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Influence of flood pulse on ecological aspects of an iliophagous fish from Eastern Amazonia, Brazil

Influência do pulso de inundação nos aspectos ecológicos de um peixe iliófago da Amazônia Oriental, Brasil

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Abstract: The aim of this study was to describe ecological aspects of the iliophagous fish *Cyphocharax abramoides*, in Eastern Amazonia, Brazil, concerning the variation of organic carbon content (OCC) in ingested food, growth pattern, and condition factor (K). The OCC present in stomach contents was obtained bimonthly and evaluated with a Kruskal-Wallis test. The growth pattern was obtained through the length-weight relationship. Bimonthly K variation was also assessed with a Kruskal-Wallis test. Our results showed differences in OCC values during the studied period, with lower OCC values in the dry period and the highest OCC values during the flooding. The growth pattern was established as positive allometric growth ($b > 3$). K values also differed within the sampling periods, which showed different periods of physiological activity. The results also suggest that changes in these parameters can be associated with physical changes of the aquatic environment due to the flood pulse. Ecological studies can increase our knowledge about the relationship between species and environment, and are relevant in a still poorly documented region of high species richness such as the Amazon.

Keywords: *Cyphocharax abramoides*. Curimatidae. Feeding. Organic matter. Growth pattern.

Resumo: O objetivo do estudo foi descrever aspectos ecológicos do peixe iliófago *Cyphocharax abramoides*, na Amazônia Oriental, Brasil, a respeito da variação da ingestão de matéria orgânica (OCC), do padrão de crescimento e do fator de condição (K). Os valores de OCC presentes nos conteúdos estomacais dos peixes foram obtidos a cada dois meses e avaliados pelo teste de Kruskal-Wallis. O padrão de crescimento foi obtido por meio da equação da relação peso-comprimento. A variação bimestral dos valores de K também foi avaliada pelo teste Kruskal-Wallis. Os resultados evidenciam diferenças nos valores de OCC ao longo do período estudado, com menores valores no período de seca e maiores valores na enchente. O padrão de crescimento foi alométrico positivo ($b > 3$). Os valores de K também variaram ao longo do estudo, o que sugere diferentes períodos de atividades fisiológicas. Os resultados também sugerem que as mudanças nesses parâmetros podem ser associadas às variações físicas no ambiente, em função do pulso de inundação. Esse estudo incrementa o nosso conhecimento sobre a relação entre espécies e ambiente, tornando-se relevante em uma região de alta biodiversidade e poucos estudos biológicos, como a Amazônia.

Palavras-chave: *Cyphocharax abramoides*. Curimatidae. Alimentação. Matéria orgânica. Padrão de crescimento.

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INTRODUCTION

Studies on ecological aspects of fishes such as feeding, growth pattern, and energy investment are important for a better understanding of aquatic communities' interactions and the biological and evolutionary features of species (Braga, 1986; Moreira & Zuanon, 2002; Fugi *et al*., 2008). These aspects directly reflect their general well-being and are useful in describing seasonal patterns (Freitas *et al*., 2011a; Rabuffetti *et al*., 2017).

In tropical rivers, feeding dynamic is strongly related to hydrological cycles such as the flood pulse (Junk *et al*., 1989). This process is characterized by seasonal variation of river water levels and, consequently, to forest flooding, which increases the foraging area for fishes (Goulding, 1980). During flooding peaks, there is greater availability of allochthonous food resources (Luz-Agostinho *et al*., 2008), as well as changes in the sedimentation process due to the entry of organic and inorganic matter into the aquatic system coming from adjacent terrestrial environments (Junk *et al*., 1989; Agostinho *et al*., 2004). This model highlights the role of connectivity between the main channel and adjacent flooded *habitats*, and predicts that terrestrial material provides most organic carbon supporting aquatic fauna in the main river channel (Zeug & Winemiller, 2008).

In regions where flood pulse is evidenced, fish assemblages show a higher richness of iliophagous species (Bowen, 1984; Fugi *et al*., 1996; Resende & Palmeira, 1999), those that explore the bottom or the perithyton, ingesting great quantity of sediment associated with unicellular algae and microorganisms and organic matter in fine particles (Moraes *et al*., 1997). These species play an important ecological role in organic matter mineralization, which favors degradation by microorganisms and accelerating the nutrient recycling (Gneri & Angelescu, 1951).

In the Amazon Basin, iliophagous fishes are mainly represented by fishes of the family Curimatidae (toothless characins), that represents more than half of fish biomass in large South American rivers (Fugi *et al*., 1996; Barthem & Goulding, 2007), as well as its great importance in the piscivorous diet (Vari, 2003). Thus, studies on the ecology of these fishes provide relevant information for more sustainable fisheries and better comprehension of abiotic factors influences, such as the hydrological periods, in the lifecycle of species. Hence, the aim of this study was to describe ecological aspects of an iliophagous fish, *Cyphocharax abramoides* (Kner, 1859), in the lower Anapu River, Eastern Amazonia (Brazil), with respect to (1) variation of organic matter intake, (2) growth pattern, and (3) condition factor of the species.

MATERIALS AND METHODS

The samples were taken in the lower Anapu River region at the Caxiuanã National Forest (1º 45' 27.5" S; 51º 27' 33.2" W), between the Xingu and Tocantins Rivers, in Eastern Amazonia, state of Pará, Brazil (Figure 1). The region is described as a

> lowland Amazon rainforest located at sea level, being influenced both by the tide and by the oscillation of Anapu River (Hida *et al*., 1999). However, both flows have very low intensity, with an annual fluctuation in the water level only about one meter (Hida *et al*., 1999) (retrieved from Freitas *et al.*, 2011b, p. 632).

The region is defined as 'ria fluvial' due to the geological drowning of the Anapu River valley, with a slight floodplain even during the flood period (Costa *et al*., 2002). The bottom sedimentation in these rivers is composed of sandy-clayey silt, dark gray color and with a great amount of organic matter (Costa *et al*., 1997). In the region four hydrological periods can be observed in the fluviometry (Figure 2): ebb (June-August), dry (September-November), filling (December-February), and flood (March-May).

Fish samples were taken bimonthly between September 2008 and July 2009, covering the entire hydrological cycle. We used three set of gill nets 1.5 m high and 100 m long, and 3-6 mm mesh size between opposite knots. The net placements were guided by a local fisherman. After capture, individuals were measured (standard length in cm – L_S) and weighed (total weight in g – W_T). Stomachs were removed through a cut in the mid-ventral region and kept in 10% formalin for 48 hours, and then preserved in 70% alcohol. Voucher specimens were deposited in the ichthyological collection of the Museu Paraense Emílio Goeldi (MPEG) in Belém (Pará, Brazil) under the codes: MPEG 15423 to 15431, MPEG 15535 to 15543, and MPEG 15839 to 15843.

The concentration of organic matter (organic carbon content – OCC) present in stomach contents of specimens was determined by the wet oxidation-redox titration method, known as the Walkley-Black method (Nelson & Sommers, 1982). The bimonthly variation of the OCC was evaluated with the Kruskal-Wallis test (H) (α = 0.05), since the parametric test premises were not observed, followed by a *post-hoc* test to identify differences in the amount of organic matter consumed within the studied period. The null hypothesis was that the concentration of organic carbon is independent of the studied period.

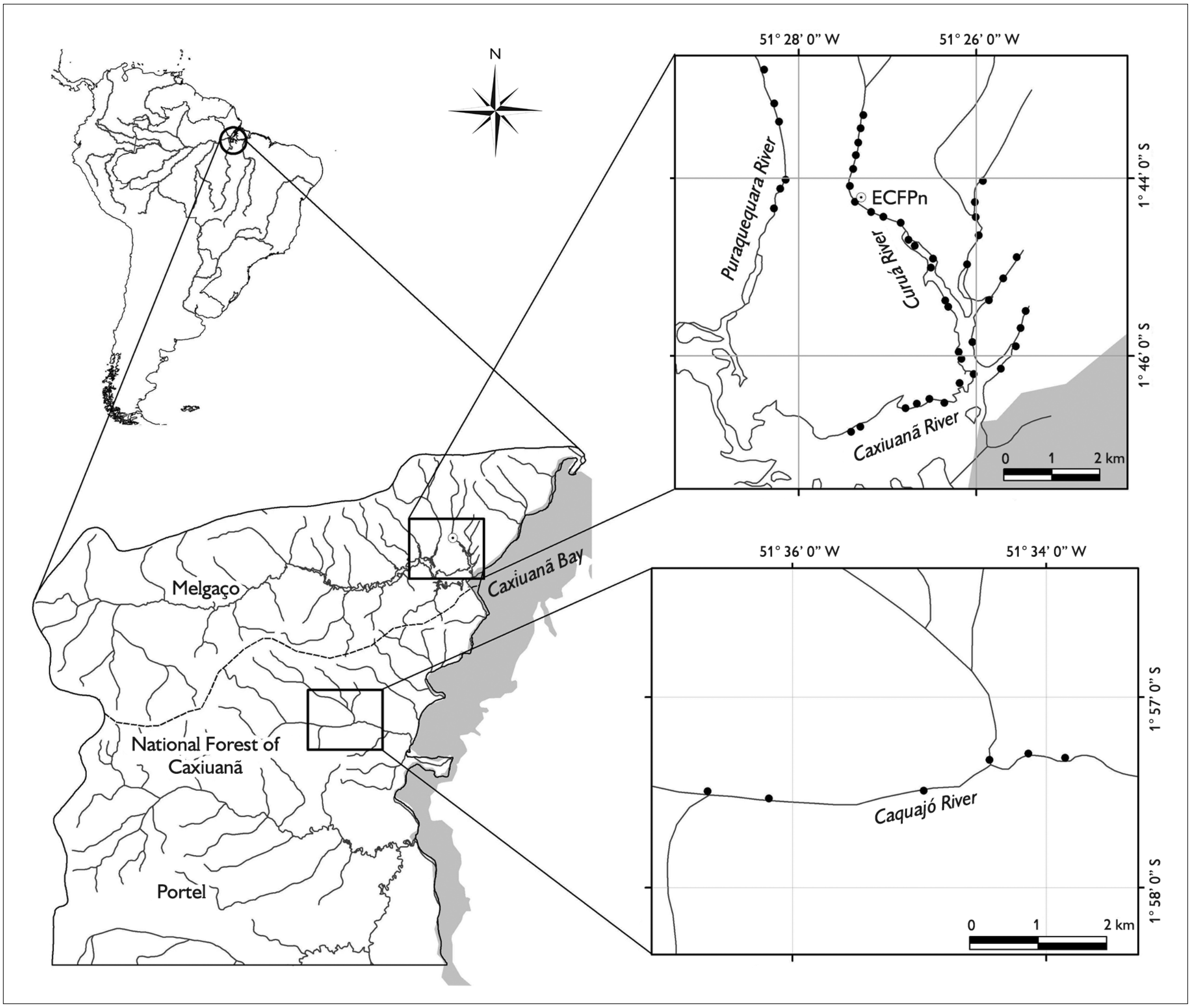

Figure 1. Sampling sites in the Caxiuanã National Forest, Eastern Amazonia, Brazil. Curuá River – *Estação Científica Ferreira Penna* (ECFPn), Caxiuanã River, Puraquequara River, and Caquajó River. Some black spots represent more than one collection site.

The growth pattern and length-weight relationship (LWR) were obtained following the modified model $W_T = a*L_S^b$ (Froese, 2006), which considers that the body relative proportions increase according to a constant *a*, and *b* is defined as the allometry coefficient (Pauly, 1984). The equation parameters were adjusted using the Solver routine of Microsoft Office Excel® 2010 software (Newton search algorithm). Considering that isometric growth corresponds to *b* equal to 3 (Froese, 2006), we applied a t-test (t) to verify whether the declivity of regression (constant *b*) showed a significant difference, indicating the type of growth (isometric or allometric). The LWR did not include individuals captured in November 2008 because their weight was not measured due to logistic problems.

The condition factor (K) was obtained through the formula $K = W_T/L_S^b$, and assumes that for a group of individuals of the same size, those weighing more are in better condition (Le Cren, 1951). To obtain the K values of the individuals captured in November 2008 (those fish that were not weighed), we used the LWR to estimate the weight of these specimens. In this way, the K values for these individuals were equal, but for statistical purposes it was chosen to maintain them to ensure an average temporal series of the K values. The bimonthly variation of K values was also evaluated with the Kruskal-Wallis test (H), followed by a *post-hoc* test, considering as null hypothesis that K values are independent of the sampled period. All analysis respected their premises and were performed with R (R Core Team, 2015), and with a significant level (P) of 5% (Zar, 2009).

RESULTS

A total of 341 specimens of *Cyphocharax abramoides* were analyzed, which presented a mean standard length equal to 11.7 cm (± 2.2 cm) and a mean total weight equal to 51.8 g (± 26.2 g).

The mean organic carbon content (OCC) was 17.5% (± 7.05%) for all studied periods. However, the OCC values varied among the sampled periods ($H = 39.66$, $P < 0.001$, Figure 3), with highest mean values in January 2009 (24.70%) and lowest in July 2009 (16.14%). Differences in OCC were observed comparing January (filling) against September (dry; $p = 0.005$), November (dry; $p < 0.001$), May (flood; $p < 0.001$), and July (ebb; $p < 0.001$).

The length-weight relationship for *C. abramoides* was established by the equation $W_T = 0.0164*L_S^{3.234}$ ($R^2 = 0.956$). The allometric coefficient (b) showed

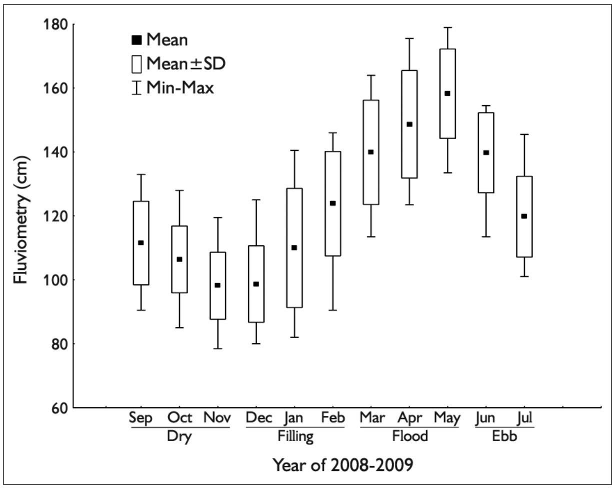

Figure 2. Fluviometry from the rivers of the Caxiuanã National Forest in the period between September 2008 and July 2009. Data were obtained from the Caiçara fluviometric station of the National Water Agency (ANA).

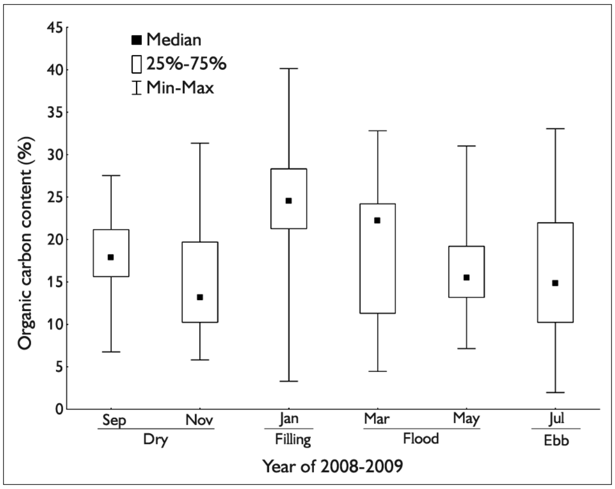

Figure 3. Bimonthly variation of the organic carbon content (OCC) present in the stomach content of *Cyphocharax abramoides* collected from September 2008 to July 2009 in the Caxiuanã National Forest, Eastern Amazonia, Brazil.

positive allometric growth ($b > 3$, $t = 4.756$, $p < 0.001$), with lower and upper limits equal to 3.137 and 3.331, respectively.

The condition factor values (K) also differed among sampling periods ($H = 42.87$, $p < 0.001$, Figure 4). The highest K value was recorded in July 2009 (0.0148) and the lowest value for March 2009 (0.0133). Differences in K values was seen when comparing January (filling) with November (dry; $p = 0.018$) and July (ebb; $p = 0.001$), and between March (flood) and September (dry; $p = 0.017$), November (dry; $p = 0.018$) and July (ebb; $p < 0.001$).

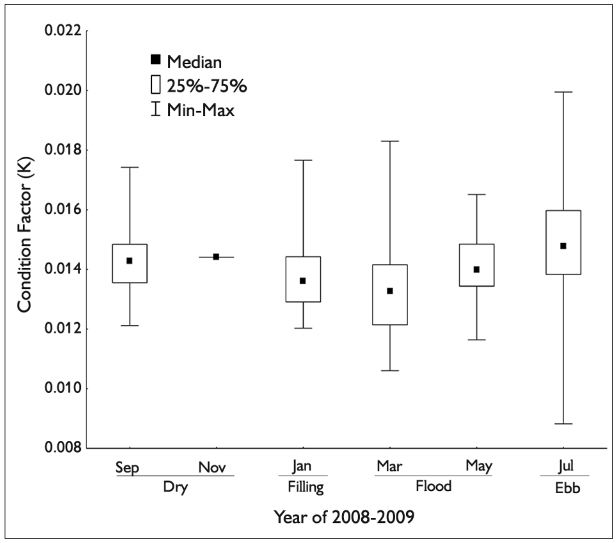

Figure 4. Bimonthly variation of the Condition Factor (K) of *Cyphocharax abramoides* collected from September 2008 to July 2009 in the Caxiuanã National Forest, Eastern Amazonia, Brazil.

DISCUSSION

The iliophage habit is common among species of the family Curimatidae (Alvarenga *et al*., 2004; Corrêa & Piedras, 2008). However, knowledge of the ecology of Curimatidae fishes is still preliminary in the Amazon.

When evaluating the percentage of organic matter in the stomach contents of *C. abramoides*, we found differences among the studied periods, with a lower consumption of organic carbon in the dry season (mainly November 2008). This fact may be related to the lower availability of organic matter on the river bottom due to the lower transport of organic particles from the terrestrial system (Nogueira *et al*., 2001; Carmassi *et al*., 2008).

The highest rates of organic matter consumption were during filling (January 2009) and flood periods (mainly March 2009) and may be related to the increased flooding areas and, consequently, to the higher input of allochthonous nutrients (Lowe-McConnell, 1999; Zeug & Winemiller, 2008). These inputs are an important part of aquatic food chains, which favor the development of organisms such as microalgae (Lin & Caramaschi, 2005), an important component in the diets of iliophagous fish (Corrêa & Piedras, 2008).

The higher concentration of organic matter during the higher water levels (filling and flood) could be associated with an event of high energy demand, such as reproduction. Many fishes synchronize the spawning season with the flood period due in particular to the increased availability of *habitats* that favor the survival of larvae and fry (Godinho *et al*., 2010). In the case of *C. abramoides* the energy obtained through feeding would be mainly destined to gonadal development (Giora & Fialho, 2003). A possible period of reproductive activity in the flood period would also explain the lower K values for the same period (March 2009), since reduction in K values may be caused by a high energy cost event, as reproduction (Freitas *et al*., 2011b).

In addition, higher values of the condition factor after the flood period (ebb; July 2009) suggest a possible physiological recovery period, during which part of the assimilated energy would not be intended for gonadal maturation. Several studies associate condition factor variation with ecological aspects such as reproduction and feeding (Braga, 1986; Ballesteros *et al*., 2009), and this becomes an important tool for biological data assessment in the absence of specifics indexes. Finally, the positive allometric growth recorded herein for *C. abramoides* was also cited by Giarrizzo *et al*. (2011) for individuals collected in the Trombetas River, a left-side tributary of the Amazon River.

Considering the variations of the percentage of organic matter in the stomach contents and the condition factor during the studied period, these parameters can be associated with the flood pulse. Even considering that the study area is a 'drowned river' and does not present a pronounced flood pulse as in other Amazonian regions (Junk *et al*., 1989), this variation already seems to influence the ecology of the iliophage *C. abramoides*. Even so, the reduced flood pulse also seems to influence the trophic ecology of other fish species in the rivers of the Caxiuanã National Forest, as evidenced for the insectivorous *Auchenipterichthys longimanus* (Günther, 1864) (Freitas *et al*., 2011a) and the piscivorous *Serrasalmus gouldingi* Fink & Machado-Allison, 1992 (Prudente *et al*., 2016). These ecological studies increase our knowledge of the relationship between species and the environment, and become especially relevant in a region of high species richness and still poorly studied biology, such as the Amazon. Moreover, given the importance of iliophagous fishes in aquatic trophic chains, this ecological information can be useful for conservation plans for the flooded forest and more sustainable exploitation of this fishery resource.

CONCLUSION

The results indicate a probable relationship between changes in the biological parameters of the iliophagous fish *Cyphocharax abramoides* and environmental variations caused by the seasonal flood pulse.

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