Revista Brasileira de Geografia Física

Homepage: www.ufpe.br/rbgfe

The Relationship between Hydrologic Variation and Fishery Resources at the Lower Amazon, Santarém, Pará

Karine Lima Silva Bentes¹, Leidiane Leão de Oliveira², Diego Maia Zacardi², Naurinete de J. da Costa Barreto³

¹Master's student at the Aquaculture Postgraduate Program, (PPG-AQUI), National Institute of Amazonian Research (INPA)/Nilton Lins University, Manaus, AM, Brazil, Corresponding author Karine_lsb@hotmail.com. ²Professor at the Institute of Water Sciences and Technology - ICTA, Federal University of Western Pará - UFOPA, Santarém, PA, Brazil. ³National Institute of Space Research, São José dos Campos, SP, Brazil.

Artigo recebido em 09/11/2017 e aceito em 24/07/2018

ABSTRACT

In the Amazon, large fluctuations in rivers' level modulate fishing and influence the quantity captured by fishermen. The objective of this study was to characterize and evaluate the effect of hydrological variation on fishery resources in the municipality of Santarém, Pará. Information on the fish species landed was obtained by interviews with fishermen from December 2013 to January 2015. Hydrological phases were characterized based on data from the Santarém hydrometeorological station (2000 to 2015). The relationship between the recorded species and environmental variables (water height, rainfall, water temperature) was verified by Canonical Correspondence Analysis (CCA). It was observed that the seasonal fluctuation of the Tapajós River is defined by four phases (rising, flood, lowing, dry), and the flood (7.77 m) and dry (2.28 m) are extreme periods. The lower volumes of production occurred from December to February, while the months of April and September presented the highest volumes. From March to June, species of the families Anostomidae, Prochilodontidae, Characidae and Pimelodidae prevail, in November and December (dry), only the family Pimelodidae. The first two axes of the CCA explained 52.4% of the relation between species and environmental variables, indicating that the hydrological period is determinant in the seasonal variation of the fish. Thus, the understanding of the hydrological variables along with the fishing resources, are subsidies for the better management of the activity.

Keywords: Hydrology, Tapajós River, Fishery.

A relação entre a variação hidrológica e os recursos pesqueiros no baixo Amazonas, Santarém, Pará

RESUMO

Na Amazônia, as grandes flutuações do nível dos rios modulam a pesca e influenciam no quantitativo capturado pelos pescadores. Nesse sentido, objetivou-se caracterizar e avaliar o efeito da variação hidrológica sobre os recursos pesqueiros no município de Santarém, Pará. As informações sobre as espécies do pescado desembarcado foram obtidas por entrevistas realizadas com os pescadores no período de dezembro de 2013 a janeiro de 2015. Fases hidrológicas foram caracterizadas com base nos dados da estação hidrometeorológica de Santarém (2000 a 2015). A relação entre as espécies registradas e as variáveis ambientais (cota, precipitação e temperatura da água) foi verificada pela Análise de Correspondência Canônica (CCA). Observou-se que a flutuação sazonal do rio Tapajós é definida por quatro fases (enchente, cheia, vazante, seca), sendo que a cheia (7,77 m) e seca (2,28 m) são períodos extremos. Os menores volumes de produção de pescado ocorreram de dezembro a fevereiro, enquanto que os meses de abril e setembro apresentaram os maiores volumes. Nos meses de março a junho, prevalecem espécies das famílias Anostomidae, Prochilodontidae, Characidae e Pimelodidae, em novembro e dezembro (seca) a família Pimelodidae. Os dois primeiros eixos da CCA explicaram 52,4% da relação entre as espécies e variáveis ambientais, indicando que o período hidrológico é determinante na variação sazonal do pescado. Assim, o entendimento das variáveis hidrológicas junto aos recursos pesqueiros, são subsídios para auxiliar a gestão e o ordenamento da atividade.

Palavras-chave: Hidrologia, rio Tapajós, Pesca.

Introduction

Due the expansion of the Fishing Industry in the West Region of Pará, it is necessary to know the hydrological dynamics of the region. It is considered the key factor in measuring the changes occurring in the aquatic environment. These environments are mainly influenced by the periodicity of rain cycles and melting in the Andes, which provokes an annual fluctuation of great amplitude in the water level of the Amazonian rivers (Isaac e Barthem, 1995; Ramalho et al., 2009).

As a consequence of the unequal distribution of water regimes, two seasons prevail well marked by a dry and rainy cycle (Junk, 1980; Batista et al., 2012), determining periods of “winter” and “summer” (Isaac e Barthem, 1995). These periods can also be defined as rainy and less rainy, when the rainy time covers the months December until May, and are mainly associated with the phenomenon of the large-scale system known as the Intertropical Convergence Zone – ITCZ (Fisch et al., 1998). As a result of these factors affecting the climate, the rhythm imposed by the hydrological variation reflects the hydrological changes between the dry and the flood season.

The seasonal fluctuation of the river assumes a unimodal pattern, reflecting in high and low tides (Barthem e Fabré, 2004). Due to this temporal fluctuation and according to hydrological criteria four phases are delimited within a seasonal cycle, these being: drought, spate, flood and ebb (Bittencourt e Amadio, 2007). In the face of these restrictions, Amazonian species develop innumerable adaptation strategies (Barthem e Fabré, 2004). Consequently, fishermen also undergo seasonal variations acting in the most diversified environments and develop numerous catch strategies to concentrate fishery and obtain a good produce (Isaac et al., 1996; Corrêa et al., 2012).

Periods such as floods and droughts directly influence the reproductive and dispersal migrations many species and fishes make (Soares et al., 2008). During the floods expansion of the

aquatic environment occur, due to the connection of the marginal areas and the river bed, allowing the entry of many species into new habitats, to explore large amounts of nutrition and refuge areas (Cunico et al., 2002). Among the main fishing environments in the river are: rivers, lakes and streams subdivided according to seasonality, creating food plains and flood forests (igapós), (Cardoso e Freitas, 2007). All these fishing areas are extremely variable, though fishermen themselves take advantage of this restriction to fish, since the biological cycles of fish depend on hydrological events (Merona, 1995).

The landscape, environments, climatic characteristics and seasonal flooding dynamics determine the distribution and ecology of the fishery resources and, consequently, the fisherman and fishing behavior (Sousa, 2009). The effects of seasonality on the composition of the fish directly influence the fishing activity of the region and are reflected in the differences in fish availability in the city markets.

In this study, we filled a knowledge gap regarding the definition of hydrological phases (flood, spate, ebb and drought), which purpose was to characterize and evaluate the effect of this hydrological variation on fishery resources in the municipality of Santarém, Pará. Knowledge of environmental factors (hydrological and climatic) allow us to evaluate the possible influence of hydro climatic extremes on fishing and is fundamental for the management of this activity in the region, also serving as the basis for future field surveys of aquatic organisms.

Material and methods

Research region

The city of Santarém (PA) is located in western Paraense, in the mesoregion of the Lower Amazon, on the right bank of the Tapajós river, in confluence with the Amazon river, under the geographical coordinates 2 ° 24'52 "S and 54 ° 42 ' 36 "W (Figure 1). Santarém has a territorial area of approximately 22,886,624 km², and an estimated population of 294,447 inhabitants, according to The Brazilian Institute of Geography and Statistics (IBGE, 2011).

Figure 1. Geographical location of the study area, city of Santarém, Pará. Source: Mota (2016).

The municipality presents a characteristic climate of tropical regions, without significant temperature changes. The average annual rainfall is 2,200 mm, and the "winter" period runs from the beginning of December to June, while "summer" occurs in the second half of the year, when rainfall levels decrease considerably (Almeida, 2010).

Data collection and analysis

Hydro climatological and catch data were obtained by species corresponding to the fishery production dispatched at the port of Santarém. The rainfall, water temperature and altitude (river water level) were obtained through the Santarém hydro meteorological station, data provided by the National Water Agency (ANA). The water level figures of the Tapajós river, were provided by the Fluvial Captaincy of Santarém, Pará, Directorate of Hydrography and Navigation - DHN (Navy of Brazil).

From this information, the data were submitted to simple statistics and grouped on a monthly basis. The hydrological curve of the river was generated by calculating the monthly averages of the river water level, which allowed identifying the months that comprise the four hydrological phases in the region: flood, spate, ebb and drought (2000 to 2015). Thus we were able to verify the annual variability that the river assumes, through the comparative graphical analysis between the historical series (2000 to 2015) and the study period (2014 to 2015).

The data used for the identification of the fish were obtained between 2014 and 2015 by means of interventions with fishermen and and/or

those responsible for the fishing boats. The interventions were performed in two alternate weeks of each month, through the application of semi-structured forms. The collected data were on: the main species captured; fishing environment; quantity of fish caught, as well as information on the perception of fishermen regarding the influence of the different hydrological phases on the fishery resources in the region.

Descriptive (mean) statistics were collected for the data collected through the forms. The Canonic Correspondence Analysis (CCA) was used, with the aid of the statistical program (PCORD 6.1), to verify the relationship between the species recorded in the landings and the studied environmental variables (water level, rain fall and water temperature).

Results and discussion

Hydrologic Regime

The variation curve of the Tapajós River in the municipality of Santarém (PA) presented hydrological variability during the analyzed period and demonstrated an annual unimodal pattern, resulting in well-defined periods of high and low tides (Figure 2). Thus, as in other studies conducted in the region (Isaac and Barthém, 1995; Isaac et al., 1996). Due to this temporal fluctuation of the river level, four hydrologic phases (flood, spate, ebb and drought) were delimited during a complete seasonal cycle. Of these, the seasons of full (high tides) and dry (low tides) stand out as the extreme periods, which corroborates to the study of Bittencourt and Amadio (2007).

Figure 2. Monthly average variation curve of the water height and characterization of the hydrological periods (rising, flood, lowing and dry) of the Tapajós river, Santarém-PA.

Through the data of fluviometric level (water level) of the Tapajós river in the period from 2000 to 2015 we were able to identify the hydrological periods (flood pulse) of the region. The determination of seasons as flood and drought was by the maximum water level (7.77 m) in May and the minimum (2.28 m) in November. Thus, we were able to show water level intervals for the determination of the months that comprise the different hydrological phases. For this, were considered floods ($3 \text{ m} \leq \text{level} \leq 7.10 \text{ m}$), flood ($7.10 \text{ m} \geq 3 \text{ m}$) and drought ($3 \text{ m} > \text{level}$). The flood alert quota of the Tapajós river for the municipality of Santarém is 7.10 m (SUDAM / UFPA, 2017).

The water level fluctuation during the hydrological periods of the Tapajós river was characterized by the following periods: flood (January to March), with average quota of 5.41 m, minimum level in January of 4.20 m and maximum level in March and 6.56 m; flood (April to June), with an average elevation of 7.44 m, and a minimum elevation of 7.37 m in April and a maximum elevation in May of 7.77 m, characterized by a low water level oscillation; ebb (July to September), with an average level of 5.33 m, a minimum level of 4.56 m in September and a maximum level of 7.05 m in July; (October to

December), with an average level of 2.63 m and its minimum and maximum levels with figures of 2.28 and 2.82 m, in November and December respectively.

Generally, the switching months from one hydrologic phase (flood, spate, ebb and drought) to another are characterized as transition months. It is possible that there is an advance or delay of the high and low tide period of the Tapajós river, depending on the active climatic phenomenon (El Niño). According to Barthém and Fabré (2004), the periods of drought follow a "downstream" pattern, and in downstream stretches this is noticed in the month of November. The reverse occurs in the flood season, which follows the "upstream" pattern, to be perceived in the municipality of Santarém in the month of May. Though for intermediate periods such as flood and ebb, affirm that both have approximately the same duration.

When comparing the Tapajós river variation by means of the historical series with the study period, comprising the years 2014 and 2015, we observed that they follow the same pattern of hydrological variability, with only alternation in the intensity of the oscillations of the river water level between months (Figure 3).

Figure 3. Variation curves of the Tapajós River water height ,Santarém-PA (Brazilian Amazon): comparison between the historical series (2000 to 2015) and the years 2014 and 2015.

We observed that the Tapajós river water level remained slightly above the historical average during 2014. At the peak of the full phase it was possible to identify the highest oscillations, in water level (8.07 m), in the month of May. On the other hand, in most of the months the water level of the river occurred below or within the average in 2015, and a highlight in November, with a lower figure (1.32 m) of the historical average (2.28 m) and remained below in the month of December (1.52 m). This pattern of the water level below the historical average can be explained by the performance of the El Niño phenomenon that reached the strong category in the August, September and October 2015 quarters, contributing to the rainfall deficit in central-northern Brazil (CPTEC / INPE, 2015).

In general, it was possible to notice that in years of El Niño performance, with a strong intensity configuration, the Tapajós River water level was below the average in November (0.96 m) and December (0.76 m) in 2015. Also, we observed a similar pattern of average variation in the hydrological river level compared to the years of study (2014 and 2015), that is, the hydrological periods flood, spate, ebb and drought) occurred within the months predicted in the time series of the water level. A similar result was observed in the Mamirauá-AM Sustainable Development Reserve, in the middle of the Solimões river, when the annual pattern of the flood pulse varied between the analyzed years. The oscillation of the water level in most of the years followed a similar behavior (Ramalho et al., 2009).

Fishing Sector

Due to the hydrological dynamics of the Amazonian ecosystems, during a seasonal cycle there is a variation in the main areas where the fisheries take place. In terms of fishing sites, environments such as rivers and lakes were more frequent than other areas mentioned by fishermen such as wetlands (varzeas), streams (igarapés) and flood forests (igapós). It is known that the hydrology of the Amazon Basin is configured by an immense complex of rivers, streams, lakes, channels and holes (Santos and Santos, 2005), mainly governed by hydrological variability, known in the region as flood pulse. This condition provides the formation of numerous environments that contain many target species for fisheries.

In the present study, the river was the mostly used fishing area by fishermen in search for fish (58%); followed by lakes (41%) and, in a smaller percentage (1%), in the other environments like streams (igarapés) and flood forests (igapós). We observed that the number of expeditions to these environments presented an alternation, mainly between rivers and lakes (Figure 4). A similar result was also found by Silva and Braga (2016), when they carried out a study in the community of Surucuá (Resex Tapajós Arapiuns) and found that the rivers and lakes are seen as strategic points, and, according to the hydrological period, one can be fuller than the other. This allows to affirm that the hydrological variation directly influences the fishing and the behavior of the fisherman in the activity.

Figure 4. Number of expeditions per capture site in the municipality of Santarém-Pará, from December 2013 to July 2015.

The river was the explored environment in practically every month (July to April). The number of fisheries held in lakes was higher in the period of May and June, though the other environments were not representative.

The predominance of catches in the region's lakes during the flood (May and June) can be explained by the strong local rains that favor fishing in flooded areas, when compared to the fisheries in the river channel, since the location of the shoals becomes difficult in water level elevation (Isaac et al., 2004). As the water level increases, there is a lateral overflow of the river to the floodplain and to the flooded forest, increasing the area of ichthyofauna dispersion, making it difficult to catch.

Unlike fishing in environments such as lakes, the catch in the river assumes a seasonal character, linked to the hydrological and life cycle of the present ichthyofauna (Isaac and Barthem, 1995; Isaac et al., 2004). In relation to the unloading of the fish, we observed that it is close to the main commercial places of the city (fairs and markets). During the study period, a total of 24 species were mentioned during the interviews. Of these 12 were more representative and mainly cover the orders Characiformes (40%); Siluriformes (33%); Perciformes (22%); Clupeiformes (4%) and Osteoglossiformes (1%) (Table 1).

The target species in the Amazon of the fishery for human consumption are directed to the fish with scales (Santos and Santos, 2005, Batista

et al., 2012, Lima et al., 2016). In this context, the orders Characiformes and Siluriformes are more representative in the discharge in the region, constituting more than half of the production that reaches the ports.

In the present study, the pattern of fish discharge in the municipality of Santarém, followed similar characteristics to those observed by Martins (2009, Castro and Sousa, 2016; Lima et al., 2016). A large part of the total discharge in species or group of species of fish presented migratory behavior of short or long distance, thus encompassing Characiformes and Siluriformes orders. The predominance of the species belonging to these orders in the city markets, in association with the large number of registered hake, can be explained by their commercial attraction, or simply because they are not included in the ban list, like in the case of catfish (*Plagioscion* spp.).

The fish production presented a total of 9,020.46 kg, with a monthly average of fish dispatch of 751.70 ± 264.25 kg. The lowest production volumes occurred between the months of December to March, corresponding to the rainy season in the region. The month of December presented a minimum catch volume (151.85 ± 50.51 kg), compared to the other months of the year. Two months had the highest volumes, the highest in April ($1,133.09 \pm 176.75$ kg) corresponding to the flood/spate transition period of the Tapajós River, followed by September, with approximately ($1,025.95 \pm 93, 26$ kg) comprising the harvest season in the region.

Table 1. Species recorded in fishing landings in Santarém city, Pará, from December 2013 to December 2015.

Common name	Scientific name	Number of occurrence in landings
CHARACIFORMES		
Aracus	<i>Leporinus</i> spp. and <i>Schizodon</i> spp.	241
Curimatã	<i>Prochilodus nigricans</i>	162
Pacus	<i>Mylossoma</i> spp., <i>Myleus</i> spp.	166
Jaraquis	<i>Semaprochilodus</i> spp.	123
Tambaqui	<i>Colossoma macropomum</i>	111
Charuto	<i>Hemiodus</i> spp.	40
Pirapitinga	<i>Piaractus brachypomus</i>	19
Piranhas	Serrasalminidae	6
CLUPEIFORMES		
Apapá	<i>Pellona</i> spp.	81
OSTEOGLOSSIFORMES		
Aruanã	<i>Osteoglossum bicirrhosum</i>	12
Pirarucu	<i>Arapaima</i> spp.	12
PERCIFORMES		
Pescada	<i>Plagioscion</i> spp.	339
Tucunarés	<i>Cichla</i> spp.	122
Acarás	Cichlidae	7
SILURIFORMES		
Surubim	<i>Pseudoplatystoma punctifer</i>	297
Dourada	<i>Brachyplatystoma rouseauxii</i>	157
Maparás	<i>Hypophthalmus</i> spp.	96
Filhote	<i>Brachyplatystoma filamentosum</i>	67
Acari-bodó	<i>Pterygoplichthys pardalis</i>	17
Cujuba	<i>Oxydoras niger</i>	2
Fura-calça	<i>Pimelodina flavipinnis</i>	12
Jaú	<i>Zungaro zungaro</i>	32
Piramatuba	<i>Brachyplatystoma vaillantii</i>	6
Pirarara	<i>Phractocephalus hemiliopterus</i>	42

Figure 5. Monthly average of fish caught and its relation to the region's hydrological variability in River Tapajós (Brazilian Amazon) during the period from December 2013 to December 2015.

The differences in the quantity of fish caught between the months of December and March in relation to the month of April that presented the peak of production may be related not only to the hydrological question, but also to the factor of legal order referring to the period of the closure. This occurs in the region between November 15 to March 15 and establishes a ban on the fishing of some species of fish, modifying the catch and commercialization of the fish. In a study by Isaac et al. (1996), who investigated the quantitative catch of the species during 1993, found that the lowest production volumes occurred between December and April and the highest in August and September, although in the year of this research there was no closed season insurance law No. 10.779 / 2003.

Another factor that can also be attributed to the variations in the production volume refers to the type of fishing vessel, as well as to the period in which the fishery was carried out. In the case of the region, these are hydrologic phases (flood, spate, ebb and drought) that modify the fisher's behavior against the capture of the target species of

commercialization. Isaac et al. (2000) found that these differences are also a reflection of the capture and transport capacity of the fishing units operating in the region, and the changes in the density of the fish populations associated with the hydrological cycle and the migratory behavior of certain species.

In terms of the seasonality of aquatic ecosystems due to the annual variation of precipitation and oscillation of the river water level, it is known that the success of fishery production is linked to the hydrological regime (Barthem and Fabré, 2004; Cardoso and Freitas, 2007). According to the fishermen, significant differences occur in the total captured during a seasonal cycle, which shows the knowledge they have about the influence of the hydrological regime on the present ichthyofauna (Figure 6). They attribute the periods of higher catch to "summer", a season of lower rainfall corresponding to the time of river ebb / drought, in contrast, they affirm that during the "winter" (greater rainfall) a drop in production occurs, a period corresponding to the spate / flood season.

Figure 6. Number of answers given to the question concerning the season of greater (a) and lower catch (b) in the Tapajós River in Santarém, Pará (Brazilian Amazon) in the period December 2013 to December 2015.

The cited periods by fishermen in which they catch the highest or lowest catch reflect the seasonality of the rivers in the Amazon region. Several studies in the region mention of the most favorable period to carry out the fishing activity according to the fisher's perception (Zacardi et al., 2014; Zacardi, 2015; Silva and Braga, 2016).

In the region of the Tapajós river, Zacardi et al. (2014), found that 65% of fishermen

attributed the summer (driest period in the region), as the best time for catching fish, because the waters presented their lowest levels, providing a higher fish concentration throughout the aquatic environments, reducing fishing time and effort. However, species present remarkable survival strategies related to river level oscillations, since, according to Merona (1995), the biological cycles

of fish are closely dependent on hydrological events, especially when related to reproduction.

The flood is characterized by the expansion of the aquatic environment. In this period due to the great dispersion of the fish it becomes difficult to catch. In times like ebb or flood the fish that have migratory behavior, go out in search of new environments that are forming (flood) or undertake dispersal migrations abandoned the areas that begin to dry (ebb). This displacement attracts fishermen to these areas. In the dry season the aquatic environments are contracted to the maximum, occurs a greater density of the fish and it is during that period that fishermen get a larger volume of fish catch (Barthem and Fabr, 2004, Braga and Rbelo, 2014, Silva and Braga, 2016).

All of these changes that occur in the Amazonian ecosystem shape the activity and fishing systems. Thus, fishermen submit to the hydrological regime and life cycle of the target species using the knowledge of the region to delineate fishing areas and determine catch strategies, to concentrate the fishery and to succeed in production (Isaac et al. (1996) and Corra et al, 2012).

Analysis of the interaction between environmental variables and species

To verify the relationship between the distribution profile of the fish species and the environmental variables, we applied the Canonical Correspondence Analysis (CCA). The correlation matrix involved 24 species and 3 environmental variables (dimension, precipitation, temperature). We observed that the correlations between the species and the environmental variables were high (0.949 and 0.913), which shows that the variables used in the study satisfactorily explained axis 1 and 2 respectively, showing that there is a greater relation between the variables. It is also verified that the eigenvalues found for the two canonical order axes were (0.220 and 0.056), axis 1 obtained the highest eigenvalue and explaining approximately 42% of the variance, followed by axis 2, which presented 11% of total observed variance.

The Monte Carlo permutation analysis, a significance test of the environmental variables introduced in the CCA package, presented an assessment of the significance of each tested variable, demonstrating in both axes that the correlations between the species distributions and the environmental variables were statistically significant ($p = 0.001$) (Table 2).

Table 2. Results of canonical correspondence analysis (CCA) for the fish Community and abiotic variables of the Tapajs River (Brazilian Amazon) during monthly hydrological periods (rising, flood, lowing and dry) between January 2014 and December 2015.

	Axis 1	Axis 2
Eigenvalue	0.220	0.056
% of explained variance	41.7	10.7
% cumulative	41.7	52.4
Monte Carlo test for eigenvalues		
Pearson correlation for species-environmental variables	0.949	0.913
<i>P</i>	0.001	0.001

The Pearson correlation coefficient between the environmental variables and the ordering of the axes reflected the importance of each studied variable in relation to the dispersion of the ichthyofauna.

We observed the distribution pattern of the species and the degree of relation between the variables (dimension, precipitation, temperature) in the order of the CCA. The first two axes explained 52.4% of the species-variable environmental variance, where the 1st ordering axis reflected a high percentage of explanation in relation to the 2nd axis, which shows that part of the variance was not explained (Figure 7).

We noted that the environmental variables are correlated. The rainfall had a positive correlation with the river level, while the water temperature correlated negatively with the other studied variables. However, the positive correlation of rainfall with the river level observed in this study does not depend only on rainfall in the region of Santarm.

What contributes in a significant way to the increase or decrease of the level of the river is the distribution and influence of the rains along all the stretches of the Tapajs river basin, besides the damming effect provoked by the flood of the Amazon river, which indicates that the excess of local rains is not always directly associated to the increase of the water level. Species such as Aracus, Streaked Prochilod (Curimat), Tambaqui and Mapar were associated to the months of March (M3) to June (M6) correlated variables (water level and rainfall). It is important to emphasize that all these species present common behaviors, especially with regard to the habit of forming

schools and to undertake migrations, as well as to the favorable habitat to explore and to live for a certain period. In this case, the environments of

flooded areas that arise are due to the fluvioimetric increase.

Figure 7. Canonical correspondence analysis (CCA) showing the relation between the fish species and the environmental gradients (vectors) in Tapajós River (Brazilian Amazon) from January 2014 to January 2015. Blue dots: fish species; red vectors: environmental gradients (COTA: Tapajós River Water Height; PRP: Rainfall; TEMP: Water Temperature); yellow ▲: months).

Among the species identified in this period, tambaqui is a species whose catch volume presents two harvests determined by hydrological variation, thus, it is also possible to identify the presence of this species during the flood, usually in the flooded forest (Batista et al., 2012).

These same authors verified that in the region of the low Amazonas, the capture of the mapará is concentrated in the lakes, during the period of the flood. Silva and Braga (2016) emphasize that the mapará fishery occurs during

this period, however, the catch occurs in the river. Species such as aracu and curimatã, also captured in the rainy season, occur mainly when leaving the lakes (Isaac et al., 2004).

A greater abundance of species is also verified belonging to the order of the siluriforms in months of ebb and dry. In this context, in the months of November (M11) and December (M12) species such as dourada and surubim prevailed. The order of siluriforms comprises a group of fish popularly known as smooth fish. The highest

dominance and consequent capture of these fish in the region occurs in the ebb and dry season, mainly in September (Isaac et al., 1996; Isaac et al., 2004, Silva and Braga 2016). The month of September (M9) was not very explanatory; however the months that presented the highest concentration of these species comprise the season of the ebb and dry in the region.

Different from the species already mentioned, hake is an example of fish that presents a sedentary habit, being adapted mainly to environments of still water. This explains the predominance of this species in the month of January, since in the region corresponds to the beginning of the flood and consequently new environments will be emerging.

Conclusions

1. Fishing is directly related to the hydrological dynamics in the region, since the fishermen themselves are aware of periods that favor a greater or lesser catch of the fish. In view of this, we perceived the fisher's close relationship with the environment, which is of fundamental importance for a better understanding of the behavior of the fish fauna and the environment they use.

2. The time series of the Tapajós River level allowed to identify the months that correspond to the hydrological phases, allowing to demonstrate two main seasons like the flood and drought, and intermediate seasons, including the periods of flood and ebb.

3. Due to the hydrological variations, much of the catch is concentrated in the river and lake environment, on species that mainly comprise characiforms and siluriforms, representing the most commercially interesting fish.

4. It was also evident that the studied environmental variables in interaction with the species distribution demonstrate the existence of a correlation, which influences some species, whether predominant or not, in certain months of the year. Thus, as a way to obtain success in the production, the fishermen submit to the ecological and biological changes of the species, going to areas where they are in greater abundance.

Acknowledgements

The authors thank the fishermen and the social actors (involved in fishing activities in the region) for the information provided for the development of this work, the Federal University of the Western Pará for the scientific initiation

grant given to the first author and to the Institute of Water Sciences and Technology, for the assignment of the infrastructure for the development of the work.

References

- Almeida, M. C., 2010. Composição, abundância e pesca da ictiofauna como indicadores do estado de conservação de dois lagos de várzea no baixo rio Amazonas (Brasil). Dissertation (Masters). Belém.
- Barthem, R. B., Fabré, N. N., 2004. Biologia e diversidade dos recursos pesqueiros da Amazônia, in: Ruffino, M. L. (Ed.), A pesca e os recursos pesqueiros na Amazônia brasileira. Manaus: Ibama/ProVárzea. p, 17-62.
- Batista, V. S., Isaac, V. J., Fabré, N. N., Gonzalez, J. C. A., Almeida, O. T., Rivero, S., Júnior, J. N. O., Ruffino, M. L., Silva, C. O., Saint-Paul, U. 2012. Peixes e pesca no Solimões-Amazonas: uma avaliação integrada. Brasília: Ibama/ProVárzea. 276p.
- Bittencourt, M. M., Amádio, S. A. 2007. Proposta para identificação rápida dos períodos hidrológicos em áreas de várzea dos rios Solimões-Amazonas nas proximidades de Manaus. Acta Amazonica 37, 303-308.
- Braga, T. M. P., Rebêlo, G. H. 2014. Conhecimento tradicional dos pescadores do baixo rio Juruá: aspectos relacionados aos hábitos alimentares dos peixes da região. Interciência, 659-665.
- 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, 605-612.
- Castro, L. A., Sousa, K. N. S. 2016. Desembarque pesqueiro no ano de 2015, na feira do pescado do município de Santarém, Pará. In: V Jornada Acadêmica e VI Seminário de Iniciação Científica da UFOPA: Pesquisa e educação na Amazônia 2016, Santarém, Pará.
- Correa, M. A. A., Kahn, J. R., Freitas, C. E. C. 2012. A pesca no município de Coari, estado do Amazonas, Brasil. Revista Brasileira de Engenharia de Pesca 6, 1-12.
- CPTEC/INPE (Centro de Previsão de Tempo e Estudos Climáticos/Instituto Nacional de Pesquisas Espaciais). Infoclima. v. 22, n. 10, novembro/2015. Available in: <http://infoclima1.cptec.inpe.br/>. Access in: 15/02/2017.
- Cunico, A. M., Graça, W. J., Verissimo, S., Mauricio, L. 2002. Influência do nível

- hidrológico sobre a assembleia de peixes em lagoa sazonalmente isolada da planície de inundação do alto rio Paraná. *Acta Scientiarum* 24, 383-389.
- Fisch, G., Marengo, J. A., Nobre, C. A. 1998. Uma Revisão Geral sobre o Clima da Amazônia. *Acta Amazonica* 28, 101-126.
- IBGE. Censo Demográfico 2010. Disponível: <http://cidades.ibge.gov.br>. Access in: 10 fev. 2010.
- Isaac, V. J., Barthem, R. B. 1995. Os recursos pesqueiros da Amazônia brasileira. *Bol. Mus. Para. Emílio Goeldi, Série. Antropol* 11, 295-339.
- Isaac, V. J., Milstein, A., Ruffino, M. L. 1996. A Pesca Artesanal no Baixo Amazonas- Análise Multivariada das Capturas por Espécie. *Acta Amazonica* 26, 185-208.
- Isaac, V. J., Ruffino, M. L., Melo, P. 2000. Considerações sobre o método de amostragem para a coleta de dados sobre captura e esforço pesqueiro no Médio Amazonas. IBAMA. Coleção Meio Ambiente. Série Estudos Pesca 22, 175-199.
- Isaac, V. J., Silva, C. O., Ruffino, M. L. 2004. A pesca no Baixo Amazonas, in: Ruffino, M. L. (Ed.), A pesca e os recursos pesqueiros na Amazônia brasileira. Manaus: Ibama/PróVarzea. p. 185-211.
- Junk, W. J. 1980. Áreas inundáveis - Um desafio para limnologia. *Acta Amazonica* 10, 775-795.
- Lima, K. F., Almeida, I. C., Teixeira, J. A., Melo, R. A. 2016. A comercialização do pescado no município de Santarém, Pará. *Revista Brasileira de Engenharia de Pesca* 9, 01-09.
- Martins, E. V. 2009. Dinâmica da economia e das relações do trabalho da pesca artesanal no município de Santarém. Dissertation (Masters), Belém, UFPA.
- Merona, B. 1995. Ecologia da pesca e manejo pesqueiro na região Amazônica. *Bol. Mus. Para. Emílio Goeldi* 11, 18.
- Ramalho, E. E., Macedo, J., Vieira, T. M., Valsecchi, J., Calvimontes, J. 2009. Ciclo hidrológico nos ambientes de várzea da Reserva de Desenvolvimento Sustentável Mamirauá – médio rio Solimões, período de 1990 a 2008. *Uakari* 5, 61-87.
- Santos, G. M. S., Santos, A. C. M. 2005. Sustentabilidade da pesca na Amazônia. *Estudos Avançados* 19 (54).
- Silva, J. T., Braga, T. M. P. 2016. Caracterização da Pesca na comunidade de Surucua (Resex Tapajós Arapiuns). *Biota Amazônia* 6, 55-62.
- Soares, E. C., Teixeira, C. V., Oliveira, A. C., Parise, M., Pinto, W. H. A. 2008. Avaliação da pesca através do banco de estatística e SIG na região de Santarém, estado do Pará, Brasil. *Revista Brasileira de Engenharia de Pesca* 3, 1-10.
- Sousa, R. G. C. 2009. Distribuição espacial da pesca no lago grande de Manacapuru (Amazonas) – bases para subsidiar políticas de sustentabilidade para a pesca regional. Dissertation (Masters). Manaus, UFAM.
- SUDAM/UFPA (Superintendência do Desenvolvimento da Amazônia/Universidade Federal do Pará). Boletim de alerta hidroclimático diário de Santarém-PA, 14/02/2017. Aplicações para alerta de desastres e ações de defesa civil. Available in: MERONA, B. Ecologia da pesca e manejo pesqueiro na região Amazônica. *Bol. Mus. Para. Emílio Goeldi*. v. 11, n. 2, p. 18, 1995.
- Zacardi, D.M., Ponte, S. C. S., Silva, A. J. S. 2014. Caracterização da pesca e perfil dos pescadores artesanais de uma comunidade às margens do rio Tapajós, estado do Pará. *Revista Amazônia: Ciência e Desenvolvimento* 10, 1-21.
- Zacardi, D.M. 2015. Aspectos sociais e técnicos da atividade pesqueira realizada no rio Tracajatuba, Amapá, Brasil. *Actapesca* 3, 31-48.