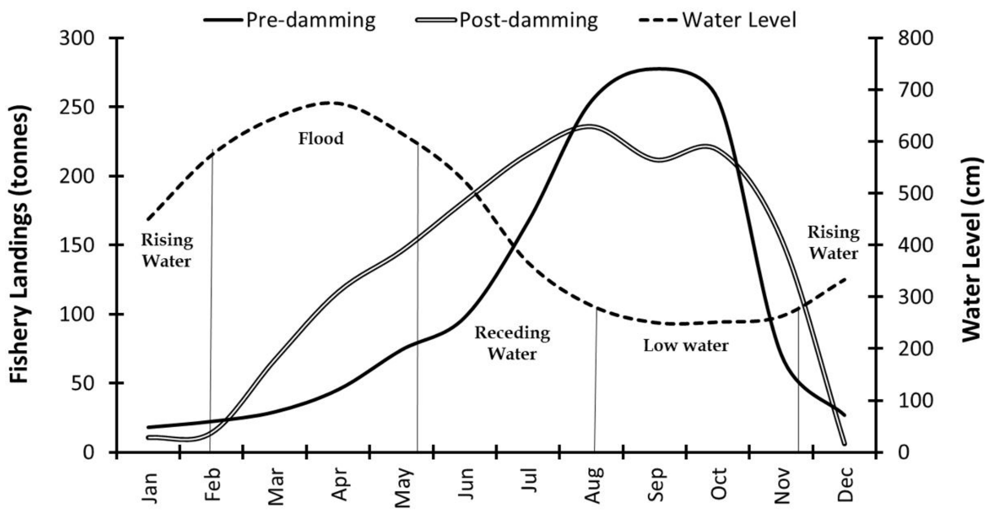

Figure 2. Average annual variation of the hydrological levels (seasonal phases) and fishery production of the Guaporé River Basin represented in the periods before (2000 to 2008) and after (2009 to 2019) the implementation of hydroelectric dams in the Madeira River Basin.

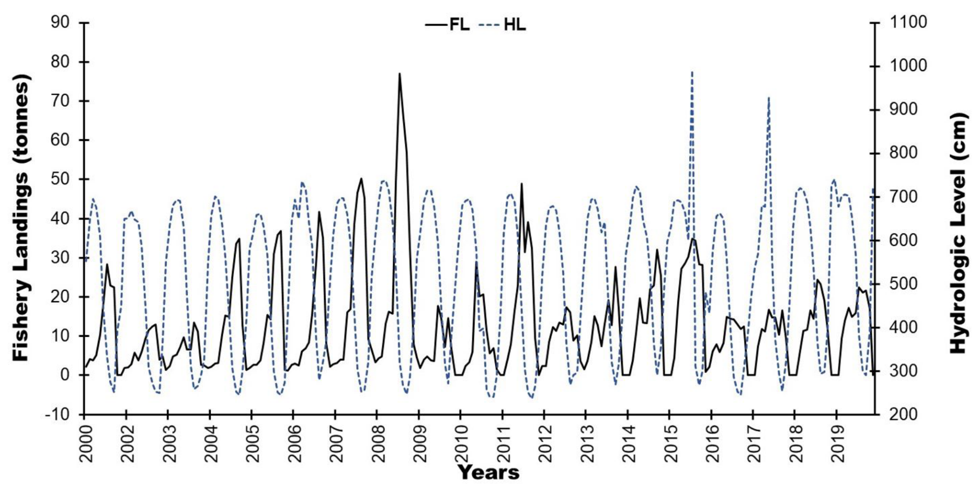

Figure 3. Fishery landings (FL) production and hydrograph of the levels (HL) of the Guaporé River for the study period evaluated.

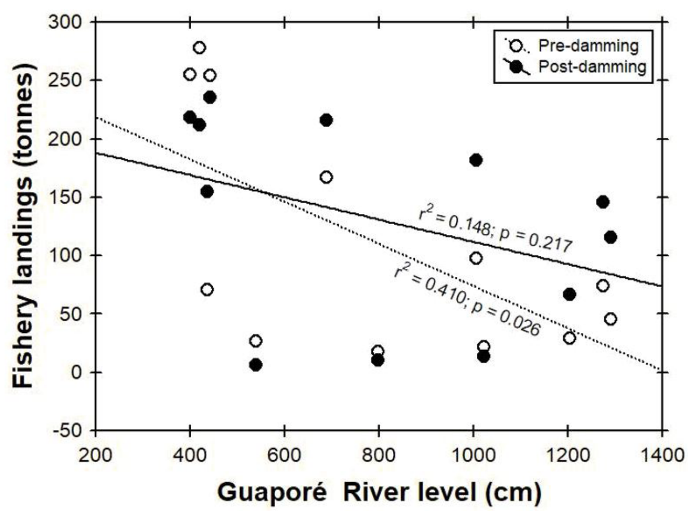

Figure 4. Linear distribution between fishery production and the water level of the Guaporé River, considering the periods before and after the implementation of hydroelectric dams in the Madeira River.

During the study period, 37 species of fish belonging to 5 orders and 17 families were recorded during landings. The orders that presented the highest species richness were Siluriformes (45.94%), Characiformes (40.45%), followed by Perciformes (10.81%). Of the total landed, the most frequent migratory species were *Prochilodus nigricans* (16.73%), *Colossoma macropomum* (9.74%) and *Brachyplatystoma filamentosum* (4.25%). For the fish that are considered sedentary, the *Cichla pleiozona* (14.95%) and the *Arapaima gigas* (8.37%) stood out, while the other fish (sedentary and migratory) totaled 44.15% (Table 1). The average values of fishery production between the periods before and after the installation of the dams when submitted to the Student's t test showed significant differences for 45.96% of the species recorded, most of which are migratory fish, with the exception of the *Pterygoplichthys pardalis*, which is sedentary species (Table 1).

Table 1. Taxonomic distribution and migratory behaviors of the species, with their respective mean values of fishery production for the periods of pre- and post-damming of the Madeira River, p <0.05 present significant differences (*) when compared using the Student's t test.

Taxon	Popular Name	Fish Code	Production (tonnes)		*p*	t-value	Migratory species
			Pre-damming	Post-damming			
Clupeiformes							
Pritigasteridae							
Pellona castelnaeana (Valenciennes, 1847)	Apapá	Pc	-	1.70 ± 1.24	0.033*	2.75	yes
Osteoglossiformes							
Arapaimatidae							
Arapaima gigas (Bloch & Schneider, 1801)	Pirarucu	Ag	31.75 ± 41.42	28.83 ± 23.24	0.906	0.12	no
Characiformes							
Anostomidae							
Leporinus spp.	Piau	Lsp	7.73 ± 1.99	5.97 ± 2.99	0.366	0.98	yes
Bryconidae							
Brycon cephalus (Gunther, 1869)	Matrinxã	Byf	0.05 ± 0.08	2.16 ± 1.53	0.032*	2.77	yes
Brycon amazonicus (Spix & Agassiz, 1829)	Jatuarana	Bm	2.05 ± 1.72	4.30 ± 2.80	0.219	1.37	yes
Characidae							
Astyanax bimaculatus (Linnaeus, 1758)	Lambari	Asb	0.03 ± 0.02	0.38 ± 0.24	0.026*	2.93	yes
Colossoma macropomum (Cuvier, 1816)	Tambaqui	Clm	36.84 ± 41.83	33.68 ± 28.57	0.904	0.12	yes
Curimatidae							
Psectrogaster amazonica (Eigenmann & Eigenmann, 1889)	Branquinha	Psa	0.17 ± 0.14	6.10 ± 1.94	-	6.10	yes
Cynodontidae							
Hydrolycus scomberoides (Cuvier, 1819)	Peixe-cachorra	Hs	0.13 ± 0.14	1.58 ± 1.10	0.040*	2.60	yes
Erythrinidae							
Hoplias malabaricus (Bloch, 1794)	Traíra	Hm	0.39 ± 0.31	4.46 ± 4.09	0.094	1.99	no
Hemiodontidae							
Anodus elongatus (Agassiz, 1829)	Cubiu	Ae	6.34 ± 2.63	1.71 ± 1.70	0.025*	2.95	yes
Prochilodontidae							
Prochilodus nigricans (Spix & Agassiz, 1829)	Curimatã	Prn	70.35 ± 79.06	51.37 ± 47.16	0.694	0.41	yes
Semaprochilodus insignis (Jardine, 1841)	Jaraqui de escama grossa	Ses	24.45 ± 28.91	3.86 ± 1.08	0.204	1.42	yes
Serrasalmidae							
Mylossoma spp.	Pacu	Ms	0.29 ± 0.31	4.98 ± 4.42	0.078	2.12	yes
Piaractus brachypomus (Cuvier, 1816)	Pirapitinga	Pb	19.21 ± 22.27	2.60 ± 2.35	0.188	1.48	yes
Serrasalmus spp.	Piranha	Ser	6.38 ± 3.08	7.47 ± 4.87	0.717	0.38	no

Table 1. Continued...

Taxon	Popular Name	Fish Code	Production (tonnes)		*p*	t-value	Migratory species
			Pre-damming	Post-damming			
Siluriformes							
Auchenipteridae							
Ageneiosus brevifilis (Valenciennes, 1840)	Mandubé	Ab	0.06 ± 0.09	3.92 ± 3.58	0.074	2.15	yes
Doradidae							
Pterodoras granulosus (Valenciennes, 1821)	Cuiú-cuiú	Ptg	7.60 ± 3.01	1.36 ± 0.44	0.006*	4.10	yes
Loricariidae							
Pterygoplichthys pardalis (Castelnau, 1855)	Acari-bodó	Hyp	6.23 ± 1.60	2.37 ± 0.86	0.005*	4.25	no
Pimelodidae							
Brachyplatystoma filamentosum (Lichtenstein, 1819)	Filhote	Bf	22.92 ± 31.70	7.90 ± 5.34	0.385	0.93	yes
Brachyplatystoma platynemum (Boulenger, 1898)	Babão	Bp	0.01 ± 0.01	0.18 ± 0.17	0.086	2.054	yes
Brachyplatystoma rousseauxii (Castelnau, 1855)	Dourada	Brf	2.68 ± 2.57	0.65 ± 0.40	0.169	1.56	yes
Hemisorubim platyrhynchos (Cuvier & Valenciennes, 1840)	Jurupoca	Hp	0.03 ± 0.07	0.47 ± 0.55	0.170	1.55	yes
Hypophthalmus edentatus (Spix & Agassiz, 1829)	Mapará	He	1.62 ± 1.11	-	0.03*	2.91	yes
Leiarius marmoratus (Gill, 1870)	Jundiá	Lm	-	0.06 ± 0.05	0.08	2.09	yes
Phractocephalus hemiliopterus (Cuvier, 1818)	Pirarara	Ph	9.65 ± 2.40	30.47 ± 20.97	0.10	1.97	yes
Pinirampus pirinampu (Spix & Agassiz, 1829)	Barba-chata	Pp	0.12 ± 0.12	7.56 ± 5.03	0.02*	2.96	yes
Platynematichthys notatus (Jardine & Schomburgk, 1841)	Coroatá	Pn	-	0.03 ± 0.03	0.07	2.36	yes
Pseudoplatystoma spp. (Schinz, 1822)	Surubim	Psp	2.11 ± 3.13	58.62 ± 32.76	0.01*	3.43	yes
Pseudoplatystoma fasciatum (Linnaeus, 1766)	Cachara	Psf	11.80 ± 14.63	41.78 ± 28.72	0.11	1.86	yes
Pseudoplatystoma tigrinum (Valenciennes, 1840)	Caparari	Pst	0.09 ± 0.13	6.12 ± 3.10	0.01*	3.89	yes
Sorubimichthys planiceps (Spix & Agassiz, 1829)	Peixe Lenha	Sp	-	0.04 ± 0.08	0.35	1.00	yes
Zungaro zungaro (Humboldt & Valenciennes, 1821)	Jaú	Zz	9.56 ± 5.34	4.42 ± 3.82	0.17	1.56	yes
Perciformes							
Cichlidae							
Aequidens plagiozonatus (Kullander, 1984)	Cará	Acr	0.012 ± 0.03	0.58 ± 0.50	0.07	-2.23	no
Astronotus crassipinis (Heckel, 1840)	Acará-açu	Asp	0.09 ± 0.12	0.26 ± 0.25	0.27	1.22	no
Cichla pleiozona (Kullander & Ferreira, 2006)	Tucunaré	Cip	54.79 ± 89.07	54.10 ± 58.90	0.99	0.01	no
Sciaenidae							
Plagioscion squamosissimus (Heckel, 1840)	Corvina	Ps	0.54 ± 0.68	10.95 ± 8.26	0.05*	2.51	yes
Total fishery means (tonnes/year)			9.084 ± 16.26	11.23 ± 21.62	0.101	-0.47	
Total fishery production pre and post damming (tonnes/periods)			336	393			

The correspondence analysis reveals in dimension 1 (inertia = 62.97%) and dimension 2 (inertia = 33.64%) a point cloud that demonstrates the distribution of fish species according to the phases of the hydrological cycle, counterclockwise and away from the central axis. On the left side of the graph, we plotted the species caught in the rising water (Ri), flood (F) and receding phase (Re), represented by fish that migrate in order to reproduce, in addition to four sedentary species, the *A. plagiozonatus*, the *Serrasalmus* spp., the *H. malabaricus* and the *P. pardalis*, which are fish that typically inhabit lake environments, while on the right side of the graph, the other species landed during the low water phase (L) were concentrated. Migrating species, such as *P. tigrinum*, *B. filamentosum*, *P. brachypomus*, *P. squamosissimus*, *P. nigricans*, the *H. scomberoides*, the *P. pirinampu*, *Mylossoma* spp., *A. brevifilis*, *B. cephalus*, *S. insignis*, *P. fasciatum*, *Pseudoplatystoma spp.*, and *H. platyrhynchos*, were more frequent (Figure 5).

In the post-damming period, the data was 94.61% projected in dimension 1 (inertia of 72.00%) and in dimension 2 (inertia of 22.61%) where the fish species were plotted in a clockwise gradient and closer to the central axis of the orthogonal lines, presenting a distribution opposite to the pre-damming period. The most representative migratory fish between the phases of the rising (Ri) and flood (F) phases were the *B. rousseauxii*, the *P. notatus*, the *S. insignis*, the *A. bimaculatus*, the *Pseudoplatystoma* spp, the *Leporinus spp.*, the *P. granulosus*, the *B. amazonicus*, the *P. amazonica*, the *B. cephalus* and, the *A. elongatus*, with the exception of the *P. pardalis*, which is a sedentary fish, and also was present during the landings. In the receding water phase (Re), the most frequent species were the *H. scomberoides*, the *P. brachypomus*, the *A. brevifilis*, the *P. castelnaeana* and the *C. macropomum*. In the period of low water (L), among the most representative fish were the *A. gigas*, the *C. pleiozona*, the *A. crassipinis*, the *H. malabaricus*, the *A. plagiozonatus* and the *Serrasalmus* spp., which are sedentary species. Migratory species, such as the *B. filamentosum*, the *P. squamosissimus*, the *Mylossoma spp.*, the *H. platyrhynchos*, the *S.-planiceps*, the *Z. zungaro*, the *P. nigricans*, the *B. platynemum*, the *L. marmoratus* and the *P. pirinampu*, were also plotted (Figure 6).

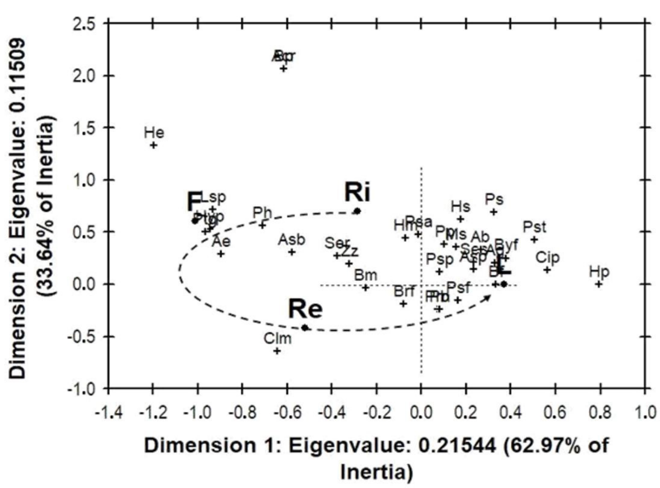

Figure 5. Distribution of the species caught in the Guaporé River Basin and the respective seasonal river phases (dotted line with arrowhead counterclockwise), for the period Pre-damming (2000 to 2008) of the Madeira River (the codes relating to the fish species are shown in Table 1). Where: Ri = Rinsing; F = Flood, Re = Receding; L = Low water

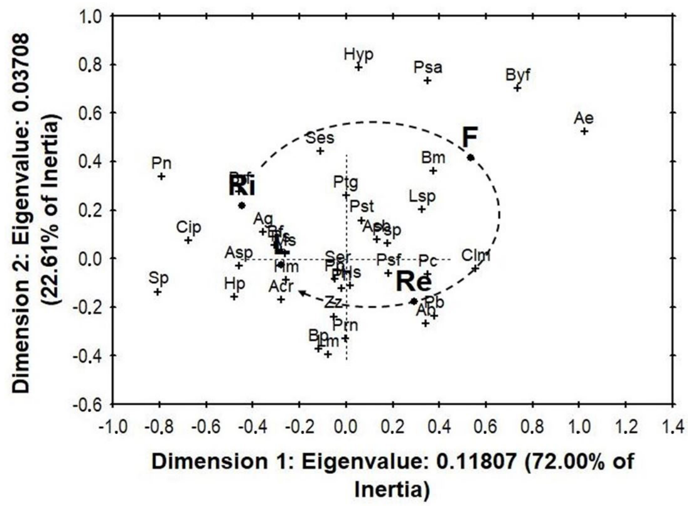

Figure 6. Distribution of fish species and the respective seasonal river phases (dotted line with arrowhead clockwise) in the Guaporé River Basin, for the post-damming period (2009 to 2019) of the Madeira River (the codes relating to the fish species are shown in Table 1). Where: Ri = Rinsing; F = Flood, Re = Receding; L = Low water.

DISCUSSION

The vast Amazon Basin possesses areas that are suitable for the construction of hydroelectric plants and fishery activity (Almeida et al., 2019). However, the inadequate use of these flooded areas can cause irreversible socio-environmental damage (Batista and Miranda, 2019), such as when the main channels of the great rivers are dammed for the production of electricity (Doria et al., 2018; Almeida et al., 2020) or when their tributaries are impeded for the practice of fish farming, which, as a result, causes fragmentation and loss of aquatic habitats (Almeida, 2006; Agostinho et al., 2007).

The Madeira River Basin has important tributaries that are used as fishing areas, including the Guaporé River (Doria and Lima, 2015; Doria et al., 2018) which, according to its geographical location, is not recognized as being an area that is or was directly or indirectly impacted by the dams, and is thus classified as a control area (COBRAPE, 2005). However, hydroelectric projects in general interfere with the riverbed, change the hydrological regime and directly alter fish and other aquatic animal communities, especially migratory species (Athayde et al., 2019; Garzon, 2019; Almeida et al., 2020).

Given the importance of the hydrological regime for the abundance and distribution of ichthyofauna, the landing data evaluated in this study showed that the seasonal phases of the Guaporé River have predictable cyclical periods (rising, flood, receding and low water phases). In this scenario, the similarity with those of other regions of the western Amazon is demonstrated (Bittencourt and Amadio, 2007; Torrente-Vilara and Doria, 2012). This seasonal flood pulse is important for the success of fisheries, since it promotes the structuring of aquatic biota (Sousa and Freitas, 2008; Garcez et al., 2009; Sousa et al., 2017). However, changes related to seasonal phases and fishery production in the periods pre- and post-damming were observed in the present study.

In the pre-damming period, the fish production values were inversely proportional to the variations in the level of the Guaporé River, presenting a pattern similar to that which occurs in recurrent fisheries in the Amazon Basin (Sousa et al., 2017), where the highest productivity occurs in the phases of receding and low water (Sousa and Freitas, 2008; Isaac et al., 2016). On the other hand, even with the flood pulse of the river remaining seasonal, in the post-damming period, the fisheries did not show the same pattern that occurred in the pre-damming period. Therefore, it is possible to note that the productive peaks oscillated between the phases of flood, receding and low water. In this sense, this question may be indicative of other environmental variations, which these habitats and ichthyofauna are undergoing (Pinto et al., 2019; Camacho Guerreiro et al., 2020).

An aggravating factor perceived in the scenario of the post-damming period was that even with the off season in fishing determined by Federal Law No. 10.779/2003 (closed season period) for the interval between the months of November to March (rising and flood periods; Brasil, 2003), peaks of fishing production occurred. This factor that may be responsible for the seasonal disarrangement of fisheries and the decrease in target species in the region (Doria et al., 2008; Sousa et al., 2017).

However, the quantity of species exploited in the study area (n = 37), was similar to that reported for the Humaitá region (n = 34), but lower than the value of species recorded in landings made near Porto Velho (n = 70) (Doria and Lima, 2015). Furthermore, total fish production recorded between the pre-damming (336 t year^{-1}) and post-damming (393 t year^{-1}) periods showed no significant differences ($p = 0.101$). In addition, they were similar to the values catches landed in the regions of the Guaporé River for the year 2005, which was 350 t year^{-1} (Doria et al., 2008) and the lower portion of the Madeira River, which totaled 317.7 t year^{-1} in 2011 (Doria and Lima, 2015).

The most abundant fish species in landings were also the five most sought after in the consumer market (Ruffino and Isaac, 1999), which are the majority of migrating species (curimatã, tambaqui and filhote) (Santos et al., 2006) and two sedentary fish (peacock bass and pirarucu) (Agostinho et al., 2007), which corroborates with the results of other studies conducted in the Amazon region, where these species are predominant in fishery landings in large urban centers (Carvalho and Fabré, 2006; Barthem and Goulding, 2007; Gonçalves and Batista, 2008; Espinoza et al., 2009; Doria et al., 2018). However, the species in the present study did not show significant differences between production averages for the pre- and post-damming periods.

Studies show that neotropical fish are quick to adapt to environmental variations (Agostinho et al., 2007). However, the results of this research indicate that most species recorded in landings did not present a seasonal pattern in the fisheries of the post-damming period. Thus, one can perceive an indication that the construction of the dam in the Madeira River channel is affecting the behavior of fish assemblies, mainly, because most of the fish recorded in the landings are migratory, whether they are of trophic or reproductive dispersion (Santos et al., 2006; Agostinho et al., 2007).

However, other factors may contribute to the reduction of fishery production in the Madeira River. As is the case with deforestation, which decreases the ciliary forests and thus the amount of allochthonous food available to fish communities (Claro-Jr et al., 2004; Castello and Macedo, 2016; Renó et al., 2016; Barros et al., 2020), while at the same time results in competition between species and the reduction of populations of less adapted fish (Ruffino, 2016). In addition, the absence of robust fishery legislation and continuous information on fishery statistics has hindered the proper management of fishing stocks on the border between Brazil and Bolivia (Maldonado et al., 2017; Aguilera, 2018).

The scenario of changes presented between the seasonal variation and the frequency of species in landings was also observed for sedentary species, such as traíra, piranha and cará recorded in the pre-damming period, where they were more frequent in the flood phase. In the post-damming period, landings of these species were maintained and even intensified, but in the low water phase, other sedentary species such as pirarucu, acará-açu and peacock bass were highlighted.

This is due to the fact that the study area contains many lakes that remain permanently connected, which, in addition to the introduction of species bred in fish farming, may have contributed to the current scenario of production of these species in local fishery landings (Maldonado and Goitia, 2011). Moreover, in the drought phase, both in the study region and in other regions of the Amazon basin, there is a high production of fish with a great diversity of fish species (Santos et al., 2006). This is common and due to the retraction of aquatic environments in the main channels of rivers and flooded areas, which favor the agglomeration of fish stocks and their easy capture (Sousa et al., 2017).

However, migrating species, such as large catfish of the genus *Pseudoplatystoma* and include cachara and caparari, are the most affected by the anthropization of aquatic environments (Santos et al., 2020). Nevertheless, in the present study these species showed high production in the post-damming period during the low water phase. This intensification in the exploitation of catfish has also been observed in landings in Manacaparu in the state of Amazonas, due to the high commercial value attributed to the meat of these fish species (Garcez et al., 2009).

Notwithstanding, the increase in the productivity of these fish in the post-damming period may be related to the migratory routes of these species that may have made their journey in the pre-damming period and have consequently been trapped in mountain areas. Therefore, this situation becomes unfavorable over the years, as these adult fish will gradually disappear due to natural mortality and overexploitation. Finally, it is well-known that the situation worsens in the downstream area, since it is prone to a possible disruption in the recruitment of individuals of these species (Hauser, 2018; Almeida et al., 2020).

Some other changes in the ecological dynamics of the fish communities have been observed, especially in regards to the presence of non-native species introduced into the Guaporé River Basin, which has been recorded since 2000. In addition, they already make up part of the fish stocks of the region, as is the case of the jaraqui-escama-grossa (*Semaprochilodus insignis*) and pirarucu (*Arapaima* sp.). Both are fish with high production and frequency in the landings recorded in the fishing colonies (Van Damme et al., 2012; Doria et al., 2018).

Both species mentioned above threaten the balance of native species, since the jaraqui has the habit of eating organic matter such as the roe of the other fish during the breeding periods (Santos et al., 2006), and the pirarucu presents a great threat to other fish, as it is a large and voracious carnivore which can grow up to 3 m and weigh up to 200 kg. Thus, there is an urgent need for the intensification of monitoring and control of the populations of these individuals, in areas where they are not native (Doria et al., 2020b).

It is also notable that there was a change in the richness of species and the quantities of fishery production between the pre- and post-damming periods of the Madeira River. In addition to other anthropogenic interferences, the hydropeaking that occurs in the region downstream of the Madeira's dams (Almeida et al., 2020), that may be altering the balance and behavior of fish assemblages in the upstream region of the Guaporé River basin, which directly interferes with fishing communities that use this natural resource (Pinto et al., 2019). In this context, the need for the implementation of public policies that focus on proper environmental management and safeguard fishing resources that exist in the Guaporé River Basin becomes obvious. Any new policies must aim to guarantee the preservation of fish stocks, in order to maintain the livelihoods of the various fishing communities that operate in the region.

CONCLUSION

The seasonal fishery production of the Guaporé River Basin, recorded in the periods before and after the Madeira River dams were installed, showed significant differences in the quantities of production according to the fish species and among the phases of the river. This suggests that these dams may be negatively influencing the production of fisheries in the region where the study was performed. Therefore, the areas recognized by the state government as areas of impact of the hydroelectric dams of the Madeira River should be expanded, since the results herein prove the effects of the dams on hydrological variations and fishing production. The latter is particularly important since the fisheries are based on migratory fish that have had their migratory route affected. The data presented here can help in future management plans and policy making, as well as in the assessment of possible impacts caused by new hydroelectric projects that may be planned for the Amazon basin.

ACKNOWLEDGMENTS

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001. Also, the authors would like to thank, Universidade Federal de Rondônia (UNIR) and, Research Laboratory (GP-PAEPAI) for the support and installations.

REFERENCES

Agostinho, A.A.; Gomes, L.C.; Pelicice, F.M. 2007. Ecologia e manejo de recursos pesqueiros em reservatórios do Brasil. Maringá: Eduem. 501p.

Aguilera, S.E. 2018. Measuring squid fishery governance efficacy: a social-ecological system analysis. The International Journal of the Commons, 12(2): 21-57. http://dx.doi.org/**10.18352/ijc.821**.

Almeida, J.R. 2006. Gestão ambiental para o desenvolvimento sustentável. Rio de Janeiro: Thex. p. 495-496.

Almeida, R.M.; Hamilton, S.K.; Rosi, E.J.; Barros, N.; Doria, C.R.C.; Flecker, A.S.; Fleischmann, A.S.; Reisinger, A.J.; Roland, F. 2020. Hydropeaking operations of two run-of-river mega-dams alter downstream hydrology of the largest Amazon Tributary. Frontiers in Environmental Science, 8: 120. http://dx.doi.org/**10.3389/fenvs.2020.00120**.

Almeida, R.M.; Shi, Q.; Gomes-Selman, J.M.; Wu, X.; Xue, Y.; Angarita, H.; Barros, N.; Forsberg, B.R.; García-Villacorta, R.; Hamilton, S.K.; Melack, J.M.; Montoya, M.; Perez, G.; Sethi, S.A.; Gomes, C.P.; Flecke, A. 2019. Reducing greenhouse gas emissions of Amazon hydropower with strategic dam planning. Nature Communications, 10: 4281. http://dx.doi.org/**10.1038/s41467-019-12179-5**.

ANA – Agência Nacional de Águas. 2015. Portal da qualidade das águas. Brasília: ANA. Available at: <http://www.gov.br/ana/pt-br> Accessed: 01 Oct., 2019.

ANA – Agência Nacional de Águas. 2019. Hidroweb v3.1.1. Brasília: ANA. (Séries Históricas). Available at: <http://www.snirh.gov.br/hidroweb/apresentacao> Accessed: 01 Nov., 2019.

Andrade, F.; Prado, I.G.; Loures, R.C.; Godinho, A.L. 2012. Evaluation of techniques used to protect tailrace fishes during turbine maneuvers at Três Marias Dam, Brazil. Neotropical Ichthyology, 10(4): 723-730. http://dx.doi.org/**10.1590/S1679-62252012000400005**.

Athayde, S.; Mathews, M.; Bohlman, S.; Brasil, W.; Doria, C.R.; Dutka-Gianelli, J.; Fearnside, P.M.; Loiselle, B. 2019. Mapping research on hydropower and sustainability in the Brazilian Amazon: advances, gaps in knowledge and future directions. Current Opinion in Environmental Sustainability, 37: 50-69. http://dx.doi.org/**10.1016/j.cosust.2019.06.004**.

Barros, D.F.; Petrere Junior, M.; Lecours, V.; Butturi-Gomes, D.; Castello, L.; Isaac, V.J. 2020. Effects of deforestation and other environmental variables on floodplain fish catch in the Amazon. Pesquisa de Pesca, 230: 105643. http://dx.doi.org/**10.1016/j.fishres.2020.105643**.

Barthem, R.B.; Goulding, M. 2007. Um ecossistema inesperado: a Amazônia revelada pela pesca. Belém: Sociedade Civil Mamirauá. 241p.

Batista, I.M.S.; Miranda, L.M. 2019. Os "Hidronegócios" nos rios da Amazônia. Revista Brasileira de História, 39(81): 117-139. http://dx.doi.org/**10.1590/1806-93472019v39n81-06**.

Bernardi, J.V.E.; Lacerda, L.D.; Dórea, J.G.; Landim, P.M.B.; Gomes, J.P.O.; Almeida, R.; Bastos, W.R. 2012. Aplicação da análise das componentes principais na ordenação dos parâmetros físico-químicos no alto Rio Madeira e afluentes, Amazônia Ocidental. Geochimica Brasiliensis, 23(1): 79-90.

Bittencourt, M.M.; Amadio, S.A. 2007. Proposta para a identificação rápida dos períodos hidrológicos em áreas de várzea do rio Solimões-Amazonas nas proximidades de Manaus. Acta Amazonica, 37(2): 303-308. http://dx.doi.org/**10.1590/S0044-59672007000200019**.

Bozelli, R.L.; Thomaz, S.M.; Padial, A.A.; Lopes, P.M.; Bini, L.M. 2015. Floods decrease zooplankton beta diversity and environmental heterogeneity in an Amazonian floodplain system. Hydrobiologia, 753(1): 233-241. http://dx.doi.org/**10.1007/s10750-015-2209-1**.

Brasil. 2003. Lei nº. 10.779, de 25 de novembro de 2003. Dispõe sobre a concessão do benefício de seguro desemprego, durante o período de defeso, ao pescador profissional que exerce a atividade pesqueira de forma artesanal. Diário Oficial da União, Brasília, 25 de novembro de 2003, nº. 230, Seção 1, p. 1-2.

Brasil. Ministério das Minas e Energia – MME. 2011. Plano Decenal de Expansão de Energia 2020. Brasília: MME/EPE. 88p. Available at: <https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-51/topico-88/Sum%C3%A1rio%20Executivo%20do%20PDE%202020.pdf> Accessed: 01 Nov., 2019.

Camacho Guerreiro, A.I.; Amadio, S.A.; Fabré, N.N.; Silva Batista, V. 2020. Exploring the effect of strong hydrological drought and floods on populational parameters of *Semaprochilodus insignis* (Actinopterygii: Prochilodontidae) from the Central Amazon. Environment, Development and Sustainability. http://dx.doi.org/**10.1007/s10668-020-00721-1**.

Carvalho, A.R.; Fabré, N.N. 2006. Da foz do Amazonas aos Andes. Ciência Hoje, 39(233): 64-67.

Castello, L.; Macedo, M.N. 2016. Large-scale degradation of Amazonian freshwater ecosystems. Global Change Biology, 22(3): 990-1007. http://dx.doi.org/**10.1111/gcb.13173**.

Claro-Jr, L.; Ferreira, E.; Zuanon, J.; Araujo-Lima, C. 2004. O efeito da floresta alagada na alimentação de três espécies de peixes onívoros em lagos de várzea da Amazônia Central, Brasil. Acta Amazonica, 34(1): 133-137. http://dx.doi.org/**10.1590/S0044-59672004000100018**.

COBRAPE – Companhia Brasileira de Projetos e Empreendimentos. 2005. Pareceres técnicos dos especialistas setoriais: aspectos físicos/bióticos. Relatório de análise do conteúdo dos Estudos de Impacto Ambiental (EIA) e do Relatório de Impacto Ambiental (RIMA) dos aproveitamentos hidrelétricos de Santo Antônio e Jirau no Rio Madeira, Estado de Rondônia. Porto Velho: Ministério Público do Estado de Rondônia. Available at: <http://philip.inpa.gov.br/publ_livres/2006/Parte%20B%20Vol%20I%20Relat%C3%B3rio%20Philip%20Fearnside.pdf> Accessed: 01 Nov., 2019.

Doria, C.R.C.; Araújo, T.R.; Souza, S.T.B.; Vilara, G.T. 2008. Contribuição da etnoictiologia à análise da legislação pesqueira referente ao defeso de espécies de peixes de interesse comercial no oeste da Amazônia brasileira, rio Guaporé, Rondônia, Brasil. Revista Biotemas, 21(2): 120-132. http://dx.doi.org/**10.5007/2175-7925.2008v21n2p119**.

Doria, C.R.C.; Brasil de Souza, S.T. 2012. A pesca nas Bacias dos rios Guaporé e baixo Mamoré, Amazônia Brasileira. In: Van Damme, P.A.; Maldonado M.; Pouilly, M.; Doria, C.R.C. (Eds.). Aguas del río Iténez o Guaporé; recursos hidrobiológicos de um patrimonio binacional (Bolivia y Brasil). Cochabamba, Bolivia: Edit. INIA. p. 283-294.

Doria, C.R.C.; Lima, M.A.L. 2015. Rio Madeira: seus peixes e sua pesca. Porto Velho: EDUFRO. 163p.

Doria, C.R.C.; Athayde, S.; Marques, E.E.; Lima, M.A.L.; Dutka-Gianelli, J.; Ruffino, M.L.; Kaplan, D.; Freitas, C.E.C.; Isaac, V.N. 2017. The invisibility of fisheries in the process of hydropower development across the Amazon. Ambio, 47(4): 453-465. http://dx.doi.org/**10.1007/s13280-017-0994-7**.

Doria, C.R.C.; Duponchelle, F.; Lima, M.A.L.; Garcia, A.; Carvajal-Vallejos, F.M.; Méndez, C.C.; Van Damme, P.A. 2018. Review of fisheries resource use and status in the Madeira River Basin (Brazil, Bolivia, and Peru) before hydroelectric dam completion. Reviews in Fisheries Science & Aquaculture, 26(4): 494-514. http://dx.doi.org/**10.1080/23308249.2018.1463511**.

Doria, C.R.C.; Athayde, S.; Lima, H.M.; Carvajal-Vallejos, F.M.; Dutka-Gianelli, J. 2020a. Challenges for the governance of small-scale fisheries on the Brazil-Bolivia transboundary region. Society & Natural Resources, 33(10): 1213-1231. http://dx.doi.org/**10.1080/08941920.2020.1771492**.

Doria, C.R.C.; Catâneo, D.T.B.S.; Torrente-Vilara, G.; Vitule, G.R.S. 2020b. Is there a future for artesanal fishing in the Amazon? The case of Arapaima gigas. Management of Biological Invasions, 11(1): 1-8. http://dx.doi.org/**10.3391/mbi.2020.11.1.01**.

Espinoza, J.C.; Ronchail, J.; Guyot, J.L.; Cocheneau, G.; Filizola, N.; Lavado, W.; Oliveira, E.; Pombosa, R.; Vauchel, P. 2009. Spatio-temporal rainfall variability in the Amazon basin countries (Brazil, Peru, Bolivia, Colombia, and Ecuador). International Journal of Climatology, 29(11): 1574-1594. http://dx.doi.org/**10.1002/joc.1791**.

Fearnside, P.M. 2014. Impacts of Brazil's Madeira River Dams: Unlearned lessons for hydroelectric development in Amazonia. Environmental Science & Policy, 38: 164-172. http://dx.doi.org/**10.1016/j.envsci.2013.11.004**.

Garcez, D.S.; Botero, J.I.S.; Fabré, N.N. 2009. Caracterização das pescarias de subsistência e comercial praticadas por ribeirinhos de áreas de várzea em Manacapuru, baixo Solimões, Amazonas, Brasil. Boletim Técnico-Científico do CEPNOR, 9(1): 43-65. http://dx.doi.org/**10.17080/1676-5664/btcc.v9n1p43-66**.

Garzon, L.F.N. 2019. Hidrelétricas no rio Madeira: desastre como meta e norma. Revista Científica FOZ, 2(1): 120-142.

Gonçalves, C.; Batista, V.S. 2008. Avaliação do desembarque pesqueiro efetuado em Manacapuru, Amazonas, Brasil. Acta Amazonica, 38(1): 135-144. http://dx.doi.org/**10.1590/S0044-59672008000100015**.

Greenacre, M.J. 2017. Correspondence analysis in practice. 3rd ed. Boca Raton: Chapman & Hall/CRC. 326p.

Harris, J.H.; Kingsford, R.T.; Peirson, W.; Baumgartner, L.J. 2016. Mitigating the effects of barriers to freshwater fish migrations: the Australian experience. Marine and Freshwater Research, 68(4): 614-628. https://doi.org/**10.1071/MF15284**.

Hauser, M. 2018. Migração dos grandes bagres amazónicos pela perspectiva dos isótopos de estrôncio em otólitos. Porto Velho. 156f. (Doctoral Thesis. Universidade Federal de Rondônia – UNIR). Available at: <http://www.ri.unir.br/jspui/bitstream/123456789/2659/1/ Tese_Mari%CC%81lia%20Hauser-4.9MB.pdf> Accessed: 01 Feb., 2021.

Inomata, S.A.; Gonzalez, G.O.; Maria, A.; Roman, S.; Máximo, R.; Souza, L.A.; Freitas, C.E.C. 2018. Sustainability of small-scale fisheries in the middle Negro River (Amazonas - Brazil): A model with operational and biological variables. Ecological Modelling, 368: 312-320. http://dx.doi.org/**10.1016/j.ecolmodel.2017.11.025**.

Isaac, V.J.; Castello, L.; Santos, P.R.B.; Ruffino, M.L. 2016. Seasonal and interannual dynamics of river floodplain multispecies fisheries in relation to flood pulses in the Lower Amazon. Fisheries Research, 183: 352-359. http://dx.doi.org/**10.1016/j.fishres.2016.06.017**.

Lima, M.A.; Doria, C.R.; Carvalho, A.R.; Angelini, R. 2020. Fisheries and trophic structure of a large tropical river under impoundment. Ecological Indicators, 113: 106162. http://dx.doi.org/**10.1016/j.ecolind.2020.106162**.

Maldonado, A.G.; Lopes, P.F.M.; Fernandez, C.A.R.; Alcala, C.A.L.; Sumalia, U.R. 2017. Transboundary fisheries management in the Amazon: Assessing current policies for the management of the ornamental silver arawana (*Osteoglossum bicirrhosum*). Marine Policy, 76: 192-199. http://dx.doi.org/**10.1016/j.marpol.2016.11.021**.

Maldonado, M.; Goitia, E. 2011. La cuenca del río Iténez en Bolivia: descripción ecológica. In: Van Damme, P.A.; Maldonado, M.; Pouilly, M.; Doria, C.R.C. (Eds.). Aguas del río Iténez o Guaporé; recursos hidrobiológicos de um patrimonio binacional (Bolivia y Brasil). Cochabamba, Bolivia: Ed. INIA. p. 5-25.

Pinto, M.D.S.; Dória, C.R.C.; Marques, E.E. 2019. Alterações temporais sobre a estrutura funcional das assembleias de peixes durante onze anos de formação de um reservatório do médio rio Tocantins, Brasil. Biota Amazônia, 9(1): 17-21.

Prado, I.G.; Andrade, F.; Monteiro, A.B.; Sousa, R.C.R.; Godinho, A.L. 2016. Influência de fatores abióticos na captura e condição de peixes imediatamente a jusante da usina hidrelétrica de Três Marias, rio São Francisco. In: Loures, R.C.; Godinho, A.L. (Eds.). Avaliação de risco de morte de peixes em Usinas Hidrelétricas. Belo Horizonte: Companhia Energética de Minas Gerais. p. 231-245.

Renó, V.F.; Novo, E.M.L.M.; Escada, M.I.S. 2016. Forest fragmentation in the lower Amazon floodplain: implications for biodiversity and ecosystem service provision to riverine populations. Remote Sensing, 8(11): 886. http://dx.doi.org/**10.3390/rs8110886**.

Rodrigues, L.C.; Simões, N.R.; Bovo-Scomparin, V.M.; Jati, S.; Santana, N.F.; Roberto, M.C.; Train, S. 2015. Phytoplankton alpha diversity as an indicator of environmental changes in a Neotropical floodplain. Ecological Indicators, 48: 334-341. http://dx.doi.org/**10.1016/j.ecolind.2014.08.009**.

Rondônia. SEDAM - Secretaria de Estado do Desenvolvimento Ambiental. 2018. Plano Estadual de Recursos Hídricos do Estado de Rondônia. Available at: <http://data.portal.sistemas.ro.gov.br/2019/02/RELATORIO-FINAL.pdf> Accessed: 01 Nov., 2019.

Ruffino, M.L. 2016. A gestão dos recursos pesqueiros no Brasil. In: Araujo, M.A.R. (Ed.). Repensando a gestão ambiental no Brasil: contribuição ao debate de reconstrução nacional. Belo Horizonte: Autor. p. 7-22.

Ruffino, M.L.; Isaac, V.J. 1999. Dinâmica populacional do Surubim-tigre, *Pseudoplatystoma tigrinum* (Valenciennes, 1840) no médio Amazonas (Siluriformes, Pimelodidae). Acta Amazonica, 29(3): 463. http://dx.doi.org/**10.1590/1809-43921999293476**.

Santos, G.M.D.; Efrem, J.; Ferreira, G.; Zuanon, J.A.S. 2006. Peixes comerciais de Manaus. Manaus: Ibama/AM, ProVarzea. 144p.

Santos, R.E.; Pinto-Coelho, R.M.; Drumond, M.A.; Fonseca, R.; Zanchi, F.B. 2020. Damming Amazon Rivers: Environmental impacts of hydroelectric dams on Brazil's Madeira River according to local fishers' perception. Ambio, 49: 1612-1628. http://dx.doi.org/**10.1007/s13280-020-01316-w**.

Santos, R.E.; Pinto-Coelho, R.M.; Fonseca, R.; Simões, N.R.; Zanchi, F.B. 2018. The decline of fisheries on the Madeira River, Brazil: the high cost of the Hydroelectric Dams in the Amazon Basin. Fisheries Management and Ecology, 25(5): 380-391. http://dx.doi.org/**10.1111/fme.12305**.

Sousa, R.G.; Freitas, C.E.D.C. 2008. The influence of flood pulse on fish communities of floodplain canals in the Middle Solimões River, Brazil. Neotropical Ichthyology, 6(2): 249-255. http://dx.doi.org/**10.1590/S1679-62252008000200013**.

Sousa, R.G.C.; Souza, L.A.; Frutuoso, M.E.; Freitas, C.E.C. 2017. Seasonal dynamic of Amazonian small-scale fisheries is dictated by the hydrologic pulse. Boletim do Instituto de Pesca, 43(2): 207-221. http://dx.doi.org/**10.20950/1678-2305.2017v43n2p207**.

StatSoft Inc. 2009. Statistica (Data Analysis Software Systems), version 9.0. Tulsa: StatSoft. Available at: <www.statsoft.com> Accessed: 01 Feb., 2021.

Thomaz, S.M.; Bini, L.M.; Bozelli, R.L. 2007. Floods increase similarity among aquatic habitats in river-floodplain systems. Hydrobiologia, 579(1): 1-13. http://dx.doi.org/**10.1007/s10750-006-0285-y**.

Timpe, K.; Kaplan, D. 2017. The changing hydrology of a dammed Amazon. Science Advances, 3(11): e1700611. http://dx.doi.org/**10.1126/sciadv.1700611**.

Torrente-Vilara, G.; Cella-Ribeiro, A.; Hauser, M.; Freitas, M.H.; Doria, C.R.C.; Zuanon, J. 2018. Spatial segregation between *Chalceus guaporensis* and *Chalceus epakros* (Osteichthyes: Characiformes) in the Madeira River, Amazon Basin. Acta Amazonica, 48(3): 239-247. http://dx.doi.org/**10.1590/1809-4392201703022**.

Torrente-Vilara, G.; Doria, C.R.C. 2012. Categorização e duração dos períodos hidrológicos do rio Guaporé. In: Van Damme, P.A.; Maldonado, M.; Poully, M.; Doria, C.R.C. (Eds.). Aguas del Iténez o Guaporé: recursos hidrobiológicos de un patrimonio binacional (Bolivia y Brasil). Cochabamba, Bolivia: Editorial INIA. 420p.

Triola, M.F. 1998. Introdução à estatística. 7ª ed. Rio de Janeiro: LTC. 410p.

Val, A.L.; Fearnside, P.M.; Val, V.M.F. 2016. Environmental disturbances and fishes in the Amazon. Journal of Fish Biology, 89(1): 192-193. http://dx.doi.org/**10.1111/jfb.12896**.

Van Damme, P.A.; Maldonado, M.; Poully, M.; Doria, C.R.C. 2012. Aguas del Iténez o Guaporé: recursos hidrobiológicos de un patrimonio binacional (Bolivia y Brasil). Cochabamba, Bolivia: Editorial INIA. 420p.

Vasconcelos, L.P.; Súarez, Y.R.; Lima-Junior, S.E. 2011. Aspectos populacionais de *Bryconamericus stramineus* em riachos da bacia do alto rio Paraná, Brasil. Biota Neotropica, 11(2): 55-62. http://dx.doi.org/**10.1590/S1676-06032011000200006**.