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Food ecology of *Hassar affinis* (*Actinopterygii: Doradidae*) in two lakes of a wet zone of international importance in Northeast Brazil

Ecologia alimentar de *Hassar affinis* (*Actinopterygii: Doradidae*) em dois lagos de uma zona úmida de importância internacional no Nordeste do Brasil

Ecología alimentaria de *Hassar affinis* (*Actinopterygii: Doradidae*) en dos lagos de una zona húmeda de importancia internacional en el Noreste de Brasil

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Abstract
The study aimed to describe the aspects of trophic ecology and feeding strategy of the Hassar affinis species in two lakes in the Baixada Maranhense region a wetland of international ecological interest (Site Ramsar). Individuals were collected monthly for one year. 372 stomachs were analyzed, of which 246 were from Lake Cajari and 126 from Lake Viana. The diet composition of the species was analyzed using the Frequency of Occurrence, Volumetric and Food Importance Index method. The result indicated that 49.1% of stomachs had content Lake Cajari. For Lake Viana, the number of stomachs analyzed indicated that 65.8% were full. The most consumed food itens by the species in Cajari were Mollusk of the species Benthonella tenella, Insect larvae of the order Coleoptera, Odonata, Diptera and Ephemeroptera. In Lake Viana, the same items were present. During the dry and rainy season in Lake Cajari there were differences in diet (item/prey) where the species consumed in greater percentage the item Mollusc in the dry period and in the rainy season Insect larvae, however for Viana lake the species did not show significant variation in feeding concerning seasonality. Regarding ontogenetic, H. affinis showed differences in feeding, both in sex and in the maturation stage. Thus, according to the analysis of stomach contents, it was confirmed that the species H. affinis has an omnivorous benthic feeding habit with a generalist strategy, evidencing the importance of the ecosystem for the food chain in both lakes.
Keywords: Food; Trophic Relations; Food strategy.

Resumo
O estudo objetivou descrever os aspectos da ecologia trófica e estratégia alimentar da espécie Hassar affinis em dois lagos da Baixada Maranhense, uma zona úmida de interesse ecológico internacional (Sítio Ramsar). Os indivíduos foram coletados mensalmente ao longo de 1 ano. Foram analisados 372 estômagos, onde 246 foram provenientes do Lago Cajari e 126 do Lago de Viana. A composição da dieta da espécie foi analisada pelo método de Frequência de Ocorrência, Volumétrico e índice de Importância alimentar. O resultado indicou que 49,1% dos estômagos tinham conteúdo no lago de Cajari. Já para o lago de Viana, o número de estômagos analisados indicou que 65,8% estavam cheios. Os itens alimentares mais consumidos pela espécie no Lago Cajari foi Molusco da espécie Benthonella tenella, Larvas de Insetos da ordem Coleoptera, Odonata, Diptera e Ephemeroptera. No Lago Viana ocorreu a presença dos mesmos itens. Durante a estação seca e chuvosa no lago de Cajari ocorreram diferenças na dieta (item/presa), onde a

espécie consumiu em maior porcentagem o item Molusco no período seco e na estação de chuva Larvas de insetos, entretanto para o lago de Viana a espécie não apresentou variação significativa na alimentação em relação a sazonalidade. Em relação a ontogenética, H. affinis apresentou diferenças na alimentação, tanto em sexo quanto em estágio maturacional. Assim, de acordo com as análises dos conteúdos estomacais confirmou-se que a espécie H. affinis possui hábito alimentar onívoro bentônico com estratégia generalista, evidenciando a importância do ecossistema para a cadeia trófica nos dois lagos.
Palavras-chave: Alimentação; Relações Tróficas; Estratégia alimentar.

Resumen
El estudio tuvo como objetivo describir los aspectos de la ecología trófica y la estrategia de alimentación de la especie Hassar affinis en dos lagos de la Baixada Maranhense, un humedal de interés ecológico internacional (Sítio Ramsar). Se recogieron individuos mensualmente a lo largo de 1 año. Se analizaron un total de 372 estómagos, de los cuales 246 eran de Cajari y 126 de Viana. La composición de la dieta de la especie se analizó mediante el método de Frecuencia de Ocurrencia, Volumétrico e Índice de Importancia Alimentaria. El resultado indicó que 49,1% de los estómagos tenían contenido. el lago Cajari. Para el lago Viana, el número de estómagos analizados indicó que (65,8%) estaban llenos y (34,1%) vacíos. Los alimentos más consumidos por la especie en Cajari fue el molusco de la especie Benthonella tenella, Larvas de insectos del orden Coleoptera, Odonata, Diptera y Ephemeroptera. En el Lago Viana, los mismos ítems estuvieron presentes. Durante la época seca y lluviosa en el lago Cajari hubo diferencias en la dieta (ítem / presa), donde la especie consumió un mayor porcentaje del ítem Molusco en la estación seca y en la temporada de lluvias Larvas de insectos, sin embargo, para el lago Viana la especie no mostró una variación significativa en la alimentación en relación con la estacionalidad. En cuanto a la ontogenética, H. affinis mostró diferencias en la alimentación, tanto en sexo como en etapa de maduración. Así, de acuerdo con el análisis de contenido estomacal, se confirmó que la especie H. affinis tiene un hábito de alimentación bentónico omnívoro con una estrategia generalista, evidenciando la importancia del ecosistema para la cadena trófica en ambos lagos.
Palabras clave: Alimentos; Relaciones Tróficas; Estrategia alimentaria.

1. Introduction

Brazil is a country that is home to natural and artificial environments with unique characteristics, water is an abundant and, at the same time, scarce resource among Brazilian regions. Its use and supply determine economic growth and development in the regions (Neves et al., 2020). The Baixada Maranhense region is a humid area of international importance and comprises a cluster of water bodies forming a set of lakes known as circle of lakes - "Rosário dos lagos" (Franco, 2008). In this region, the vegetation is rich and varied with the existence of mangroves, alluvial fluvial-marine fields, close to the lakes to dense gallery forests along the rivers, with babassu trees forming "islands" in the highest lands, little affected by the floods (Muniz 2007).

The ecological characteristics of the Baixada Maranhense were important for the managers of the State of Maranhão to include it as an Environmental Protection Area in 1991; this state-protected area and also a "Ramsar site" indicated by Brazil, based on the intergovernmental treaty of Ramsar, which recognizes the ecological importance and the social, economic, cultural, scientific and recreational value of wetlands (MMA, 2015). Thus, knowledge of their fishing resources is essential for the design of actions aimed at their protection (MMA, 2015). Its lacustrine environments with different dynamics aggregate areas with the presence of numerous organisms such as aquatic macrophytes, insects in addition to several species of fish (Franco, 2008). The trophic structure of these environments adds important aspects related to fish biology, as well as gathers information about aspects related to fish diet and how they use the resources, which reflect a direct relationship with the forest (Costa et al., 2021).

The fish fauna of the APA of Baixada Maranhense is relevant and of economic and social commercial importance for the region. Works developed by Reis (2016) in the environmental protection area of Baixada Maranhense describes a fauna composed of fish of the orders Siluriformes, Characiformes and Perciformes with about 3488 individuals collected from the most varied species, among them Hoplias malabaricus the most abundant followed by Curimata macrops and Cichlassoma orientale, Platydoras brachylecis, Loricaria catrapachta, Cichlassoma orientale, Pygocent , Mugil curema, Hemiodus

parnaguae, Gymnotus carapo, Cichlassoma orientale among others demonstrating the great ichthyofaunistic diversity and the importance of these ecological, social and economic species for the region.

The aquatic systems of the Baixada Maranhense are mainly regulated by the rains that occur in the region, and in such environments, in certain months of the year, there is a decrease in river flow, drastically modifying the environments, characterizing the so-called dry season (Gonçalves, 2005).

Bayley et al. (2018) studying biological, ecosystem and fishery data for Prochilodus nigricans in the central Amazon reports that the abundance of P. nigricans at the age of two was positively related to the breadth of the coastal zone and indicated that the population can be regulated by dependence density in relation to their main feeding habitat.

Castello et al., (2019) analyzing the effect of floods on the abundance of fish of the species Colossoma macropomum describes that these flood patterns can influence food and development stages, since the availability of food and habitat are determined by interactions between flood events, availability of nutrients, cycling and biotic production processes, since these environments due to their dynamics are areas that present a high biological production and are widely exploited by fish from main channels and lakes.

An understanding of the effects of seasonal changes on species abundance and distribution in relation to feeding aspects is an important factor, since the effect of the flood cycle on the abundance of individuals in the year can, in turn, vary during the different phases of the flood period, since fish diets change frequently and tend to vary with the quality and quantity in the habitat (Fuiman & Werner 2002).

A fundamental issue in trophic ecology is to identify the factors that determine the model of food use by fish, since several of them may be involved in the process of development of the species, to better adapt to the environment (Ribeiro, 2016). Thus, such studies can also provide data on habitat, availability of food resources in the environment, biotic integrity, and understanding of interactive processes within aquatic communities (Hahn & Delariva, 2003).

This information is particularly important in nationally protected areas of international interest, such as the Baixada Maranhense Environmental Protection Area, which is a genuinely Amazonian region, influenced by the effect of the flood pulse that occurs annually and which makes new habitats and a wide variety of food available to fish assemblies in this region (Santos, 2015).

Given the above, research is important due to the lack of studies and the need to document the ecology of H. affinis, a species popularly known as mandi-de-flor, belonging to the order of Siluriformes, family Doradidae, and that in the region is a species of economic importance, and that geographically has recorded occurrence for the Amazon region (Fayal 2007).Therefore, the great occurrence of this species and the scarcity of studies on ecology makes it necessary to develop studies aimed at establishing regulations for fishing and studies on food ecology, since such studies contribute to the establishment of standards aimed at maintaining and conserving fish stocks (Cantanhêde 2016). Thus, the hypothesis of this work was the verification of the fact that the seasonal changes in the water bodies caused by the very dynamics of the lacustrine environments of the APA of Baixada Maranhense can modify the feeding habit of the species. Therefore, the objective was to describe the main aspects of trophic ecology and the feeding strategy of H. affinis in two lakes in Baixada Maranhense.

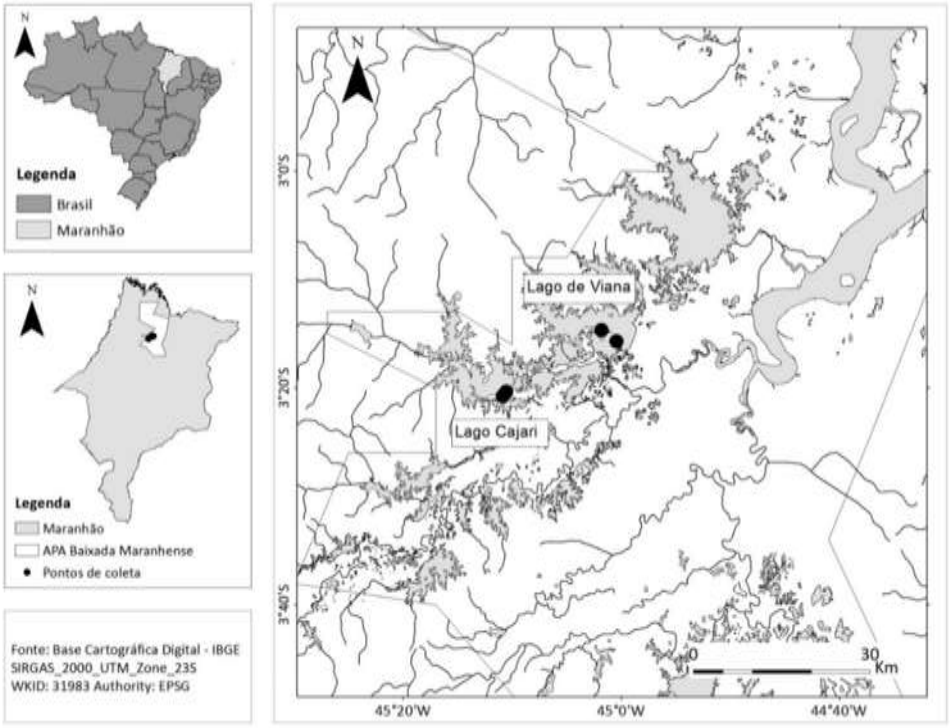
2. Methodology

Study area and data collection

The study area selected for this work comprises the lakes “Cajari” (03º18'58 "S; 45º11'08" W) and “Viana” (03º14'08” S; 45º05'09” W), respectively located in the municipalities of Penalva and Viana (Figure 1). The APA da Baixada Maranhense

is described as one of the seven ecological regions of the State (Cantanhêde 2016). Both regions were chosen because they are lowland lakes, formed by the flooding of the waters of the Pindaré River, a tributary of the left bank of the Mearim River (Piorski et al. 2005). These regions have great economic and ecological importance for riverside communities, in addition to being highly diversified areas with a great ichthyological diversity.

Figure 1 - Location of the study area in Baixada Maranhense (Brazil).



Source: Authors.

The specimens were collected monthly from July to December 2014 and January to June 2015, so that the species collected met a wide range of length with individuals from all stages of development.

The specimens were stored in polystyrene boxes, packed in individual bags, labeled, and packaged in ice for analysis at the Laboratory of Fisheries and Aquatic Ecology - LabPEA, of the State University of Maranhão - UEMA.

In the laboratory, basic animal data were recorded, such as total length (CT) standard length (CP), zoo length (CZ) total weight (PT), then the individuals were dissected and the weights of each intact organ were recorded, then the stomachs were opened for analysis of stomach contents.

Diet analysis

The description of the species' diet was made through the analysis of gastric content. Food items were determined and classified using a stereoscopic microscope and identified at the lowest possible taxonomic level with the aid of bibliographies such as Chinery (1977), Chu (1949), Leite and Sá (2010), Rios (1994) and Benetti (2006), in addition to consultations with specialists, professionals in the field of systematics and taxonomy at the State University of Maranhão.

Food activity was assessed by identifying the degree of stomach repletion that was classified into four categories: Stage 1- empty stomach; Stage 2- almost full stomach (1/4 of food); Stage 3 - partially full stomach (1/2 of food); Stage 4- full stomachs, adapted from the scale proposed by Hérran (1987).

The composition of the diet was analyzed using the Frequency of Occurrence (Fo), Volumetric Frequency (Fv) (HYSLOP, 1980) and Relative Abundance (Pi) methods.

The frequency of occurrence was calculated considering the number of stomachs that contained a certain food item in relation to the total stomachs with content, following the following formula: % *F*o = (*N*i * 100 / N), Where: Fo = frequency of occurrence of item i in the diet of the species, ni = number of times that food item i is repeated in the stomachs, N = total number of items in the stomachs analyzed (HYSLOP, 1980).

The volumetric participation of each item was estimated based on its percentage contribution concerning to the volume of all stomach contents, using test tubes. The two methods were combined to obtain the food importance index (IAi), developed by Pinkas et al. (1971). The (IAi) aggregates the main assessment methods (abundance, biomass and frequency of occurrence) within a single index: IAi = (N% + W%) FO%, where N%, W% and FO%, by this method it was possible to describe the dominant items in the feeding of *Hassar affinis*.

The dietary strategy of the studied species was analyzed using the graphic method of Costello (1990), modified by Amundsen et al. (1996), where information on food ecology was obtained through the graphic relationship between the specific prey abundance and its frequency of occurrence.

For the ontogenetic analysis, the fish were divided into two groups according to the stage of maturation of the gonads: juvenile - immature individuals (A) and adults - developing individuals (B), mature (C) and spawned (D), according to Vazzoler (1996).

To determine possible seasonal and ontogenetic differences and to compare variations in feeding between females and males, the statistical method of Shapiro-Wilk test was used, which serves to verify normality; when this condition was met, the Student t-test was used.

The test used to verify the homogeneity of the variances was Bartlett, however, when this condition was not met, the Mann-Whitney U non-parametric test (Zar 1999) was used. These statistical analyzes were performed with Statistica 7.0, where all the statistical tests used had a significance level of 5%.

The Proportional Overlap Index (Schoener, 1968) was calculated to assess the possible degree of overlap in the diet among large zoological groups (crustaceans, crustacean larvae, fish, insect larvae, vegetables, Mollusca, sediment) between the sexes and maturation stages. It was calculated using the formula: Ro = 1 - 1/2 ($\sum$ | Pij - Pik |), where: Ro is the overlap value; Pij and Pik are the proportional compositions of food item i for the species, respectively.

According to the values obtained, through the overlap, the index range varies between 0 to 1, where the overlap value will be 0, when the categories present completely different diets and 1 when the groups present total overlap of the food items.

3. Results

A total of 372 specimens of Hassar affinis were collected. In the lake Viana it was possible to observe a total of 86 females and 40 males and for the lake of Cajari 175 females and 72 males. The total length of the females varied between 19.0 and 13.5 cm and for the males between 16.5 and 12.0 cm in the lake Viana, for the lake Cajari the length of the females varied between 17.5 and 10.3 cm, while males were between 16.2 and 11.3 cm. The specimens analyzed were distributed in all length classes (Table 1). The largest number of fish collected was represented by females in both lakes, which exhibited, on average, greater weights compared to males.

Table 1 - Average and standard deviation of weight and size of males and females of H. affinis in the lakes of Cajari and Viana (Baixada Maranhense, Brazil)

				Hassar affinis			
				Average		Standard deviation	
	SEX	N	CT MAX/MIN	Weight	Length	Weight	Length
Cajari	FEMEAS	175	17,5/10,3	36,26211	14,02228571	12,12863007	1,260457602
	MACHOS	72	16,2/11,3	31,22792	13,58333333	9,737282922	1,064404879
Viana	FEMEAS	86	19,0/13,5	55,22244	15,67209302	16,00850648	1,281327543
	MACHOS	40	16,5/12,0	46,862	15,005	9,852082482	0,858128554

Source: Authors.

For stomach content analysis, 373 stomachs were used, of which 247 came from the Cajari lake, where 122 (49.1%) contained some food content, while 125 (50.8%) were empty. For the lake of Viana, 126 stomachs were analyzed, in which 83 (65.8%) were full and 43 (34.1%) were empty.

The proportion found of stomachs that contained some type of food for the species in the lake of Cajari is indicated in Table 2, where for summer and winter all indexes were very representative, the data indicate that the flood season (winter) the percentages in the indexes were higher, demonstrating a greater consumption of items during this season.

As for the lake of Viana (Table 2), the data show that in the dry season the species disappeared, a period that corresponds to July to November, the data also reveal that the species reoccurred only in December and it was possible to observe the presence of stomachs mainly in the ¼ and empty stages.

For the rainy season, it was possible to observe that the species occurred during all the collection months (January to June) and that the stomachs were mainly in the ½ and full stages, in this lake it was also possible to observe the presence of many stomachs in the empty stage (Table 2).

Table 2 - Percentage of occurrence of repletion stages in the stomachs of *Hassar affinis* in the lake of Cajari and Viana, Baixada Maranhense, Brazil.

		CAJARI				**VIANA**			
	MESES	**1 / 4 (FO%)**	**1 / 2 (FO%)**	**Full (FO%)**	**Empty (FO%)**	**1 / 4 (FO%)**	**1 / 2 (FO%)**	**Full (FO%)**	**Empty (FO%)**
Dry period	**July/14**	20	12,1	17,6	20,3	-	-	-	-
	August/14	13,3	18,1	23,5	10,1	-	-	-	-
	September/14	23,3	6,06	17,6	20,3	-	-	-	-
	October/14	26,6	18,1	29,4	10,1	-	-	-	-
	November/14	13,3	27,2	0	16,9	-	-	-	-
	December/14	3,33	18,1	11,7	22	27,7	6,38	7,54	23,2
Rainy period	**January/15**	0	18,1	12,5	15,9	2,77	6,38	18,8	23,2
	February/15	33,3	5,45	0	17,3	0	8,51	3,77	2,32
	March/15	40	21,8	0	15,9	19,4	23,4	20,7	16,2
	April /15	0	29,09	0	17,3	11,1	10,6	22,6	23,2
	May /15	13,3	16,3	50	13	16,6	10,6	26,4	11,6
	June /15	13,3	9,09	37,5	20,2	22,2	34	0	0

Source: Authors.

The analysis of the eating habits of *H. affinis* in the lakes of Cajari and Viana allowed the identification of 9 items that were grouped into five categories. The composition of the diet proved to be generalized, but with few food items, such as Crustaceans, Molluscs, Insects, organic debris, and sediment (Table 3).

The species *Benthonella tenella* from the phylum Mollusca, within the food spectrum of animal origin, was the item most consumed by *H. affinis*. The second most important group was Insect Larvae of the orders Coleoptera, Odonata, Díptera, Ephemeroptera in both lakes. The item Organic Waste in the two lakes obtained large percentages even though it was accidentally consumed (Table 3). The other items exhibited low frequency in feeding the species.

Table 3 - General description of the *H. affinis* diet in the lakes of Cajari and Viana, Baixada Maranhense by Frequency of Occurrence (FO%).

FOOD ITEMS		FO% Cajari Lake	FO% Viana Lake
CRUSTACEANS	Nauplius larva	1,61%	3,77%
	Megalopod larva	2,42%	1,88%
INSECTS	Coleoptera	3,23%	5,66%
	Odonata	2,83%	3,77%
	Diptera	2,02%	3,77%
	Ephemeroptera	4,04%	2,83%
MOLLUSKS	*Benthonella tenella*	15,7%	20,7%
ORGANIC DETRIT	Seeds	10,1%	18,8%
	Sheets	6,88%	25,4%
SEDIMENT	---------	10,9%	26,4%

Source: Authors.

The volumetric frequency analyzes for the lake of Cajari indicated that in the rainy season the item Mollusk was the most voluminous in the feeding of *H. affinis*, with about 29.1%. And in the dry season it was the item insect larvae with 45.9%. For Lago de Viana, the volumetric frequency indicated that in the dry season as well as in the rainy season, the item with the highest volume was mollusk with 38.4% and 20.4%, respectively.

The data on Relative Importance Index (IAi) for the rainy and dry periods show that in the Cajari lake within the spectrum of animal origin, the item Mollusk was the most consumed, however, the feeding of the species to the lake of Viana in the rainy season was composed by Mollusc 0.12% (IAi) and for dry season, the most consumed item was Insect larvae with 0.27% (Table 4).

Table 4 - Volumetric Frequency (FV%) and Food Importance Index (IAi%) of the items observed in the stomachs of *H. affinis* in Cajari and Viana Baixada Maranhense, comparing the rainy and drought periods.

	CAJARI LAKE				VIANA LAKE			
ITEMS	IAi% Rainy	IAi% Dry	FV% Rainy	FV% Dry	IAi% Rainy	IAi% Dry	FV% Rainy	FV% Dry
Mollusk	0,53	0,42	29,1	24,0	0,12	0,14	20,4	38,4
Organic Waste	0,36	0,12	45,4	11,6	0,56	0,26	39,7	26,9
Insect Larva	0,05	0,32	11,8	45,9	0,04	0,27	9,17	15,3
Crustacean larvae	0,002	0,03	1,50	6,36	0,007	0,18	2,75	7,69
Sediment	0,05	0,10	12,0	12,0	0,25	0,12	27,8	11,5

Source: Authors.

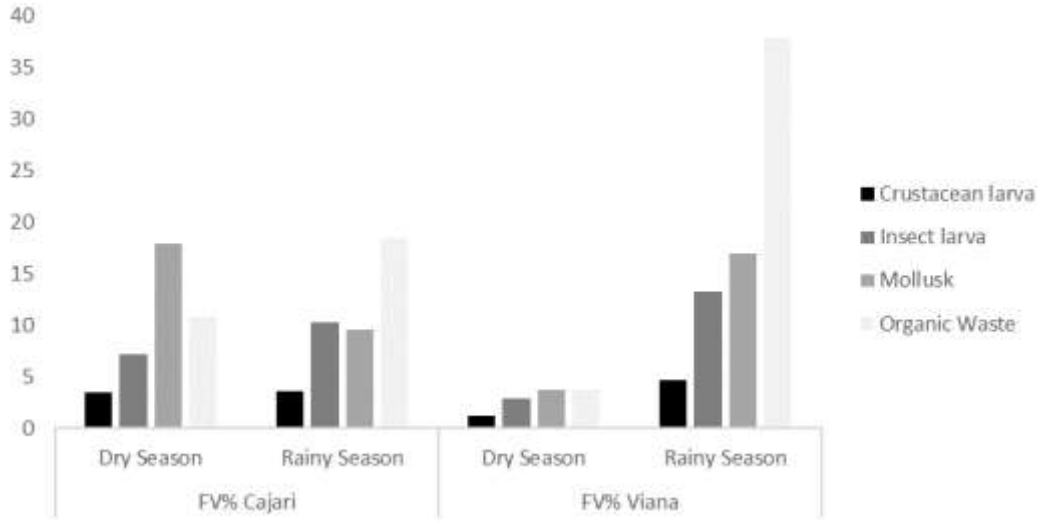
The species *Benthonella tenella*, from the phylum Mollusk, in both lakes, was the item that showed significant frequency concerning seasonal patterns, followed by insect larvae (Figure 2).

Statistical analysis showed that there was a significant difference concerning seasonality in the feeding of *H. affinis* in the Cajari lake (Student t-test, $p < 0.05$). In the dry season, the item that presented the greatest representativeness was Mollusk with 17.9%, and in the rainy season, it was insect larvae within the spectrum of animal origin, being the most frequent item (10.2%) (Figure 2).

Organic waste also obtained good representation in both seasons. For the other items, the values did not reach 15%. It was not possible to observe for the Cajari lake a decrease in the species' feeding activity in the seasonal periods.

For Lake Viana, variations in seasonality (Figure 3), according to the statistical analysis, showed no differences in food in relation to the dry season and the rainy period (Mann-Whitney U test, $p > 0.05$). The species consumed Mollusk in higher percentages, and it is also possible to observe for Lake Viana that *H. affinis* had greater feeding activity in the rainy season.

Figure 2 - Frequency of occurrence of food items observed in stomachs of *H. affinis* in the lakes of Cajari and Viana, APA da Baixada Maranhense, considering seasonal patterns.



Source: Authors.

Regarding the items ingested between males and females of *H. affinis*, for the lake of Viana, it was possible to observe that there was a significant difference ($p < 0.05$, Mann-Whitney U test). The species showed a preference for the item Mollusk, where males consumed about 23.4% and females 28.2%, and for insect larvae found with 21.6% in the stomachs of males and 15.1% in females.

In the Cajari lake, the feeding between males and females of *H. affinis* also showed differences ($p < 0.05$, Student's t test), the shellfish item being consumed by males with a percentage of 23.4% and by females with 28.2%; the item Insect larvae also obtained a considerable percentage, with 21.6% in males and 15.1% in females (Table 5).

Table 5 - Comparison of *H. affinis* feeding between males and females, juveniles and adults in the lakes of Cajari and Viana in the Baixada Maranhense, Brazil.

ITEMS		**VIANA LAKE**				**CAJARI LAKE**			
		Juvenile%	Adults%	Male%	Female%	Juvenile%	Adults%	Male%	Female%
Crustacean larva	Nauplius larva	-	6,36	4,25	4,04	2,70	6,36	4,25	4,04
	Megalopod larva	-	3,63	4,25	2,02	-	3,63	4,25	2,02
Insect Larvae	Coleoptera	-	6,36	4,25	5,05	5,40	6,36	4,25	5,05
	Odonata	-	2,72	8,51	4,04	8,10	2,72	8,51	4,04
	Díptera	-	4,54	6,38	4,04	5,40	4,54	6,38	4,04
	Ephemeroptera	-	1,81	2,12	2,02	2,70	1,81	2,12	2,02
Mollusk	*Benthonella tenella*	50	24,5	23,4	28,2	27,0	24,5	23,4	28,2
Organic waste	Seeds	25	15,4	14,8	18,1	18,9	15,4	14,8	18,1
	Sheets	25	13,6	19,1	18,1	18,9	13,6	19,1	18,1
Sediment		-	20,9	12,7	14,1	10,8	20,9	12,7	14,1

Source: Authors.

The analysis of the diet between juveniles and adults showed that there was a difference in the feeding ($p < 0.05$, Student's t-test) of *H. affinis*, with the consumption of the item Mollusk occurring in 50% in the stomachs of juveniles and 24.5 % in adults for lake Viana.

In the lake of Cajari, food also showed a significant difference ($p < 0.05$, Student's t-test), with the item Mollusca also being highly representative with 27.0% in juveniles and 24.5% in adults.

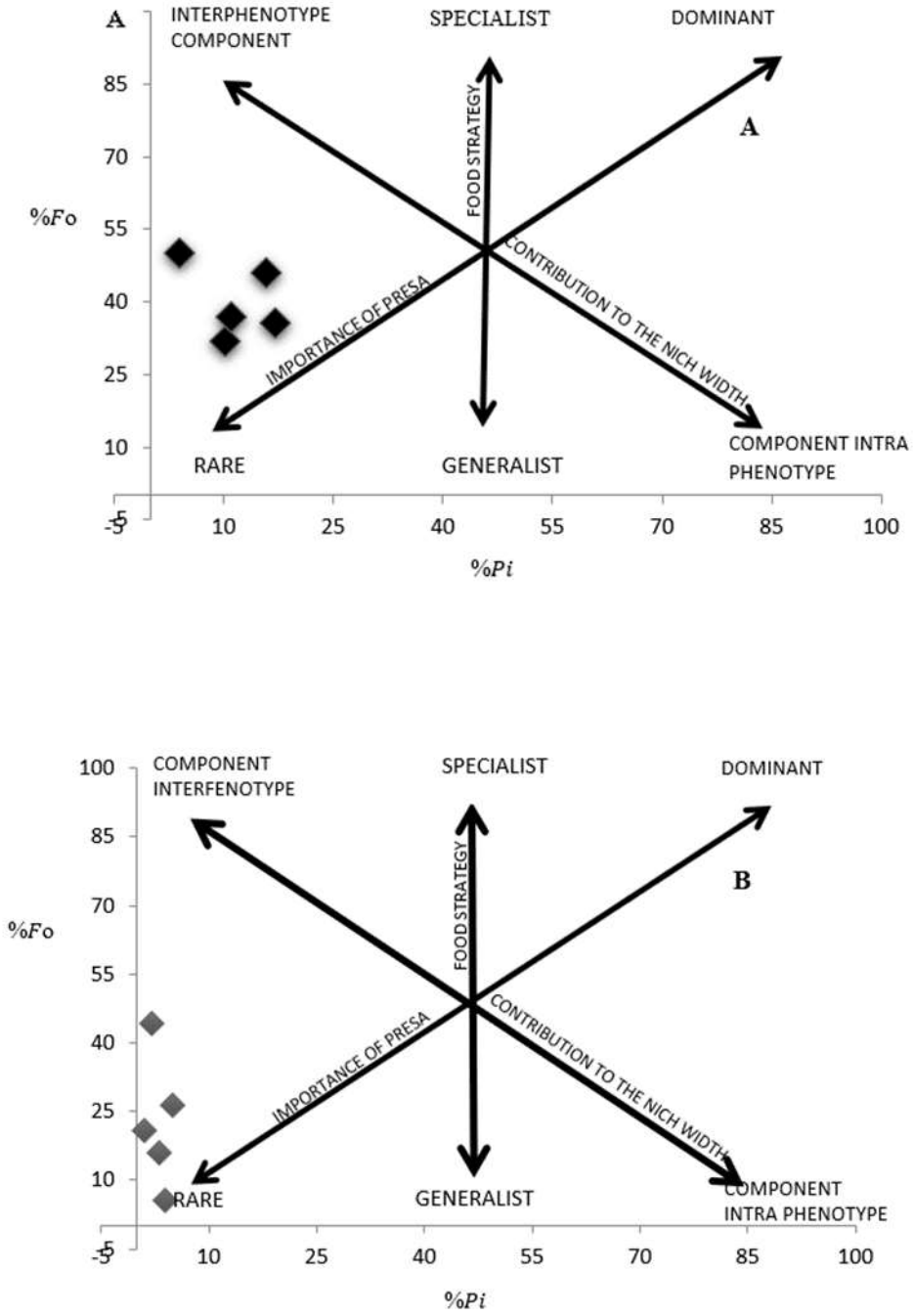
The item larvae of insect were consumed only by adults with 15.4% in the lake of Viana. The presence of this item not being found in the stomachs of juveniles; for the lake of Cajari, the item was found in both juveniles and adults with 21.6% and 15.4%, respectively (Table 5).

The proportional overlap value for the *H. affinis* diet in relation to the sexes was 0.95 for males and females in Lake Viana, 0.85 for males and females in Lake Cajari, for maturation stages it was 0.66 for juveniles and adults in Viana and 0.61 for Lake Cajari. These results indicate that there is no overlap of the species' diet in relation to maturation stage and sex, suggesting that the feeding of the species occurs in a balanced way, without intraspecific competition for resources.

The results for feeding strategy (Figure 3), obtained through the graphic relationship between frequency of occurrence and specific prey abundance, indicate that the species *H. affinis* proved to be a species that has generalist behavior in both analyzed lakes, consuming multiple items simultaneously in small proportions. However, intraspecific competition does not seem to occur, since males and females and juveniles and adults feed on alternate (non-coincident) items.

The data indicate that the species is capable of enjoying several resources simultaneously in the environment, being thus characterized as a species that has a low niche range within the ecosystem, in which the population always eats the same items and in small quantities (Figure 3).

Figure 3 - Amundsen diagram where the feeding strategy is represented through the graphical relationship between the frequency of occurrence and the pre-specific abundance in the *H. affinis* diet in the Cajari (A) and Viana (B) Lakes Apa of Baixada Maranhense, Brazil.



Source: Authors.

4. Discussion

The *Hassar affinis* species analyzed in the present work, both for the Cajari lake and for the Viana lake, showed the bentophagous and omnivorous feeding habit, with items in the food of animal and vegetable origin.

Fish of this genus are species that use various food tactics, such as: snatching or sucking sand and mud to separate the organisms they seek; capture prey in motion; stand still and wait for small organisms to pass close enough to be captured; breaking shells; bite the tissues that protrude from the outer lining of the body of some invertebrates (Gerking, 1994).

Data obtained in the study by Gonçalves, (2007) in a reservoir in Mogi Guaçu, (SP) with the *Iheringichthys labrosus*, describes that the relationships between food and oral morphology of species of the order of the Siluriformes, may be associated with the size of the mouth in these species, as they seem to have a smaller size mouth, which allows the selection of food on the substrate.

Studies have shown that omnivorous species feed mainly on aquatic insects, fruits and debris (Venere & Garutti, 2011). Dias et al. (2020) studying the abundance and biomass of fish from dams in Paraná and Tocantins describes as omnivorous organisms that consume plants ranging from algae to higher plants and invertebrate animals and fish, a characteristic similar to that observed in the species of the present study, although the consumption of the fish item is not observed in the species in question.

According to Gonçalves (2007) studying the food items consumed by the *I. labrosus*, a species of the same order in a reservoir, in Mogi Guaçu, (SP) allowed to describe the species as invertivorous and bentophagous, despite not having used the term invertivore to describe the feeding of the species *H. affinis* related in the present work, Gonçalves, (2007) describes in the *I. labrosus* diet, the presence of benthic invertebrates as components of the species' diet, as well as the present research for the *H. affinis* diet.

Garcia (1995) observed that 80% of the food source of benthic fish in the Anavilhanas Archipelago, Rio Negro was constituted by aquatic invertebrates associated with the bottom organic matter; similar results to those observed in the present research, where it was possible to evidence the presence of mollusks associated with sediment. Similar results have also been described by Resende et al. (2000) with fish of the same family in the Miranda Pantanal River of Mato Grosso do Sul where he describes that the species belong to a very peculiar benthic group, which ingest small food available on the shallow bottom or on the submerged macrophytes.

Arantes (2009), in his work with a species of the family Doradidae, describes results like the present work, where he classifies the species with an opportunistic omnivorous habit. Dias et al. (2020), studying dam species also highlights the opportunistic habit for omnivorous species. For Agostinho et al. (1992), in most cases of fish in this family, different food items were found in the stomach of the same individual, which is following with the omnivorous habit of the species.

Omnivory is a common eating behavior in many species of the Doradidae family (Barbosa, 2012). Studies by Ringuelet et al. (1967) and Marques (2005) classified *Oxydoras kneri* as an omnivorous species. Results obtained by Oliveira (2005) in their works with the same species describe that the food ingested was predominantly native, with the items larvae of insects and debris found more frequently in their studies.

Marques (2005), analyzing the stomach contents of a species of the same order, observed that it presents itself with generalist behavior since it consumes several items simultaneously. Food plasticity is particularly striking in freshwater fish, especially in seasonal environments, where many of them ingest benthic invertebrates and fish (Lowe-Mcconnell, 1987).

Generalist species, which are more tolerant and consequently more favored (or in the abundance or number of species (Fernando & Holcík, 1991; Hahn & Fugi, 2007). Fish species with greater plasticity in their diet are favored due to their ability to consume a widest range of resources available (Agostinho et al, 2007).

In the present work, it was possible to describe the generalist and opportunistic behavior of the species. Results different from those described were observed in a study carried out by Lima et al. (2015), in the Parapanema River with the species *Rhinodoras dorbignyi*, a taxon of the same family, where the author describes the specialist behavior, consuming

mainly dipteran larvae. Dias et al. (2005), report that the characterization of a species' eating habits can change according to the dynamics of food resources and that the occurrence of generalist or specialized species is determined in habitats due to the characteristics of available resources.

Hahn et al. (1997), state that the food activity in fish is generally higher in lentic environments when compared to channels and rivers. This fact occurs due to the existence of more trophic specializations in lagoons, since in these environments the source of food is available throughout the year, while in rivers the food resources vary seasonally (Lowe Mcconnell, 1999).

The large percentage of empty stomachs is due to external factors such as seasonality as well as the biology of the species since the capture of prey can increase during changes between cold seasons to hot seasons, which favor foraging activity (Menezes, 1983).

Kurzmann et al. (2007), studying *Rhinodoras dorbignyi* species of the same order, showed that most of the evaluated stomachs were partially empty. These data are like those observed in this work. The decrease in food in the stomachs is the result of a high energy cost, which is reflected in the growth rates and which occurs in the period in which the species is preparing for reproduction (Ibañez-Aguirre & Gallardo-Cabello, 2004).

About the disappearance of the species at a certain time within the dry period, it is due to a natural regime, caused by the dynamics of the environment, since this region the rainy and dry regime is well marked, and during this time there are changes in these bodies of water, thus, this natural regime causes changes in the dynamics of the water and in the aquatic communities themselves (Cecilio et al., 1997).

In the rainy season, there is an increase in the hydrological level of these environments, allowing communication with lentic bodies around them, which provides the availability of microhabitats, which can be used by many species for reproduction, feeding, migration (Saint-Paul et al., 2000).

Regarding the composition of food, Barbosa (2012), studying the ecological aspects of *Lithodoras dorsalis* (Doradidae), states that the item Gastropoda is one of the items consumed by the species. In stomachs of another species of the same Doradidae family, Arantes et al. (2009) and Vermulm and Giamas (2008) observed the presence of gastropods, and according to these authors the habit of exploring the bottom of water bodies is a characteristic of the Doradidae family, as other representatives also use bentofauna as a food source.

Like *Lithodoras dorsalis*, the species *H. affinis* investigated in the present study in the lakes of Viana and Cajari presents food with the consumption of Gastropoda. This Bentophagous tendency has also been confirmed in the works developed by Lauzane and Loubens (1985) for *Oxydoras niger* in Rio Mamoré, Bolivia, which was classified as Bentophagus, in addition to *Trachydoras paraguayensis* also considered bentophagus by Hahn et al. (1991).

The tendency to Bentophagy of *H. affinis* was confirmed by the Relative Importance Index (IAi), which demonstrated that in addition to gastropod the species obtained a good representation of the item Insect Larvae, in addition to the predominance of organic detritus. Claro-Júnior et al. (2007), studying a species of fish from the same family *Hassar orestis*, described as main items of the species feeding, debris, including a number of invertebrates associated with the sediment, such as insect larvae, microcrustaceans, protozoa, bacteria and algae. Results that corroborate with this work since the species in the present study also fed on invertebrates associated with sediments. Study carried out by Kurzmann et al. (2007), in the Ibicuí River, in the south region of Brazil with *Rhinodoras dorbignyi* of the Doradidae family, indicated that this taxon has as main item in its diet insects of the orders Trichoptera, Diptera and Ephemeroptera.

The predominance of aquatic insects in fish feeding has been evidenced by many authors (Hahn et al., 1997; Hartz et al., 2000). A diet composed of benthic invertebrates is a source of nutrition for more than half of the fish biomass in South

America, and larval forms of insects are the food category most used by the ichthyofauna (Zavala-Camin, 1996). According to Silva et al. (2020) studying associations between the structure of the fish assembly and hydrology in the lower Amazon River, species that feed on aquatic insects are mainly associated with periods of flood, this is because, consequently, there is greater abundance and diversity of food resources. Another fact is that rivers and lakes are environments that have sandy substrates and that contribute greatly to the abundance of benthic fauna (Hartz et al., 2000).

Kurzmann et al. (2007) and Freitas (2010), studying the feeding of various fishes, described in their studies that no significant differences were observed in feeding between sexes and between length classes. These results differ from those observed in the present study, since differences in feeding were observed between sexes and the length classes of *H. affinis* for both lakes.

Ontogenetic changes in the diet of some fish are relatively common as shown in several groups (Agostinho et al., 2003; Novaes et al., 2004; Guedes et al., 2015). Feeding flexibility, according to Dill (1983) is an adaptive characteristic of the fish life cycle, being used as a strategy in relation to food availability.

Lowe-McConnell (1999) also points out that, despite the distinct anatomical specializations for food, observed for several species of fish, most of them show considerable plasticity in their diets, governed mainly by food availability and environmental variations to which populations and species are subjected. For Joblin (1996), the ontogenetic variation in food lies in the fact that the cost-benefit ratio of the prey is based on the question of the energy required to maintain growth rates.

Hahn and Fugi (2007) state that, in natural environments, the abundance of available food resources undergoes cyclical changes, modifying the fish's diet; these changes are, however, predictable and gradual and, therefore, allow evolutionary adaptations of species about the best use of resources, avoiding intraspecific competition.

In fish, the composition of the diet can present seasonal variations (Piorski et al., 2005). These variations can occur due to changes in food availability caused by changes in the habitats available for foraging, changes due to biological patterns of prey organisms and changes caused by the feeding activities of the fish itself (Wooton, 1990).

Kurzmann et al. (2007), studying the species *Rhinodoras dorbignyi* of the family Doradidae described that there was a difference in the species' diet, in relation to seasonality. These results are like those observed in this work, for the lake of Cajari where *H. affinis* showed variation in feeding during the different seasons.

According to Lowe-McConnell (1999), most fish, in tropical regions, exhibit flexibility in the composition of the food consumed, where it is mainly governed by food availability and the environmental changes to which populations and species are subjected. For Hahn (1997), the food plasticity of fish is mainly associated with the high diversity and abundance of potential prey, which exhibits seasonal variations according to their life cycle. However, for Lake Viana, variations in seasonality have shown that there are no differences in the species' diet in relation to the dry season and the rainy season, probably due to the characteristics of the lake that allow mollusks to persist in both seasons.

Marques (2005) studying a species of the same order, in a river in the municipality of Jardim - MS described the feeding activity is more intense in the dry months, revealing a drop in the feeding activity in the following months. These results are different from those observed in the present study since *H. affinis* in the lake of Viana was fed with high frequency in the rainy season, showing a drop-in food activity in the dry season. According to Lowe-Mcconnell (1987), the diet can vary with the season, the abundance of food-organism, the activity of the fish, the biotope changes and, other species of fish present.

Junk (1984) describes that the change in the level of rivers resulting from rainfall and flood peaks affects the quantity and quality of food. Through the analyzes for the seasonality of *H. affinis* in the lake of Viana it was possible to observe a feeding similar to that described in the studies of Junk (1984) and Barbosa (2012), where a species from the same family fed

mainly on açaí fruits (*Euterpe oleracea*) in the periods from August to December, the time of greatest fluctuation of these vegetable and bivalve gastropods in the transition period from dry to rain.

The use of a specific food item to the detriment of another, due to availability, can be explained by the theory of Optimal Foraging (Macarrthur & Pianka, 1996), according to which each species seeks to balance the energy spent to acquire food and the energy obtained by consuming this resource to maximize the energy gain of its diet.

The analysis of stomach content and the value obtained for the index of overlap with the maturation stage and sex revealed a great similarity of the eating habits of *H. affinis* in both lakes. The trophic partition is an important strategy to avoid interspecific competitions and to guarantee the coexistence of species (Brannas, 2008). Furthermore, according to Goulding (1980), food overlap is most evident when food is scarce. When food resources become limiting, the species can compete and specialize according to its preferences (Gabler & Amundsen, 2010).

The data obtained for the species analyzed in the two lakes indicate that the Environmental Protection Area of the Baixada Maranhense is characterized as an important region and that favors the continuity of fishing stocks, but the feeding ecology of the species shows seasonal variations between the analyzed lakes, these fish stocks have experienced a reduction worldwide at a worrying rate, which requires more efficient strategies for managing these resources, which in these regions is mainly caused by the development and growth of urban Amazonian regions (Pereira et al., 2020).

Thus, further studies on the feeding of the species should be done to show the complexity of the environments in the Baixada Maranhense APA, to contribute with significant information for public policies for the conservation of fisheries resources in the region.

5. Conclusion

The *Hassar affinis* species consumed mainly the item Mollusk (Benthonella tenella) and insect larvae (Coleoptera, Odonata, Diptera and Ephemeroptera), presenting itself as an omnivorous and benthic species.

H. affinis was characterized as a generalist consuming several items in small proportions (but which do and are important for the trophic spectrum of the species). There is no significant food overlap between sexes and maturation stages, suggesting a species with a diet without intraspecific competition.

The results of the research also show that the region, despite its particularities and the effects of very marked seasonality in the region, the data indicate that the environment is balanced and has favorable conditions for the development of the species since it is offering enough food in both seasons.

Additional studies on the feeding ecology of this species are suggested, in order to provide data, mainly on ecology, since studies in the literature on feeding *H. affinis* are scarce and this information can help to understand the degree of conservation status of the environment and species, can help and ensure the sustainable use of fish stocks, so important economically and ecologically, moreover, can contribute to filling gaps not only in terms of food, but also regarding the distribution and use of habitat by species.

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