FEEDING HABITS OF *Lutjanus synagris* (TELEOSTEI: LUTJANIDAE) IN THE AMAZON COAST OF THE NORTHEAST REGION OF BRAZIL*

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ABSTRACT

The feeding habit of lane snapper *Lutjanus synagris* was analyzed qualitatively and quantitatively, related to seasonality, its ontogenetic development, and the relationship between food and biotic and abiotic conditions on the Amazon Coast of Maranhão, between June 2018 and May 2019. Numerical, gravimetric, and ecological index methods were used to show the relative importance or preference of a category or food item in the diet. The food composition was studied related to the sex, size of the predator and seasonality. Of 359 stomachs sampled, 54 were empty due to regurgitation and presented a vacuity coefficient (Cv%) of 15.04%. In the analysis of diets between the sexes, it was possible to identify a greater participation of fish (30.43%) and Crabs (26.10%) for females, Shrimp (36.23%) and Organic Matter Not Identified (OMNI) (18.84%) in males. The diet showed spatial differences in length distributions. The analysis of stomach contents showed the presence synthetic materials (mesoplastics ranging from 5.0 mm to 2.5 cm) in 5.52% of the samples. The main food items found were from the Brachyura and Caridea species. The results clearly demonstrate that lane snapper prefers benthic prey, presenting a carnivorous and generalist-opportunistic habit. Its diet is also composed of demersal-pelagic species, such as Cephalopods and Teleost fish.

Keywords: Lane snapper; diet; trophic dynamics; size-related diet shift; polymers.

HÁBITOS ALIMENTARES DE *Lutjanus synagris* (TELEOSTEI: LUTJANIDAE) NA COSTA AMAZÔNICA DA REGIÃO NORDESTE DO BRASIL

RESUMO

O hábito alimentar do ariacó *Lutjanus synagris* foi analisado qualitativamente e quantitativamente, relacionados à sazonalidade, seu desenvolvimento ontogenético e a relação entre alimento e condições bióticas e abióticas na Costa Amazônica do Maranhão, entre junho 2018 e maio de 2019. Métodos numéricos, gravimétricos e índices ecológicos foram usados para mostrar a importância ou preferência relativa de uma determinada categoria ou item alimentar na dieta. Foi analisada a variação na composição alimentar em relação ao sexo, tamanho do predador e sazonalidade. Dos 359 estômagos amostrados, 54 estavam vazios por regurgitação e apresentaram coeficiente de vacuidade (Cv%) de 15,04%. Na análise das dietas entre os sexos, foi possível identificar uma maior participação de peixes (30,43%) e caranguejos (26,10%) para fêmeas, camarões (36,23%) e Material Orgânico Não Identificado (OMNI) (18,84%) nos machos. A dieta da espécie mostrou diferenças espaciais particulares nas distribuições de comprimento. A análise do conteúdo estomacal mostrou presença materiais sintéticos (mesoplásticos variando de 5 mm a 2,5 cm) em 5,52% das amostras. Os principais itens alimentares encontrados foram de espécies dos grupos Brachyura e Caridea. Os resultados claramente demonstram que o ariacó tem preferência por presas bentônicas, apresentando hábitos carnívoro e generalista-oportunista. Sua dieta também é composta por espécies demersal-pelágicas, como cefalópodes e peixes teleósteos.

Palavras-chave: Ariacó; dieta; dinâmica trófica; mudança de dieta relacionada ao tamanho; polímeros.

INTRODUÇÃO

The Lutjanidae species are part of one of the main marine fishing resources in tropical and subtropical areas from the western Atlantic, central-eastern United States, and Bermuda, including the Caribbean and the Gulf of Mexico and the entire coast of Brazil (Grimes, 1987; Hoese and Moore, 1998; Duarte and Garcia, 1999). They are widely exploited in Northeast Brazil by the commercial fishing, both for the volume of

production obtained, as well as for their great economic importance and high market value (Rezende et al., 2003; Dorenbosch et al., 2005). Among the main fishery production systems on the Amazon coast, those that focus on snapper stand out (Isaac and Barthem 1995; Isaac-Nahum, 2006; Bentes et al., 2012; Gomes et al., 2012).

The Lutjanidae family is composed of fish considered as opportunistic predators, which are particularly important in the environment because they perform an ecological control function (Sale, 1991; Mora, 2015) consuming a variety of prey and exhibiting an ontogenetic change in their diets as they become mature (Szedlmayer and Lee, 2004; McCawley et al., 2006; Wells et al., 2008). Many species are marine migrants and part of their life is associated with coastal systems (Ferreira et al., 2004; Cerqueira et al., 2017).

The lane snapper *Lutjanus synagris* (Linnaeus, 1758) during its early stages of development are relatively common in coral, rock, and estuarine areas since this environment present favorable conditions and structural complexity for refuge during its early and juvenile phase (Nagelkerken et al., 2000). Adult fish prefer reef areas, platforms, or continental slopes (Costa et al., 2005; Frédou and Ferreira, 2005; Klippel et al., 2005; Frédou et al., 2009), as they are areas where trophic interactions occur between organisms of different species at different stages of the life cycle (Layman, 2000).

Studies on the trophic ecology of Lutjanidae and the relationship with the environment enable the development of a functional representation of the ecosystem for its management (Duarte and Garcia, 1999). In addition, the food ecology of fish based on the analysis of stomach contents is essential for understanding their nutritional demands and interactions with the environment and other organisms (Pimentel and Joyeux, 2010).

As they are classified as high-quality fish, the fishing activities of these resources in the Northeast region of Brazil are intense, making these species vulnerable to overfishing, increasing their levels of exploitation (Lessa et al., 2004; Klippel et al., 2005; Bezerra and Godelman, 2014) and raise concerns about the preservation of fish stocks in coastal areas. Thus, information on the trophic dynamics of *L. synagris* may allow the development of models of functional ecosystems and assist on its management and conservation of the species (Duarte and Garcia, 1999).

In view of the importance of this resource in the studied region and the scarcity of information about its biological aspects, the present study aimed to qualitatively and quantitatively assess the dietary spectrum of *L. synagris* related to seasonality, its ontogenetic development, and the relationship between the food and biotic/abiotic conditions on the Amazon coast in the state of Maranhão, Brazil. For this, the hypothesis was tested that seasonality and body size are important factors for changes in the composition of *L. synagris* diet in the study area.

MATERIAL AND METHODS

Study area

The coast of the state of Maranhão, Brazil, is approximately 640 km long and has a large continental platform, with shallow coastal waters that are directly affected by large river basins. The western region of the state coast contains the Maranhão coastline recess, which is a long area of corals, mangroves, and islands; and the east region contains large and small plains with lagoons among dunes (Lençóis Maranhenses National Park), mangroves, and an area termed Delta of Americas (Stride, 1992; Saraiva, 2009). The Amazon Coastal Zone is the highest continuous area of mangrove in the world, with approximately 8,900 km^2; 50% of this area is in the Maranhão Costal Zone (Kjerfve et al., 2002).

The samples come from the captures by artisanal fisheries in the state of Maranhão, covering Barra de Guajerutiua (01°30'28.56"S, 44°43'10.41"W), Bate Vento (1°17'57.85"S, 44°53'34.45"O), Raposa (02°25'23"S, 44°06'12"O), Santana Island (2°17'26.38"S, 43°41'07.46"O), Parcel de Manuel Luís (0°53'52.66"S, 44°17'06.96"O), which are in the region classified as Legal Amazon (Figure 1) (IBGE, 2014).

The hydrographic and climatic status of the region, and the characterization of seasonality were based on temperature and rainfall data available by the Geoenvironmental Center of the State University of Maranhão and by the National Institute of Meteorology (INMET). The climate of the region is tropical, characterized by a dry mild winter and a hot rainy summer (Peel et al., 2007).

Sample collection and data analysis

The fish were captured monthly (June 2018 to May 2019) using a standard set of handlines (0.80 and 0.100 mm) equipped with hooks (nº. 7 and 8), respectively, a 500-meter gillnets (0.60 mm mesh) and acquired by purchasing them from fishers in the municipality of Raposa. The samplings were authorized by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) through the license of the Biodiversity Authorization and Information System (SISBio) nº 65644-1.

All specimens were measured to obtain their total length (T$_L$) and weight (T$_W$). Subsequently, they were eviscerated for confirmation of their sex and removal of their stomachs. The maturity categories of juvenile and adult were differentiated through the analysis of the gonadal maturation for both sexes, which was based on Brown-Peterson et al. (2011), Lowerre-Barbieri et al. (2011) and Santana (2016). The specimens were selected for analysis of stomach contents and distributed into length classes according to the formula of Sturges (1926).

The stomach items of each fish were preserved in 5% formaldehyde, identified, and classified by using specific identification keys, according to Fischer (1978), Cervigón et al. (1992), Castro (1997), Menezes et al. (2003), Lavrado and Sa Viana (2007), and Almeida (2008). The adult organisms found were counted separately, and teleosts at larval and juvenile stages were identified according to Carpenter (2002a; 2002b) and database of identified species of the Fishbase.

The quantification of the stomach items was done through the number of anatomical fragments, when possible. Specimens that presented empty stomachs were subjected to vacuity calculations [Cv% = (number of empty stomachs / total number of evaluated stomachs) × 100] (Falautano et al., 2007). The importance of the
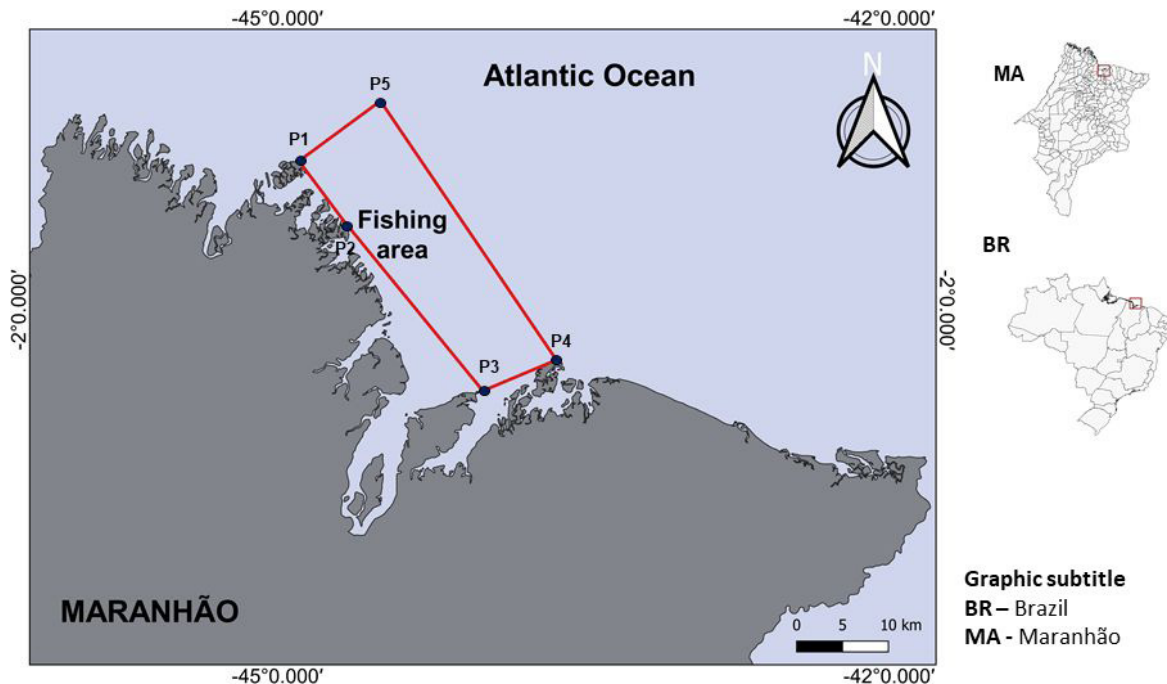
Figure 1. Location of the sampling area (P1. Barra de Guajerutiua; P2. Bate Vento; P3. Raposa; P4. Santana Island; P5. Parcel de Manuel Luís).

different prey types found was evaluated by using the following relative measures of prey quantity (RMPQs): percentage of occurrence frequency [FO% = (number of stomachs containing a prey item / total number of not empty stomachs) × 100]; percentage of abundance (Fni% = [number of s of a prey item / total number of all of prey items) × 100]; percentage weight of the items [Wi% = (weight of the prey item / total weight of all prey items) × 100]. Based on the values of the RMPQs we estimated the index of relative importance (IRI) (Pinkas et al., 1971), using the weight instead of volume [IRI% = (N% + Wi%) × (F%)]. The numerical and gravimetrical methods were applied following the methodology of Hacunda (1981) and Fonteles Filho (2011), adopting a repletion degree (0 = empty, 1 = 25% full, 2 = 50% full, 3 = 75% full, and 4 = completely full) and a digestion degree (completely digested, semi-digested, and not digested). The polymers in the *L. synagris* diet were identified and classified based on Montagner (2018).

The feeding resources were subjected to similarity analysis using the Bray-Curtis coefficient. The dominance of the items was obtained through the Simpson index (Simpson, 1949). The diversity of the items was calculated using the Shannon index (Shannon, 1963). Species richness was proposed using the Margalef index (Margalef, 1985) and the Pielou Equitability index (Pielou, 1966) was used to identify the items distribution.

Data analyses

The seasonal evaluation of ecological indices (dry and rainy) was performed by t-test. However, the Kolmogorov-Smirnov test was used to assess normality and thus allow the application of parametric statistics. For cases where there was no normal

distribution, a logarithmic transformation was performed as an attempt to apply the t-test. Data that did not present normal distribution, even after transformation, the Mann-Whitney test was applied (Zar, 1984).

The data were tested for homogeneity of variance using the Levene test to verify whether a one-way ANOVA could be used (Zar, 1984), with Tukey's posterior test. For data that did not meet the assumptions necessary to perform the one-way ANOVA, a Kruskal-Wallis test with Dunn's posterior test was used to compare several independent samples (groups) to assess significant differences in item quantification. Statistical analyzes were performed using the software Statistica 10.0 and Past 3.14 (Paleontological Statistics).

RESULTS

The sample consisted of 359 specimens of the species *Lutjanus synagris*, 149 males and 210 females. The total length ranged from 24.9 to 53.3 cm, with an average of 35.73 ± 4.63 cm for females and 34.55 ± 4.67 cm for males (Student's t-test, $p < 0.05$). The total weight of the organisms ranged from 180.0 to 972.26 g, with an average of 483.13 ± 114.80 g for females and 464.45 ± 111.13 g for males (Student's t-test, $p < 0.05$). The maturity categories found were juveniles (24.9 to 27.9 cm) with 22 specimens and adults (28 to 53.3 cm) with 337 specimens. The distribution of the total length showed a tendency for the class of 36 to 40 cm for females, and 32 to 36 cm for males, with a high proportion of adult specimens for both sexes. The sex ratio in the study period was 1 female to 0.7 males. In general, there was no statistically

significant difference between these values at the 5% level (Calculated $\chi^2 = 10.36$ <Table $\chi^2 = 19.67$).

The identification of food items in the 359 stomachs showed that 54 were empty by regurgitation and presented a coefficient of vacuity (Cv%) of 15.04%. The repletion degree found showed the following percentages: 31.20% specimens for degree 1; 22.28% for 2; 19.50% for 3; and 11.98% for 4. The Kruskal-Wallis test demonstrated that the degrees of repletion were affected by the sampling periods (p <0.05). Comparing the pairs for the degree of repletion by Dunn's posterior test, it was noticed that full stomachs were less representative than the other repletion classifications, presenting lower averages in the dry period and higher in the rainy period with a significant difference between February 2019 with the highest average, in relation to June and July 2018, and March 2019. The degree of repletion 1 presented a significant difference (p <0.05) in August 2018 and February 2019. There was no seasonal trend for the degree of repletion 2, however, there was a significant difference (p <0.05) in January 2019 compared to the others. The degree of repletion 3 showed a trend of higher averages in the months of February and March 2019, with January significantly lower than the others (p <0.05). It was observed that grade 4 had a significantly lower (p <0.05) average than the other groups in the months of August, October, and December 2018. However, the highest values for grade 4 were found from January 2019 to May 2019, the period of greatest rainfall (Figure 2).

The analysis of digestion degree of stomach contents showed that 44.63% were completely digested, 38.24% were semi-digested, and 17.13% were not digested. The stomachs with complete digestion presented repletion degree 1 in all samplings,

indicating that the food content in the stomach was composed by large amount of gastric mucus, and were more frequent in August 2018 and February 2019.

The diet presented a cumulative curve of 272 items, which were classified into 9 categories: Crustaceans, Mollusks, Porifera, Plants, Vertebrates, Annelids, Fish and Shrimp Fragments, Organic Matter Not Identified (OMNI), and Polymers. The identification of some items could be made in specific level due to the low action of the digestion (Table 1).

In the analysis of diets between the sexes, it was possible to identify a greater participation of fish (30.43%) and Crabs (26.10%) in the diet of females, Shrimp (36.23%) and OMNI (18.84%) in males. The prey consumed by the males was more diverse, with a higher occurrence of pelagic items. The comparison of diet between male and female did not show statistically significant differences (ANOVA, p >0.05). The numerical frequency analysis showed that the most abundant items in the stomachs of males and females of *L. synagris* were Crustaceans (34.91%), followed by Vertebrates (17.67%), OMNI (16.92%), and fish and shrimp fragments (9.56%). The numerical frequency of Mollusks, Annelids, Porifera, and Angiosperms/seaweeds unidentified represented together 15.42% of the items found in the stomachs.

The decapod crustaceans represented the most common prey found in the stomachs of *L. synagris* and they were represented by Brachyura and Caridea species. Mollusks were represented by Veneridae, Ostreidae, and Loliginidae. The identification of Porifera, Angiosperms, and Annelids was not refined because of their high digestion degree. The fishes were identified as species from the families Trichiuridae, Haemulidae, Ariidae,
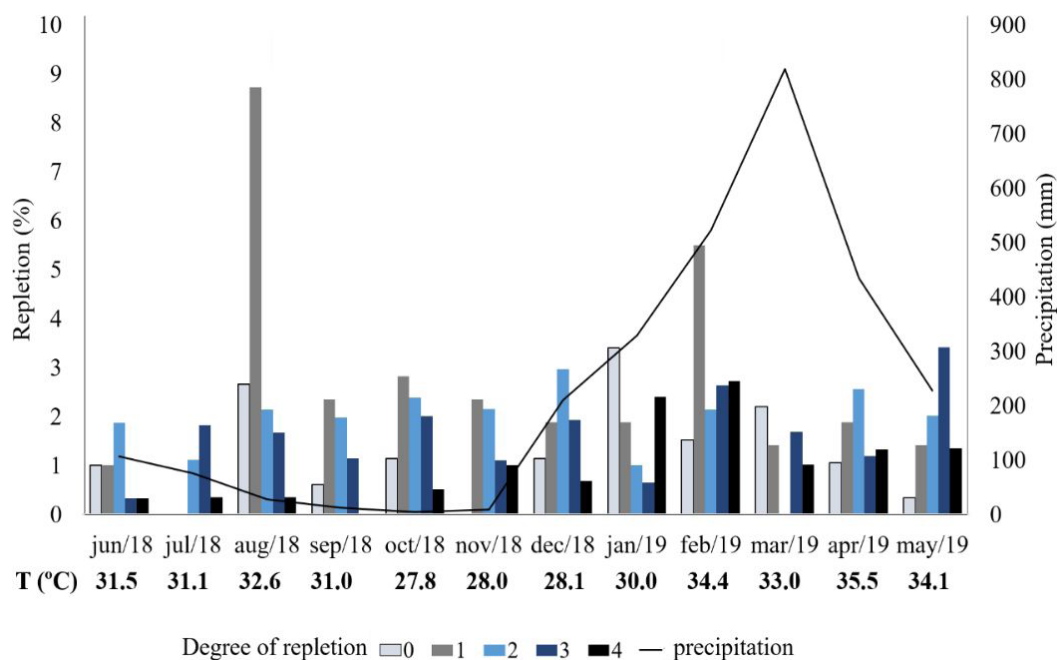

Figure 2. Stomach's repletion degree, monthly rainfall, and the average temperature in the study region.

Table 1. Prey consumed by *Lutjanus synagris* in the Amazon coast of the state of Maranhão, Brazil.

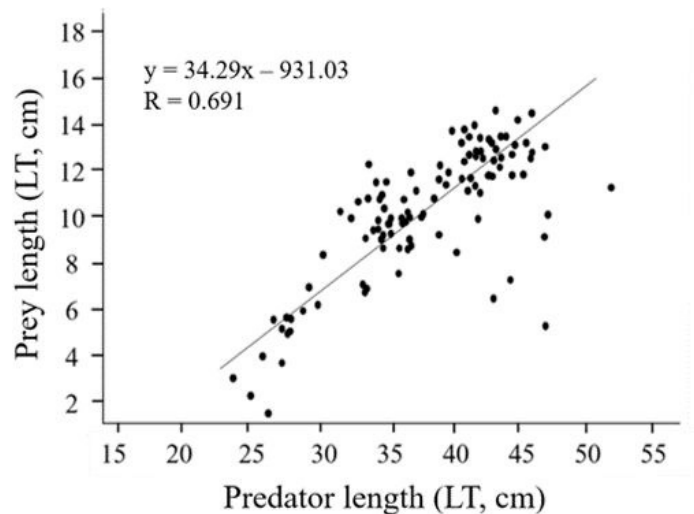| Prey Items	Dry (n = 131)			Rainy (n = 141)			General (n = 272)		
	%Fni	%FO	%IRI	%Fni	%FO	%IRI	%Fni	%FO	%IRI
Crustaceans									
Crustacean larva	3.05	3.15	0.41	2.13	1.02	0.12	2.57	2.09	0.26
Callinectes sp.	14.5	11.58	10.06	9.22	7.14	6.74	11.76	9.33	9.13
Ucides cordatus	5.34	2.11	0.57	2.84	1.02	0.22	4.04	1.55	0.4
Penaeus sp.	20.61	18.95	21.78	12.76	10.21	10.77	16.54	14.5	16.44
Annelids									
Polychaete	-	-	-	2.13	2.05	0.22	1.1	1.04	0.07
Mollusks									
Anomalocardia sp.	-	-	-	2.13	3.06	0.33	1.1	1.55	0.1
Crassostrea sp.	-	-	-	2.13	2.05	0.22	1.1	1.04	0.07
Loligo sp.	-	-	-	3.54	5.1	1.44	1.83	2.6	0.5
Porifers									
Sponges	-	-	-	5.68	6.13	2.32	2.94	3.1	0.75
Vegetables									
Angiosperms/ seaweeds unidentified	7.64	7.37	2.21	7.09	4.09	1.38	7.35	5.7	1.86
Vertebrates									
Trichiuridae	2.29	2.11	0.46	4.25	4.08	1.43	3.32	3.1	0.9
Haemulidae	1.52	2.11	0.23	7.81	11.2	4.57	4.78	6.73	1.73
Ariidae	2.29	2.11	0.36	2.84	3.06	0.71	2.58	2.6	0.53
Mugilidae	8.39	3.15	1.29	5.67	4.08	1.53	6.99	3.63	1.45
Others									
Fish and Shrimp Fragments	13.75	18.94	17.96	567	5.1	4.08	9.56	11.92	10.73
OMNI	16.04	22.11	43.19	17.73	25.51	62.08	16.92	23.83	53.36
Polymers	4.58	6.31	1.48	6.38	5.1	1.84	5.52	5.7	1.72

%Fni = numerical frequency of items; %FO = frequency of occurrence of items; %IRI = relative importance index of items). OMNI = Organic Matter Not Identified.

and Mugilidae. The other components found can be considered accidental or occasional due to their low frequency.

The diet composition in relation to the maturity category of the *L. synagris* showed that the diet of juveniles was predominantly composed of OMNI (42.5%) and Angiosperms/seaweeds unidentified (17.5%). Fish and shrimp fragments were the third most frequent items found in the stomach contents (15%). The diet included larvae of Decapods, Mollusks, Polychaetes, and Porifera, however, with a lower frequency of occurrence. The diet of adults was predominantly composed of Crustaceans (35.83%), followed by Vertebrates (24.42%), and OMNI (24.42%). Four families of Teleosts were found as prey to adults. Remains of bivalves and gastropods were also present in small amounts. The analysis of the diet per length class showed a consistent pattern: organisms that presented longer lengths consumed larger and heavier prey, whereas juveniles consumed smaller prey and more organisms in suspension (Figure 3). The class groups of organisms showed significant differences in diet analysis and were influenced by the size of the body and trophic dynamics (ANOVA, $p < 0.05$).

The stomach content analysis showed presence of synthetic materials as mesoplastic sizes (5.0 mm – 2.5 cm) in 5.52% of the specimens. A total of 15 plastic particles were found in the

stomachs of 11 specimens. These compounds were represented by nylon fiber (2.12%), swab cable (0.84%), expanded polystyrene (2.36%), and plastic bags (0.72%). The occurrence of polymers

$y = 34.29x - 931.03$
$R = 0.691$

Figure 3. Predator length vs. prey length scatter diagram for *Lutjanus synagris*.

is significant in the sampling, and only specimens smaller than 28 cm did not show the ingestion of polymers.
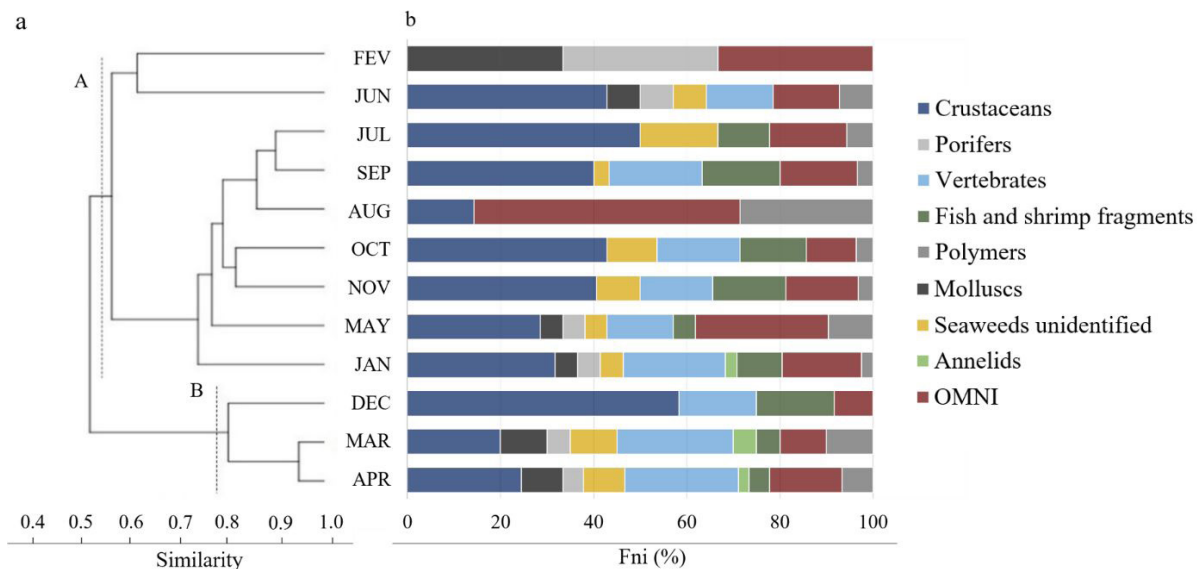
The temporal variance of the diet and feeding strategy of *L. synagris* for grouped sexes formed two different groups after the analysis through similarity dendrogram for the sampling period and %Fni. The group *a* had similarity of 55%, represented by January, February, May, and June in the rainy season and by July, August, September, October, and November in the dry season, presenting a diet predominantly composed of Crustaceans and OMNI. The group *b* had a similarity of 80%, represented by March and April in the rainy season and by December in the dry season. The main items consumed in group *b* were Crustaceans and Vertebrates. The months that presented best grouping were July and September for group *a*, and March and April for group *b* (Figure 4a-b).

Crustaceans, Fish and Shrimp fragments and OMNI were the most consumed items during the dry months in the Amazon coast in the state of Maranhão. *Penaeus* sp. and *Callinectes* sp. were the most frequent and essential food in the diet of *L. synagris* in this period, while Annelids, Mollusks, and Porifera were not found in their diet. OMNI was the most frequent item in rainy months, but the diet was more diversified, with a record of different organisms, such as Mollusks (*Crassostrea* sp. and *Loligo* sp.) and high occurrence of Teleosts (Haemulidae) and Crustaceans. This can be explained by the contribution and frequency of food items during the seasons of the year in the sampling area, which presented significant differences in the abundance of items in June, September, March, and April (Kruskal-Wallis, *p* <0.05).

The *L. synagris* diet was significantly influenced by trophic dynamics and seasonality (Kruskal-Wallis, *p* <0.05). Crustaceans, Fish, Shrimp fragments, and OMNI were the most consumed items during the dry months on the Amazon coast of the state of Maranhão. *Penaeus sp*. and *Callinectes sp*. were the most frequent and essential foods in the diet of *L. synagris* in this period, while Annelids, Mollusks and Porifera were not found in their diet. OMNI was the most frequent item in the rainy months, but the diet was more diversified, with records of different organisms, such as Mollusks (*Crassostrea sp*. and *Loligo sp*.) and a high occurrence of Teleosts (Haemulidae) and Crustaceans. This can be explained by the contribution and frequency of food items during the seasons in the sampling area. After comparing with the pairs by Dunn's posterior test, an abundance of items was noticed in June, September, March, and April.

The relationship between ecological indexes and seasonality did not show significant differences (Student's t-test, *p* >0.05) for the set of data referring to diversity and equitability. However, for dominance and richness, there was significant stationary variation (Mann-Whitney, *p* <0.05). The Simpson dominance index (D) calculated in this study showed a value of 0.69 for the rainy season. The Shannon diversity index (H') points to a low diversity for the two periods of seasonality. The richness of the items shows that the rainy season had a higher value, however, in none of the seasons, there was a great wealth of items. The Pielou (J) equitability value of 0.56 shows that 56% of the maximum theoretical diversity was obtained through the analysis of food items, representing a relatively uniform distribution of all items for the rainy season (Table 2).

Figure 4. Prey consumed by *Lutjanus synagris* in the Amazon coast of the state of Maranhão, Brazil **a.** Dendrogram for cluster analysis of the similarity between June 2018 and May 2019 of *Lutjanus synagris* samples. **b.** Percentage of the numerical frequency of items found (%Fni). OMNI = Organic Matter Not Identified.

Table 2. Ecological indexes referring to seasonality during the period of collection of *Lutjanus synagris* samples. Values are shown as average plus standard deviation.

Ecological Indexes	Dry	Rainy
Dominance - Simpson D	0.19±0.12*	0.69±0.31*
Diversity - Shannon H	1.80±0.23	1.85±1.22
Richness - Margalef	1.79±1.27*	2.41±2.02*
Equitability - Pielou J	0.35±0.10	0.56±0.27

* = significant difference by the Mann-Whitney, p <0.05.

DISCUSSION

The analysis showed intense feeding activity for specimens of *L. synagris*, which had degrees of stomach repletion indicating daily or continuous feeding in their area of occurrence. However, the frequency of repletion in full condition was higher in the rainy season. Some stomachs of *L. synagris* were empty due to regurgitation, indicating that the organisms cannot withstand the pressure variation at the time of capture due to the expansion of the gas in their swimming bladder that compresses the stomach wall during the hauling, which makes them everted. Fonteles Filho (1969), Ogawa and Menezes (1972) found similar results regarding the feeding activity and the number of stomachs everted at the time of capture in studies on the feeding of *L. purpureus* in the Northeast region of Brazil.

Regarding digestion, stomachs that presented only mucus as stomach content can indicate that these organisms present a fast metabolism. Moreover, the digestion degree is probably related to the temperature because the increase in temperature increases the metabolism of the animal (Lolis and Andrian, 1996). According to Kamukuru and Mgaya (2004), Schwartzkopf et al. (2017) the amount of food consumed by Lutjanidae species is clearly influenced by the parameters such as tide, time of day, and place of capture. Juárez-Camargo et al. (2020) analyzing the variability of the eating habits of *L. synagris* and *L. griseus* on the coast of Campeche obtained a low repletion index (30%) and a moderate degree of digestion of the items, corroborating that digestion also it is influenced by the number of acids secreted in the stomachs and by the presence of a much shorter intestine in carnivorous fish, making digestion faster (Lagler et al., 1997). However, the large proportion of empty stomachs can also reflect methodological problems, such as the method of capture, photoperiod, the way organisms are stored for transport, as well as the distance from the place of capture to the laboratory (Zavala Camin, 1996).

The *L. synagris* showed preference for benthic prey, presenting carnivorous and generalist-opportunist habits; their diet is also composed by demersal-pelagic species, such as cephalopods and teleost fishes. According to Duarte and Garcia (1999), Pimentel and Joyeux (2010), the diet of *L. synagris* is composed of small crustaceans, small teleosts, polychaetes, and mollusks with strong correlation with the benthic environment, which classifies the species as a generalist opportunist predator of demersal habit. According to the feeding groups found, the demersal resources were the most representative and crustaceans presented the highest frequency of occurrences. Although fish intake increased in the diet according to the species ontogeny, this food did not stand out among the other food items.

The results of the present study showed a difference in food items between size classes, denoting the importance of these items for the species; and that *L. synagris* responds to changes in the availability of potential prey. Greater interaction with the environment occurs as this species develops and food resources become more diverse, presenting preference by larger prey. Thus, some morphological adaptations and transformations in these organisms and some changes related to the ontogenetical conditions of their feeding can determine the diet composition (De Melo Rosa et al., 2015; Hernandez et al., 2018). The presented results confirm those obtained by Szedlmayer and Lee (2004), who found a higher frequency of crustaceans and fishes in adult specimens of *L. synagris* in the Gulf of Mexico, with a similar pattern for other marine fish species.

Studies in the Northeast Region of Brazil and in areas of occurrence of *L. synagris* report the importance of these food resources in the diet of Lutjanidae species (Randall, 1967; Sánchez, 1994; Guevara et al., 1994; Sierra, 1997; Sierra et al., 2001; Claro and Lindeman, 2004; Monteiro et al., 2009; Freitas and Abilhoa, 2011). Trophic guilds were identified, among the food items, as benthic, demersal, and pelagic organisms. Contrastingly, despite the great variability of food items consumed, few of them predominated in the diet of *L. synagris*. Similar results were found by Franks e VanderKooy (2000), Kamukuru and Mgaya (2004) for *Lutjanus fulviflamma* in Tanzania.

The diet of a given species is related to the morphology and feeding behavior, as well as the constitution and availability of food resources to the specific conditions of the environment. The most representative foods items in the diet of *L. synagris*, such as decapods and teleosts, are characterized as abundant in the continental shelf of the Northeast Region of Brazil, due to the favorable environmental conditions for their reproduction, feeding, and maintenance. In addition, the Amazon coast of Maranhão is rich in coastal estuarine and marine areas, which contributes to the development of many fish and crustaceans (D'Incao, 1998; Costa et al., 2003; Santos et al., 2006; Boos et al., 2016).

The diet composition can change depending on the location, capture period, and fishing technique. This is confirmed by Duarte and Garcia (1999) in a study about the diet of *L. synagris* in the Gulf of Salamanca, Colombia, which showed that these dependences are related to the capture logistic and characteristics of the local epifauna. Valdés and Silva (1977) showed that *L. synagris* in an artificial reef area in Cuba presented a diet predominantly composed of fishes 56% represented by the species *Opsanus phobetron*.

According to the results of the IRI%, Brachyuras, Penaeidae, and Haemulidae were the most representative prey groups. Similar results showed that congener species, such as *L. fulviflamma* in Tanzania, presented a diet predominantly composed by crustaceans, with shrimps representing 40% of the IRI% (Kamukuru and Mgaya, 2004). The food preference of *L. synagris* on crustaceans

confirms that the main forage area of this species is next to the oceanic substrate. However, Rashetnikov et al. (1974) and Sierra and Claro (1979) pointed out that the importance of Brachyura may be due to the higher rates of food digestion.

The correlation between the sampling period and the seasonality, temperature and intensity of the rains showed changes in the composition of the *L. synagris* diet. The diet of the specimens showed a dominance by crustaceans (Penaeidae and Brachyuras) during the dry period and a diet rich in OMNI in the rainy months. Food resources in the Amazon coast of the state of Maranhão are abundant during the rainy season because estuarine systems are the main providers of nutrients, maintaining high rates of primary productivity and biomass contents, contributing directly or indirectly to the biodiversity and productivity in the coastal zone. This is strongly explored by Goulding (1980), Gerking (1994), and Wootton (1999) in studies on the effect of seasonality on feeding habits of aquatic organisms; and by Dittmar (1999), Castro (1997), and Silva Júnior et al. (2013) in coastal areas of Maranhão.

The diversity and richness indexes showed that the diversity of food items was higher in rainy months than in dry months. The maximum number of food items was found in the rainy months. This is due to increases in the amount of nutrients disperse in coastal environments because of high rainfall depths. According to Yanez-Arancíbia (1985), the temperature, which is related to rainfall depths and nutrients available in coastal environments, affect the diversity of species. Similar result was reported by Ribeiro et al. (2012), who found higher diversity of food items during the winter season in the Ilha dos Caranguejos, in Maranhão. The diversity and richness index found in the present study was higher than those reported by Yisa et al. (2011) and Brazil et al. (2009), denoting a relatively richer biodiversity.

The fishing area of *L. synagris* in the coast of Maranhão has transition regions that are defined by geological oceanographic processes that favor the emergence of high-productivity areas (Floeter et al., 2001), which affect the trophic ecology of the ichthyic communities in these ecosystems. The state of Maranhão presents a complete hydrographical network with rivers, estuaries, and coral areas (Martins and De Oliveira, 2011). This environment contributes to the dynamics of Lutjanidae species, which use such locations for shelter and feeding because of the rich diversity of food resources and their easy capture, making them faster than their prey (Randall, 1967; Lowe-McConnell, 1999).

The feeding behavior of an animal is related to the environmental conditions and availability of food resources and reproductive period (Sierra et al., 2001). Thus, species that have prey capture activity related to reef environments present feeding strategies that allow them to explore diverse aquatic environments, contributing to an extensive trophic chain with great plasticity for adaption to food availability (Ross and Moser, 1995; Monteiro et al., 2009; Pimentel and Joyeux, 2010).

The present study provided evidence of ingestion of plastic particles and residues by *L. synagri*s in the state of Maranhão. The Lutjanidae species have many feeding strategies and most tropical fishes have the capacity of adaptation to diets according to the food availability (Pimentel and Joyeux, 2010; Nelson, 2016).

However, when the food chain is unbalanced because of marine pollution, many species suffer with environmental problems, resulting in behavioral changes, competition for resources, and threats to immediate predation. Plastic residues were found in tissues of marine and estuarine fishes in the Northeast region of Brazil (Possatto et al., 2011; Miranda and Carvalho-Souza, 2016; Pegado et al., 2018). The proportion of microplastic found on estuarine fishes by Ramos et al. (2012) showed a higher ingestion level (13.4%) than that found in the present study (5.70%).

The anthropogenic residues are dispersed by transference and circulation processes that contribute to the accumulation of fragments in oceanic environments (Woodall et al., 2014; Van Cauwenberghe et al., 2015). Moving of marine fluids, saline subduction, and other oceanographic processes over coasts near river mouths can contribute to the concentration of residues in marine sediments (Talley et al., 2002; Stabholz et al., 2013). Studies related to the feeding habits of demersal-pelagic fish have shown an association of polymer intake in the diet in areas at east of the Mediterranean Sea (Anastasopoulou et al., 2013). Romeo et al. (2015) point out that these particles are more frequently ingested by generalist organisms that consume small abundant prey, which is a characteristic consistent with the feeding habits of *L. synagris*.

CONCLUSION

The feeding habits of *L. synagris* in a coastal area in northeastern Brazil indicated a wide variety of items consumed, associated with the amount of stomachs with food, showing that the species is a non-selective predator, whose feeding is apparently directed to the relationship with the seasonality and population structure of the captured organisms, with the substrate and with the food availability.

The data of the present study showed an essential evaluation on the feeding habit of *L. synagris*, once such studies are scarce in Brazil; the results also presented a discovery of ingestion of plastic residues by the species, denoting that the study about this species can be a tool for evaluation of ecosystems regarding impacts and contamination by plastics to better understand the magnitude of this problem and, thus, develop measures for its mitigation in areas where these organisms reproduce and feed.

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