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

SPATIAL AND SEASONAL VARIATION OF PEACOCK BASS (*Cichla* spp.) FISHERY: AN ANALYSIS OF CATCHES LANDED IN MANAUS, AMAZONAS STATE, BRAZIL*

Glenda Katherine de Souza DIAS[1]*
Lucirene Aguiar de SOUZA[2]
Carlos Edwar de Carvalho FREITAS[2]

[1]Instituto Nacional de Pesquisas da Amazônia – INPA, Programa de Pós-graduação em Biologia de Água Doce e Pesca Interior. Av. André Araújo, 2936, Petrópolis, CEP: 69067- 375, Manaus, AM, Brazil. g.k.souzadias@gmail.com (*corresponding author)

[2]Universidade Federal do Amazonas – UFAM, Faculdade de Ciências Agrárias, Departamento de Ciências Pesqueiras. Av. General Rodrigo Otávio, 3000, Coroado, CEP: 69.080-900, Manaus, AM, Brazil.

*This study was financed in part by the Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq (136368/2017-4).

Received: June 23, 2020
Approved: October 27, 2020

ABSTRACT

This study analysed the commercial fishing for peacock bass (*Cichla* spp.) and its variation according to the river regime and the fishing environments, based on landing data in Manaus. The landing data were provided by the Z-12 Fishermen's Association and the monthly quotas (m) of Rio Negro by the National Water Agency, corresponding to the years 2012 and 2013. The Catch per Unit of Effort (CPUE) was obtained by dividing the total catch and the number of boats. A Generalized Linear Model was used to analyse the relationship between CPUE and the river level. Through the Analysis of Variance we compared the averages of capture between the fishing areas and Fisher's LSD test revealed which environments had different capture averages. Student's t-test was used to compare the mean of capture between white and black water environments. The largest catches and CPUEs occurred during receding water, and the relationship between CPUE and river level was inverse. Black water environments obtained the highest CPUEs, as well as the highest capture averages. There were differences in the average catches between fishing areas, but not between water types. This study shows how peacock bass exploitation occurs and can assist in management measures for this species.

Keywords: fishing production; river regime; CPUE; freshwater fishery.

VARIAÇÃO ESPACIAL E SAZONAL DA PESCA DO TUCUNARÉ (*Cichla* spp.): UMA ANÁLISE DAS CAPTURAS DESEMBARCADAS EM MANAUS, ESTADO DO AMAZONAS, BRASIL

RESUMO

Este estudo analisou a pesca comercial do tucunaré (*Cichla* spp.) e sua variação de acordo com o regime do rio e os ambientes de pesca, com base em dados de desembarque em Manaus. Os dados de desembarque foram fornecidos pela Associação dos Pescadores Z-12 e as cotas mensais (m) do Rio Negro pela Agência Nacional de Águas, correspondentes aos anos de 2012 e 2013. A Captura por Unidade de Esforço (CPUE) foi obtida pela divisão da captura total e o número de barcos. Um modelo linear generalizado foi usado para analisar a relação entre a CPUE e o nível do rio. Por meio da Análise de Variância comparamos as médias de captura entre as áreas de pesca e o teste LSD de Fisher revelou quais ambientes apresentaram diferentes médias de captura. O teste t de Student foi usado para comparar a média de captura entre ambientes de água branca e preta. As maiores capturas e CPUEs ocorreram durante o recuo da água, e a relação entre a CPUE e o nível do rio foi inversa. Ambientes de águas negras obtiveram as maiores CPUEs, bem como as maiores médias de captura. Houve diferenças nas capturas médias entre as áreas de pesca, mas não entre os tipos de água. Este estudo mostra como ocorre a exploração do tucunaré e pode auxiliar nas medidas de manejo dessa espécie.

Palavras-chave: produção pesqueira; regime fluvial; CPUE; pesca de água doce.

INTRODUCTION

The Amazon basin encompasses a huge and complex ecosystem, including several aquatic habitats and sub-basins, which are limnologically distinct and broadly classified by the color of the water: black, clear and whitewater (Val et al., 2010). The hydrological cycle is another source of complexity. The intra-annual oscillation, with effects clearly defined in the flood pulse concept (Junk et al., 1989), promotes substantial changes in the environment, connecting and isolating habitats by the alternating seasons of high and low water (Bittencourt and Amadio, 2007; Hurd et al., 2016). Inter-annual climate events, such as El Niño and La Niña, could exacerbate the annual seasonality effects and cause critical impacts on the environment and its biota (Marengo and Oliveira, 1998; Freitas et al., 2012).

The Amazonian environment hosts one of the most important commercial freshwater fisheries on Earth, and the exploitation of abundant fish stocks, which are the main source of animal protein for riverine populations, generates income for small-scale fishers (Santos and Santos, 2005; Cardoso and Freitas, 2007). The peacock bass (*Cichla* spp.) is a genus of large cichlids, regionally known as *tucunaré* and, in commercial and recreational fisheries, has a high value (Batista and Petrere Júnior, 2003; Santos and Santos, 2005). It is a sedentary and piscivorous species, which preferentially inhabits lentic habitats, such as lakes and stretches of rivers with slow currents. It is a parental care fish, breeding predominantly during the receding water season (Andrade et al., 2001; Nascimento et al., 2001; Rabelo and Araújo-Lima, 2002; Gandra, 2010; Campos et al., 2015; Souza et al., 2015).

Although the peacock bass (*Cichla* spp.) has a high value in the regional markets and, as a consequence, is important to the commercial fisheries in the Amazon, there are few studies that analyze its catch sizes. This study describes the seasonal and spatial patterns of peacock bass fishery, based on catch data for fish landed in Manaus, the main urban center in the central portion of the Amazon basin. For this, we tested the following hypotheses: 1) The catches of the peacock bass vary according to the fishing environment; 2) The catches of the peacock bass vary according to the water type.

MATERIAL AND METHODS

Study Area

The catches landed at the Panair port in Manaus are caught all over the Amazonas state, thus the whole state was defined as the study area (Figure 1). Data regarding fish captures and fishing effort were collected at the Panair port, the main fish-landing site in Manaus and the capital of the Amazonas state. Manaus is a city with more than 2 million inhabitants, of which about 120 thousand are directly linked to fishing activity (Gandra, 2010), with most of the fish caught in the Amazon River basin being landed in the city.

Data Collection

Interviewers belonging to the Z-12 Fishers Association collected the catch data for 2012 and 2013, as well as information regarding the fishing fleet. Data were collected daily at the Panair port, though interviews with the fishers during fish landings. Hydrological data measured at the fluvial station in Manaus, where the water levels of the Negro River have been measured since 1901, were obtained from the Brazilian National Water Agency (Agência Nacional de Águas). The year 2012 was marked by the historic flood recorded on May 29 when the Rio Negro reached the 29.97 m level (Satyamurty et al., 2013). Several studies were consulted in order to correctly classify the rivers and lakes by

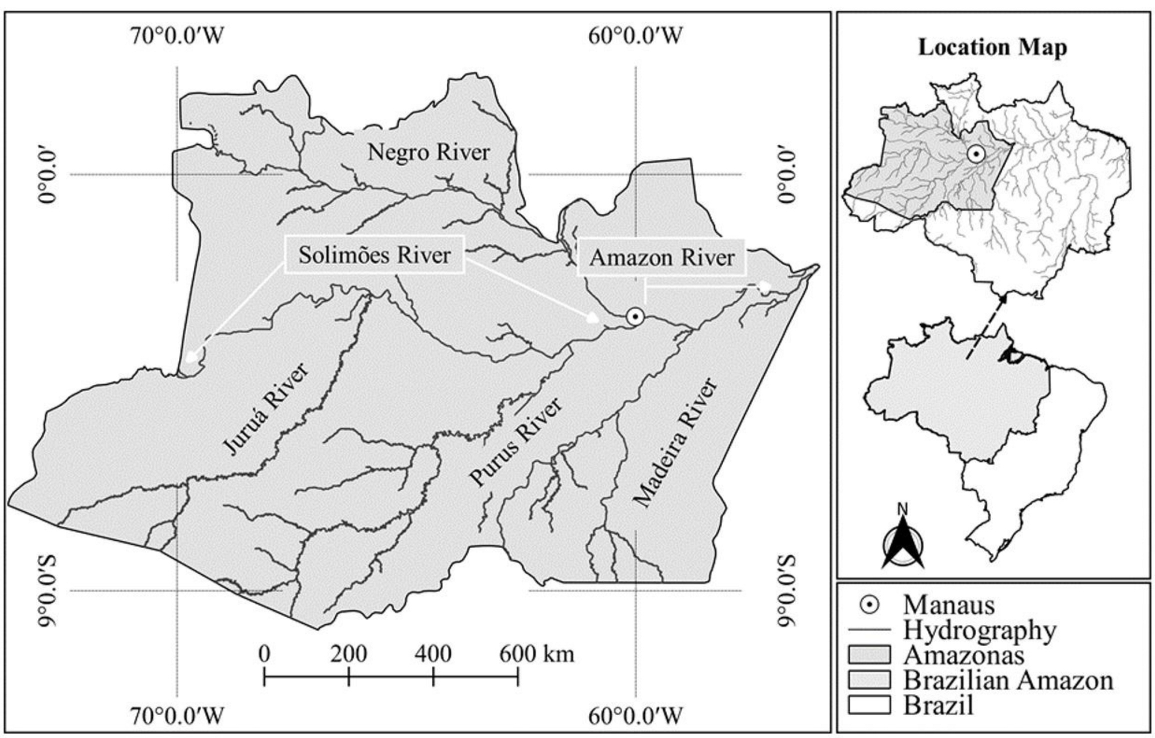

Figure 1. The Amazonas state, including its main rivers and the city of Manaus, where the Panair port is located.

their type of water (Guarim, 1979; Santos and Ribeiro, 1988; Cravo et al., 2002; Barthem and Goulding, 2007; Lages, 2010; Horbe et al., 2013; Silva, 2013).

Data Analysis

Capture data were clustered as catches (kg) per boat, catches (kg) per river. Afterwards, the rivers were classified by their type of water, in sensu Sioli (1968), as black and whitewater, and the data also was stored as catches (kg) per type of water. The Catch per Unit of Effort (CPUE) is an estimate of the abundance of fish stock (Sparre, 1997) and was estimated using the equation:

$$CPUE = \frac{P}{E} \quad (1)$$

where, P is the monthly landed catch and E is the fishing effort, assumed as the number of boats.

A generalized linear model using the log-transformed CPUE monthly estimate as the response variable, and a quadratic function of the monthly average of the water level as the explanatory variable, was employed to evaluate the influence of the hydrological cycle on the peacock bass fishing yield. Akaike Information Criterion (AIC) was used as criteria to evaluate the model's fit. Packages *car* (Fox and Weisberg, 2019), *ggplot2* (Wickham, 2016) and *MASS* (Venables and Ripley, 2002) from the Software R (R Core Team, 2019) were employed for modeling.

An analysis of variance (ANOVA) was performed to test the null hypothesis that the fishing yield is the same for all rivers. As this hypothesis was rejected, a paired Fisher test (LSD) was performed. This post hoc test is more appropriate, since the quantity of data per fishing ground is different. A Student's t test was performed to test the hypothesis that the fishing yield is the same for each type of water: black and whitewater. The ANOVA, Fisher test and t test were done using the software STATISTICA (Weiß, 2007).

RESULTS

The total landings of peacock bass (*Cichla* spp.) were 548,190 kg and 430,010 kg in 2012 and 2013, respectively (Figure 2). The largest catches for both years were observed at the end of the period of receding water (October), with 133,630 kg in 2012 and 82,650 kg in 2013. In contrast, the period of rising water showed the smallest catches; April 2012 registered catches of 1,900 kg, and May 2013, 1,650 kg. There was a historic flood of the Negro River in 2012 (Satyamurty et al., 2013) and no peacock bass were landed in May of this year.

In total, 208 and 252 fishing boats were responsible for the catches of 2012 and 2013, respectively. The total CPUE estimated for 2012 was 10,170.00 ± 423.92 (kg/number of boats) and, for 2013, total estimated CPUE was 9,648.60 ± 368.67 (kg/number of boats). For both years, the smallest CPUEs were in May and June, during the high-water season. And the greatest CPUEs for both years were reached in October, during the period of receding water (Figure 3).

The GLMs indicate the negative relationship between the CPUE and the water level for both years. Nevertheless, the explained deviance of the model for 2012 ($p<0.001$) accounted for 68.29% (Figure 4) and was substantially higher than in 2013 ($p = 0.0359$), when it accounted for only 36.98% (Figure 5).

In 2012, the catches of peacock bass occurred in 27 fishing grounds (rivers and lakes). However, in 2013, just 23 fishing grounds were exploited. The Manaquiri River, which is a blackwater environment, achieved the greatest CPUE (4,600 kg/number of boats) in 2012 (Figure 6). While the Coari River, also a blackwater system, showed the highest CPUE (2,344.83 kg/number of boats) in 2013 (Figure 6). Nevertheless, the location that most contributed to the total catches, taking the two years together, was the Purus River (336,450 kg), which is a whitewater environment. This river was

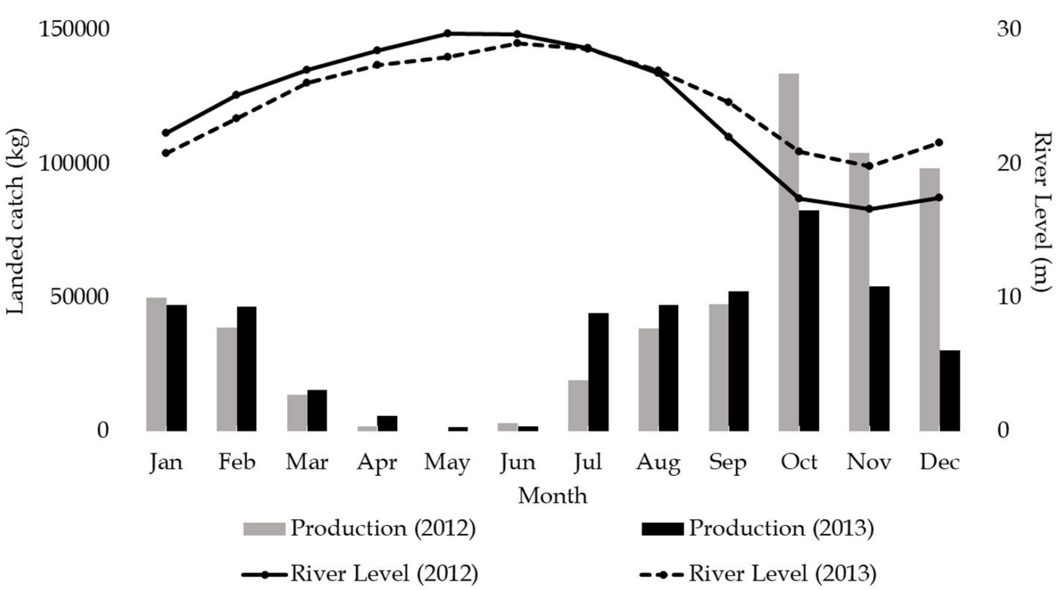

Figure 2. Monthly catches of peacock bass (*Cichla* spp.) and water levels of the Negro River, for 2012 and 2013.

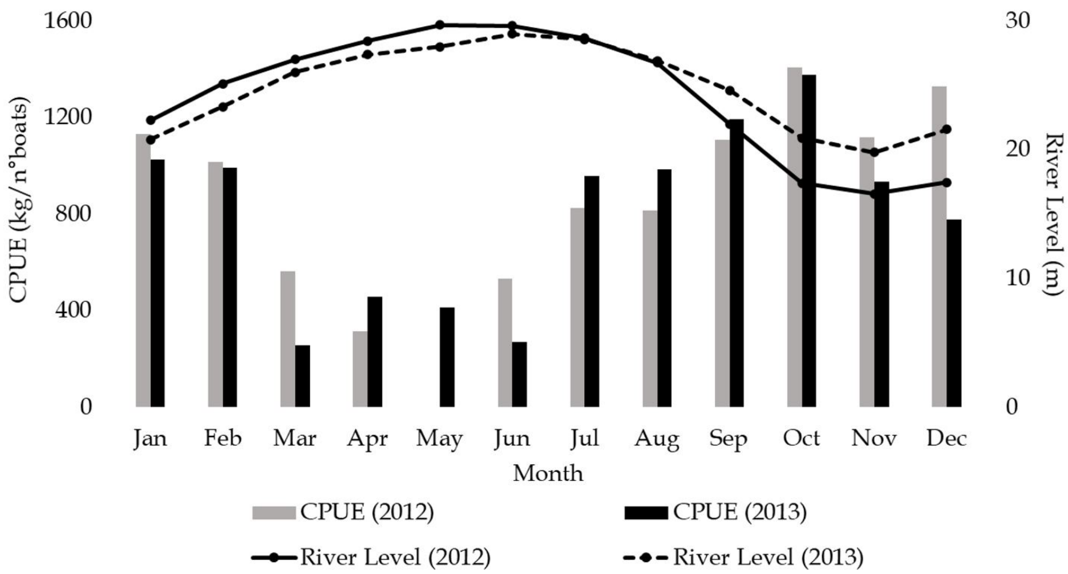

Figure 3. Monthly CPUE (kg/number of boats) for peacock bass (*Cichla* spp.) and the water levels in 2012 and 2013.

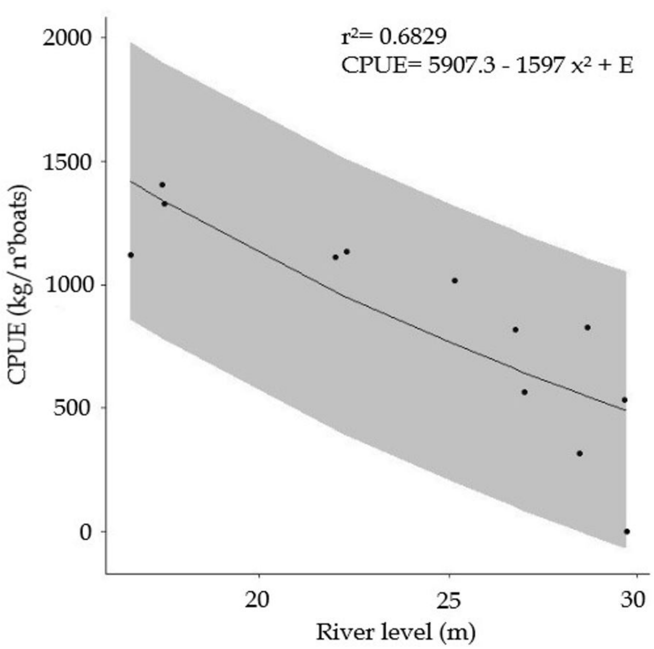

Figure 4. Relationship between the CPUE (kg/number of boats) in 2012 – gray area represents the confidence interval.

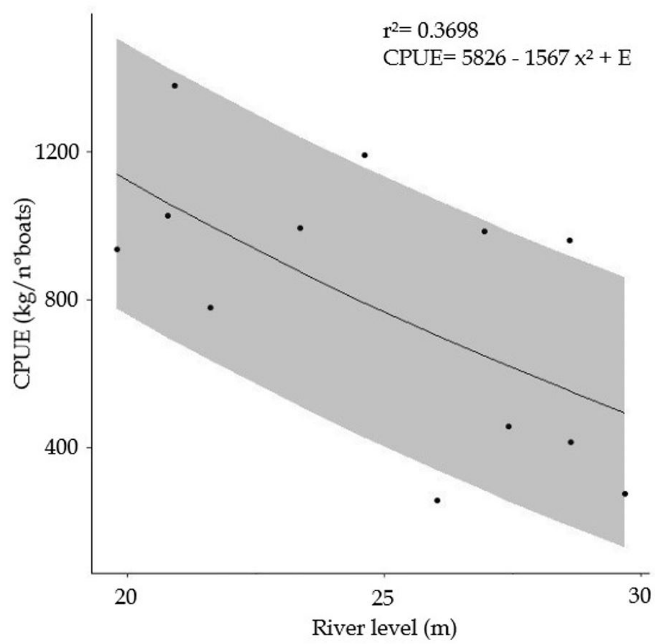

Figure 5. Relationship between the CPUE (kg/number of boats) in 2013 – gray area represents the confidence interval.

also the most exploited area, with 95 and 130 boats fishing them in 2012 and 2013, respectively.

There are differences in fishing yields among the fishing grounds for 2012 (df = 26, F = 6.037, p<0.001) and 2013 (df = 22, F = 1.80, p = 0.0145). The LSD test shows that there were just two groups of fishing grounds per fishing yield, both for 2012 and 2013 (Table 1). On the other hand, the fishing yield was the same according to type of water, both in 2012 (df = 574, t = - 0.743, p = 0.452) and 2013 (df = 495, t = - 1.31, p = 0.189).

DISCUSSION

The largest fishing yield of peacock bass, observed during receding water season, corroborated the pattern observed, which indicated that this season presents better conditions for fisheries of lake species (Rabelo and Araújo-Lima, 2002; Muñoz, 2006; Alves and Barthem, 2008). In the receding water season, when the habitat of the flooded forest becomes smaller, the peacock bass moves toward open water where it is easier to catch. This

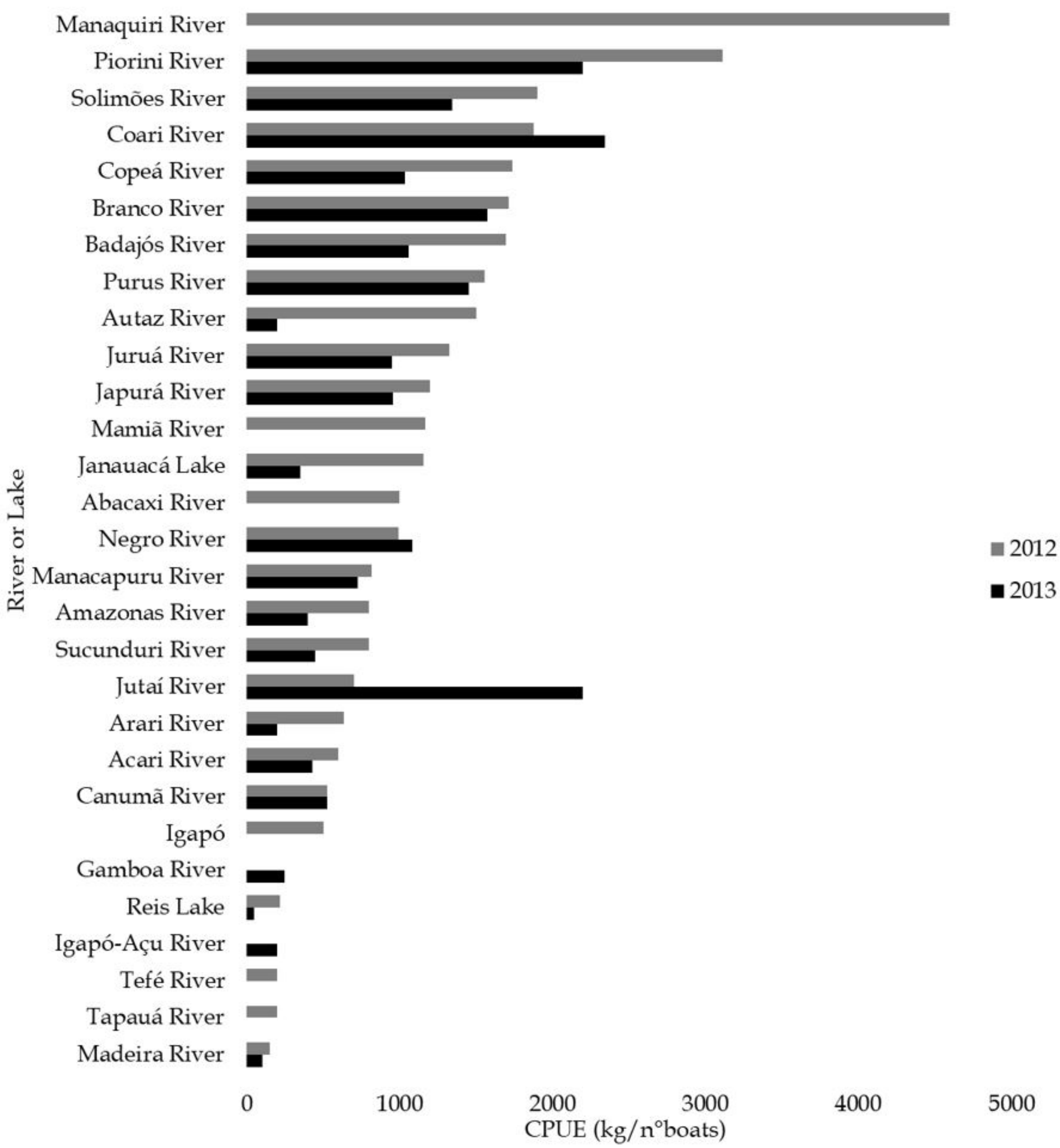

Figure 6. Peacock bass CPUEs estimated per fishing ground, in 2012 and 2013.

synchronic movement of the peacock bass with the water level is also related to greater prey availability near the banks of the rivers and lakes during this season (Rabelo and Araújo-Lima, 2002; Aguiar-SANTOS et al., 2018). Other studies also indicated the variability of landings according to river regime (Isaac et al., 2015; Sousa et al. 2017; Lopes and Freitas, 2018). The peacock bass is among the main species landed, not only in the present study area (Faria Junior and Batista, 2019), but also in other regions (Silva et al., 2017) and in reservoirs where it was introduced (Agostinho et al. 2007; Novaes et al., 2015).

The inverse relationship between peacock bass catches and water level could be exacerbated in years of extreme floods, such as happened in 2012 (Cerdeira et al., 2000; Barthem and Fabré, 2004). Zuanon (2008) explains that extreme flooding events could be favorable to the fish stocks, since strong recruitments one or two years after these events could produce profitable fisheries, due the increase of juvenile survivors as consequence of higher availability of refuges against predators and food. This pattern could describe more accurately what happens with several migratory characins, which explore the floodplain habitats for nursery (Ruffino, 2014). Considering the feeding habit of the peacock bass that seeks its prey in the flooded areas, the high water levels may be unfavorable for this species, since the high water level can increase the availability of refuge for its prey (Martelo et al., 2008; Siqueira-Souza et al., 2016).

Table 1. Catch areas identified on landing of peacock bass (*Cichla* spp.) catches for the years 2012 and 2013 and classified according to statistical significance by the LSD test. a = p<0.005, b = p>0.05.

River or Lake			
2012		2013	
Manaquiri River (mean: 3,066.7)	a	Jutaí River (mean: 2,200.0)	a
Piorini River (mean: 2,621.1)	a	Piorini River (mean: 2,000.0)	a
Badajós River (mean: 1,440.0)	a	Coari River (mean: 1,172.4)	a
Juruá River (mean: 1,325.0)	a	Badajós River (mean: 1,057.1)	a
Solimões River (mean: 1,237.9)	a	Japurá River (mean: 954.55)	a
Copeá River (mean: 1,215.0)	a	Juruá River (mean: 953.33)	a
Mamiã River (mean: 1,166.7)	a	Copeá River (mean: 922.22)	a
Coari River (mean: 1,080.0)	a	Purus River (mean: 853.62)	a
Abacaxi River (mean: 1,000.0)	a	Branco River (mean: 846.34)	a
Purus River (mean: 923.75)	a	Solimões River (mean: 840.63)	a
Branco River (mean: 847.53)	a	Negro River (mean: 831.67)	a
Japurá River (mean: 815.91)	a	Acari River (mean: 430.0)	a
Manacapuru River (mean: 745.45)	a	Janaucá Lake (mean: 350.0)	a
Negro River (mean: 707.25)	a	Sucunduri River (mean: 300.0)	a
Jutaí River (mean: 700.0)	a	Manacapuru River (mean: 241.67)	a
Sucunduri River (mean: 640.0)	a	Gamboa River (mean: 166.67)	a
Janaucá Lake (mean: 614.90)	a	Arari River (mean: 142.86)	a
Acari River (mean: 600.0)	a	Madeira River (mean: 100.0)	a
Amazonas River (mean: 600.0)	a	Reis Lake (mean: 50.0)	a
Canumã River (mean: 525.0)	a	Canumã River (mean: 525.0)	b
Igapó (mean: 500)	a	Amazonas River (mean: 400.0)	b
Arari River (mean: 318.75)	a	Autaz River (mean: 200.0)	b
Tapauá River (mean: 200.0)	a	Igapó-Açu River (mean: 200.0)	b
Tefé River (mean: 200.0)	a		
Reis Lake (mean: 176.0)	a		
Madeira River (mean: 150.0)	a		
Autaz River (mean: 1,500.0)	b		

The fishing yield of peacock bass is consistently higher in blackwater environments when compared to those in whitewater ones. Amazonian blackwater rivers host several species of peacock bass, including *Cichla temensis,* which is the largest of all (Holley et al., 2008; Campos et al., 2019) and is the main target species for recreational fishers (Barroco et al., 2018). Nevertheless, it is important to clarify that some fishing grounds, which are classified as blackwater environments, are rivers and their associated lakes with headwaters in the Amazon sedimentary plain, which are different from the true blackwater systems with headwaters in the Guyana Plateau. The rivers Manaquiri, Coari and Jutaí are typically of the first category, since they are tributaries of the Solimões River, a typical whitewater river (Santos and Ribeiro, 1988; Trevisan and Forsberg, 2007; Barbosa et al., 2016; Moquet et al., 2016). The waters of these tributaries remain black during low water seasons and are greatly influenced by the Solimões River during high-water seasons (Sousa, 2005). The ria lake systems formed near the confluence of these tributaries and the main stem of the Solimões river (Bertani et al., 2015) and seem to be preferential habitats for peacock bass (Sousa, 2005).

The Purus River is a traditional fishing area in the Amazon Basin (Petrere Júnior, 1985; Batista and Petrere Júnior, 2003), and the high levels of exploitation of this basin over the year could explain the reduced CPUE estimates seen in our study. Batista and Petrere Júnior (2003) stated that the greater part of the capture of k strategist species, such as peacock bass, landed in Manaus is caught in the floodplain lakes of the Purus River basin. Actually, studies on the total fish production showed that this basin is the most productive followed by the Solimões, Madeira, Amazonas and Juruá Rivers (Sousa, 2005; Corrêa et al., 2018). During the years 2012 and 2013, Corrêa et al. (2018) found that the Purus River fisheries' contribution to the total capture landed in Manaus was 29.72% and 33.19%, respectively.

The broad distribution of the pool of *Cichla* species in the Amazon basin, with some of them, such as *C. temensis* and

C. orinocencis, inhabiting blackwater environments and others, such as *C. monoculus*, *C. piquiti*, *C. melanie*, *C. thyrorus* and *C. jarina*, whitewater environments are all known in the Amazon basin by the same common name "tucunaré". This fact could explain the absence of differences in catches by water type. Willis et al. (2015) and Sousa et al. (2016) highlight how *C. temensis* remains in environments with similar characteristics, confirming the species' low vagility. Since *Cichla* has non-migratory behavior, it is clear that stock assessment studies and management proposals should be developed per species in specific areas of the basin (Santos et al., 2012). Campos and Freitas (2014) detected an over-fishing status for *C. monoculus* which is caught in a floodplain area of the lower stretch of the Solimões River.

CONCLUSIONS

The highest captures and CPUE of peacock bass during the receding water indicates this period as the best for capturing this species. The non-landing of this species in an atypical flood year, suggests that this is unfavorable for commercial fishing. During low level water period, with less effort it is possible to make large captures, hence the relationship between the river level and CPUE is inverse, since as the river level decreases, CPUE increases.

The exploitation of commercial fishing occurs mainly in whitewater environments and it is multi specific, which reflected in the peacock bass capture data in this study. Even so, the largest CPUEs in blackwater environments, such as lakes, and rivers with the characteristics of lakes, reveal that in these types of water bodies there is less effort in capturing this species.

Due to the fact that the focus of this study was commercial fishing, in order to gain a better understanding of whether there really is a greater abundance of peacock bass in any of the different types of water (white or black water) or waterbodies (river, lakes), an analysis of experimental fisheries in each aquatic system is necessary. Studies such as the aforementioned can shed light on how the exploitation of the peacock bass occurs and can help manage fisheries of this species.

REFERENCES

Agostinho, A.A.; Pelicice, F.M.; Petry, A.C.; Gomes, L.C.; Júlio Jr., H.F. 2007. Fish diversity in the upper Paraná River basin: habitats, fisheries, management and conservation. Aquatic Ecosystem Health & Management, 10(2): 174-186. http://dx.doi.org/10.1080/14634980701341719.

Aguiar-Santos, J.; de Hart, P.A.P.; Pouilly, M.; Freitas, C.E.C.; Siqueira-Souza, F.K. 2018. Trophic ecology of speckled peacock bass *Cichla temensis* Humboldt 1821 in the middle Negro River, Amazon, Brazil. Ecology Freshwater Fish, 27(4): 1076-1086. http://dx.doi.org/10.1111/eff.12416.

Alves, M.C.B.; Barthem, R.B. 2008. A pesca comercial dos "tucunarés" *Cichla* spp. (Perciformes, Cichlidae) no reservatório da UHE-Tucuruí, rio Tocantins, PA. Boletim do Instituto de Pesca, 34(4): 553-561.

Andrade, F.; Schneider, H.; Farias, I.; Feldberg, E.; Sampaio, I. 2001. Análise filogenética de duas espécies simpátricas de tucunaré (*Cichla*, Perciformes), com registro de hibridização em diferentes pontos da bacia Amazônica. Revista Virtual de Iniciação Acadêmica da UFPA, 1(1): 1-11.

Barbosa, P.M.; Melack, J.M.; Farjalla, V.F.; Amaral, J.H.F.; Scofield, V.; Forsberg, B.R. 2016. Diffusive methane fluxes from Negro, Solimões and Madeira rivers and fringing lakes in the Amazon basin. Limnology and Oceanography, 61(S1): S221-S237. http://dx.doi.org/**10.1002/lno.10358**.

Barroco, L.S.A.; Freitas, C.E.C.; Lima, Á.C. 2018. Estimation of peacock bass (*Cichla* spp.) mortality rate during catch-release fishing employing different post-capture procedures. Brazilian Journal of Biology = Revista Brasileira de Biologia, 78(2): 195-201. http://dx.doi.org/**10.1590/1519-6984.18915**.

Barthem, R.B.; Fabré, N.N. 2004. Biologia e diversidade dos recursos pesqueiros da Amazônia. In: Ruffino, M. L. A pesca e os recursos pesqueiros na Amazônia brasileira. Manaus: Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis/Provárzea. p. 17-62.

Barthem, R.B.; Goulding, M. 2007. Um ecossistema inesperado. Belém: Amazon Conservation Association (ACA) and Sociedade Civil Mamirauá. 241p.

Batista, V.D.S.; Petrere Júnior, M. 2003. Characterization of the commercial fish production landed at Manaus, Amazonas State, Brazil. Acta Amazonica, 33(1): 53-66.

Bertani, T.C.; Rossetti, D.F.; Hayakawa, E.H.; Cohen, M.C.L. 2015. Understanding Amazonian fluvial rias based on a Late Pleistocene–Holocene analog. Earth Surface Processes and Landforms, 40(3): 285-292. http://dx.doi.org/10.1002/esp.3629.

Bittencourt, M.M.; Amadio, S.A. 2007. Proposta para identificação rápida dos períodos hidrológicos em áreas de várzea do rio Solimões-Amazonas nas proximidades de Manaus. Acta Amazonica, 37(2): 303-308.

Campos, C.P.; Catarino, M.F.; Freitas, C.E.C. 2019. Stock assessment of the peacock bass *Cichla temensis* (Humboldt, 1821), an importante fishing resource from the Midlle Negro River, Amazonas, Brazil. Brazilian Journal of Biology = Revista Brasileira de Biologia, 80(3): 506-510. http://dx.doi.org/**10.1590/1519-6984.203124**.

Campos, C.P.; Freitas, C.E.C. 2014. Yield per recruit of the peacock bass *Cichla monoculus* (Spix and Agassiz, 1831) caught in Lago Grande at Manacapuru (Amazonas – Brazil). Brazilian Journal of Biology = Revista Brasileira de Biologia, 74(1): 226-230. http://dx.doi.org/**10.1590/1519-6984.17312**.

Campos, C.P.; Freitas, C.E.C.; Amadio, S. 2015. Growth of the *Cichla temensis* Humboldt, 1821 (Perciformes: Cichlidae) from the middle rio Negro, Amazonas, Brazil. Neotropical Ichthyology, 13(2): 413-420. http://dx.doi.org/**10.1590/1982-0224-20140090**.

Cardoso, R.S.; Freitas, C.E.C. 2007. Desembarque e esforço de pesca da frota pesqueira comercial de Manicoré (Médio Rio Madeira), Amazonas, Brasil. Acta Amazonica, 37(4): 605-612. http://dx.doi.org/**10.1590/S0044-59672007000400016**.

Cerdeira, R.G.P.; Ruffino, M.L.; Isaac, V.J. 2000. Fish catches among riverside communities around Lago Grande de Monte Alegre, Lower Amazon, Brazil. Fisheries Management and Ecology, 7(4): 355-374. http://dx.doi.org/**10.1046/j.1365-2400.2000.007004355.x**.

Corrêa, M.A.A.; Nascimento, S.C.B.; Sonoda, D.Y.; Souza, L.A. 2018. A produção e a receita pesqueira como indicadores econômicos da pesca artesanal na Amazônia Central. Revista de Ciencias Sociales, 2(4): 13-31. http://dx.doi.org/**10.30810/rcs.v2i4.900**.

Cravo, M.D.S.; Xavier, J.J.B.; Dias, M.C.; Barreto, J.F. 2002. Características, uso agrícola atual e potencial das Várzeas no estado do Amazonas, Brasil. Acta Amazonica, 32(3): 351-365. http://dx.doi.org/**10.1590/1809-43922002323365**.

Faria Junior, C.H.H.; Batista, V.S.S. 2019. Frota pesqueira comercial na Amazônia Central: composição, origem, espécies exploradas e mercado. Revista Agroecossistemas, 11(1): 146-168. http://dx.doi.org/**10.18542/ragros.v11i1.5248**.

Fox, J.; Weisberg, S. 2019. An R companion to applied regression. 3rd ed. Sage: Thousand Oaks CA. Available from: <https://socialsciences.mcmaster.ca/jfox/Books/Companion> Accessed: May 24, 2020.

Freitas, C.E.C.; Rivas, A.A.F.; Campos, C.P.; St'Ana, I.; Kahn, J.R.; Corrêa, M.A.A.; Catarino, M.F. 2012. The potential impacts of global climatic changes and dams on Amazonian fish and their fisheries. In: Turker, H. (Ed.). New advances and contributions to fish biology. Croatia: InTech Rijeka. p. 176-195. https://doi.org/**10.5772/54549**.

Gandra, A.L. 2010. O mercado de pescado da região metropolitana de Manaus. Série: O mercado de pescado nas grandes cidades latino-americanas. CFC/FAO/INFOPESCA, 91 p. Available from: <http://infopesca.org/sites/default/files/complemento/publilibreacceso/282/Manaus-completo.pdf> Accessed: May 30, 2020.

Guarim, V.L.M.S. 1979. Ocorrência e distribuição de *Chromobacterium violaceum* (Schroeter) Bergonzini 1881, na Amazônia Central. Acta Amazonica, 9(3): 501-506. http://dx.doi.org/**10.1590/1809-43921979093501**.

Holley, M.H.; Maceina, M.J.; Souza, M.T.; Forsberg, B.R. 2008. Analysis of trophy sport fishery for the speckled peacock bass in the Rio Negro River. Fisheries Management and Ecology, 15(2): 93-98. http://dx.doi.org/**10.1111/j.1365-2400.2007.00587.x**.

Horbe, A.M.C.; Queiroz, M.M.A.; Moura, C.A.V.; Toro, M.A.G. 2013. Geoquímica das águas do médio e baixo Rio Madeira e seus principais tributários–Amazonas–Brasil. Acta Amazonica, 43(4): 489-504. http://dx.doi.org/**10.1590/S0044-59672013000400011**.

Hurd, L.E.; Sousa, R.G.C.; Siqueira-Souza, F.K.S.; Cooper, G.J.; Kahn, J.R.; Freitas, C.E. 2016. Amazon floodplain fish communities: habitat connectivity and conservation in a rapidly deteriorating environment. Biological Conservation, 195: 118-127. http://dx.doi.org/**10.1016/j.biocon.2016.01.005**.

Isaac, V.J.; Almeida, M.C.; Cruz, R.E.A.; Nunes, L.G. 2015. Artisanal fisheries of the Xingu River basin in Brazilian Amazon. Brazilian Journal of Biology = Revista Brasileira de Biologia, 75(3): 125-137. http://dx.doi.org/**10.1590/1519-6984.00314BM**.

Junk, W.; Bayley, P.B.; Sparks, R.E. 1989. The flood pulse concept in river-floodplain systems. Canadian Special Publication of Fisheries and Aquatic Sciences, 106(1): 110-127.

Lages, A.D.S. 2010. Geoquímica da água preta de rios do município de Apuí, Amazonas. Manaus. 53f. (Dissertação de Mestrado, Universidade Federal do Amazonas). Available from: <https://tede.ufam.edu.br/handle/tede/3270> Accessed: May 30, 2020.

Lopes, G.C. DOS S.; Freitas, C.E.C. 2018. Avaliação da pesca comercial desembarcada em duas cidades localizadas no Rio Solimões – Amazonas. Biota Amazônia, 8(4): 36-41. http://dx.doi.org/**10.18561/2179-5746/biotaamazonia.v8n4p36-41**.

Marengo, J.A.; Oliveira, G.S.D. 1998. Impactos do fenômeno La Niña no tempo e clima do Brasil: desenvolvimento e intensificação do La Niña 1998/1999. [online] URL: http://mtc-m16b.sid.inpe.br/col/cptec.inpe.br/walmeida/2004/06.30.08.07/doc/Marengo_Impactos%20do%20fenomeno.pdf

Martelo, J.; Lorenzen, K.; Crossa, M.; Mcgrath, D.G. 2008. Habitat associations of exploited fish species in the Lower Amazon river–floodplain system. Freshwater Biology, 53(12): 2455-2464. http://dx.doi.org/**10.1111/j.1365-2427.2008.02065.x**.

Moquet, J.-S.; Guyot, J.-L.; Crave, A.; Viers, J.; Filizola, N.; Martinez, J.-M.; Oliveira, T.C.; Sánchez, L.S.H.; Lagane, C.; Casimiro, W.S.L.; Noriega, L.; Pombosa, R. 2016. Amazon River dissolved load: temporal dynamics and annual budget from the Andes to the ocean. Environmental Science and Pollution Research International, 23(12): 11405-11429. http://dx.doi.org/**10.1007/s11356-015-5503-6**.

Muñoz, H. 2006. Biología del tucunaré (*Cichla* aff. *monoculus*) y pesca artesanal en el Río Bajo Paraguá (Santa Cruz - Bolivia). Revista Boliviana de Ecología y Conservación Ambiental, 1(19): 89-99. Available from: <http://www.cesip.org.bo/rebeca/index.php/rebeca/article/view/70> Accessed: 13 Oct. 2020.

Nascimento, F.L.; Catella, A.C.; Moraes, A.S. 2001. Distribuição espacial do tucunaré, *Cichla* spp. (Pisces, Cichlidae), peixe amazônico introduzido no Pantanal, Brasil. Embrapa Pantanal. Boletim de Pesquisa e Desenvolvimento, 24: 17p. [online] URL: https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/809809>

Novaes, J.L.C.; Freire, A.E.; Amorim, R.R.A.; da Costa, R.S. 2015. Diagnóstico da pesca artesanal em um reservatório do semiárido brasileiro. Boletim do Instituto de Pesca, 41(1): 31-42. Available from: <https://www.pesca.sp.gov.br/boletim/index.php/bip/article/view/41_1_31-42> Accessed: 13 Oct. 2020.

Petrere Júnior, M. 1985. A pesca comercial no rio Solimões-Amazonas e seus afluentes: análise dos informes do pescado desembarcado no Mercado Municipal de Manaus (1976-1978). Ciencia e Cultura, 37(12): 1987-1999.

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from: <https://www.R-project.org/> Accessed: May 30, 2020.

Rabelo, H.; Araújo-Lima, C.A.R.M. 2002. A dieta e o consumo diário de alimento de *Cichla monoculus* na Amazônia Central. Acta Amazonica, 32(4): 707-724. http://dx.doi.org/**10.1590/1809-43922002324724**.

Ruffino, M.L. 2014. Status and trends of the fishery resources of the Amazon Basin in Brazil. In: Welcomme, R.L., FAO – Food and Agriculture Organization (Org.). Inland fisheries evolution and management: case studies from four continents. Rome: FAO. p. 1-19.

Santos, C.H.D.A.D.; Sousa, C.F.S.D.; Paula-Silva, M.N.; Val, A.L.; Almeida-Val, V.M.F.D. 2012. Genetic diversity in *Cichla monoculus* (Spix and Agassiz, 1931) populations: implications for management and conservation. American Journal of Environmental Sciences, 8(1): 35-41. http://dx.doi.org/**10.3844/ajessp.2012.35.41**.

Santos, G.M.; Santos, A.C.M. 2005. Sustentabilidade da pesca na Amazônia. Estudos Avançados, 19(54): 165-182. http://dx.doi.org/**10.1590/S0103-40142005000200010**.

Santos, U.D.M.; Ribeiro, M.D.N.G. 1988. A hidroquímica do rio Solimões-Amazonas. Acta Amazonica, 18(3-4): 145-172. http://dx.doi.org/**10.1590/1809-43921988183172**.

Satyamurty, P.; Costa, C.P.W.; Manzi, A.O.; Candido, L.A. 2013. A quick look at the 2012 record flood in the Amazon Basin. Geophysical Research Letters, 40(7): 1396-1401. http://dx.doi.org/**10.1002/grl.50245**.

Silva, A.P.; Ummus, M.E.; Tardivo, T.F. 2017. Produção e sazonalidade das principais espécies capturadas pela pesca artesanal no rio Araguaia/TO. Boletim de Pesquisa e Desenvolvimento, 20(1): 32. Available from: <http://www.infoteca.cnptia.embrapa.br/handle/doc/1077518>. Accessed: Oct. 13, 2020.

Silva, M.D.S.R.D. 2013. Bacia hidrográfica do Rio Amazonas: contribuição para o enquadramento e preservação. Manaus. 199f. (Tese de Doutorado, Universidade Federal do Amazonas). Available from: <https://tede.ufam.edu.br/handle/tede/3152>. Accessed: June 1, 2020.

Sioli, H. 1968. Hydrochemistry and geology in the brasilian Amazon region. Amazoniana: Limnologia et Oecologia Regionalis Systematis Fluminis Amazonas, 1(3): 267-277. http://hdl.handle.net/21.11116/0000-0004-5124-8.

Siqueira-Souza, F.K.; Freitas, C.E.C.; Hurd, L.E.; Petrere, M. 2016. Amazon floodplain fish diversity at different scales: do time and place really matter? Hydrobiologia, 776(1): 99-110. http://dx.doi.org/**10.1007/s10750-016-2738-2**.

Sousa, K.N.S. 2005. A pesca profissional em sistemas de lagos no eixo fluvial Solimões-Amazonas e principais tributários do Estado do Amazonas. Manaus. 177f. (Tese de Doutorado, Instituto Nacional de Pesquisas da Amazônia, Universidade Federal do Amazonas). Available from: <https://bdtd.inpa.gov.br/handle/tede/1494> Accessed: June 1, 2020.

Sousa, R.G.C.; Humston, R.; Freitas, C.E.C. 2016. Movement patterns of adult peacock bass Cichla temensis between tributaries of the middle Negro River basin (Amazonas–Brazil): an otolith geochemical analysis. Fisheries Management and Ecology, 23(1): 76-87. http://dx.doi.org/**10.1111/fme.12166**.

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**.

Souza, L.A.; Freitas, C.E.C.; Sousa, R.G.C. 2015. Relação entre guildas de peixes, ambientes e petrechos de pesca baseado no conhecimento tradicional de pescadores da Amazônia Central. Boletim do Instituto de Pesca, 41(3): 633-644.

Sparre, P. 1997. Introdução à avaliação de mananciais de peixes tropicais. Parte 1: Manual. Rome: FAO. [online] Available from: <http://www.fao.org/3/w5449p/w5449p00.htm> Accessed: June 1, 2020.

Trevisan, G.V.; Forsberg, B.R. 2007. Relationships among nitrogen and total phosphorus, algal biomass and zooplankton density in the central Amazonia lakes. Hydrobiologia, 586(1): 357-365. http://dx.doi.org/**10.1007/s10750-007-0705-7**.

Val, A.L.; Almeida-Val, V.M.F.; Fearnside, P.M.; Santos, G.M.; Piedade, M.T.F.; Junk, W.; Nozawa, S.R.; Silva, S.T.; Dantas, F.A.C. 2010. Amazônia: recursos hídricos e sustentabilidade. In: Tundisi, J. (ed.) Recursos Hídricos. Academia Brasileira de Ciências (ABC) & Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP), São Paulo. p. 95-109. Available from: <https://www.researchgate.net/publication/278964916> Accessed: July 31, 2018.

Venables, W.N.; Ripley, B.D. 2002. Modern applied statistics with S. 4th ed. New York: Springer.

Weiß, C.H. 2007. StatSoft, Inc., Tulsa, OK.: STATISTICA, Version 8. AStA Advances in Statistical Analysis, 91: 339-341. http://dx.doi.org/**10.1007/s10182-007-0038-x**.

Wickham, H. 2016. ggplot2: Elegant Graphics for Data Analysis. New York: Springer-Verlag. 269p.

Willis, S.C.; Winemiller, K.O.; Montana, C.G.; Macrander, J.; Reiss, P.; Farias, I.P.; Ortí, G. 2015. Population genetics of the speckled peacock bass (*Cichla temensis*), South America's most important inland sport fishery. Conservation Genetics, 16(6): 1345-1357. http://dx.doi.org/**10.1007/s10592-015-0744-y**.

Zuanon, J. 2008. Peixes, pesca e clima na Amazônia: um ensaio sobre os efeitos das mudanças climáticas globais sobre os recursos pesqueiros na região do Rio Negro, Amazonas, Brasil. Rio Negro, Manaus e as Mudanças no Clima. 1st ed. Manaus: Editora do ISA, p.31-39.