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ARTICLE

Feeding habits of *Macrodon ancylodon* (Actinopterygii, Sciaenidae) in northeast, Brazil

Hábitos alimentarios de *Macrodon ancylodon* (Actinopterygii, Sciaenidae) en el noreste de Brasil

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Resumen.- Se estudiaron los hábitos alimenticios de la pescadilla real *Macrodon ancylodon* basado en 280 muestras en la costa de la provincia de Maranhão, noreste de Brasil. La dieta mostró un predominio de peces, crustáceos y ocasionalmente cefalópodos. Las dietas de los machos y hembras fueron similares y se encontraron diferencias en la proporción de presas entre los juveniles, subadultos y adultos. Durante la temporada de lluvias las presas fueron más diversas que en la temporada seca. En la estación seca *M. ancylodon* se alimenta más de Penaeidae (*Penaeus* sp. y *Penaeus schmitti*), *Callinectes* sp. y Engraulidae (*Cetengraulis* sp.). Se observó un aumento del espectro de alimentos en la temporada de lluvias, con presas de 5 especies de peces (*Anchovia clupeoides*, *Cetengraulis edentulus*, *Macrodon ancylodon*, *Mugil curema* y *Sardinella brasiliensis*), 3 especies de crustáceos (*Penaeus schmitti*, *Parapenaeus politus* y *Callinectes* sp.) y 2 cefalópodos (*Loligo* sp. y *Loligo plei*). Las diferencias en la ingestión de presas se encontraron durante el año, en la estación de lluvia, donde los individuos de esta especie presentaron mayores contenidos estomacales. El canibalismo se encontró con mayor intensidad para los peces maduros.

Palabras clave: Pescadilla real, dieta, contenido del estómago, Maranhão

Abstract.- The feeding habits of *Macrodon ancylodon* were studied based on 280 specimens from the Maranhão coast, northeast Brazil. The diet showed a predominance of fishes, crustaceans and occasionally cephalopods. The diets of males and females were similar and difference was found in the proportion of prey items among juveniles, sub adults, and adults ($P > 0.05$). During rainy season the prey items were more diverse than dry season. In the dry season *M. ancylodon* feeds more Penaeidae (*Penaeus* sp. and *Penaeus schmitti*), *Callinectes* sp. and Engraulidae (*Cetengraulis* sp.). An increase of food spectrum was observed in rainy season, preyed upon 5 species of fish (*Anchovia clupeoides*, *Cetengraulis edentulus*, *Macrodon ancylodon*, *Mugil curema* and *Sardinella brasiliensis*), 3 species of Crustacea (*Penaeus* sp., *Penaeus schmitti*, *Parapenaeus politus*, and *Callinectes* sp.) and 2 Cephalopoda (*Loligo* sp. and *Loligo plei*). Differences in the ingestion of prey items were found during the year, where in the rainy season this species presented larger stomach contents. Cannibalism was encountered more intensively for mature fish.

Key words: Weakfish, diet, stomach contents, cannibalism, Maranhão

INTRODUCTION

The king weakfish, *Macrodon ancylodon* (Bloch & Schneider 1801) (Sciaenidae: Teleostei) is a fish species of economic importance in artisanal fishing of Maranhão state, Brazil. In 2010, this species had a production of 10,507 ton being the 9th species more captured in Brazil (MPA 2012)[1]. This species has the 3rd largest production, representing 6.9% (2,724.9 t) of total fish caught by the state of Maranhão in 2006 (IBAMA 2008).

Members of Sciaenidae Family are distributed in the Atlantic, Indian and Pacific oceans and comprise 70 genera and 270 species (Nelson 1994). They are bottom dwelling carnivores, feeding on benthic invertebrates and small fishes (Nelson 1994). Camargo & Isaac (2004) also stated that the species of this family are widely distributed among habitats of estuaries on the north coast of Brazil, due to its tolerance to salinity variations. *M. ancylodon*

[1]MPA. 2012. Boletim Estatístico da Pesca e Aquicultura, 128 pp. Brasília.

has demersal habits and has spread throughout the tropical coastal waters of the Occidental Atlantic, Venezuela to Argentina (Cervigón 1993, Figueiredo & Menezes 1980). Is a shallow endemic species, about 35 cm in total length, inhabiting over muddy substrate or sandy-mud bottoms in coastal waters to about 60 m depth (Chao & Musick 1977, Cervigón 1993). Several studies about the biological aspects of this species were conducted on reproduction (Yamaguti 1967, Militelli & Macchi 2004, Camargo & Isaac 2005), fisheries (Santana 1998, Magro *et al.* 2000), diet (Camargo & Isaac 2004, Piorski *et al.* 2004), genetic (Simôni *et al.* 2006) and growth (Cardoso *et al.* 2012).

The study of feeding ecology and habitat use of species provides the knowledge of basic aspects of their biology which is important to understand the dynamics and ecology of populations and communities (Krebs 1998). *Macrodon ancylodon* feeding habits have been the subject of other studies in this area and in the southern of Brazil (Tanji 1974, Fernandes 1982, Juras & Yamaguti 1985, Fonseca & Castro 2000, Camargo & Isaac 2004, Piorski *et al.* 2004), giving important information about this theme, but still missing current information on, for example, how the seasonal, sexual and ontogenetic variations can vary in relation to dietary composition.

Despite the wide distribution and abundance in the Brazilian coast, trophic aspects of *M. ancylodon* are poorly known, representing an obstacle for implementations of actions for the management and conservation of natural resources. In order to determine the potential of a sustainable fishery resource, it is necessary a comprehensive study that involves, among others, the study of trophic structure that is established in an aquatic ecosystem. Thus, studies on food habits of fishes of commercial importance can support management plans focused on the rational exploitation of fish stocks and other marine organisms.

In order to provide scientific information to contribute to the knowledge on the diet and understanding the trophic dynamic, particularly on the food at different body sizes and in different seasons of *M. ancylodon* in Maranhão state, this study aimed to analyze the feeding composition of this species by gut contents analysis, with the hypothesis that there is no difference between diets in relation to season, sex or stage of development of individuals of this species.

MATERIALS AND METHODS

The study was conducted on the Maranhão Island (02°23'10''-02°51'42''S and 43°58'37''-44°25'24''W), located in the gulf of Maranhão, which is located in the central region of the state, Brazil (Fig. 1).

Temperature variations in the water column of the continental shelf of Maranhão are shallow, with values ranging from 25.6 to 26.9ºC (Ramos *et al.* 2009). This region is characterized by having only 2 seasons: dry (July to December) and rainy (January to June). The salinity variations in this area is more evident than the temperature, with a high salinity in the dry season.

Samples were obtained bimonthly between December 2007 and October 2008, from the artisanal commercial fishing fleet of fishing communities belonging to Maranhão Island. All specimens were measured for total length (TL), total weight (TW), and dissected to check sex and the gonad stage. Maturity categories were determined according to gonad maturation for both sexes, as described by Vazzoler (1996), which classifies through the maturational stages, individuals juvenile and adults. Stomachs were removed, frozen, and analyzed in the Laboratory of Fisheries and Aquatic Ecology of the Universidade Estadual do Maranhão.

The degree of stomach fullness was determined during the analysis: full, 1/2, 1/4 or empty proposed by Zavala-Camin (1996), and the degree of digestion: digested, semi-digested and undigested (Hyslop 1980). The importance of prey items was evaluated using the percentage frequency of occurrence (%FO) and the percentage in number (%NF) (Hynes 1950, Hyslop 1980). The results derived from these two methods were conjugated by the Preponderance Index (PI), based on Juras & Yamaguti (1985):

$$PI_i = (FO_i.P_i) / \Sigma_{i=1\rightarrow n}(FO_i.P_i)\ 100$$

where 'I' is each one of the 'n' analyzed items. Prey species were identified to the lowest possible taxonomic level and quantified from their remains (*e.g.*, complete prey items, bones and crustacean exoskeletons) according to Figueiredo & Menezes (1980) and Costa *et al.* (2003).

In order to determine differences (seasonal, ontogenetic variations and to compare feeding between females and males) of prey consumed, it was utilized the Shapiro-Wilk's test to verify the normality. The test used to verify the homogeneity of variances was Bartlett. However,

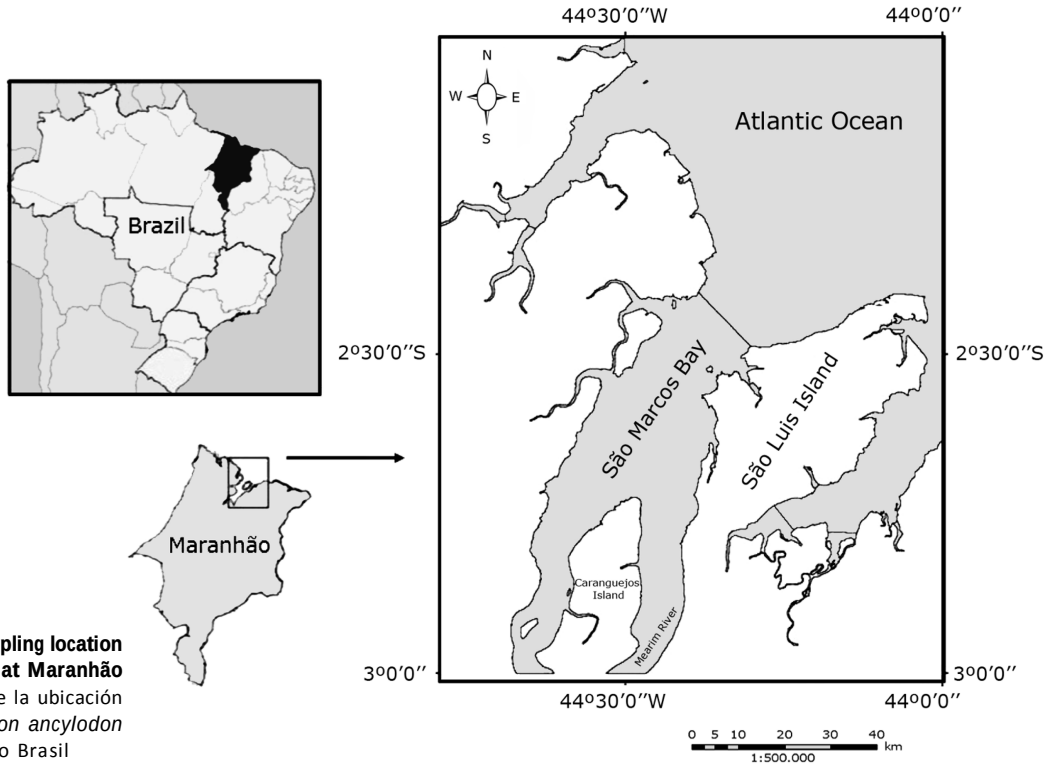

Figure 1. Map of the sampling location of *Macrodon ancylodon* at Maranhão coast of Brazil / Mapa de la ubicación de muestreo de *Macrodon ancylodon* en la costa de Maranhão Brasil

when this condition was not satisfied, it was used the nonparametric Mann-Whitney U test (Zar 1999). These statistical analyses were conducted with Statistica version 7.0. All statistical tests used a significance level of 5%.

The Morisita-Horn index (IMH) was used for similarity analysis of the relative abundance of species between samples, to assess the possible feeding overlap among major zoological groups (crustaceans, fish and cephalopods). According to Magurran (1991) values obtained by the overlap index range from 0 to 1, where IMH < 0.5 indicates low similarity and IMH > 0.75 indicates high similarity. To characterize the diversity of species-items in the stomach contents Shannon-Wiener (H') index was used. The statistical package used was PAST version 2.17.

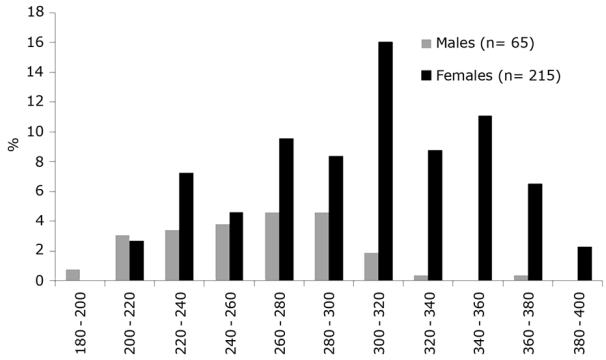

Figure 2. Length distribution of *Macrodon ancylodon* in northeastern Brazil (n= 280) / Distribución de la talla de *Macrodon ancylodon* en el noreste de Brasil (n= 280)

Results

A total of 280 individuals were analysed, 65 were males and 215 females. The maturity categories used were juveniles (187-310 mm) with 34 individuals, subadults (203-382 mm) with 78, and adults (210-399 mm) with 168. The total length varied between 187 to 399 mm, with mean of 300.8 ± 47.4 mm for females and 259.9 ± 35.9 mm for males (*t* test, $P < 0.05$). The distribution of total length showed a modal tendency on the class of 300-320 for females (Fig. 2), and high proportion of adults (61%) in the total sample. Sexual segregation was observed and the number of females was significantly higher in size from 260 mm FL (Mann-Whitney U test, $P < 0.05$). The eviscerated weight of all individuals ranged between 45.5-660.0 g and average of 217.9 ± 118.3 g.

The diet was composed of 106 items, among 24 taxa (Table 1). Only a few numbers of individuals could be identified to species level, but because of their importance as food items they are included in Table 1. Prey items are listed by taxonomic criteria, at the lowest possible taxonomic level. The food spectrum of *M. ancylodon* was represented mainly by fish (Teleostei) and shrimp (Penaeoidea) (Fig. 3).

The Mann-Whitney U test did not showed significances in the diet between ontogenetic variations (H= 2.49, *P*= 0.34 for %FO). Fish were the predominant item in %FO in all categories. Due to the advanced stage of digestion, it was difficult to determine the family of prey items. Teleostei was the more important item with 69% of occurrence for fish items in all categories. The fish family Engraulidae and the crustacean Penaeoidea represented 18.4 and 15.3%, respectively of prey item for adult specimens. Crustaceans of the Infraorder Isopoda and Brachyura were very occasional, and were important only for adult specimens (Fig. 3).

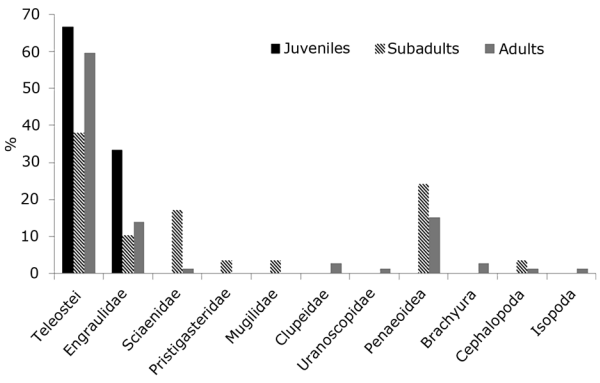

Figure 3. Diets of juveniles, subadults and adults of *Macrodon ancylodon* expressed in frequency of occurrence / Las dietas de juveniles, subadultos y adultos de *Macrodon ancylodon* expresas en frecuencia de ocurrencia

Table 1. Prey items of *Macrodon ancylodon* in the coast of Maranhão. %FO= frequency of occurrence, W= weight / Ítems de presas de *Macrodon ancylodon* en la costa de Maranhão. % FO= frecuencia de ocurrencia, W= peso

Prey items	Dry n= 39		Rainy n= 67		Total n= 106	
	%FO	W	%FO	W	%FO	W
Crustacea						
Penaeoidea Penaeidae	15.38	4.73	2.99	1.60	7.55	6.33
Penaeus sp.	2.56	0.33	1.49	1.92	1.89	2.25
Penaeus schmitti	5.13	5.40	2.99	2.00	3.77	7.40
Parapenaeus longirostris			2.99	21.80	1.89	21.80
Brachyura Portunidae						
Callinectes sp.	5.13	1.28			1.89	1.28
Pisces						
Teleostei	46.15	36.44	56.72	124.66	52.83	82.25
Engraulidae	10.26	22.12	10.45	45.81	10.38	67.93
Cetengraulis sp.	2.56	38.54			0.94	38.54
Anchovia clupeoides			2.99	18.81	1.89	18.81
Centegraulis edentulus			1.49	11.07	0.94	11.07
Sciaenidae	2.56	1.45	1.49	1.75	1.89	3.20
Macrodon ancylodon			5.97	27.25	3.77	27.25
Pristigasteridae			1.49	12.75	0.94	12.75
Mugilidae						
Mugil curema			1.49	6.43	0.94	6.43
Clupeidae						
Sardinella brasiliensis			1.49	9.31	0.94	9.31
Uranoscopidae						
Astroscopus y-graecum			1.49	3.64	0.94	3.64
Cephalopoda						
Loligo sp.			1.49	1.88	0.94	1.88
Loligo plei			1.49	3.30	0.94	3.30
Isopoda					0.94	0.34
Others			1.49	0.34		
Fishbones	2.56	0.00			0.94	0.00
Fish scales	2.56	4.38			0.94	4.38
Otoliths	2.56	3.44			0.94	3.44
Parasites	2.56	0.22			0.94	0.22

Teleostei and particularly Engraulidae were more important prey for juveniles (87 and 11% of the consumed prey of this maturity category, respectively). Crustacean preys were important only for subadults and adult specimens (24.14 and 19.44% of the consumed prey of each maturity category, respectively). In addition, we found a high dietary overlap between individuals of different size classes, the diets of adults and subadults were more similar (IMH= 0.70 for %FO) than between juveniles and subadults (IMH= 0.34 for %FO). The lowest values occurred between juveniles and adults in relation to frequency of occurrence (IMH= 0.26 for %FO).

The diets of males and females differed significantly (Mann-Whitney U test, $P < 0.05$ for %FO), with a high dietary overlap between males and females (CH= 0.82 for %FO). Teleostei was the dominant food occurring in the stomach of both sexes (55.8% females and 52.4% males). Prey items of females were more diverse than males. Only females showed habits of cannibalism, representing 5.8% of the items contained in the stomachs.

There were no seasonal oscillations in the prey items (H= 0.04, *P*= 0.82) (Fig. 4), but in the rainy season it was observed a greater diversity in the diet of *M. ancylodon* (H'= 2.02). In all period Teleostei, Engraulidae and Penaeoidea were the predominant items ingested. In dry season, Penaeidae and Portunidae were abundant. Teleostei and Engraulidae were found in several stomachs

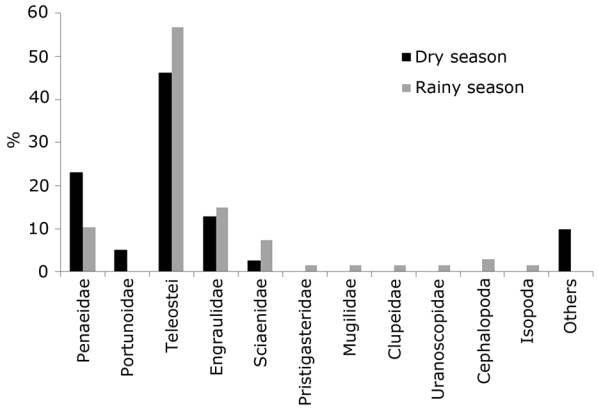

Figure 4. Seasonal composition of *M. ancylodon* prey items in northeastern Brazil / Composición estacional de los ítems alimenticios de *M. ancylodon* en el noreste de Brasil

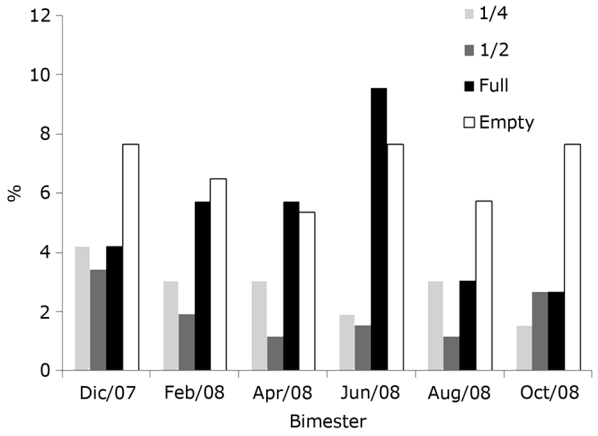

Figure 5. Percentage of stage repletion of *Macrodon ancylodon* in northeastern Brazil / Porcentaje del índice de repleción de *Macrodon ancylodon* en el noreste de Brasil

during the year, but mainly in rainy season (Table 1). Pristigasteridae, Mugilidae, Clupeidae and Uranoscopidae were found only in the rainy season.

In the rainy season it was observed an increase of full stomachs, in June, 43.6% of samples of this month were full. In October were presented the major proportion of empty stomachs with 52.6% (Fig. 5).

Habits of cannibalism were detected in the rainy season, only for female individuals in subadult and adult stages. This species can be characterized as carnivorous, prone to feeding fish and crustaceans being considered tertiary consumers in the food web. Others structures like otoliths, scales, bone fish and parasites were found but only in the dry season and in a small proportion.

Discussion

Studies that mentioned *Macrodon ancylodon* feeding habits are rarely and it were carried out many years ago (Tanji 1974, Juras & Yamaguti 1985, Fonseca & Castro 2000). The presence of fishes and principally crustaceans in the stomach contents of Sciaenidae fishes is relatively common, as found in several studies, for instance of *Bairdiella ronchus* in south coast of Brazil (Vendel & Chaves 1998), *Stellifer rastrifer* in south coast of Brazil (Chaves & Vendel 2008), *Micropogonias furnieri* in Venezuela (Ruiz *et al*. 2001), *Isopisthus parvipinnis*, *Larimus breviceps* in south-western Atlantic (Soares & Vazzoler 2001) and *Menticirrhus americanus* in southeastern Brazil (Turra *et al.* 2012).

The food habits of *M. ancylodon* can be best categorized as carnivore. This kind of food habits is sustained by data of Piorski *et al.* (2004) and Fonseca & Castro (2000) in a study carried out in Maranhão coast and by Tanji (1974) and Juras & Yamaguti (1985) who examined the stomachs of this species from the southeastern coast of Brazil.

Fish was the most important food group in the diet of *M. ancylodon* (Teleostei, Engraulidae), while crustacean was the secondary prey (Penaeidae), the same results found by Piorski *et al*. (2004). This food habits is similar to that observed from Tanji (1974) and Juras & Yamaguti (1985) who examined the stomachs of *M. acylodon* from the southeastern coast of Brazil. The other food items were analyzed for the species of lesser importance, such as Isopoda and Cephalopoda. These items were consumed during the rainy season. Lowe-McConnell (1962) also found shrimp and fish as food for *M. ancylodon* of Guyana.

The major representation of fish as main food items may be due to adaptations by morphological characteristics (*e.g.*, terminal mouth, caniniforms teeth and short stomach) of *M. ancylodon* (Piorski *et al.* 2004) and/or attributed to the wide availability of this item in the environment. According to Zavala-Camim (1996), the behavior of a particular species is not only associated to the abundance of certain prey organisms in the environment, but the size of the prey, the shape and arrangement of the mouth of the predator, the size of the teeth, the morphology of the digestive system and the foraging tactics. Mouth position, dentition, gill rakers, digestive tract, pores and barbels, nares and body shape are considered as important aspects in locating and ingesting prey in the water column for Sciaenidae fishes (Chao & Musick 1977). Palmeira & Monteiro-Neto (2010) indicates that mouth position was

the most important morphometric variable discriminating feeding adaptation for *Menticirrhus littoralis*. This morphometric features is positively correlated with the diet of this species, together with eye diameter, nose open length and width of the caudal peduncle played an important role in explaining the differences observed for this Sciaenidae species.

M. ancylodon not show significance difference in the dynamic feed between sexes. It was also observed by other studies for the same species (Tanji 1974, Juras & Yamaguti 1985, Fonseca & Castro 2000, Ruiz 2001). This behavior is similar to that based on data from *Micropogon furnieri* (Tanji 1974) and from *Stellifer rastrifer* (Chaves & Vendel 1998).

The shift of food habits with size of fish, especially Sciaenidae fishes, is well known (Chao & Musick 1977, McMichael & Ross 1987, Vendel & Chaves 1998, Fonseca & Castro 2000, Raymundo-Huizar *et al.* 2005, Giberto *et al*. 2007, Palmeira & Monteiro-Neto 2010). Usually a big fish eat larger prey and variety of food organisms, while the smaller fish consume smaller prey and less diversity of food items. The food habits of *M. ancylodon* seemed to follow these trends. Juvenile fish exhibited a restricted diet, feeding predominantly on Teleostei while mature fish progressively eat a major variety of larger food organisms. Thus, crustacean and fish became progressively the most important food items in the diet of elder *M. ancylodon*. This change can be attributed to the size of the prey organism in relation to the size of the predator and to the facility of obtaining larger preys. The food items selected at any time of the year seem to depend on abundance of prey and to their availability to the predators (Juras & Yamaguti 1985, Lucena *et al.* 2010).

M. ancylodon has a large period of spawning with two peaks, one between July and August and other between December and February coinciding with the transition periods of the precipitation season (Ikeda 2003, Camargo & Isaac 2005, Santos 2007). This seems to affect the feeding activity of the fish that have relatively higher percentages of empty stomachs during that season. In studies conducted at the river mouth of the Amazon and Tocantins rivers, was found lower participation of *M. ancylodon* with empty stomachs in the rainy season (January to July) (JICA 1998). This behavior was also found in this study on the coast of Maranhão, in which there were a higher proportion of stomachs with content than empty in this period. Magro *et al.* (2000) in study carried out in the south region of Brazil also observed a bigger incidence of empty stomachs in adults of *M. ancylodon* during reproductive period. Restrained feeding intensity in fishes during reproduction season has been observed by some works for other species (Carvalho-Neta & Castro 2008, Ribeiro *et al*. 2012). Fonseca & Castro (2000) observed that the condition factor and hepatosomatic index were opposed to the repletion index values for this species in Maranhão coast.

In the present study, the feeding intensity peak was observed during rainy season predominantly in mature fishes, which coincide with the spawning period. According to Juras & Yamaguti (1985) and Zavala-Camin (1996), the poor feeding verified during the spawning period may be attributed to the fact that the gonads enlarge greatly and occupy major space in the abdominal cavity during the spawning season, preventing or limiting the intake of food. The higher percentage of empty stomachs can be due to less frequent feeding activity among larger fish (Hynes 1950). It was noted in this study a similar trend in the feeding behavior of *M. ancylodon*. Other hypothesis is that in the reproductive period, the absorption of the prey is faster to supply reproductive gametes for the energy needed.

The study area is characterized by having a tropical climate, oceanographic and geomorphological features provide high productivity and biodiversity, mainly in the raining season (Dittmar 1999, Castro 1997, Silva-Júnior *et al*. 2013). In the present study both sexes of *M. ancylodon* showed higher diversification in the composition of the diet in wet season. Some studies noted that the increase of nutrients from rainfall favors primary production and consequently in increasing the diversity of organisms in this period (Willey & Cahoon 1991, Lana *et al*. 2000). Araújo *et al.* (2009) explain that the rainy season has a greater amount species than in the dry season, because the formation of a greater number of microhabitats occurs, with better use of available resources due to high water levels.

Acha *et al.* (2002) noted that cannibalism appears to be genetically based but controlled or induced by different environmental situation. Cannibalism might occur when there is a reduction in food supply, or in the case of a large number of individuals of a given size, as well as of the year. In such cases, there may be a shortage of food for individuals with certain sizes, which can lead to ingestion of eggs and juveniles fish (Smith & Reay 1991, Folkvord 1997). This fact could have occurred with of *M. ancylodon*, which presented a great portion of the same

species item in the stomachs mainly for mature female's specimens.

It is concluded that features observed in the diet of *M. ancylodon* demonstrate significant adaptation of the species to the coast of Maranhão State, as the main food resources used were selected because they are almost mostly indigenous as to the source of origin. The species can be classified as carnivorous, with a strong tendency towards specialization in food family Engraulidae fish and decapod crustaceans.

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