Feeding habits of *Centropomus undecimalis* (Actinopterygii, Centropomidae) in the Parnaíba river delta, Piauí, Brazil

Alimentação do *Centropomus undecimalis* (Actinopterygii, Centropomidae) no estuário do delta do rio Parnaíba, Piauí, Brasil

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ABSTRACT
The objective of this work was to evaluate the feeding of *Centropomus undecimalis* in the estuary of the Parnaíba river delta, with emphasis on diet composition during seasonal variations between dry and rainy seasons. The samples were obtained from artisanal fishing with gillnets, from June 2014 - July 2015. The individuals were measured, weighed and dissected to remove the stomachs. The fish diet was analyzed using the methods: Gravimetric, Frequency of Occurrence, Dominance of the item and Food Index. One hundred and seven stomachs were sampled, of which 72% had food content. The diet consisted of eight Teleostei fish and crustaceans during the dry and rainy seasons, as well as organic material of remains, sediments and plastic. Similarities were observed in stomach contents, indicating specialization, but at individual scale (inter-phenotypic). Thus, it may not occur for the entire population. The analyses of the diet allowed to confirm that *C. undecimalis* is a carnivorous species for the food chain of the estuary of the Parnaíba River delta, and the diet varies according to prey abundance in the environment.

Keywords: food chain, diadromous, ontogeny, energy transfer

RESUMO

O objetivo deste trabalho foi avaliar a alimentação do *Centropomus undecimalis* no estuário do delta do rio Parnaíba, com ênfase na composição da dieta durante as variações sazonais entre as estações seca e chuvosa. As amostras foram obtidas a partir da pesca artesanal com rede de emalhar, de junho 2014 – julho 2015. Os indivíduos foram medidos, pesados e dissecados para retirada dos estômagos. A dieta dos peixes foi analisada usando os métodos: Gravimétrico, Frequência de ocorrência, Dominância e Índice alimentar. Cento e sete estômagos foram amostrados, destes 72% apresentaram conteúdo alimentar. A dieta foi composta por Teleostei e crustáceos durante as estações seca e chuvosa, além de restos de materiais orgânicos, sedimentos e plástico. As similaridades foram observadas no conteúdo estomacal, indicando especialização, mas em escala individual (inter-fenotípica), podendo não ocorrer para toda a população. As análises da dieta permitiram confirmar que o *C. undecimalis* é espécie carnívora para a cadeia alimentar do estuário doo delta do rio Parnaíba, e a dieta varia de acordo com a abundância de presas no ambiente.

Palavras-chave: Cadeia alimentar, diádromos, ontogenia, transferência de energia

1 INTRODUCTION

Studying fish diets is of paramount importance for the understanding of its space and time habitat use, as well as for the comprehension of the relations among different species. It also allows the identification of variations within a trophic structure at a given environmental condition, such as climatic shifts or food availability over time (Mendonça *et al*., 2004; Agostinho *et al*., 2009; Monteiro *et al*., 2009; Malinowski *et al*., 2019). Information about a fish's diet helps to improve knowledge about its biology and its relationships with the food chain (Figueiredo *et al*., 2014; Leite *et al.* 2021)

The Parnaíba river delta exhibits considerable richness of fish species, as well as crustaceans and molluscs, many presenting economic and social importance. The delta shelters an Environmental Protection Area (APA) and an overlapping protected area with sustainable use of natural resources in the Extractive Reserves (RESEX). Fisheries resources from the delta are mainly represented by the following species: mangrove-crab *Ucides cordatus* (Linnaeus, 1763), common snook *Centropomus undecimalis* (Bloch, 1792), broadband anchovy *Anchoviella lepidentostole* (Fowler, 1911), freshwater native mussel *Cyanocyclas brasiliana* (Deshayes, 1854), freshwater prawns *Macrobrachium amazonicum* (Heller, 1862) and *Macrobrachium acanthurus* (Wiegmann, 1836), and the swimming crab *Callinectes bocourti* (A. Milne-Edwards, 1879) (Melo, 1996; Guzzi, 2012; Farias *et al*., 2015). Although fishing activities are mostly carried out by artisanal fishermen, these species are subjected to different fishing efforts, which might cause an

imbalance in the number of species, and thus interfere in food habits of different species (Winik *et al*., 2007; Tonini *et al*., 2007; Odum & Barret, 2008).

The common snook represents the main fish landings of Parnaíba river delta, due to its both abundance and high economic value, factors that increases its vulnerability to fisheries exploration (Lira *et al*., 2017). This species is mostly captured in drift nets by artisanal fleets, from January to May, during the rainy season, when its abundant due to its reproductive cycle (Farias *et al*., 2015, Fernandes & Cunha, 2017). Estuaries provides an energy flow by high diversity of food items which directly influences food availability, and the delta of the Parnaíba river demonstrates strong relationship between its dry and wet seasons, with the abundance of fish species (Barletta *et al*., 2017). As a diadromous estuarine fish species, *C. undecimalis* tolerates a wide range of salinity, with its young developmental stages generally being found in freshwater habitats (Tonini *et al*., 2007; Amaral Junior *et al*., 2009; Corrêa *et al*., 2010). This species' diet consists of different items according to its life stage; juveniles live in shoals in shallow waters, and show preference for crustaceans, whilst adults are usually solitary and feed especially on small fishes (Peterson & Gilmore, 1991).

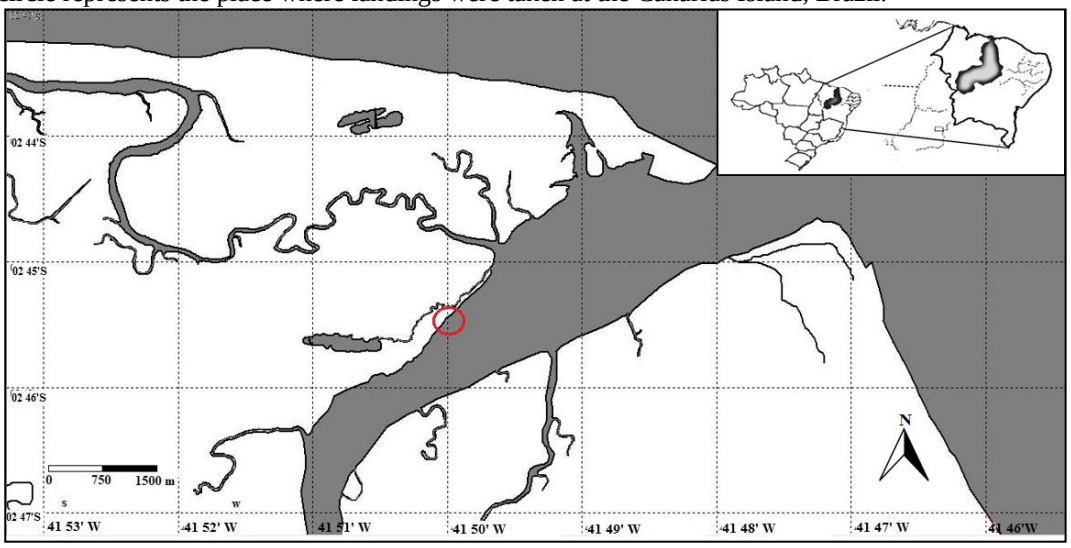
Estuarine environments undergo constant seasonal variations throughout the year, thus exposing living organisms to such hydrological shifts. These changes might hamper fishing activities, fish reproduction and feeding of several species (Watanabe *et al*., 2014; Blaber & Barletta, 2016; Barletta *et al*., 2019). These environments provide an adequate energy flow due to the high diversity of food, and the Parnaíba river delta shows a strong relationship with the dry and rainy season in the abundance of fish species (Barletta *et al*., 2017). The aim of this study was to characterize the trophic dynamics of *C. undecimalis* in the Parnaíba river delta, identifying diet composition and seasonal variation in its diet.

2 MATERIAL AND METHODS

2.1 STUDY AREA

The Parnaíba river basin is located in the Northeast region of Brazil. It has a drainage area of approximately 331,000 km² and is 1,432 km long (CPRM, 2017). The study was conducted in the Lower Parnaíba area, located in the Canárias Island, which is the second largest island of the Parnaíba river delta, with approximately 32 km² of area. This island is part of an Environmental Preservation Area known as RESEX (Resex Marinha Delta do Parnaíba), located between the States of Maranhão (MA) and Piauí (PI), at the coordinates 02 °45 '59 "S and 41 ° 50' 41" W (Figure 1).

Figure 1. Location of the study area, where *Centropomus undecimalis* is fished at the Parnaíba river delta. The red circle represents the place where landings were taken at the Canárias Island, Brazil.



The climate characteristics according to the Köpper classification are Tropical humid, with rainy summer and hot winter, and temperatures ranging from 20 to 32ºC (Aguiar, 2004). In this area, the annual rainfall in period between 1978 - 2014 was 1.033,5 mm, on average (Bastos *et al.*, 2016). The meteorological data presented in this study were obtained from the agrometeorological station of the Instituto Nacional de Meteorologia (INMET), llocated in the experimental area of Embrapa Meio-Norte, municipality of Parnaiba which comprises an approximate area of 431 km^2 (Aguiar, 2004). This station is the source of meteorological data closest to the studied area, becoming a reference for studies carried out in the lower Parnaiba portion.

2.2 SAMPLING

Fish samples were collected at the fishing port located at the Canárias Island (MA) from June 2014 to May 2015. Sampled specimens of *C. undecimalis* derived from artisanal fisheries that uses drift nets, with mesh sizes between adjacent knots varying from 10 to 16 cm. Total length (TL in centimeters) and weight (TW in kilograms) were measured for each individual. Subsequently, the specimens were dissected for stomachs removal and fixation using a 10% formalin solution, and transported to the Laboratory of Ichthyology (LABIC) of the Federal University of Delta Parnaíba.

In the laboratory, the stomachs were dissected in order to remove its contents, which were placed in Petri dishes for stereoscopic microscope screening and taxonomic identification, with the aid of the taxonomic keys developed by Figueiredo & Menezes (1987, 1980a, 1980b, 1985, 2005). The process was performed by separating each feed

item and classifying them into different categories (Table 1). All items were counted and individually weighted on a precision scale (0.001 g). Item identification was made to seek the lowest possible taxonomic level; however, some samples were in an advanced stage of digestion, thus they were accounted in the "remains" category. These were characterized as animal organic matter (OM), composed of muscles, scales, bones, otoliths, vertebrae, exoskeleton fragments and by inorganic mattes (IM), composed by sediments such as sand and synthetic fibers (plastic).

2.3 DATA ANALYSIS

The seasonal analysis considered the Dry season (July-December/2014) and the Rainy season (January-June/2015) based in the study from Marengo *et al.* (2011) using weather data from 1970-1990, found that in portion of the region northeast of Brazil, the rainy season takes place between February and May, while the dry season takes place between August and October.

Fish size and weight were analyzed according to the season (rainy and dry), in order to seek for variations year-round. Data were subjected to Shapiro-Wilk test ($p< 0.05$) to verify distribution, followed by Mann-Whitney U test ($p< 0.05$). Data were analyzed using Frequency of occurrence method, as well as the quantitative method of Gravimetric Frequency, in which each registered food item in the gastric contents was quantified by mass and expressed as the percentage of the total mass of all items found in the stomach through the equation: $\%FW=(W/WT)x100$ where: W= item mass, WT = total mass of the food items x 100 (Hynes, 1950).

The Frequency of occurrence (%FO) (Hyslop, 1980) was calculated by: $\%FO=(ni/N)x100$, where: %FO = frequency of occurrence of the sampled item; ni = number of stomachs in which item i was found; and N = total of analyzed stomachs.

The methods were combined in order to verify the food importance by means of the Feeding Index (IAi), as proposed by Kawakami & Vazzoler (1980), through the calculation: $IAi =(\%FOx\%FW)x100/\Sigma (\%FO\ x\%FW)$, where: IAi = feeding index, %FO= frequency of occurrence of the sampled item; and %FW= frequency gravimetric. Then, Feeding Index was used to evaluate the differences in the prevalence of major food categories between the rainy and dry seasons using the Mann-Whitney (U) test at a 5% probability level (Zar, 2010). A Spearman's correlation test between rainfall data and Food Index was also performed.

The values of food items were also tested for statistical differences between two seasons through a one-way analysis of similarity (ANOSIM) (Clarke, 1993), using a square-root transformation weight with randomization permutation (n = 9999), at the significance level of 5%.

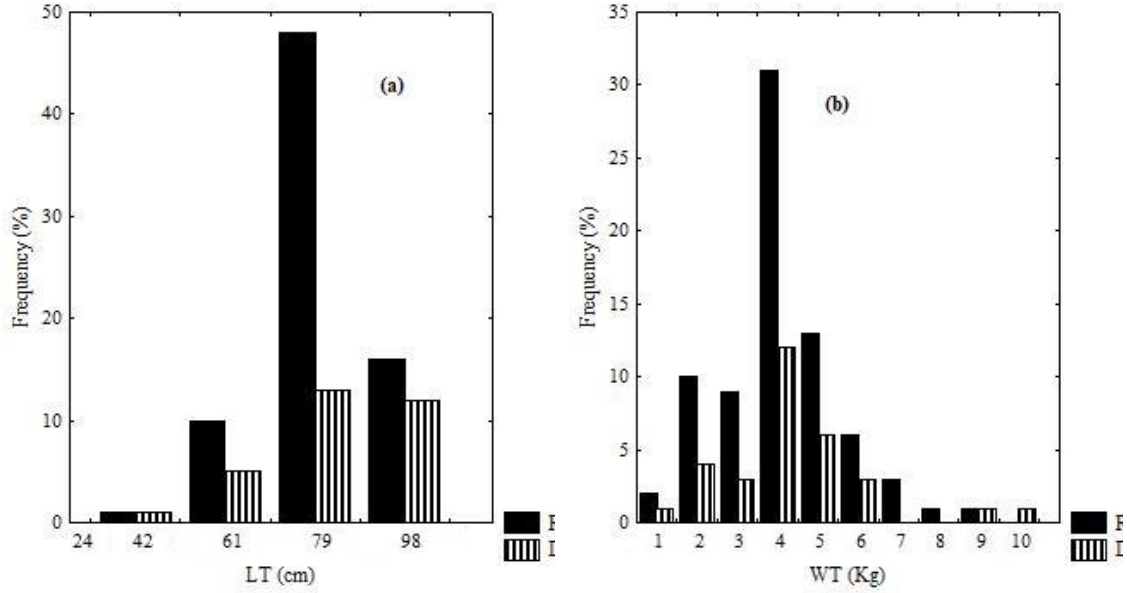
In order to evaluate the degree of food overlap between two seasons, the Morisita-Horn index (Horn, 1966) was used, using the formulation: $C_H=2\sum ni\ Pij\ x\ Pik/\sum ni\ P^2ij+\sum ni\ P^2ik$, where, Pij= proportion of item i in relation to the total resources used by species j; Pik= proportion of item i in relation to the total resources used by species k; n= total number of food items. The values of C_H= range from 0 to 1, and closer to 1, the greater the overlap.

With the objective to determine feeding strategy, diagrams were used according to the analyses of Costello (1990), with modifications suggested by Bennemann *et al*. (2006), where: %Pi=(DO/FO)*100 represents the y axis and the frequency of occurrence on the x axis, Pi = specific abundance, and DO = dominance of the item and FO= frequency of occurrence.

3 RESULTS

A total of 107 individuals were obtained, of which 72% presented stomach content. Fish total length ranged from 39 to 98 cm (73.5 ± 10.9 SD) (Figure 2a). Regarding the relation of the number of individuals, more individuals were found during the rainy season (n = 76) in comparison to the dry season (n = 31). Fish sizes were similar between rainy season (73.5 ± 10.6 SD) and dry season (74.1 ± 11.8 SD), not presenting statically significant differences (Mann-Whitney U test, p> 0.05, p= 0.77, U= 10.00). The total weight found in the sampled specimens varied from 0.5 to 10 kg (Figure 2b), which were also not statically different between both seasons (Mann-Whitney U test, p>0.05, p= 0.83, U=10.00).

Figure 2. Length (a) and weight (b) of *Centropomus undecimalis* collected at the Parnaíba river delta.



The diet composition of *C. undecimalis* revealed major categories of food composed of Teleostei fish (87.42%) and Crustaceans (7.31%). The remaining items (5.27%) were composed of organic and inorganic matter, seagrass (0.01%) (Figure 3a and Table 1). Eight Teleostei families were identified: Ariidae (*Cathorops* spp., *Cathorops spixii*, *Cathorops agassizii*), Carangidae (*Chloroscombrus chrysurus*), Clupeidae, Engraulidae (*Lycengraulis grossidens*), Haemulidae, Mugilidae (*Mugil* spp.), Sciaenidae (*Macrodon ancylodon*, *Stellifer* spp., *Stellifer stellifer*, *Stellifer brasiliensis*), and Trichiuridae (*Trichiurus lepturus*) (Figure 3b). In addition, a few crustacean specimens of the family Penaeidae and of the order Amphipoda were also found (Table 1).

Figure 3. Feeding index (IAi) the major categories (a) and Teleostei families (b) found in the diet of *Centropomus undecimalis* in the Parnaíba river delta.

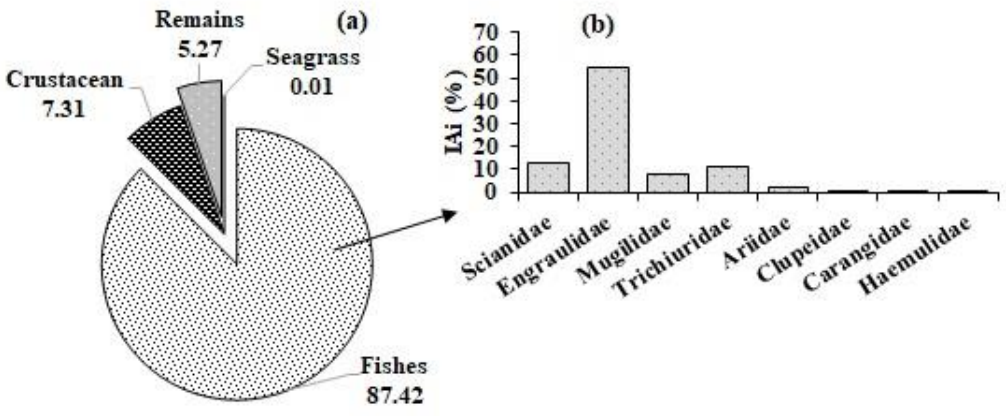


Table 1. Contribution by Frequency of occurrence (%FO), Frequency gravimetric (%FW), Feeding index (%IAi) and different category in the diet of *Centropomus undecimalis* from the Parnaíba river delta, Piauí, Brazil.

Itens	Rainy			Dry		
	%FO	%FW	%IAi	%FO	%FW	%IAi
Fishes	**67.47**	**82.25**	**88.50**	**52.94**	**82.77**	**86.33**
Teleostei	33.73	40.80	80.92	32.35	51.00	80.60
Engraulidae	2.41	4.09	0.58	5.88	3.50	1.00
Trichiurus lepturus	1.20	2.01	0.14	2.94	6.21	0.89
Mugil spp.	2.41	8.51	1.21			
Sciaenidae	3.61	10.56	2.24			
Stellifer spp.	2.41	3.60	0.51			
Cathorops spixii	3.61	0.88	0.19			
Lycengraulis grossidens	9.64	3.72	2.11	5.88	4.60	1.32
Stellifer stellifer	1.20	4.52	0.32			
Cathorops spp.	1.20	1.49	0.11			
Macrodon ancylodon				2.94	11.37	1.63
Cathorops agassizii	2.41	0.40	0.06			
Clupeidae				2.94	6.10	0.88
Stellifer brasiliensis	1.20	0.87	0.06			
Chloroscombrus chrysurus	1.20	0.68	0.05			
Haemulon spp.	1.20	0.13	0.01			
Crustacean	**10.84**	**12.44**	**7.04**	**17.65**	**8.79**	**7.58**
Penaeidae	9.64	12.42	7.04	17.65	8.79	7.58
Amphipoda	1.20	0.02	0.01			
Seagrass	**3.61**	**0.04**	**0.01**			
Plastic	**1.20**	**0.00**	**0.00**			
Remains	**16.87**	**5.27**	**4.45**	**29.41**	**8.44**	**6.09**

The highest value of the feeding index was found for Teleostei, followed by Engraulidae, *Trichiurus lepturus* and finally Penaeidae, whilst the rest of the items varied (Table 1). Seventy-seven fish (72%) revealed stomach contents, of which 45% were found during the rainy season and 27% in the dry season. Regarding the seasonal variation of the food items, no difference was found in the categories Teleostei ($U = 18.00$, $p > 0.05$), Crustacean ($U = 12.00$, $p > 0.05$) and seagrass ($U = 17.50$, $p > 0.05$) between dry and rainy seasons. However, Teleostei (IAi= 11.25%) fish were abundantly found in the stomach content of *C. undecimalis* in the dry season, while crustacean were found mostly during the rainy season (IAi= 14.99%) (Figure 4a and Table 1).

Rainfall was significantly higher in the rainy season ($U = 1.00$, $p < 0.05$), and the variation of the pluviometric index in the rainy season was 9 - 267 mm ($\sum$= 618.3; 103.05 ± 111.11 SD), while in dry season was 2.7 mm ($\sum$= 16.3; ± 3.39 SD) (Figure 4b). The Spearman correlation analysis between rainfall and items indicated that there was a

negative coefficient with teleostei and seagrass, while with the crustaceans it was positive coefficient, however this environmental variable was not significantly correlated with diet (Table 2).

C. undecimalis diet did not display significant differences between seasons (ANOSIM, R=0.04, p >0.05), thus indicating a similarity, reinforced by the Morisita-Horn index (C_H= 0.89), as it revealed a high overlap in the diet between seasons.

Figure 4. Mean ± 0.95 confidence intervals in the main categories of diet of *Centropomus undecimalis* (a) and pluviometric index (b) in the Parnaíba river delta.

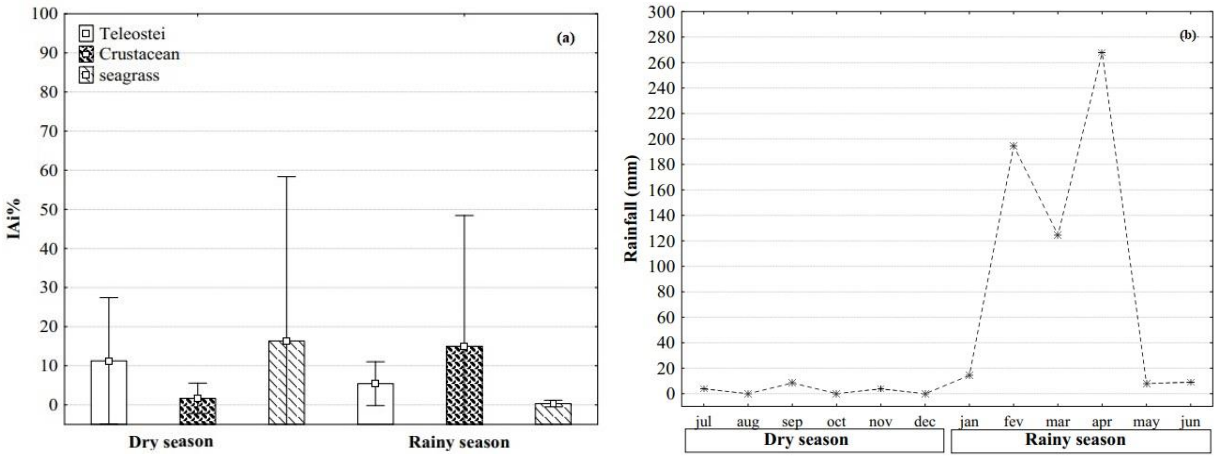
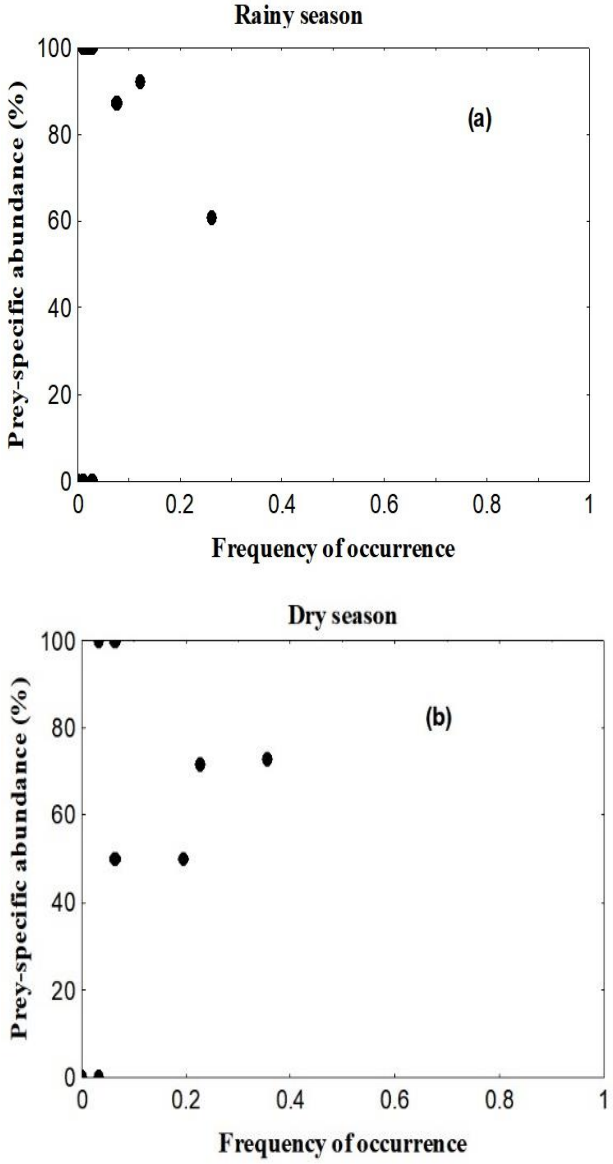


Table 2. Spearman rank order correlations (marked correlations are significant at p < 0.05) in the diet of *Centropomus undecimalis* from the Parnaíba river delta, Piauí, Brazil.

Pair of variables	Spearman R	p-level
Rainfall and Teleostei	-0.12	0.69
Rainfall and Crustaceans	0.26	0.41
Rainfall and Seagrass	-0.02	0.94

When analyzing the relation for prey-specific abundance and frequency from the Costello diagrams modified by Bennemann *et al*. (2006) by season (rainy and dry), results indicate a specialization strategy with a high inter-individual phenotypic component (the points are located in the upper left corner), and points on the lower left side revealing rare items (Figure 5ab).

Figure 5. Costello's diagram modified by Bennemann *et al.* (2006) for food strategy of *Centropomus undecimalis* in the Parnaíba river delta. (a) rainy season: The points are located in the upper left corn indicates specialization strategy with a high inter-individual phenotypic component (b) dry season: points on the lower left side items with rare importance.



4 DISCUSSION

A fish's diet is a good indicator of habitat use and targeted preys throughout its life cycle. This information reveals the main species available at a certain time of the year, and indicates which preys are used as energy source for e.g. reproduction and growth (Gonzalez *et al.*, 2019; Stevens *et al.*, 2019). Knowing a diet's composition and seasonal variations in the fish stomach improve knowledge of about a species' feeding behavior, such as tendencies to specialization and generalization (Bennemann *et al.*, 2006). Also combined with other indices to verify feeding strategy, species-specific prey preference,

wide range of food items, and rare occurrence (Hyslop, 1980; Costello, 1980; Amundsen *et al.*, 1996; Bowen, 1996). The common snook *C. undecimalis* is a typical opportunistic fish species that exhibits higher similarity levels in its diet composition (fish >80%), depending on prey abundance on the habitat (Blewet, 2006). Amundsen *et al.* (1996) argued that some species may shift its strategy according to the abundance of the prey, and specialization varies either at an individual (phenotypic) or population level within same species niche. Data from diet of the common snook in delta of Parnaíba, and for many different studies published, indicates the species as carnivorous with some preference for small pelagic fish species like engraulids (Tonini *et al*., 2007; Lira *et al.*, 2017; Gonzalez *et al*., 2019).

C. undecimalis diet in the present study, showed higher preference for Teleostei and Crustacea that were entirely or partially digested, also shows that the common snook is an active predator in the local estuary food chain. Lira *et al.* (2017) studied the food ecology of *C. undecimalis* and *C. parallelus* in two tropical estuaries in northeastern Brazil, observed preferences for Teleostei and Crustacea. Farias *et al.* (2015) reported major of the food items (species) in the local fisheries landings, supporting observation on the common snook diet. Due to relation of prey abundance in the environment, which may encompassing prey life habitat uses during ontogeny. In addition to Teleostei and Crustacea, sediments (sand) and grass (needle grass) were also found in a few sampled stomachs, especially when fish fed on crustaceans, which were then considered an accidental ingestion, as the fish probably consumed these animals close to the sediment at the bottom according to Lira *et al*. (2017), sediments and algae observed in the stomachs are found in most of the studies carried out in specimens of this Centropomidae family, which is due to the fish's feeding behavior, resulting from the specialization of its mouthpiece to grab different preys. Synthetic fishing net fibers were also found, showing that fish in the estuary are vulnerable to plastic contamination during feeding (Barletta *et al.*, 2019; Ferreira *et al.*, 2019). The common snook is a carnivorous species that feeds on several other fish species, as demonstrated in our study. However, the study of its diet allowed the identification of other food items that are commonly consumed by this species, besides characterizing the main captured preys in the Parnaíba river delta. Itagaki (2005) argued that *C. undecimalis* are typically visual predators, making it more likely that peak feeding activity occurs during the day, when the light would facilitate prey viewing.

Regarding seasonal variations, it was found that Teleostei and Crustacea were present in feeding during both dry and rainy seasons, with not significant differences found, as observed in our results. Crustacea showed higher IAi values during the rainy season, which might be explained by the relation between the group's abundance in the rainy season, as reported in other studies (Lira *et al*., 2017; Fernandes & Cunha, 2017; Stevens *et al.*, 2020). Landings from shrimp trawlers and freshwater prawn traps were mainly observed between January and April in delta of Parnaíba throughout the rainy season (Farias *et al.*, 2015; Fernandes & Cunha, 2017). *C. undecimalis* is a diadromous species with wide-range habitat selection that tolerates high salinity variations, which increases the chance of finding different preys throughout the year (Stevens *et al.*, 2019). Increased precipitations also improve nutrient composition, which is known to be associated with high number of sea-dependent species that migrate to estuarine regions looking for shelter, as well as with food intake (Daros *et al.*, 2016; Stevens *et al.*, 2019). Therefore, exploring climate change as anomalies in the precipitation regime on the year of the study (extremely dry ~ 600 mm), may result in low environmental productivity and similarity for the species diet, according to observation reported for the region (Bastos *et al*., 2016). Moreover, emigrations are responsible for the differences in composition between seasons, which increases the contribution of marine resources in the diet of these animals throughout the year (Neumann-Leitão *et al*., 2003; De Paiva *et al*., 2017; Lira *et al*., 2017; Nunes *et al*., 2018).

Both the analyzed Teleostei and crustaceans group items in the diet of *C. undecimalis*, demonstrated seasonal variations regarding the food index variable, indicates a significant trend in both number and type of food found during the dry and rainy seasons, with a differential contribution of mass (W%) in each group at different times of the year. Teleostei fish were the leading items found throughout both seasons, with higher gravimetric mass, and with great importance as dietary resources. Crustaceans were also found in both seasons. In a Thailand estuary, Premcharoen (2014) observed different groups of fish with significant dietary contribution for predators using the volumetric method, and ecological input in this ecosystem. Figueiredo *et al*. (2014), when studying the dietary habits of *Macrodon ancylodon* (Bloch & Schneider, 1801) throughout dry and rainy seasons, observed a dietary abundance in both seasons, but throughout the study, Teleostei fish were found in higher quantities in comparison to crustaceans. Similar taxonomic groups, families and species were also reported as preys for Ladyfish *Elops saurus* (Linnaeus, 1766) at the delta of Parnaíba, indicating that

species is strongly opportunistic for available preys on the local environment (Santos *et al*., 2020).

According to the food importance index (IAi), Teleostei and crustaceans are important dietary items for *C. undecimalis* in the Parnaíba river delta. The large amount of fish as dietary items observed, according to Tonini *et al.* (2007), is an important indicator that the species has a strong ichthyophage tendency, and that it needs a high protein diet with adequate availability. In summary, common snooks are opportunistic predators that feed on a wide variety and specific-sized prey that are abundant in their environment (Blewett *et al*., 2006). Observing both the size and type of fish observed in the diet composition also varied according to *C. undecimalis* growth, as also observed for common snook in Florida. When fish are not yet at first maturity (L_{50}) its preferred shrimp, whilst after maturity is achieved, different species of fish were more abundant on the stomachs (Blewett *et al*., 2006). However, such an evaluation was not possible in our study, as young fish samples were not abundant, seen that fish were collected using nets that allowed only for larger fish to be captured. Size and weight were not different along the year and between seasons, confirming fishing gear selectivity by adult's individual for commom snook caught in delta.

No difference in the distribution of the feeding index during the seasonal variation was observed in this study. However, regarding the Teleostei category, the family Engraulidae was more prominent in the diet of *C. undecimalis*. In other studies, the category Teleostei was also present during the seasonal variation (Lira *et al*., 2017; Gonzalez *et al*., 2019; Ferreira *et al*., 2019). Nevertheless, food preference may change from one region to another and during seasonal variations depending on group-species availability on the environment (Zavala-Camin, 1996).The number of filled stomachs and preys species is a strong indicator if the analyses were representative to study feeding performance of the predator, and also of its variation between season, sex, size, and phase during of its ontogeny (Ferry & Cailliet, 1996). In the present study 107 stomachs were sampled, being considered enough to characterize the composition of the main food items for the common snook during year-round, and between season (rainy and dry). The main prey-species did not vary between seasons showing some similarity between preys and season. Fishes were more representative on the stomach (> 80%), followed mainly by crustaceans, that apparently increased in the rainy season, but not sensitive by the test performed. On the other hand, many different conditions should be evaluated on the sample and data analysis. Initially, the fishing gear selectivity should be considered, with

a clear fishing effort on the adult population (mean size 75 cm TL), associated also with the spawning season in delta estuary which may facilitate catches, as observed from increases in the fishing landing during rainy season (Farias *et al.*, 2015).

Prey abundance may vary between inter-annual cycles, associate to anomalies causing warm temperatures and low rain, reducing habitat, and after a good rainy year, species recruitment can be recovered, improving feeding opportunity. The Morisita-Horn index indicates not significant variation on the diet (0.89). Additionally, were observed that increases in the number of stomachs on the samples began to indicate reduction in the number of new items, reinforcing the hypothesis for diet preference, and may also associate to prey abundance in delta. And for the last consideration, diagram from Costello (1990) modified by Bennemann *et al*. (2006) showed that common snook improved their diet on few groups of fishes indicating specialization, but in individual scale, and not for entire population, effect from common snook abundance and distribution by size, weight, and gear selection of its ontogeny, also expressing higher inter-phenotypic component.

5 CONCLUSION

C. undecimalis has a varied diet but it feeds mainly on Teleostei and Crustacea specimens during both dry and rainy seasons in the estuary of the Parnaíba river delta, but probably in individual scale and not for entire population. The results indicates that this species feeds throughout the water column and can be characterized as an important carnivorous species for the local food chain. In addition, our results might assist in the elaboration of a management plan to assist in the sustainable exploitation of this species in the Parnaíba river delta.

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REFERENCES

AGOSTINHO, A. A., PELICICE, F. M. & MARQUES, E. E. (Eds.). 2009. **Reservatório de peixe angical: bases ecológicas para o manejo da ictiofauna**. Rima, 188 p.

AGUIAR, R. B. 2004. Projeto cadastro de fontes de abastecimento por água subterrânea, estado do Piauí: diagnóstico do município de Parnaíba. (Org.) Aguiar, R. B.; Gomes, J. R. C. CPRM - **Serviço Geológico do Brasil**, Fortaleza, 24 p.

AMUNDSEN, P. A., GABLER, H. M. & STALDVIK, F. J. 1996. A new approach to graphical analysis of feeding strategy from stomach contents data-modification of the Costello (1990) method. **Journal of fish biology**, 48(4): 607-614.

BARBOSA, C. & FRÉDOU, F. L. 2011. Dieta da pescada curuca *Plagioscion magdalenae* (Steindachner 1878) (Perciformes: Sciaenidae) da baía de Marajó (Estuário Amazônico). **Boletim do Laboratório de Hidrobiologia**, 24(1): 51-56.

BARLETTA, M., LIMA, A. R. & COSTA, M. F. 2019. Distribution, sources and consequences of nutrients, persistent organic pollutants, metals and microplastics in South American estuaries. **Science of the Total Environment**, 651(1): 1199-1218.

BARLETTA, M., LIMA, A. R., DANTAS, D. V., OLIVEIRA, I. M., NETO, J. R., FERNANDES, C. A. & COSTA, M. F. 2017. How can accurate landing stats help in designing better fisheries and environmental management for Western Atlantic estuaries? In: Finkl C. & Makowski C. (Eds.). **Coastal Wetlands: Alteration and Remediation**. Coastal Research Library, Springer, Cham, 21: 631-703.

BASTOS, E. A., ANDRADE JÚNIOR, A. S., RODRIGUES, B. H. N. 2016. Boletim agrometeorológico de 2015 para o município de Parnaíba, Piauí, Teresina. **Embrapa Meio-Norte, Documentos**, 38 p.

BENNEMANN, S. T., CASATTI, L. & OLIVEIRA, D. C. D. 2006. Alimentação de peixes: proposta para análise de itens registrados em conteúdos gástricos. **Biota Neotropica**, 6(2): 1-8.

BLABER, S. J. M. & BARLETTA, M. 2016. A review of estuarine fish research in South America: what has been achieved and what is the future for sustainability and conservation. **Journal of Fish Biology**, 89(1): 537-568.

BLEWETT, D. A., HENSLEY, R. A. & STEVENS, P. W. 2006. Feeding habits of common snook, *Centropomus undecimalis*, in Charlotte Harbor, Florida. **Gulf and Caribbean Research**, 18(1): 1-14.

BOWEN S. H. 1996. Quantitative description of the diet. In: MURPHY B. R. & WILLIS D. W. (Eds.) **Fisheries techniques**. **American Fisheries Society, Bethesda**, 513-522.

CLARKE, K. R. 1993. Non-parametric multivariate analysis of changes in community structure. **Australian Journal of Ecology**, 18(1): 117-143.

CORRÊA, C. F., LEONARDO, A. F. G., TACHIBANA, L. & JUNIOR, L. C. 2010. Frequência alimentar para juvenis de robalo-peva criados em água doce. **Revista Acadêmica: Ciência Animal**, 8(4): 429-436.

COSTELLO, M. J. 1990. Predator feeding strategy and prey importance: A new graphical analysis. **Journal of Fish Biology**, 36(2): 261-263.

DAROS, F. A., SPACH, H. L. & CORREIA, A. T. 2016. Habitat residency and movement patterns of *Centropomus parallelus* juveniles in a subtropical estuarine complex. **Journal of fish biology**, 88(5): 1796-1810.

DE PAIVA, A. C., CHAVES, P. D. T. D. C. & ARAÚJO, M. E. D. 2008. Estrutura e organização trófica da ictiofauna de águas rasas em um estuário tropical. **Revista brasileira de Zoologia**, 25(4): 647-661.

DE PAIVA, A. C., COELHO, P. A. & TORRES, M. F. A. 2017. Influência dos fatores abióticos sobre a macrofauna de substratos inconsolidados da zona entre-marés no Canal de Santa Cruz, Pernambuco, Brasil. **Arquivos de Ciências do Mar**, 38(1-2): 85-92.

NUNES, Z. M. P., DE SOUSA PEREIRA, M. E. G., DA SILVA, B. B., DA ROCHA, R. M., ASP-NETO, N. E. & DA SILVA, C. S. 2018. Bioecologia do robalo-flexa, *Centropomus undecimalis*, em lagoa costeira tropical no norte do Brasil. **Boletim do Instituto de Pesca**, 41(3): 457- 469.

FERREIRA, G. V., BARLETTA, M. & LIMA, A. R. 2019. Use of estuarine resources by top predator fishes. How do ecological patterns affect rates of contamination by microplastics. **Science of the Total Environment**, 655: 292-304.

FERNANDES, C. A. F. & CUNHA, F. E. DE A. 2017. **Relatório final do monitoramento da pesca aspectos reprodutivos e biomassa do robalo-flecha**. Acessível em http://www.comissaoilhaativa.org.br. (Acessada 01/09/ 2018).

FIGUEIREDO, J. L. & MENESES, N. A. 1980. **Manual de Peixes Marinhos do Sudeste do Brasil: Teleostei I**. Universidade de São Paulo, São Paulo, Museu de Zoologia, 2: 110.

FIGUEIREDO, J. L. & MENESES, N. A. 1980. **Manual de Peixes Marinhos do Sudeste do Brasil: Teleostei II**. Universidade de São Paulo, São Paulo, Museu de Zoologia, 3: 90.

FIGUEIREDO, J. L. & MENESES, N. A. 1980. **Manual de Peixes Marinhos do Sudeste do Brasil: Teleostei III**. Universidade de São Paulo, São Paulo, Museu de Zoologia, 4: 96.

FIGUEIREDO, J. L. & MENESES, N. A. 1985. **Manual de Peixes Marinhos do Sudeste do Brasil: Teleostei IV**. Universidade de São Paulo, São Paulo, Museu de Zoologia, 5: 105.

FIGUEIREDO, M. B., NETA, R. N. F. C., NUNES, J. L. S. & DE ALMEIDA, Z. D. S. 2014. Feeding habits of *Macrodon ancylodon* (Actinopterygii, Sciaenidae) in northeast, Brazil. **Revista de biologia marina y oceanografia**, 49(3): 559-566.

FROESE, R. & PAULY, D. 2017. ***Centropomus undecimalis* (Bloch 1792) Common snook**, accessible at http://www.fishbase.se/summary/345. (Accessed 24/09/2017).

GONZALEZ, J. G., MÉNARD, F., LE LOC'H, F., DE ANDRADE, H. A., VIANA, A. P., FERREIRA, V. & FRÉDOU, T. 2019. Trophic resource partitioning of two snook fish

species (Centropomidae) in tropical estuaries in Brazil as evidenced by stable isotope analysis. **Estuarine, Coastal and Shelf Science**, 226: 106287.

HORN, H. S. 1966. Measurement of" overlap" in comparative ecological studies. **The American Naturalist**, 100(914): 419-424.

HYSLOP, E. J. 1980. Stomach contents analysis-A review of methods and their application. **Journal of fish biology**, 17(4): 411-429.

ITAGAKI, K. I. 2005. Potencial de Recrutamento das Larvas e juvenis de robalo peva, *Centropomus paralleus* (Teleostei: Centropomidae) no Sistema Cananéia-Iguape, São Paulo, Brasil. **PhD. Thesis**. Universidade de São Paulo, São Paulo, Brasil, 159 p.

JUNIOR, H. A., DOS SANTOS, J. J., DE SOUZA, F. & GERHARDINGER, R. C. 2009. Monocultivo de robalo *Centropomus parallelus* em água doce. **REDVET, Revista Electrónica de Veterinaria**, 10(10).

LEITE, E. F., DE GODOI, D. S., JACYNTHO, L. A., MACENO, J. F. S. & DO AMARAL DUARTE, C. R. (2021). Feeding habits and reproductive biology of *Astyanax abramis*. **Brazilian Journal of Development**, 7(1): 2582-2597.

LIRA, A. S., FRÉDOU, F. L., VIANA, A. P., EDUARDO, L. N. & FRÉDOU T. 2017. Feeding ecology of *Centropomus undecimalis* (Bloch, 1792) and *Centropomus parallelus* (Poey 1860) in two tropical estuaries in Northeastern Brazil. **Pan-American Journal of Aquatic Sciences**, 12: 123-135.

MAI, A. C. G. & VIEIRA, J. P. 2013. Review and consideration on habitat use, distribution and life history of *Lycengraulis grossidens* (Agassiz, 1829) (Actinopterygii, Clupeiformes, Engraulidae). **Biota Neotropical**, 13(3): 121-130.

MAI, A. C. G., ROBE, L. J., MARINS, L. F. & VIEIRA, J. P. 2017. Genetic relationships between landlocked and coastal populations of *Lycengraulis grossidens* (Engraulidae) in south-eastern South America: evidence for a continental colonisation route with secondary transitions to the coastal region. **Marine and Freshwater Research**, 68(2): 342-351.

MALINOWSKI, C., CAVIN, J., CHANTON, J., CHASAR, L., COLEMAN, F. & KOENIG, C. 2019. Trophic Relationships and Niche Partitioning of Red Drum *Sciaenops ocellatus* and Common Snook *Centropomus undecimalis* in Coastal Estuaries of South Florida. **Estuaries and coasts**, 42(3): 842-856.

MARENGO, J. A., ALVES, L. M., BESERRA, E. A. & LACERDA, F. F. 2011. Variabilidade e mudanças climáticas no semiárido brasileiro. **Recursos hídricos em regiões áridas e semiáridas**, 1: 384-422.

MELO, G. A. S. DE. 1996. **Manual de identificação dos brachyura (caranguejos e siris) do litorâneos brasileiro***s*. Editora Plêiade, Fundação de Amparo à Pesquisa do Estado de São Paulo, 604 p.

MENDONÇA, M. C. F. B. D. 2004. Autoecologia do camurim, *Centropomus undecimalis* (Bloch 1792), (Perciformes: Centropomidae) em ambiente hipersalino em Galinhos, RN, Brasil. **PhD. Thesis**. Universidade Federal de São Carlos, Santa Catarina, Brasil, 145 p.

MONTEIRO, A. D. S., OLIVEIRA, A. H. M., PELICICE, F. M. & OLIVEIRA, R. J. 2009. Alterações na disponibilidade de recursos alimentares na dieta das principais espécies de peixes. **Reservatório de peixe angical: bases ecológicas para o manejo da ictiofauna**. São Carlos, 77-86.

NEUMANN-LEITÃO, S., SCHWAMBORN, R., GUSMÃO, L. M. D. O. & NASCIMENTO-VIEIRA, D. A. D. 2003. Diel andseasonal changes in the macrozooplankton community of a tropical estuary in Northeastern Brazil. **Revista brasileira de Zoologia**, 20(3): 439-446.

ODUM, E. P. & BARRET, G. W. 2008. **Fundamentos de Ecologia**. São Paulo: Cengage Learning, 632 p.

PETERSON, M. S. & GILMORE, G. R. 1991. Eco-physiology of juvenile snook *Centropomus undecimalis* (Bloch): life-history implications. **Bulletin of Marine Science**, 48(1): 46-57.

PLAVAN, A. A., GURDEK, R., MUÑOZ, N., GUTIERREZ, J. M., SPÓSITO, M., CORREA, P. & CARIDE, A. 2017. Seasonal composition, abundance and biomass of the subestuarine fish assemblage in Solís Chico (Río de la Plata estuary, Uruguay). **Brazilian Journal of Biology**, 77(3): 622-631.

POMPEU, O. S., GODINHO, H. P. & GODINHO, A. L. 2003. Dieta e estrutura trófica das comunidades de peixes de três lagoas marginais do médio São Francisco. **Águas, peixes e pescadores do São Francisco das Minas Gerais**, 1: 183-194.

PREMCHAROEN, S. 2014. Feeding Patterns of Resident Fishes In Thai Mangrove Estuary: Implications for Conservation and Sustainable Use of Coastal Resources. **European Journal of Sustainable Development**, 3(3): 201.

SANTOS, T. A., GONÇALVES, T. S., NASCIMENTO, P. S. D., FERNANDES, C. A. F. & CUNHA, F. E. D. A. 2020. Seasonal variation on diet of juvenile *Elops saurus* Linnaeus, 1766 (Ladyfish) in the Parnaiba River Delta. **Acta Limnologica Brasiliensia**, 32.

SANTOS, A. C. A. & ARAÚJO, F. G. 1997. Hábitos alimentares de *Gerres aprion* (Cuvier, 1829), (Actinopterygii, Gerreidae) na baía de Sepetiba, Rio de Janeiro. **Sitientibus**, 17: 185-195.

SANTOS, C. L., DOS SANTOS, I. A. & DA SILVA, C. J. 2009. Ecologia trófica de peixes ocorrentes em bancos de macrófitas aquáticas na baia Caiçara, Pantanal Mato-Grossense. **Revista Brasileira de Biociências**, 7(4): 473-476.

SERVIÇO GEOLÓGICO DO BRASIL – CPRM. 2017. **Relatório situacional dos recursos hídricos superficiais da bacia hidrográfica do rio Parnaíba**. SACE – Sistema de Alerta de Eventos Críticos Residência de Teresina – RETE, 16 p.

STEVENS, P. W., DUTKA-GIANELLI, J., NAGID, E. J., TROTTER, A. A., JOHNSON, K. G., TUTEN, T. & WHITTINGTON, J. A. 2019. Niche Partitioning Among Snook (Pisces: Centropomidae) in Rivers of Southeastern Florida and Implications for Species Range Limits. **Estuaries and Coasts**, 43(2): 396-408.

WATANABE, K., KASAI, A., ANTONIO, E. S., SUZUKI, K., UENO, M. & YAMASHITA, Y. 2014. Influence of salt-wedge intrusion on ecological processes at lower trophic levels in the Yura Estuary, Japan. **Estuarine, Coastal and Shelf Science**, 139: 67-77.

WINIK, S., CARNEIRO, M. H. & MENDONÇA, J. T. 2007. Alimentação da Guaivira *Oligoplites saliens* (BLOCH 1793) (Perciformes: Caranidae) proveniente da pesca na região de Cananéia-SP. Série Relatórios Técnicos, São Paulo, 27: 6.

ZAVALA-CAMIN, L. A. 1996. **Introdução aos estudos sobre alimentação natural em peixes**. EDUEM, Maringá, 125 p.