

Piscivory by *Hoplias* aff. *malabaricus* (Bloch, 1794): a question of prey availability?

Piscivoria por *Hoplias* aff. *malabaricus* (Bloch, 1794):
uma questão de disponibilidade de presas?

Ana Karla Araujo Montenegro¹, Ana Carolina Brito Vieira¹, Maria Marcolina Lima Cardoso²,
Jane Enisa Ribeiro Torelli de Souza¹ and Maria Cristina Crispim¹

¹Laboratório de Ecologia Aquática – LABECO, Departamento de Sistemática e Ecologia,
Universidade Federal da Paraíba – UFPB, Cidade Universitária, Campus I, CEP 58059-900, João Pessoa, PB, Brazil
e-mail: biokarla_21@hotmail.com; carolgnv@hotmail.com; janetorelli@yahoo.com.br; ccrispim@hotmail.com

²Pós-graduação em Ecologia – PGE, Universidade Federal do Rio Grande do Norte – UFRN,
Av. Sen. Salgado Filho, 3000, Lagoa Nova, CEP 59078-970, Natal, RN, Brazil
e-mail: marcolinaipj@yahoo.com

Abstract: Aim: In order to understand the factors which influence the predatory activity of the *Hoplias* aff. *malabaricus*, the present study evaluated feeding habits of this species and its relation to prey availability, in addition to environmental variables. **Methods:** Six samplings were conducted in the Taperoá II reservoir, semi-arid of Paraíba state, Brazil, between October 2005 and October 2006. Measures were taken: rainfall, the reservoir volume, transparency, dissolved oxygen, pH, temperature, nitrate, nitrite, ammonia and phosphate. The activity, diet and feeding habits of *H. aff. Malabaricus*, from the method of frequency of occurrence of food items and point methods, conjugates in IAI (Alimentary Index). Spearman correlation analysis, a glm and CCA were performed between biotic and abiotic variables, and we used the CPUE as a measure of fish abundance. **Results:** Eleven taxa of fish were recorded, four of which were predated by adult “trahira”. Insects and other items were also common in the stomachs of juveniles. According to statistical analysis, it was observed that the highest consumption of cichlids was correlated with its increase in CPUE in the environment, while no relationship was observed for *A. bimaculatus*, *C. bimaculatum* and *S. notonota* abundances. The environmental factors as nutrients, transparency and water volume were related to selection of species by trahira. **Conclusions:** Intrinsic characteristics of preys as swimming speed, food habit and the food preference of the predator possibly be the main factors to selection of species. Other mechanisms as heterogeneity of habitat and environmental factors can also influence the consumption of prey by trahira.

Keywords: feeding, predation, reservoir, semiarid, fish.

Resumo: Objetivo: A fim de se compreenderem os fatores que influenciam a atividade predatória de *H. aff. malabaricus*, o presente trabalho avaliou o hábito alimentar e a sua relação com a abundância de suas principais presas e algumas variáveis ambientais. **Métodos:** Realizaram-se seis amostragens no Açude Taperoá II, semi-árido paraibano, Nordeste do Brasil, de outubro de 2005 a outubro de 2006. Foram tomadas as medidas de: pluviosidade, volume do açude, transparência, oxigênio dissolvido, pH, temperatura, nitrato, nitrito, amônia e fosfato. Analisou-se a composição da ictiofauna, a atividade, dieta e hábito alimentar de *H. aff. malabaricus*, a partir do método de frequência de ocorrência dos itens alimentares consumidos e do métodos de pontos, conjugados no IAI (Índice de Importância Alimentar). Análises de correlação de Spearman, glm e CCA foram realizadas entre as variáveis bióticas e abióticas, e utilizou-se o CPUE como uma medida de abundância das espécies de peixes. **Resultados:** Registraram-se 11 taxa de peixes, dos quais quatro foram presas da traíra adulta. Insetos e outros itens foram registrados nos estômagos dos juvenis. De acordo com as análises estatísticas, observou-se que o maior consumo de ciclídeos foi correlacionado com a sua abundância no ambiente, enquanto nenhuma relação foi observada para *A. bimaculatus*, *C. bimaculatum* e *S. notonota*. Fatores ambientais, como nutrientes, transparência e volume da água estiveram relacionados com a seletividade do consumo da traíra. **Conclusão:** Características intrínsecas como rapidez de locomoção, atividade alimentar da presa e a preferência alimentar do predador possivelmente sejam os principais fatores de seleção dos recursos consumidos. Outros mecanismos como a heterogeneidade de habitat e fatores ambientais podem também influenciar o consumo de presas pela traíra.

Palavras-chave: alimentação, predação, reservatório, semi-árido, peixe.

1. Introduction

Predation is one of the most important factors controlling the structure and abundance of fish communities in freshwater environments. Understanding the mechanisms responsible for predator-prey interactions is amongst the most important means of determining patterns of population dynamics (Piana et al., 2006). Piscivorous fishes have a profound direct or indirect effect on the overall community and on water quality, given their top positions on trophic webs and the underlying regulation of prey population sizes (Nowlin et al., 2006). Several studies investigated the role of predation on population dynamics (e.g. Novakowski et al., 2007). Some of the well known positive effects of predation come about from the selective pressure directed to weaker prey individuals, and the control of dominant species, therefore maintaining appropriate levels of diversity (Popova, 1978). However, negative effects, mostly due to intense predatory activities affecting the dynamics and abundance of prey species, have also been reported (Wootton, 1990).

Amongst the most important piscivorous fishes of freshwater environments in Brazil, the “trahira” (*Hoplias* aff. *malabaricus* Bloch, 1794) is a sedentary, opportunistic predator and tolerating several habitats, from open to macrophyte-dominated areas (Milani et al., 2010, Petry et al., 2010). This species has a broad geographic span in the Neotropical region, being virtually present at every hydrographic basin of Brazil, and with at least seven documented subspecies (Petry et al., 2010).

Several studies on the biology and importance of the “trahira” to the dynamics of Brazilian environments have been conducted, particularly, in the Rio Paraná Basin (Petry et al., 2010; Novakowski et al., 2007; Luz-Agostinho et al., 2008; Peretti and Andrian, 2004), Amazonas (Galacatos et al., 2004) and Pantanal (Milani et al., 2010; Brandão-Gonçalves et al., 2010). Further, experimental studies on its feeding biology and its role on trophic cascades have also been documented (Botham et al., 2005; Botham and Krause 2005; Piana et al., 2006). Nevertheless, compared to these areas, semi-arid regions have received little scientific attention and data on the feeding biology of “trahiras” remain scant.

Along with biological interactions, several abiotic factors influence community dynamics, namely, temperature conditions, water quality and hydrological regimes. Although the semi-arid is amongst the most atypical biomes in the world, its intrinsic mechanisms of ecosystem function remain

poorly understood, particularly when compared to other biomes (Humphries and Baldwin, 2003).

In semi-arid regions, the low and irregular pluviometric rates, as well as intense evaporation caused high fluctuations in water level and seasonal changes in water quality (Pérez-Martínez et al., 1991), and led to adaptations of morphological, physiological and behavioral nature to harsh conditions (Cowx et al., 1984; Wilhite, 2000).

Because, the hydrological cycles can add complexity to the predator-prey relationship and studies of the dynamics of piscivorous fish their prey are absent in aquatic semi-arid regions, we aimed to test the following hypothesis: a) as *Hoplias* aff. *Malabaricus* is a sedentary predator, its diet is related to prey availability; b) the environmental factors play an important role in prey capture by *H. aff. malabaricus*.

Encouragement of the present study were threefold, namely, the scarcity of studies conducted in the study region, the ecological role played by the subject species on freshwater environments and its economical importance as animal protein for local human populations.

2. Material and Methods

2.1. Study site

Taperoá II reservoir is located at the Taperoá River basin, in the central region of Paraíba State (07° 11' 44" S to 07° 13' 44" S and 36° 52' 03" W to 36° 50' 09" W) (Figure 1). It has a surface area of 4.6 Km², maximum water capacity of 15,148,900 m³, maximum depth of 5.7 m and mean depth of 1.4 m. The reservoir supplies water to Taperoá city and, during periodic events of overflow, to neighboring cities nearby the intermittent Taperoá River.

The semi-arid region of Paraíba has two well-defined seasons, namely, the rainy season, lasting between three and four months, and the dry season, lasting between eight and nine months. The weather at this region is classified as BSh' (Köppen climate classification), indicating a hot and dry semi-arid climate, with a rainy season lasting throughout the summer and fall. This region has the lowest precipitation indexes of Brazil (i.e. 300 mm per year).

Sampling was carried out during the 2005 dry season (October and December), 2006 rainy season (March and June), and 2006 dry season (August and October). Pluviometric and water volume data were provided by Agência Executiva de Gestão das Águas do Estado da Paraíba (AESAs, 2007) (Figure 2).

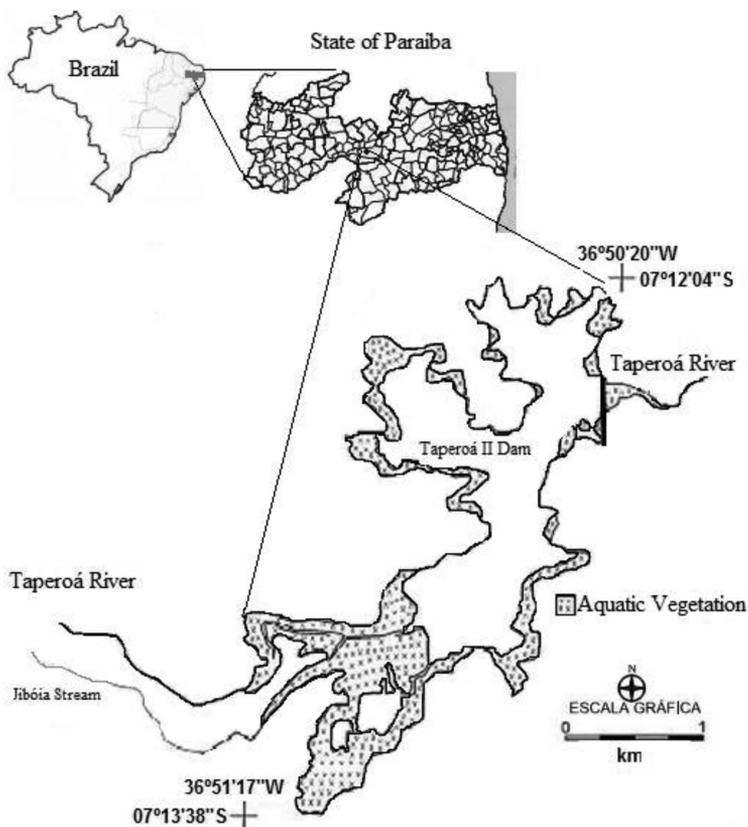


Figure 1. Taperoá II dam location in Taperoá, Paraíba, Brazil.

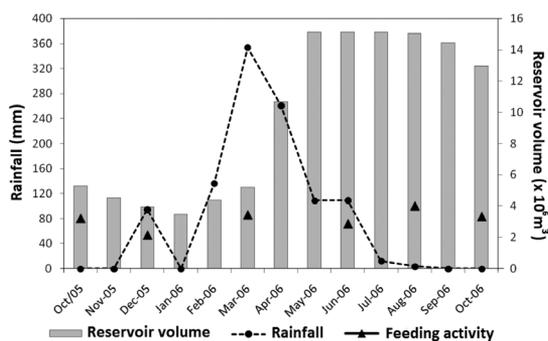


Figure 2. Pluviometric indexes in the Taperoá region, volume in the Taperoá II Reservoir, and feeding activity of *H. aff. malabaricus* during the study period (Source: AESA, 2007).

Weather during the study period encompassed three distinct seasons, namely, a dry season between October 2005 and January 2006, a rainy season between February and June 2006 and another dry season between July and October 2006. The highest pluviometric rate (353 mm) was recorded in March, a somewhat atypical level for the region. Water volume in the Taperoá II reservoir showed high fluctuations throughout the study period,

varying between $3.930.838 \text{ m}^3$ in December 2005 and $15.148.900 \text{ m}^3$ in May, June and July 2006 (overflow).

However, contrary to what was observed at preceding years (1998 and 2003), the reservoir did not dry completely during the study period (Figure 2). Multi-species macrophyte banks (*Eichhornia crassipes*, *Salvinia* sp., *Egeria densa* and Cyperaceae) predominated during periods of high water volume.

2.2. Sampling procedures

Six samplings were performed during a 24 hours period, where samples were collected in the deepest sector of the reservoir on the limnetic and shore zones, at four hours intervals, totaling six samples per sampling day. Fish specimens were collected using the following fishing instruments: cast nets and seine nets (15 mm mesh net between adjacent knots, nylon bags with 0.2 mm of net opening; length and width of 5 and 2 m, respectively), and gillnets (meshes of 15, 20, 25, 35 and 40 mm, between adjacent knots; length and height of 20 and 2 m, respectively). During each interval gillnets and cast nets were used in the reservoir edges, 30 and 15 times, respectively, whereas the seine net

was used 10 times, in the edges and in the limnetic zone of the reservoir.

Abiotic variables were estimated in field or analyzed at the Aquatic Ecology Laboratory, Departamento de Sistemática e Ecologia, Universidade Federal da Paraíba from collected water samples. These variables included: water temperature (Inconterm mercury thermometer; 0.1 °C precision), pH (Handlab portable pHmeter), water transparency (Secchi disk), dissolved oxygen (Winkler's method modified according to Golterman et al. (1978), ammonia (phenol method), nitrite (colorimetric method), nitrate (cadmium reduction method), orthophosphate (ascorbic acid method) and total phosphorous (persulphate) (Eaton et al., 1998).

2.3. Biological evaluations

Assessment of prey availability in the reservoir was conducted evaluating fish composition during the study period. In field, the collected specimens were preserved on a 10% formalin solution and subsequently transferred to the Laboratory. Taxonomic identifications followed Fowler (1954), Britiski (1972), Britiski et al. (1984) and Vari (1991), and were confirmed by a taxonomist (Dr. Ricardo S. Rosa). Voucher specimens were deposited at the Ichthyologic Collection of Universidade Federal da Paraíba (UFPB catalogue numbers: 6175, 6176, 6177, 6178, 6179, 6180, 6181, 6182, 6183, 6184 and 6185).

As a measure of fish abundance, we used the catch per unit effort of fishing (n° individuals/m² of net/hour or n° individuals/m² net/throw) using the mean of catches in data analysis. To determine population size structure, specimens were measured (standard length), being classified as adults or juveniles by the observation of the maturation stage of gonads.

Stomachs removed from 59 collected individuals were instantly fixed using a 10% formalin solution in field and subsequently (in lab) preserved in a 75% alcohol solution. Feeding activity was determined based on stomach repletion degree, classified according to Hahn et al. (1997). Its contents were analyzed as a means to determine the diet and feeding habits of the species. Feeding items were identified to the lowest possible taxonomic level based on specialized literature and with the aid of taxonomic specialists. Diet was determined based on the frequency of occurrence of feeding items consumed (Zavala-Camin, 1996) and from the points method (Hynes 1950; Fugi et al., 1996).

Importance of feeding items in the diet of the collected individuals was determined based on the Alimentary Index (IA_i) (Kawakami and Vazzoler 1980), calculated by combining values from the frequency of occurrence and points methods.

The selectivity index of J. Chesson (1978a) was used to compare the items consumed by *H. aff. malabaricus*, considering its availability in the environment (Equation 1):

$$\alpha_i = \frac{f_i / P_i}{\sum_{i=1}^N f_i / P_i} \quad (1)$$

When $\alpha_i < 1/n$, a negative selection occur. When $\alpha_i > 1/n$, indicate a positive selection, and when $\alpha_i = 1/n$, selective feeding does not occur. Because $n = 11$ here, then $1/n = 0.09$. We choose this index because has been widely used for can to incorporate easily in biological models and unlike other models can be applied to more than two preys, and consider constant and non-constant preys (Chesson, 1978a).

2.4. Data analysis

A Pearson Correlation Test was performed to relate the selectivity of the predator and abundance of prey in the environment. Before of Canonical Correspondence Analysis, a stepwise generalized linear regression with backward selection was used to understand the extent to which the measured biological and environmental variables (precipitation, water volume, transparency, nitrite, nitrate, ammonia, phosphate, and prey abundance) explained patterns of predation by *H. aff. malabaricus*. The CCA tested how the environment variables influenced the selectivity index. Significance of the first two axes was tested using a permutation test (10000 interactions). Before CCA the data were standardized by dividing each value of one variable by its sum of the raw and multiplying by 100. All analyses were conducted using R software (R Development Core Team, 2007).

3. Results

According to the analysis of environmental variables, observed values summarized in Table 1.

Within fish composition, a total of 889 individuals from eleven taxa, ten genera, nine families and four orders were identified in environment. Temporal variations in species abundance were detected. Particularly, fewer individuals were collected during the rainy season

(78 and 109 specimens during March and June of 2006, respectively) (Table 2).

Size (standard length) of the 59 *H. aff. malabaricus* individuals collected varied between 2.0 and 34.2 cm, with a 32.2 cm amplitude (mode: 22.9 cm). Individuals varying between 19.0 and 25.0 cm, categorized as adults, were the most frequent throughout the study period. During the 2005 dry season (August and October), both juveniles and adults were collected. Higher abundance of this species coincided with periods of low water volume in the reservoir (dry season of 2005).

Diet consisted of 19 items, 52.63% of which were recorded during the 2005 dry season, 57.89% during the 2006 rainy season and 36.84% during

the 2006 dry season (Table 3). Fish represent the main item in the diet of *H. aff. malabaricus* (fish remains, IAI = 51.44%), from 2005 to the 2006 rainy season, confirming the piscivorous habits of adults of this species, given that 83.05% of the collected individuals were adults. In fact, benthic invertebrates, mostly *Melanoides tuberculata* (Müller, 1774), IAI = 21.76% during the 2006 rainy season; and insect remains, IAI = 18.58% during the 2006 dry season; largely contributed to diet of this species, particularly, for small individuals (i.e. juveniles).

Species which made up the diet of 49 *H. aff. malabaricus* adult individuals were *Characidium bimaculatum* (Fowler, 1941), *Astyanax bimaculatus* (Linnaeus, 1758), *Steindachnerina notonota*

Table 1. Means (\pm standard deviations) of environmental variables by station, Taperoá II reservoir, Taperoá - PB.

Environmentals variables	Dry/05	Rain/06	Dry/06
Temp.(C°)	28.25 (\pm 0.35)	28.35 (\pm 2.05)	24.25 (\pm 2.6)
pH	8.12 (\pm 0.10)	8.1 (\pm 0.12)	8.4 (\pm 0.98)
Secchi (cm)	84 (\pm 1.4)	80 (\pm 28.2)	97.5 (\pm 31.8)
D.O. (mg.L ⁻¹)	8.85 (\pm 0.49)	5.02 (\pm 0.3)	7.12 (\pm 0.24)
Nitrite (μ g.L ⁻¹)	10.27 (\pm 0.38)	3.3 (\pm 1.5)	1.35 (\pm 0.9)
Nitrate (μ g.L ⁻¹)	94.3 (\pm 99.98)	94.4 (\pm 25.3)	20.05 (\pm 1.6)
Ammonium (μ g.L ⁻¹)	22.25 (\pm 31.81)	31.35 (\pm 23.8)	60.4 (\pm 7.7)
Orthophosphate (μ g.L ⁻¹)	0.49 (\pm 0.35)	15.5 (\pm 2.1)	0

Table 2. Fish species recorded in Taperoá II reservoir during the study period, with their average length (\pm standard deviation) and abundance, Taperoá city, Paraíba State. AM = average length.

Taxon/Sampling period	AM(\pm)	O/05	D/05	M/06	J/06	A/06	O/06	Total
Characiformes								
Anostomidae								
<i>Leporinus piau</i> (Fowler, 1941)	12.96 (3.35)	5	6	4	-	28	46	89
Characidae								
<i>Astyanax bimaculatus</i> (Linnaeus, 1758)	5.81 (1.22)	72	10	8	25	48	38	201
<i>Astyanax fasciatus</i> (Cuvier, 1819)	7.18 (0.75)	17	6	12	-	79	28	142
Crenuchidae								
<i>Characidium bimaculatum</i> (Fowler, 1941)	2.45 (0.52)	7	-	4	41	34	36	122
Curimatidae								
<i>Steindachnerina notonota</i> (Miranda-Ribeiro, 1937)	8.44 (1.09)	45	43	26	1	3	2	120
Erythrinidae								
<i>Hoplias aff. malabaricus</i> (Bloch, 1794)	20.69 (7.31)	6	23	9	7	7	7	59
Prochilodontidae								
<i>Prochilodus brevis</i> (Steindachner, 1875)	29.50	-	-	1	-	-	-	1
Siluriformes								
Loricariidae								
<i>Hypostomus</i> sp.	15.50 (2.60)	-	1	1	-	1	-	3
Cyprinodontiformes								
Poeciliidae								
<i>Poecilia vivipara</i> (Bloch & Schneider, 1801)	1.87 (0.40)	7	36	10	15	45	10	123
Perciformes								
Cichlidae								
<i>Cichlasoma orientale</i> (Swainson, 1839)	6.43(1.74)	-	1	-	-	1	2	4
<i>Oreochromis niloticus</i> (Linnaeus, 1798)	6.32 (1.90)	-	1	3	20	1	1	26

(Miranda Ribeiro, 1937), *Synbranchus marmoratus* (Bloch, 1795) and Cichlidae - *Oreochromis niloticus* (Linnaeus, 1758) and *Cichlassoma orientale* (Kullander, 1983), identified from fish remains (Table 3). A somewhat restricted diet was recorded during the 2005 dry season. *S. marmoratus* was not collected in the environment, but recorded solely from stomach content analyses. Although higher prey diversity was recorded during and after the 2006 rainy season, total abundance of prey was higher during dry seasons. Evidence of cannibalism was not observed.

For statistical analyses, only prey species recorded in stomach content analyses were included. Cichlids were the main alimentary item in three of six samples (Table 4), despite its low abundance in the environment. Among the consumed items, *A. bimaculatus*, *C. bimaculatum*, and *S. notonota*, despite their high abundance in the environment, registered low preference by the trahira (Table 4). Other species, such as *A. fasciatus*, e *L. piau*, and *P. vivipara*, presented great abundance in the environment, but were not consumed. The results of selectivity index confirm the preference by cichlids. The correlation test shows a significant correlation

Table 3. Index of food importance (IAi – Alimentary Index) of food items *Hoplias* aff. *malabaricus* registered in Taperoá II Reservoir, Taperoá – PB, during study period.

Species/Sampling period	Oct./05	Dec./05	Mar./06	June/06	Aug./06	Oct./06
Number of stomachs	6	23	9	7	7	7
Feeding Items						
Seeds					0.17	
Vegetable remains			4.39			
Organic matter		7.27	0.08		32.12	
Zoobenthos						
Odonata			4.48	8.66	4.24	11.96
Nematoda		0.57				
<i>Melanooides tuberculata</i>			10.44			
Insects remains		6.58	1.46		18.58	0.08
Fishes						
Fish scales					2.62	
Fishes remains	47.46	83.89	29.19			80.00
<i>Astyanax bimaculatus</i>			13.44		9.09	
<i>Characidium bimaculatum</i>	52.54			2.82	4.33	
<i>Synbranchus marmoratus</i>			4.44			
<i>Steindachnerina notonota</i>			32.06			
Cichlidae		1.68		88.51	28.86	

Table 4. CPUE, Selectivity index of *H. aff. malabaricus* over four prey, and the correlation test among selectivity index and CPUE in Taperoá II Reservoir.

Sampling period	Analysis	<i>bimaculatus</i>	<i>bimaculatum</i>	<i>S. notonota</i>	Cichlids
Oct./05	CPUE	6.11 ± 8.83	0.19 ± 0.34	0.94 ± 1.62	0.00 ± 0.00
	SI	0.00	1.00*	0.00	0.00
Dec./05	CPUE	1.73 ± 2.27	0.00 ± 0.00	1.34 ± 1.90	0.21 ± 0.29
	SI	0.00	0.00	0.00	1.00*
Mar./06	CPUE	0.31 ± 0.27	0.17 ± 0.24	0.81 ± 1.15	0.06 ± 0.09
	SI	0.91*	0.00	0.09*	0.00
June/06	CPUE	3.13 ± 5.23	1.14 ± 1.97	0.14 ± 0.24	1.39 ± 2.41
	SI	0.00	0.02	0.00	0.98*
Aug./06	CPUE	1.56 ± 1.50	1.42 ± 2.00	0.11 ± 0.07	0.04 ± 0.06
	SI	0.01	0.01	0.00	0.98*
Oct./06	CPUE	1.24 ± 0.81	1.50 ± 2.12	0.06 ± 0.09	0.06 ± 0.04
	SI	0.00	0.00	0.00	0.00
	Correlation test	-0.48	-0.37	0.22	1
	p-value	0.3254	0.459	0.671	<0.001

SI = Selectivity Index./*When α is greater than 0,09, indicates a feed preference./CPUE's values were multiplied by 10^{-2} .

Table 5. Results of best minimum model in step-wise generalized linear regression that explains variations in prey eaten by *H. aff. malabaricus* in Taperoá II Reservoir.

Dependent	Model	Estimate	Std.Error	P
Cichlids	Nitrate	0.0283	0.0003	<0.01
	Secchi	0.1125	0.0014	<0.01
	Volume	0.0364	0.0018	<0.05
	Ammonia	0.0243	0.0010	<0.05
<i>S. notonota</i>	Ammonia	-0.0001	0.00002	<0.01
	Phosphorus	0.0010	0.00001	<0.01
<i>A. bimaculatus</i>	Ammonia	-0.0005	0.0003	<0.01
	Phosphorus	0.0098	0.0001	<0.01
<i>C. bimaculatus</i>	Nitrite	-0.046	0.0068	<0.05
	Phosphorus	-0.016	0.0022	<0.05
	Ammonia	-0.0614	0.0075	<0.05

between the selection of cichlids with increase in abundance of these prey species ($\text{cor.test} = 1$; $p < 0.001$; Table 4). The consumption over other species was not related to its abundance in the environment.

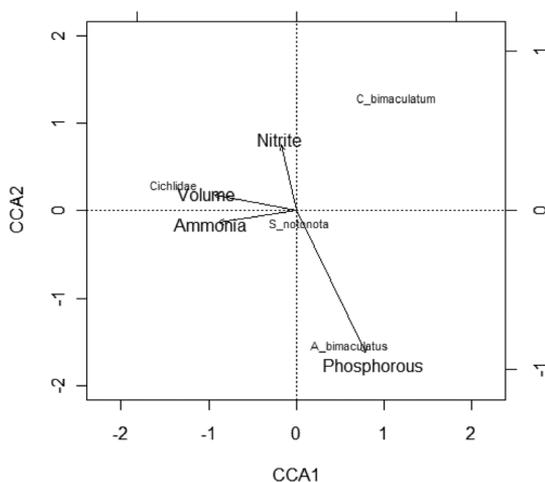
A stepwise multiple regression has shown that cyclid consumption was associated to an increasing in transparency, nitrite and ammonia and water volume (Table 5). The variables with interference on the selection of *S. notonota* and *A. bimaculatus* were ammonia (negative relationship) and phosphorus (positive relationship) (Table 5), and nitrite, phosphorus and ammonia were negatively related to *C. bimaculatum* (Table 5).

By linking the selectivity index with environmental variables in a CCA, the first axis explained 54.5% of the variance and axis 2 explained 36.2%. The explanatory factor 1 axis is the volume of the reservoir (-0.51) and ammonia (-0.48). Axis 2 was explained by phosphorus (-0.88) and nitrite (-0.41). CCA indicated that cichlids over the selectivity index was related to increased volume of the reservoir (-0.27) and *C. bimaculatum* was negatively correlated with the volume (0.22), the selectivity of *A. bimaculatus* was more related to the second axis (-0.24) (Figure 3).

The permutation test showed that axis 1 correlations were significant ($df = 1$; $F = 12.349$; $p = 0.02$) and that axis 2 correlations were marginally significant ($df = 1$; $F = 9.1955$; $p = 0.055$).

4. Discussion

We observed a higher proportion of fishes in the diet of *H. aff. malabaricus*, as indicated by previous studies (Hahn et al. 2004; Loureiro and Hahn, 1996). Furthermore, our results showed that *H. aff. malabaricus* select only a fraction of the available prey fishes and its diet did not entirely correspond to fish composition observed at the Taperoá II

**Figure 3.** CCA of environmental variables versus selectivity index (IAi) of prey consumed by *H. aff. malabaricus* in Taperoá II dam.

reservoir, suggesting that this species selectively captures its prey regardless of the abundance of all potential fishes in the environment. Other studies also suggested that diet is not necessarily an effect of prey availability in the environment (e.g. P. L. Chesson, 1978b) and assign it to a randomness in diet selection by the sedentary habit of trahira and environmental conditions as changes turbidity (as indirect factor of nutrient input) and water volume, as well as atypical predatory behaviors triggered by population increases of particular prey species, also play important roles in determining diet (Turesson, 2003; Vucic-Pestic et al., 2010). With the exception of March 2006, during which IAi values corresponded to fish composition at the reservoir, inconsistency between potential prey (fish composition) and diet (stomach contents) were always observed.

Factors such as habitat preference, environmental conditions, prey size and mobility can play a major role on selectivity than prey abundance (Luz-Agostinho et al., 2008; Milani et al., 2010). *H. aff. malabaricus* is an ambush predator, selectively occupying sites with high structural complexity, such as macrophyte banks, where prey abundance tends to be high, thus increasing success of prey capture (Luz-Agostinho et al., 2008), as observed in the present study during the 2006 rainy season. Aquatic macrophytes play an important role in lowland lakes by increasing microhabitat heterogeneity and, consequently, resources for prey (i.e. food and refuge), therefore reducing predator efficiency (Agostinho et al., 2007). With a decrease in microhabitat diversity, as observed during periods of low water volume in the reservoir (e.g. the 2005 dry season), predation becomes a laborious activity, given the reduced number of foraging sites. This pattern is supported by the low IAI values (prey ingestion) in dry seasons in the present study.

Although we had indentified 11 species in Taperoá reservoir, only four species were consumed by trahira: *C. bimaculatum*, *S. notonota*, *A. bimaculatus* and *O. niloticus*. The predation pressure towards *C. bimaculatum* individuals was higher during dry seasons. This was probably due to lower water volumes constraining the availability of macrophyte banks (i.e. refuge sites), therefore exposing individuals of this species. Characids are small-sized fishes with short life-cycles, typically abundant along margins of lakes and in association to macrophyte banks (Smith and Barrella, 2000).

The feeding on *S. notonota* seems to be at random, once it occurred in only one month, and the selectivity index indicated no preference by this item, despite its abundance in the environment. *S. notonota* is a small-bodied species (maximum length 10.7 cm), and despite trahira also eats small preys, its absence of selection over this one is probably related to its alimentary habits, for it is a detritivorous species, and inhabits preferentially deep areas (Montenegro et al., 2012).

Predation towards *A. bimaculatus* individuals corresponded to diminishment of the volume of the reservoir, and to the increasing in phosphorus concentrations, and the increasing in transparency as well, probably due to the low shelter and food availability in macrophyte beds, increasing the predation risk of *A. bimaculatus*. Also, although *A. fasciatus* was also common at the reservoir, sharing similar trophic niche and body size to *A. bimaculatus* (Agostinho et al., 1997), the former species was not

consumed. This is probably due to *A. bimaculatus* being more abundant along margins of lakes, thus, corresponding to foraging sites of “trahiras”. This was observed in the present study and also by Arcifa et al. (1991) in a eutrophic reservoir at the south region of Brazil. Furthermore, factors such as prey-detection (sight) and swimming performance may also be related to the mechanisms of prey selection by “trahiras”.

Although the food selection did not occur over more abundant species in Taperoá reservoir, we identify a feed preference over cichlids. Cichlids were mostly consumed by “trahiras” during periods of higher water volume, particularly during the later rainy seasons, which corresponded to higher abundances of individuals of this group probably as a result of accidental escapes of small individuals of *Oreochromis niloticus* from nearby fish cages (personal communication from local fishermen). The alimentary habits of cichlids, being planktivores (Figueredo and Giani 2005) and occupying the water column, should be related to increased susceptibility to predation by trahira. In fact, predatory pressure is higher for cichlids than for other species and the increase in abundance of cichlids increases the consumption by trahira. The lower swimming speed and agility of cichlids than other species, as *Astyanax bimaculatus* and *fasciatus* (Novakowski et al., 2007) also can result in different vulnerability rates.

Although trahiras can eat large preys, they are known for their consumption on small prey because are gape-limited predators (Prejs, 1987; Loureiro and Hahn, 1996). Our results, support the idea of gape-limitation by trahiras, as the piscivorous consumed only small sized prey species in Taperoá reservoir.

In sum, our results do not support the hypothesis that *Hoplias* aff. *malabaricus* diet is related to prey availability, because the prey preference is seems to be the main factor to selection on prey. Regardless of prey abundance, the trahira has a preference by cichlids and increased the consumption with increasing abundance of cichlids, although not represent the most abundant prey. We suggest that the intrinsic characteristics of the prey, such as size and agility play a central role in selection.

Also, we had evidences that environmental conditions can affect the consumption by semi-arid piscivorous, but are still deserve further experimental studies to identify how consumption rates change with increase in nutrients, transparency, and habitat heterogeneity. As native predators can decrease

the competition among preys may favor a higher diversity of prey species (Kunte, 2007; Morin, 1981), factors that affect the rate of consumption of trahira can reduce the indirect benefic role of this piscivorous on prey communities. Also, the reduction in consumption rate by trahira can affect the degree of control over exotic species.

Acknowledgements

We thank PELD/Caatinga – CNPq, for financially supporting the project and CAPES for providing a master degree grant to Ana Karla A. Montenegro.

References

- Agência Executiva de Gestão das Águas do Estado da Paraíba - AESA. 2007. Available from: <<http://www2.aesa.pb.gov.br/meteoro/chuvas.shtml>>
- AGOSTINHO, AA., THOMAZ, SM., GOMES LC. and BALTAR, SLSMA. 2007. Influence of the macrophyte *Eichhornia azurea* on fish assemblage of the Upper Paraná River floodplain (Brazil). *Aquatic Ecology*, vol. 41, p. 611-619. <http://dx.doi.org/10.1007/s10452-007-9122-2>
- AGOSTINHO, AA., HAHN, NS., GOMES, LC. and BINI, LM. 1997. Estrutura trófica. In VAZZOLER, AEAM., AGOSTINHO, AA. and HAHN, NS., org. *A planície de inundação do Alto Rio Paraná: aspectos físicos, biológicos e socioeconômicos*. Maringá: UEM. p. 229-248.
- ARCIFA, MS., NORTHCOTE TG. and FROEHLICH, O. 1991. Interactive ecology of two cohabiting characin fishes (*Astyanax fasciatus* and *Astyanax bimaculatus*) in an eutrophic Brazilian reservoir. *Journal of Tropical Ecology*, vol. 7, p. 257-268. <http://dx.doi.org/10.1017/S0266467400005423>
- BOTHAM, MS. and KRAUSE, J. 2005. Shoals Receive more Attacks from the Wolf-Fish (*Hoplias aff. malabaricus* Bloch, 1794). *Ethology*, vol. 111, p. 881-890. <http://dx.doi.org/10.1111/j.1439-0310.2005.01122.x>
- BOTHAM, MS., KERFOOT, CJ., LOUCA, V. and KRAUSE, J. 2005. Predator choice in the field: grouping guppies, *Poecilia reticulata*, receive more attacks. *Behavioral Ecology and Sociobiology*, vol. 59, p. 181-184. <http://dx.doi.org/10.1007/s00265-005-0018-7>
- BRANDÃO-GONÇALVES, L., OLIVEIRA SA. and LIMA-JUNIOR, SE. 2010. Hábitos alimentares da ictiofauna do córrego Franco, Mato Grosso do Sul, Brasil. *Biota Neotropica*, vol. 10, n. 2, p. 21-30. <http://dx.doi.org/10.1590/S1676-06032010000200001>
- BRITISKI, HA. 1972. Peixes de água doce do Estado de São Paulo. In BRITISKI, HH., ed. *Poluição e Piscicultura, notas sobre ictiologia, poluição e piscicultura*. São Paulo: Comissão Interestadual da Bacia Paraná-Uruguaí, Faculdade de Saúde Pública da USP. p. 79-108.
- BRITISKI, HA., SATO, Y. and ROSA, ABS. 1984. *Manual de identificação de peixes da região de Três Marias*. 3. ed. Brasília: CODEVASF. 143 p.
- CHESSON, J. 1978a. Measuring preference in selection predation. *Ecology*, vol. 58, p. 211-215. <http://dx.doi.org/10.2307/1936364>
- CHESSON, PL. 1978b. Predator-prey theory and variability. *Annual Review of Ecology and Systematics*, vol. 9, p. 323-347. <http://dx.doi.org/10.1146/annurev.es.09.110178.001543>
- COWX, IG., YOUNG, WO. and HELLAWELL, JM. 1984. The influence of drought on the fish and invertebrate populations of an upland stream in Wales. *Freshwater Biology*, vol. 14, p. 165-177. <http://dx.doi.org/10.1111/j.1365-2427.1984.tb00030.x>
- EATON, AD., GREENBERG, AE. and CLESCERI, LS. 2008. *Standard Methods for the examination of water and wastewater*. Washington: APHA.
- FIGUEREDO, CC. and GIANI, A. 2005. Ecological interactions between Nile tilapia (*Oreochromis niloticus*) and the phytoplanktonic community of the Furnas Reservoir (Brazil). *Freshwater Biology*, vol. 50, p. 1391-1403. <http://dx.doi.org/10.1111/j.1365-2427.2005.01407.x>
- FOWLER, HW. 1954. Os peixes de água doce do Brasil. *Arquivo Zoológico do Estado de São Paulo*, vol. 9, p. 1-400.
- FUGI, R., HAHN, NS. and AGOSTINHO, AA. 1996. Feeding styles of five species of bottom-feeding fishes of the high Paraná River. *Environmental biology of fishes*, vol. 46, p. 297-307. <http://dx.doi.org/10.1007/BF00005006>
- GALACATOS, K., BARRIGA-SALAZAR, B. and STEWART, DJ. 2004. Seasonal and habitat influences on fish communities within the lower Yasuni River basin of the Ecuadorian Amazon. *Environmental Biology of Fishes*, vol. 71, p. 33-51. <http://dx.doi.org/10.1023/B:EBFI.0000043156.69324.94>
- GOLTERMAN, HL., CLYMO, RS. and OHNSTAD, MAM. 1978. *Methods for physical and chemical analysis of freshwaters*. 2nd ed. Oxford: Blackwell.
- HAHN, NS., FUGI, R. and ANDRIAN, IF. 2004. Trophic ecology of the fish assemblages. In THOMAZ, SM., AGOSTINHO, AA. and HAHN, NS., ed. *The Upper Paraná River and its floodplain: Physical Aspects, Ecology and Conservation*, Backhuys Publishers, Leiden, p. 247-269.

- HAHN, NS., FUGI, R., ALMEIDA, VLL., RUSSO, MR. and LOREIRO, VE. 1997. Dieta e atividade alimentar de peixes do reservatório de Segredo. In AGOSTINHO, AA. and GOMES, LC. *Reservatório de Segredo: Bases ecológicas para o manejo*. Ed. Universidade Estadual de Maringá. 387 p.
- HUMPHRIES, P. and BALDWIN, DS. 2003. Drought and aquatic ecosystems: an introduction. *Freshwater Biology*, vol. 48, p. 1141-1146. <http://dx.doi.org/10.1046/j.1365-2427.2003.01092.x>
- HYNES, HBN. 1950. The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. *Journal of Animal Ecology*, vol. 19, n. 1, p. 36-58. <http://dx.doi.org/10.2307/1570>
- KAWAKAMI, E. and VAZZOLER, R. 1980. Método gráfico e estimativa de índice alimentar aplicado no estudo de alimentação de peixes. *Boletim do Instituto Oceanográfico*, vol. 29, p. 205-207. <http://dx.doi.org/10.1590/S0373-55241980000200043>
- KUNTE, K. 2007. Competition and species diversity: removal of dominant species increases diversity in Costa Rican butterfly communities. *Oikos*, vol. 117, p. 69-76. <http://dx.doi.org/10.1111/j.2007.0030-1299.16125.x>
- LOUREIRO, VE. and HAHN, NS. 1996. Dieta e atividade alimentar da traíra *Hoplias* aff. *malabaricus* (Bloch, 1794) (Osteichthyes, Erythrinidae), nos primeiros anos de formação do reservatório de Segredo-PR. *Acta Limnológica Brasiliensis*, vol. 8, p. 195-205.
- LUZ-AGOSTINHO, KDG., AGOSTINHO, AA., GOMES, LC. and JÚLIO, HF. 2008. Influence of food pulses on diet composition and trophic relationships among piscivores fish in the upper Paraná River floodplain. *Hydrobiologia*, vol. 607, p. 187-198. <http://dx.doi.org/10.1007/s10750-008-9390-4>
- MILANI, V., MACHADO, FA. and SILVA, VCF. 2010. Assembléias de peixes associados às macrófitas aquáticas em ambientes alagáveis do Pantanal de Poconé, MT, Brasil. *Biota Neotropica*, vol. 10, n. 2, p. 261-270. <http://dx.doi.org/10.1590/S1676-06032010000200029>
- MONTENEGRO, AKA., TORELLI, JER., CRISPIM, MC. and MEDEIROS, AMA. 2012. Population and feeding structure of *Steindachnerina notonota* Miranda-Ribeiro, 1937 (Actinopterygii, Characiformes, Curimatidae) in Taperoá II dam, semi-arid region of Paraíba, Brazil. *Acta Limnológica Brasiliensis*, vol. 23, n. 3, p. 1-12.
- MORIN, PJ. 1981. Predatory salamanders reverse the outcome of competition on among three species of anuran tadpoles. *Science*, vol. 212, p. 1284-1286. PMID:17738837. <http://dx.doi.org/10.1126/science.212.4500.1284>
- NOVAKOWSKI, GC., HAHN, NS. and FUGI, R. 2007. Alimentação de peixes piscívoros antes e após a formação do reservatório de Salto Caxias, Paraná, Brasil. *Biota Neotropica*, vol. 7, p. 149-154.
- NOWLIN, WH., DRENNER, RW., GUCKENBERGER, KR., LAUDEN, MA., ALONSO, GT., JOSEPH, EF. and SMITH, JL. 2006. Gape limitation, prey size refuges and top-down impacts of piscivorous largemouth bass in shallow pond ecosystem. *Hydrobiologia*, vol. 563, p. 357-369. <http://dx.doi.org/10.1007/s10750-006-0024-4>
- PERETTI, D. and ANDRIAN, IDF. 2004. Trophic structure of fish assemblages in five permanent lagoons of the high Paraná River floodplain, Brazil. *Environmental Biology of Fishes*, vol. 71, p. 95-103. <http://dx.doi.org/10.1023/B:EBFL.0000043155.76741.a1>
- PÉREZ-MARTÍNEZ, C., MORALES-BAQUERO, R. and SANCHEZ-CASTILLO, P. 1991. The effect of the volume decreasing on the trophic status in four reservoirs from Southern Spain. *Verhandlungen des Internationalen Verein Limnology*, vol. 24, n. 3, p. 1382-1385.
- PETRY, AC., GOMES, LC., PIANA, PA. and AGOSTINHO, AA. 2010. The role of the predatory trahira (Pisces: Erythrinidae) in structuring fish assemblages in lakes of a Neotropical floodplain. *Hydrobiologia*, vol. 651, p. 115-126. <http://dx.doi.org/10.1007/s10750-010-0281-0>
- PIANA, PA., GOMES, LC. and AGOSTINHO, AA. 2006. Comparison of predator-prey interaction models for fish assemblages from the neotropical region. *Ecological Modelling*, vol. 192, p. 259-270. <http://dx.doi.org/10.1016/j.ecolmodel.2005.07.002>
- POPOVA, OA. 1978. The role of predaceous fish in ecosystems. In GERKING, SD., ed. *Ecology of Freshwater Fish Production*. Oxford: Blackwell Scientific. p. 215-249.
- PREJS, A. 1987. Risk of predation and feeding rate in tropical freshwater fishes: field evidence. *Oecologia*, vol. 72, p. 259-262. <http://dx.doi.org/10.1007/BF00379276>
- R Development Core Team. 2007. R: a language and environment for statistical computing. version 2.6.0. R Foundation for Statistical Computing. Available from: <<http://www.R-project.org>>.
- SMITH, WS. and BARRELLA, W. 2000. The ichthyofauna of the marginal lagoons of the Sorocaba River, SP, Brazil: composition, abundance and effect of the anthropogenic actions. *Revista Brasileira de Biologia*, vol. 60, n. 4, p. 627-632. <http://dx.doi.org/10.1590/S0034-7108200000400012>

- TURESSON, H. 2003. *Foraging behaviour in piscivorous fish: mechanisms and patterns*. Lund: University of Lund. [PhD Thesis].
- VARI, RP. 1991. *Systematics of the neotropical Characiform genus Steindachnerina Fowler (Pisces: Ostariophysi)*. Washington: Smithsonian Contributions Press. Smithsonian Contributions to Zoology, vol. 507.
- VUCIC-PESTIC, O., BIRKHOFFER, K., RALL, KB., SCHEU, S. and BROSE, U. 2010. Habitat structure and prey aggregation determine the functional response in a soil predator-prey interaction. *Pedobiologia*, vol. 53, n. 5, p. 307-312. <http://dx.doi.org/10.1016/j.pedobi.2010.02.003>
- WILHITE, DA. 2000. Drought as a natural hazard. In WILHITE, DA., ed. *Drought: a Global Assessment*. London: Routledge. vol. 1, p. 3-18.
- WOOTTON, RJ. 1990. *Ecology of teleost fishes*. London: Chapman and Hall.
- ZAVALA-CAMIN, LA. 1996. *Introdução aos estudos sobre alimentação natural em peixes*. Maringá: EdUEM. 129 p.

Received: 02 August 2012

Accepted: 10 July 2013