FEEDING ECOLOGY OF *Cichlasoma amazonarum* (TELEOSTEI, CICHLIDAE) IN THE CENTRAL AMAZON LAKES, BRAZIL.

ECOLOGIA ALIMENTAR DE *Cichlasoma amazonarum* (TELEOSTEI, CICHLIDAE) EM LAGOS DE DA AMAZÔNIA CENTRAL, BRASIL.

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KEY WORDS:

Diet;

Mamirauá;

Trophic niche;

Cichlids.

ABSTRACT

The diet of the cichlid *Cichlasoma amazonarum* was investigated through an analysis of 270 gastric contents obtained from monthly samples collected from five lakes located in the Central Brazilian Amazon, throughout the year of 2012. The composition of the diet was assessed using the methods of frequency of occurrence and relative dominance (frequency of biomass), which were combined in the Alimentary Importance Index (AIi) in accordance with the hydrological cycle's extreme periods of drought and high waters. The intestinal coefficient was investigated to demonstrate the feeding tendencies of the species. The breadth and diversity of the trophic niche were also compared for these periods. The intestinal coefficient for the species (0.95), combined with the results of the analysis of food content, showed a species that demonstrates carnivorous/insectivorous habits. During the high water season, the diet is composed of unidentified animal matter, unidentified larvae and insects; and in the drought season, plant matter, unidentified animal matter and insects. Although there was no significant difference in dietary diversity between seasonal extremes, the analysis of the breadth of the trophic niche characterises the species as feeding specialists.

PALAVRAS - CHAVE:

Dieta;

Mamirauá;

Nicho trófico;

Ciclídeos

RESUMO

A alimentação do ciclídeo *Cichlasoma amazonarum* foi investigada por meio da análise de 270 conteúdos gástricos, obtidos de amostragens mensais realizadas em cinco lagos de localizados na Amazônia Central Brasileira, ao longo do ano de 2012. A composição da dieta foi avaliada pelos métodos de frequência de ocorrência e dominância relativa (frequência de biomassa), que foram combinados no Índice Alimentar (IAi) de acordo com períodos extremos do ciclo hidrológico, cheia e seca. O coeficiente intestinal foi investigado para indicar tendências alimentares da espécie. A largura e diversidade do nicho trófico também foram comparadas considerando tais períodos. O Coeficiente Intestinal para a espécie (0,95) aliado aos resultados da análise do conteúdo alimentar evidenciaram que a espécie apresenta hábito alimentar carnívoro/insetívoro. Durante a estação cheia, a dieta é composta por material animal não identificado, insetos e larvas não identificadas; e na seca, por material vegetal, material animal não identificado e insetos. Embora não tenham apresentado diferenças significativas na diversidade da dieta entre os extremos sazonais, a análise de largura de nicho trófico caracteriza a espécie como especialistas alimentares.

INTRODUCTION

Knowledge of the diet of fish aids in understanding the relationship between a species and its environment, including biological, ecological and evolutionary aspects. These interactions allow the fish to develop adaptations in the use of food (LOWE-McCONNELL, 1999; SILVA, 1993). Fish differ greatly in terms of the type of food consumed, more than any other type of vertebrates (NIKOLSKI, 1963). Most freshwater fish can change from one food to another, as soon as there are changes in environmental conditions and relative abundance of food resources, since natural environments vary spatially and temporally (WINEMILLER, 1989; ABELHA et al., 2001; GOULDING, 1980; HAHN et al., 1997; LOWE-McCONNELL, 1999; WOOTTON, 1999).The activity of fish, changes in its habitat and the presence of other species in the same environment are also powerful factors in the investigation of the feeding ecology of fish (LOWE-McCONNELL, 1999). In the Central Amazon, particularly ecosystems, environmental peculiarities result from the annual fluctuation of the water level, which can exceed a magnitude of 10 m (JUNK et al., 1997a; JUNK; PIEDADE, 2005; SCHÖNGART; JUNK, 1997; RAMALHO et al., 2009). This results in drastic changes in environmental conditions, requiring specific adaptations of the ichthyofauna and their diet (GOULDING, 1980; SOARES et al., 2006; JUNK et al., 1997).

The aquatic environments of the ecosystems in the Amazon are colonised by a high diversity of aquatic plant species, belonging to the most varied taxonomic groups (PIEDADE et al., 2005; GUTERRES et al., 2008). In the high water period, there is a rapid colonisation of the available areas and the banks of macrophytes can occupy up to 75% of the surface area of a lake (JUNK; PIEDADE, 1993; JUNK; PIEDADE, 1997). In the drought period, however, with the reduction of flooded areas, plant mortality is high, reducing the community by up to 90% (JUNK, 1980). Such changes in seasonal patterns provoke profound alterations both in regards to habitat availability, as well as in their physical conditions, changing the structure and composition of the fish communities (HENDERSON, 1999).

Cichlids comprise one of the most numerous groups of fish in the world, with about 450 of them occurring in South America and a little more than 250 in the Amazon (SANTOS et al., 2006). The majority exhibit territoriality, marked sexual dimorphism and strong parental care of offspring (KEENLEYSIDE, 1979). *Cichlasoma amazonarum* (KULLANDER, 1983) is a small species, and can reach up to 15 cm in length (KULLANDER, 2003). It has sedentary habits and is abundant in banks of aquatic macrophytes in white waters. However, information about its biology is still very scarce.

This study sought to evaluate the composition of the diet, the breadth of the trophic niche and the diversity of the diet of *Cichlasoma amazonarum* in regards to hydrological modifications that influence the availability of their food in Central Amazon lakes.

MATERIAL AND METHODS

Samples of *C. amazonarum* were collected monthly from January to December 2012 in habitats formed by aquatic macrophytes in five lakes (Araçazinho, Juruá Grande, Pagão, Taracoá and Tracajá), all located in the Mamirauá Sustainable Development Reserve – RDSM (03º08'S, 64º45'W and 2º36'S, 67º13'W) Figure 1.

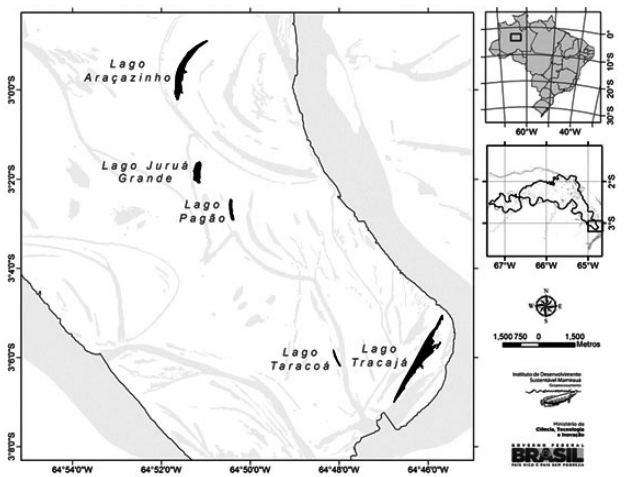

Figure 1 - Location map of the lakes sampled in the Mamirauá Sustainable Development Reserve, Amazonas.

The fish were captured in trawl nets with a mesh of five millimeters between opposite knots, identically cast five times per lake. Banks of aquatic macrophytes measuring 4x4m were enclosed and randomly chosen at each collection point. Every month, 80m^2 of aquatic macrophytes were sampled in each lake studied. The fish caught were killed by the administration of an overdose of the anesthetic Eugenol for 10 minutes. Later, they were fixed in a 10% solution of formaldehyde and, after 24 hours, were transferred to drums containing 70% alcohol. The material evidence can be found at the Laboratory of Fish Biology at the Mamirauá Institute for Sustainable Development (ISDM), in Tefé (AM). The standard length of the samples was between 18.01 and 97.08 mm (50.04 ± 17.00 mm).

The fish were dissected for analysis of their digestive tracts (stomachs and intestines). The stomachs removed from the digestive tracts were examined under a stereomicroscope and food items were identified to the lowest possible taxonomic level, with the help of specialised literature and the consultation of specialists. Invertebrates were identified according to Rupert et al. (2005). The presence of sediment in the stomach contents was recorded, but this was not included in the diet analysis. The items were grouped into seven broader food categories: Insects, Mollusks, Fish, Plant Matter, unidentified Animal Matter (decomposed animal fragments), unidentified Larvae and Organic Matter (consisting of small, rotting animal and plant fragments).

The importance of each taxon was calculated based on its frequency of occurrence (FO%) in relation to the number of stomachs with food (Hyslop, 1980). In these analyses, relative dominance was evaluated, calculated based on the biomass (FB%) of the food items, reflecting the proportional importance of the most significant items in the diet. From the values obtained for FB% and FO%, the Alimentary Importance Index (AIi) was calculated for each item found (KAWAKAMI; VAZZOLER, 1980), estimating the relative importance of each food category to the species studied.

To allow a clearer evaluation of the seasonal variations observed, the results were grouped into two extreme periods of the hydrological cycle of 2012: High water, from November to June, and Drought, considering the months of July, August, September and October.

The degree of repletion (DR) of the stomachs was verified by visually estimating them on a 4-step scale: 0 - empty (without food content); 1 - partially empty (up to 25% replete); 2 - partially full (between 25% and 75% replete); 3 - completely full (75% to 100% replete). Taking into consideration the results of the degree of repletion, the relative frequency of the four categories of repletion was calculated. The variation of the average monthly water levels in 2012 was obtained based on monitoring data from the Mamirauá Institute for Sustainable Development and presented with the degree of repletion.

The intestines were measured with a digital caliper rule (accurately in mm) to determine the

intestinal coefficient (IC), which was calculated using: IC = LDT / SL, where LDT = the length of the digestive tract, SL = the standard length of the fish. According to Bértin (1958), in general, the intestinal coefficient varies from 0.2 to 2.5 in carnivores, 0.6 to 8.0 in omnivores and 0.8 to 15.0 in herbivores.

To calculate the amplitude of the trophic niche, the LEVINS Index (1968) was used ($B = 1/\sum Pi^2$, where Pi^2 is the proportion of item i in the individual's diet), standardised according to Hurlbert (1978). This index provides values of the breadth of the niche between 0 and 1 (the closer to 1, the diet is considered to be more generalist, and the closer to 0, more specialist), using the formula $B' = (B - 1)/(n - 1)$, where B' is the value of the breadth of the niche in the Levins index, and n is the number of food categories used. The diversity of the diet was quantified by the Shannon-Wiener Diversity indices (using the values of AIi) and the equitability of Pielou (KREBS, 1989). The Z test was applied to compare the averages between the periods of high water and drought.

RESULTS

270 samples were analysed and, of those, only 187 stomachs contained food, 121 in the high water season and 61 in the drought season (Table 1). The presence of empty and partially empty stomachs was observed in the two hydrological periods. During the drought season, 39.25% of the stomachs were found completely empty (repletion 0), whereas in the high water season this rate was 25.15% (Figure 2).

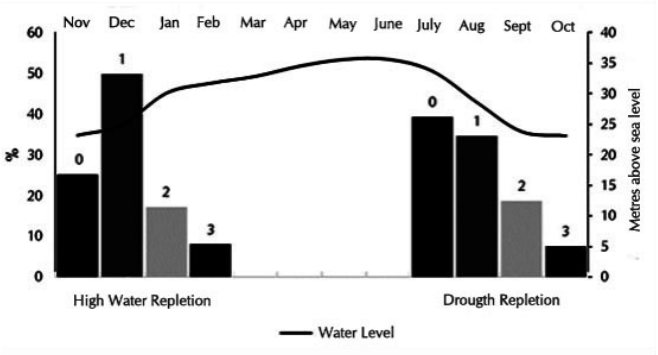

Figure 2. Degree of repletion of the gastric contents of *Cichlasoma amazonarum* collected in the lakes of the Mamirauá Sustainable Development Reserve and the variation of the water level in 2012. 0 - empty; 1 - partially empty; 2 - partially full; 3 - completely full (n = 270).

The intestines of *C. amazonarum* are devoid of *pyloric caeca* and appear to be quite short, with an intestinal coefficient of 0.95 ± 0.24. The measurements of intestinal length varied from 33.38 mm to 95.55 mm (62.61 ± 16.15 mm). According to the classification of Bértin (1958), this coefficient is typical of the feeding habits of carnivorous species that have an IC between 0.2 and 2.5.

The analysis of stomach contents indicated a diet composed of 19 food categories, where 10 categories are grouped under Insects (Table 1). The categories which occurred most in the stomachs of *C. amazonarum* in the high water season and the drought season were unidentified animal matter and insects. The frequency of occurrence, relative dominance and the Alimentary Importance Index of all food categories found are shown in the table below.

The values of the AIi indicate unidentified animal matter (49.47%), insects (16.10%) and unidentified larvae (15.53%) as the most important items in the diet of *C. amazonarum* during high water periods, and plant matter (41.57%), unidentified animal matter (29.95%) and insects (12.75%) in the drought period (Figure 3). As the items of

unidentified animal matter and insects are always present, at a level of considerable importance, during both extremes of the seasonal cycle, these are the most important components of the diet of *C. amazonarum* as a whole (Table 1).

Table 1. Percentage breakdown of the diet of *Cichlasoma amazonarum* in the Mamirauá Sustainable Development Reserve during the year 2012. (n.i. = not identified).

Food Items	FO %		FB%		Ali %		Total Ali %
	High waters	Drought	High waters	Drought	High waters	Drought	
Insects	**26.4**	**40.98**	**15.77**	**9.90**	**16.10**	**12.74**	**28.85**
Blattaria	0.00	1.64	0.00	1.03	0.00	0.08	
Coleoptera	3.31	3.28	1.35	1.22	0.20	0.20	
Diptera	0.00	4.92	0.00	0.19	0.00	0.05	
Ephemeroptera larvae	0.00	1.64	0.00	0.06	0.00	0.01	
Hemiptera	0.83	0.00	0.90	0.00	0.03	0.00	
Hymenoptera (*Formicidae*)	0.00	1.64	0.00	0.06	0.00	0.01	
Orthoptera	2.48	1.64	7.86	3.21	0.88	0.26	
Insect fragments n.i.	9,92	14.75	3.15	1.54	1.42	1.11	
Insect larvae n.i.	9.09	11.48	2.00	2.57	0.83	1.44	
Insect pupae n.i.	0.83	0.00	0.50	0.00	0.02	0.00	
Mollusks	**5.79**	**1.64**	**2.35**	**0.13**	**0.53**	**0.01**	**0.53**
Mollusks n.i.	3.31	1.64	1.65	0.13	0.25	0.01	
Gastropods	2.48	0.00	0.70	0.00	0.08	0.00	
Fish	**3.31**	**11.48**	**9.31**	**8.55**	**1.19**	**3.08**	**4.27**
Fish fragments	1.65	0.00	5.26	0.00	0.39	0.00	
Fish scales	1.65	11.48	4.06	8.55	0.30	4.78	
Plant matter	**9.92**	**34.43**	**7.36**	**38.43**	**2.82**	**41.57**	**44.39**
Seeds	2.48	11.48	2.85	30.46	0.32	17.05	
Plant fragments	7.44	22.95	4.51	7.97	1.52	8.92	
Larvae n.i.	**22.30**	**1.639**	**18.03**	**0.19**	**15.53**	**0.01**	**15.54**
Animal matter	**40.50**	**42.62**	**31.65**	**22.37**	**49.47**	**29.95**	**79.43**
Organic matter	**24.00**	**19.67**	**15.52**	**20.44**	**14.36**	**12.63**	**26.99**
Stomachs with content (n)			**122**	**61**			
Total (n)			**190**	**80**			

Comparison of the values of the breadth of the niche of *Cichlasoma amazonarum* between the extreme periods of the hydrological cycle exhibited little abundance of the dietary niche, in high water (B = 0.27) and in drought (B = 0.16) periods. An increase of 37.86% during the high water season was detected. The estimated value of this analysis showed that individuals behaved in more specialist ways than generalist regarding the trophic breadth of their diet. As to its diversity, considering the extremes of the hydrological cycle, similar values in high water (H ' = 0.80) and in drought (H' = 0.87) periods were obtained, and with respect to the evenness in the drought period (J ' = 0.89) and the rainy period (J '= 0.97), no significant differences were recorded (Z = 0.40).

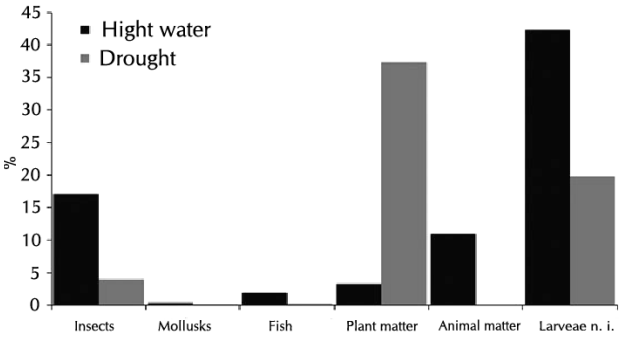

Figure 3. Alimentary Importance Index (Ali) of the categories ingested by *Cichlasoma amazonarum* in lakes in the Mamirauá Sustainable Development Reserve (n = 270)

DISCUSSION

The large quantity of empty stomachs recorded in this study have also been reported by other authors (GOULDING, 1980; HAHN, et al., 1999; RABELO; ARAÚJO-LIMA, 2002; YAMAMOTO, et al., 2004). Some of them relate the drought period to a time of restricted feeding for many species of non-piscivorous fish.

The most representative resources of the food of the *Cichlasoma amazonarum* analysed in this

study indicate a carnivorous diet, predominantly composed of unidentified animal matter and insects. In the high water season, unidentified animal matter and insects were generally the resources most consumed by the fish studied, and those most consumed in the drought season were plant matter and unidentified animal matter.

A previous study of another member of the genus, *Cichlasoma facetum* in a hypertrophied urban lake (YAFE et al., 2002), characterised the species as omnivorous with a propensity towards carnivorous, with insects and fish being the most consumed food categories. In that study, plant matter was also well represented. Among the items that comprised the diet of *C. amazonarum*, insects and unidentified animal matter accounted for a significant proportion of consumed prey, especially in the high water season. Many predators find their prey drifting with the marginal vegetation or the substrates used both for food and for reproduction (GIL; HART, 1999). In this condition, aquatic insects stand out among the prey, some for having the habit of burying in the substrate or seeking shelter in plant fragments accumulated at the bottom (MCCAFFERTY, 1981), and others, like the small fish, for seeking shelter in aquatic macrophytes, which form the banks of the floating vegetation studied.

The investigations carried out on the feeding habits of *Cichlasoma urophthalmus* suggest that this species is carnivorous, consuming mainly invertebrates throughout the hydrological cycle (MARTINEZ-PALACIO; ROSS, 1988). The structures of the food and the short intestines observed in the species *Cichlasoma urophthalmus* suggest that the digestion of plant matter does not occur efficiently. These morphological characteristics may be shared with *Cichlasoma amazonarum*. In the present study, we suggest that plant matter (fragments of leaves and roots), found in large quantities in the drought season (41.57%), have been swallowed accidentally as a result of predation on small invertebrates among the floating vegetation of the macrophyte banks. The superior representation of plant matter in the diet of *C. amazonarum* in the drought season suggests an intense foraging activity on indigenous insects (mainly larval forms) in this season.

It is more difficult to distinguish the dominant prey from those that are supplementary or accidental (ROSECCHI; NOUAZE, 1987). Other studies of cichlids have already pointed to this trend in carnivorous-insectivorous feeding habits, with a clear preference for insects (WINERMILLER et al., 1995; MOUREIRA; ZUANON, 2002; CASATTI et al., 2003; ABELHA; GOULART, 2004; MONTANÃ; WINEMILLER, 2009; LINS, 2011). Few of these studies have clearly observed the occurrence of accidental ingestion or the presence of supplemental prey (MONTANÃ; WINEMILLER, 2009; LINS, 2011).

The hydrological regimen has great importance in the feeding habits of fish (GOULDING, 1980; HAHN et al., 1997; WOOTTON, 1999). During high waters, a good quantity of organic matter from flooded terrestrial vegetation leads to an excessive increase in microorganisms, followed by a large explosion of macroinvertebrates (insects, crustaceans, mollusks), which, in turn, are used as food by the ichthyofauna (JUNK, 1980; LOWE-McCONNEL, 1999). In the drought season, the availability of food becomes more restricted for those that are not piscivorous (GOULDING, 1980). Moreover, as emphasised by Junk (1980), the hydrological changes affect, not only the quantity, but also the quality of the food.

Our interpretation of the results obtained in this study suggests that *C. amazonarum* is a specialist species, carnivorous-insectivorous, and not omnivorous, with a diet restricted to a relatively small number of prey types. The occurrence of specialists or generalists in a particular habitat is

influenced by the dynamics and abundance of their food resources. Mérona; Rankin-De-Mérona (2004), having studied 23 species of fish from the lakes of the Central Amazon, and which belong to different trophic guilds, classified many of them as specialists with respect to their eating behaviours. Fish and insects were the most important food resources throughout the year of that study.

Apparently there is a predominance of specialists in lakes and of generalists in rivers (LOWE-McCONNELL, 1999), considering that specialisation is not an adaptive feature in communities that exploit temporary habitats, such as areas (ARAÚJO-LIMA et al., 1995).

The breadth of the niche was not significant for any of the hydrological seasons and, therefore, *C. amazonarum* could be considered an oligophagous species, or one which feeds on few food items. During periods of high water, there is greater availability of foreign food, along with a dispersion of the fish to different habitats, increasing foraging activity. To compensate for periods of major food shortages, the fish store fat in the abdominal cavity during periods of abundance (JUNK, 1989). In turn, a smaller breadth of the trophic niche in the drought season and a smaller number of food items, especially foreign insects, are characteristics which can be related to a reduction of the complex structure of the aquatic macrophytes.

CONCLUSION

According to the research conducted in this study of *C. amazonarum* in lakes, it was concluded that their diet is predominantly composed of matter of animal origin and insects. In the high water period, there was ingestion of unidentified animal matter, insects and unidentified larvae. During the drought period, *C. amazonarum* consumed plant and animal matter, as well as insects. Because *C. amazonarum* have short intestines and exhibit the intestinal coefficient characteristic of species with carnivorous feeding habits, the results suggest that *C. amazonarum* has carnivorous/insectivorous feeding habits. Although no significant differences were recorded in dietary diversity between the seasonal extremes, the breadth of the trophic niche showed that individuals of the species studied behave like feeding specialists.

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