RELATIVE EFFECT OF SEASONALITY AND BODY SIZE ON THE DIET OF JUVENILE *Lutjanus synagris* (PERCIFORMES: LUTJANIDAE) AT A SANDY BEACH IN SOUTHEASTERN BRAZIL

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ABSTRACT

The relative effect of seasonality and body size on the diet composition of juvenile *Lutjanus synagris* was investigated at a sheltered sandy beach (20º18'S; 40º16'W) on the coast of Espírito Santo state, Brazil. Monthly collections were carried out during the daytime from May 2004 to April 2005, using a beach seine. The specimens captured in each season (*e.g.* cold/dry, May to October 2004; hot/rainy, November 2004 to April 2005) were separated into three total length (TL) classes (≤ 40; 41–50; ≥ 51 mm). The stomach contents of 540 specimens with TL ranging from 22 to 135 mm were analyzed. Among the 13 food items consumed by *L. synagris*, the most important were Amphipoda (Index of Relative Importance, IRI = 81.2), Isopoda (IRI = 13.8) and Mysidacea (IRI = 4.4). Significant variations in the diet composition were observed between the seasons (PERMANOVA; $P < 0.001$), but not between the size classes ($P = 0.170$). There was, however, a significant interaction between these two factors ($P<0.001$), indicating that the differences between the seasons did not occur in every class. The most important items in the cold/dry and hot/rainy seasons were, respectively, Mysidacea and Amphipoda, for every class. The average length of the preys varied significantly ($P<0.05$) between the size classes, increasing progressively with the TL of the fishes. Overall, the results indicate a carnivore-opportunist food habit for *L. synagris*, with significant seasonal changes in the relative importance of the food items.

Keywords: food habit; trophic dynamics; Actinopterygii; sheltered beach; Atlantic ocean

EFEITOS RELATIVOS DA SAZONALIDADE E DO TAMANHO DO CORPO NA DIETA DE JUVENIS DE *Lutjanus synagris* (PERCIFORMES: LUTJANIDAE) EM UMA PRAIA ARENOSA NO SUDESTE DO BRASIL

RESUMO

O efeito relativo da sazonalidade e do tamanho do corpo na composição da dieta de juvenis de *Lutjanus synagris* foi avaliado em uma praia arenosa abrigada (20º18'S; 40º16'W) no litoral do estado do Espírito Santo, Brasil. Coletas mensais diurnas foram conduzidas no período de maio/04 a abril/05, usando uma rede de arrasto de praia. Os espécimes capturados em cada estação (fria/seca, maio a outubro de 2004; quente/chuvosa, novembro de 2004 a abril de 2005) foram separados em três classes de comprimento total (CT) (≤ 40; 41–50; ≥ 51 mm). O conteúdo estomacal de 540 espécimes com CT variando de 22 a 135 mm foi analisado. Entre os treze itens alimentares descritos para a dieta de *L. synagris*, os mais importantes foram Amphipoda (Índice de Importância Relativa, IIR = 81,2), Isopoda (IIR = 13,8) e Mysidacea (IIR = 4,4). Variações significativas na dieta foram observadas entre as estações do ano (PERMANOVA; $P<0,001$), mas não entre as classes de tamanho ($P = 0,170$). Houve, porém, uma interação significativa entre estes dois fatores ($P<0,001$), indicando que as diferenças entre as estações não ocorreram em todas as classes. Os itens mais importantes nas estações fria/seca e quente/chuvosa foram, respectivamente, Mysidacea e Amphipoda, para todas as classes. O tamanho médio das presas variou significativamente ($P<0,05$) entre as classes de tamanho, aumentando progressivamente com o CT dos peixes. No geral, os resultados indicam que *L. synagris* têm um hábito alimentar carnívoro-oportunista e muda sua dieta ao longo do ano.

Palavras chave: hábito alimentar; dinâmica trófica; Actinopterygii; praia abrigada; oceano Atlântico

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INTRODUCTION

The first year of life is a period of rapid growth for fish species and is commonly marked by alterations in food habits (WOOTTON, 1990). Such alterations generally occur due to morphological changes that accompany growth, as well as modifications in the availability of prey during the daily or seasonal cycle (GERKING, 1994; CORRIGAN *et al*., 2011; DAVIS *et al*., 2012). Studies of the diet of juveniles may help in the understanding of the relative importance of factors acting as drivers of such changes in the food spectrum and also the trophic role of these fish in nursery habitats. In addition, ecological information may even apply to the culture of economically important fish species, for instance, in the production of different types of food for specific sizes of fish (ZAVALA-CAMIN, 1996).

Lutjanids are important fishery resources in tropical and subtropical regions (MOURA *et al*., 2011; CAVALCANTE *et al*., 2012), and occupy high trophic levels in the marine ecosystems (DUARTE and GARCIA, 1999). The young live mainly in shallow areas, while adults look for deeper waters off the coast where they usually spawn (FREITAS *et al*., 2014). The lane snapper *Lutjanus synagris* (Linnaeus, 1758) is distributed from North Carolina (USA) to southeastern Brazil, but is more abundant in the Antilles, Campeche Bank and on the northern coast of South America (ALLEN, 1985). This species inhabits coral reefs, seagrass banks, estuaries and dark brackish waters over muddy bottoms (MCEACHRAN and FECHHELM, 2005; GARCIA-JÚNIOR *et al*., 2010). It is considered important in the commercial and recreational fisheries in the northern region of the Gulf of Mexico (GMFMC, 1981) and Brazil, where it occupies the first position in the artisanal fishery of Abrolhos Bank (FONSECA, 2009).

Despite its economic importance in Brazilian waters, studies on the diet of *L. synagris* have been carried out manly in the Caribbean Sea (*e.g.* DUARTE and GARCIA, 1999; FRANKS and VANDERKOOY, 2000). The limited information available coming from the Brazilian coast suggests this species acts as an important predator in the food webs of coastal habitats, such as reefs and estuaries (FONSECA, 2009; PIMENTEL and JOYEUX, 2010). Therefore, the functional role of juvenile snappers at alternative nursery grounds such as sheltered sandy beaches is unknown, although they can figure among the most abundant species in these environments (*e.g.* ARAUJO *et al*., 2008). This study aims to fill this gap by investigating if seasonality and body size are important drivers of changes in the diet composition of *L. synagris* inhabiting a sheltered sandy beach in southeastern Brazil.

MATERIAL AND METHODS

Study area

The samplings were carried out at a sheltered beach on Ilha do Frade (20º18'S; 40º16'W), located about 380 m from the coast, between the north (Canal da Passagem) and south (Baía de Vitória) inlets of the estuary that surrounds Vitória (capital of Espírito Santo state, southeastern Brazil) (Figure 1). Its coastline is formed predominantly by granitic rocks, with small sandy beaches between the rocky formations. These beaches are occupied in some periods of the year by macroalgae (*e.g. Ulva* Linnaeus, 1753 and *Sargassum* C. Agardh, 1820) detached from adjacent rocky shores by wave action. As in other metropolitan regions, diverse potentially impacting activities occur around the study area, including the extensive urbanization of the island and its surroundings, the presence of three large ports (*i.e.* Vitória, Capuaba and Tubarão) and the entry into Baía de Vitória of part of the industrial and domestic sewage produced by 1.02 million inhabitants. However, a relatively diversified fish fauna composed of more than 159 species has been recorded around Ilha do Frade (HELMER and PERRONE, 1991; ARAUJO *et al*., 2008).

The climate of the region is tropical hot and humid, with an average annual temperature of about 24ºC. Two seasons may be clearly identified over the year: one relatively hot (average monthly temperature from 24.8 to 26.8 ºC) and rainy, which extends from November to April; and one relatively cold (average monthly temperature from 21.5 to 24.3 ºC) and dry, which extends from May to October (Figure 2).

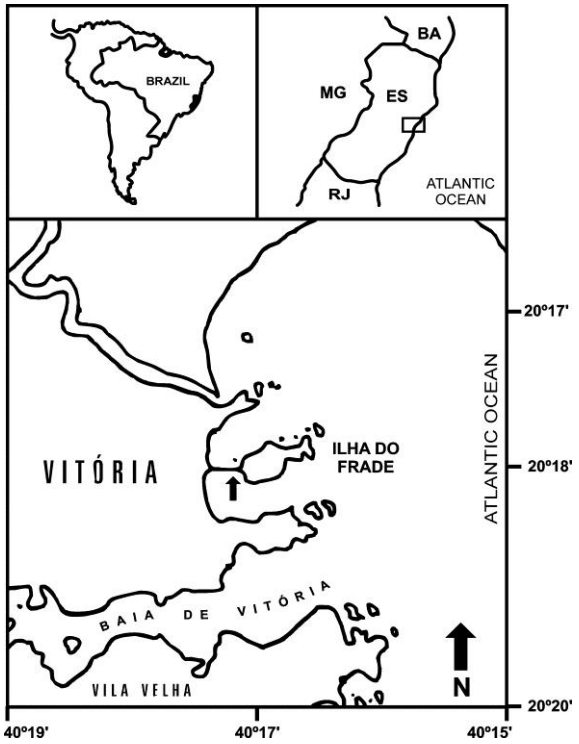

Figure 1. Location of the sampling site (smaller arrow) on the coast of Ilha do Frade, Vitória, Espírito Santo state, Brazil.

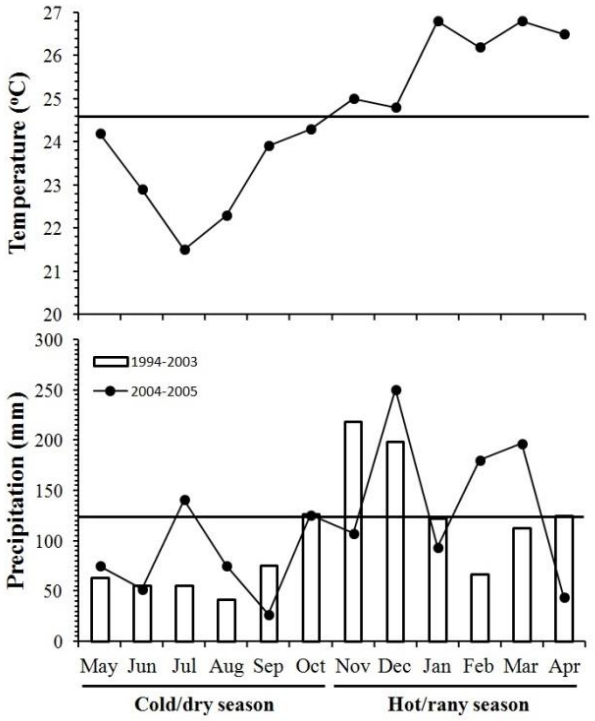

Figure 2. Monthly precipitation (mm) and average temperature (ºC) between May 2004 and April 2005 in the region of Ilha do Frade. The precipitation values are presented for the period of study (2004–2005) and for the ten years immediately previous to this period (1994–2003). The continuous horizontal lines represent the annual averages. Source: INCAPER (meteorological station of Vitória, Espírito Santo state, at 20º30'00"S and 40º31'07"W; altitude: 36 m).

Sampling methods

Monthly collections were carried out during the daytime from May 2004 to April 2005, using a beach seine (6 × 2 m, with a mesh of 1 cm between opposite knots). Every month, eight 10-meter trawls lasting approximately five minutes each were carried out at low tide. The trawls were conducted parallel to the beach to a maximum depth of 1.5 m. All of the captured fish were immediately fixed in a 10% formaldehyde solution to interrupt the digestive process. The individuals of *L. synagris* were later identified (following MENEZES and FIGUEIREDO, 1980), counted, measured [total length (TL) in mm] and had their stomachs removed for stomach content analysis. The food items in each stomach were spread on a Petri dish and identified under a stereoscopic microscope (following BRUSCA and BRUSCA, 2003; MENEZES and FIGUEIREDO, 1980) major item groups. After the removal of excess humidity using paper towels, the number of individuals and the weight (± 0.001 g precision) were recorded for each taxon identified in the stomach contents. The length of the largest prey found in each stomach was measured using a caliper (± 0.01 mm precision), considering the longer axis.

Data analysis

The percent frequency of occurrence (%F), the numeric proportion (%N) and the mass proportion (%M) of the food items found in the stomachs were used to describe the diet of the species (HYSLOP, 1980). These values were combined to identify the main food items through the Index of Relative Importance (IRI) proposed by PINKAS *et al*. (1971): IRI = (%N + %M) × %F. The values of this index were expressed in percentages using the following equation: %IRI = (IRI/Σ IRI) × 100.

In order to analyze if seasonal and size-related changes in the diet of the species occurred, the fishes captured in each season were grouped into three TL classes with at least 20 individuals each: ≤ 40 mm; 41–50 mm; ≥ 51 mm. The %IRI of the prey was calculated separately for each size class in each season.

A similarity matrix was constructed using the Bray-Curtis coefficient based on the values of the %IRI. This matrix was submitted to cluster analysis applying the Unweighted Pair Group Method with Arithmetic Mean (UPGMA). In order to test if there were significant differences in the diet composition between seasons and size classes (independent variables), a permutational multivariate analysis of variance was used (PERMANOVA; ANDERSON *et al*., 2008), where all of the prey were analyzed simultaneously (dependent variables). This analysis was based on a similarity matrix constructed using the Bray-Curtis coefficient calculated from the %M data of the prey in each stomach, after being log(%M + 1)-transformed. The values of *P* were obtained using 5000 permutations.

Differences in the average length of the largest food items between size classes were investigated using a one-way ANOVA and the *a posteriori* test of Tukey. Before these analyses, the length data of the items were log transformed to reach homogeneity of the variances (based on the Levene test) and normality (based on the Kolmogorov-Smirnov test), as suggested by SOKAL and ROHLF (1981).

RESULTS

A total of 540 specimens of *L. synagris* were caught during samplings, all with TL (range: 22 to 135 mm; mode = 30 mm; s^2 = 12.3 mm) below the minimum size at first maturity (*i.e.* TL = 187 mm, *sensu* FREITAS *et al*., 2011a). Considering all of the species caught (45), *L. synagris* was dominant in number of individuals (20.1% of the total catch) and occurred in all of the sampling months, except June 2004 (cold/dry season). Approximately 86% of the individuals of *L. synagris* were captured in the hot/rainy season. About 78% belonged to the ≤ 40 mm class, 10% to the 41–50 mm class and 11% to the ≥ 51 mm class.

Eighty-seven percent (n = 472) of the specimens presented food items in their stomachs. Five large groups of food items were found in the stomach contents: Teleostei, Crustacea, Mollusca, Echinodermata and Annelida. The diet was composed of thirteen taxa, with small crustaceans as the most important food items in the diet of *L. synagris*. Among them, Amphipoda was the main item, followed by Isopoda, Mysidacea and Penaeidae. The other items presented the %IRI below 0.01 (Table 1).

Table 1. Percentage values of frequency of occurrence (%F), numeric proportion (%N), mass proportion (%M) and Index of Relative Importance (%IRI) of each food item identified in the stomachs of *Lutjanus synagris* on the cost of Ilha do Frade, southeastern Brazil. N = 472 stomachs.

Items	%F	%N	%M	%IRI
TELEOSTEI				
Syngnathidae	0.42	0.03	0.33	< 0.01
Teleostei	1.06	0.09	3.51	< 0.01
CRUSTACEA				
Amphipoda	64.41	67.47	38.57	81.20
Brachyura	1.69	0.10	1.51	< 0.01
Euphausiacea	1.06	0.08	0.28	< 0.01
Isopoda	46.82	15.77	24.07	13.81
Mysidacea	17.58	13.39	14.67	4.40
Penaeidae	11.65	2.58	15.36	0.56
Larvae of Decapoda	1.69	0.26	0.13	< 0.01
Crustacea	2.54	0.16	1.40	< 0.01
MOLLUSCA				
Gastropoda	0.21	0.01	0.01	< 0.01
ECHINODERMATA				
Larvae of Echiuroidea	0.21	0.01	0.01	< 0.01
ANNELIDA				
Polychaeta	0.64	0.04	0.13	< 0.01

The cluster analysis based on the values of the %IRI differentiated the diet primarily as regards seasonality, separating the samples from each season into two groups, with a similarity of approximately 46% (Figure 3). Similarity between the size classes varied substantially in each group (relatively higher in the cold/dry season than in the hot/rainy season). In the group comprising the hot/rainy season, the ≥ 51 mm and the 41–50 mm classes were more similar (78%), while in the cold/dry season, the higher similarity occurred between the 41–50 mm and the ≤ 40 mm classes (92%) (Figure 3).

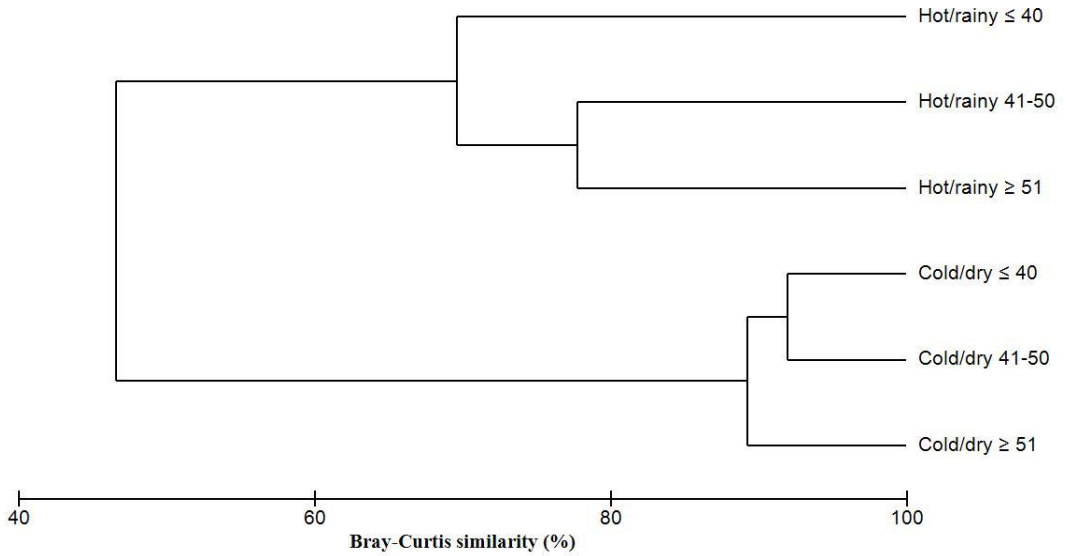

Figure 3. Dendrogram based on the Bray-Curtis similarity between the values of Index of Relative Importance (%IRI) of the food items consumed by *Lutjanus synagris* from three size classes in the cold/dry and hot/rainy seasons at a sandy beach in southeastern Brazil.

In the cold/dry season, Mysidacea were relatively more important than in the hot/rainy season for all size classes (the opposite for Amphipoda). For individuals from the ≤ 40 mm class, Mysidacea (%IRI = 86.1) were more important in the cold/dry season and Amphipoda (%IRI = 84.7) in the hot/rainy season. For fish from the 41–50 mm class, a diet similar to the one presented by the ≤ 40 mm class was observed in the cold/dry season, with Mysidacea (%IRI = 76.6) dominating; but in the hot/rainy season, Amphipoda (%IRI = 45.5) and Isopoda (%IRI = 45.2) were more important. A similar food pattern was observed for individuals from the ≥ 51 mm class in the cold/dry season, with Mysidacea (%IRI = 86.3) dominating again. However, in the hot/rainy season, in addition to Amphipoda (%IRI = 39.8) and Isopoda (%IRI = 16.3), Penaeidae (%IRI = 33.4) were important items. In general, Isopoda and Penaeidae were relatively more important to the larger size classes (41–50 mm and ≥ 51 mm) and were consumed, particularly, in the hot/rainy season (Figure 4).

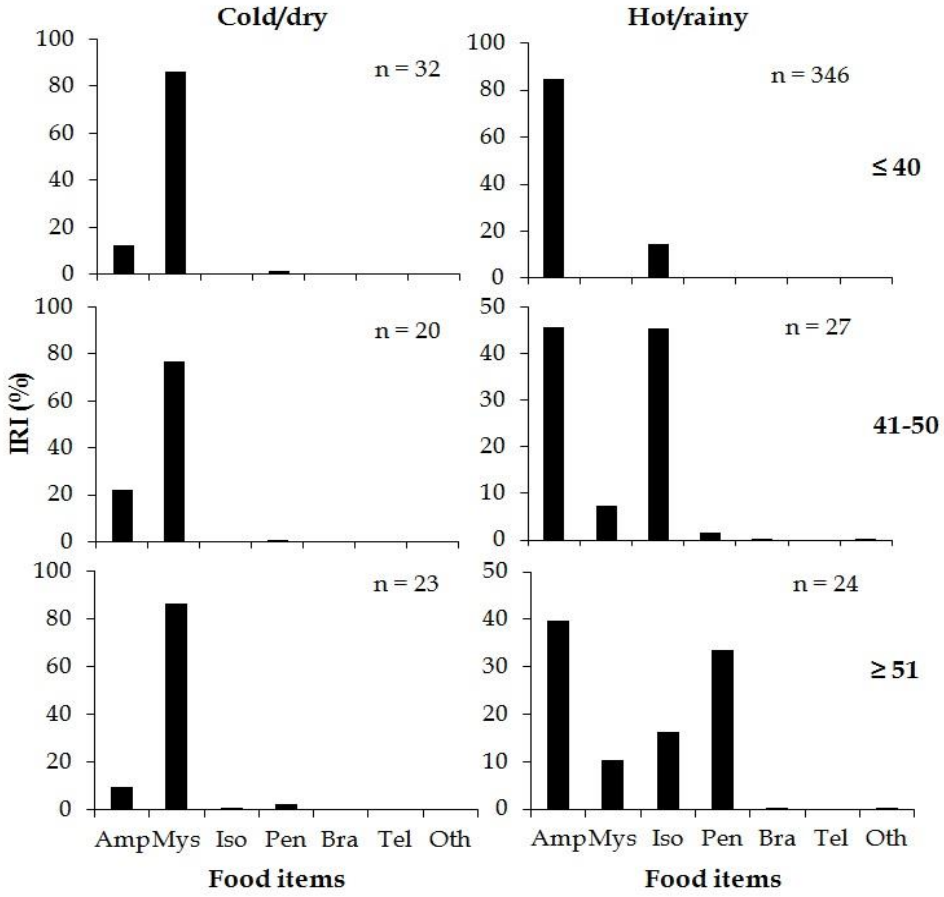

Figure 4. Histograms of seasonal variations in the Index of Relative Importance (%IRI) of food items consumed by *Lutjanus synagris* from three size classes at a sandy beach in southeastern Brazil. Amp = Amphipoda, Mys = Mysidacea, Iso = Isopoda, Pen = Penaeidae, Tel = Teleostei, Bra = Brachyura and Oth = Others (*e.g.* unidentified crustaceans, larvae of Decapoda, Euphaseacea, Gastropoda, Echiuroidea and Polychaeta).

Significant variations were found in the diet of *L. synagris* between seasons (PERMANOVA: $F_{1,\ 466}$ = 24.15; P<0.001), but not between size classes (PERMANOVA: $F_{1,\ 466}$ = 1.54; P = 0.170). There was, however, a significant interaction between these two factors (PERMANOVA: $F_{2,\ 466}$ = 4.48; P<0.001), indicating that differences between seasons did not occur in all classes. In order to

identify the source of this interaction, each class was tested individually against the seasons. In these analyses, only the ≥ 51 mm class did not vary significantly (PERMANOVA: $F_{1,44} = 2.04$; $P = 0.101$).

Were obtained lengths of 465 food items (≤ 40 mm class, n = 371; 41–50 mm class, n = 47; ≥ 51 mm class, n = 47). The items measured were Amphipoda, Isopoda and Mysidacea. The average length of the captured items varied significantly ($P<0.05$) between size classes, increasing progressively with the TL of the fish. However, the pairwise comparisons showed that these differences were significant only between the ≤ 40 mm class and the other two (Figure 5).

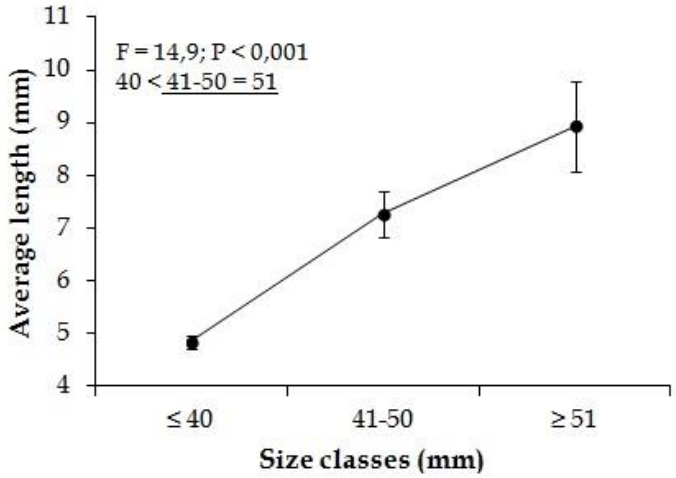

Figure 5. Variation of the average length (± SE) of the larger food items consumed by *Lutjanus synagris* from three size classes at a sandy beach in southeastern Brazil. The results of the ANOVA and the pairwise comparisons using the Tukey test are also presented.

DISCUSSION

The diet composition of *L. synagris* changed, firstly, as regards seasonality, indicating that environmental factors may have influenced that change. Seasonal variations in the diet were also observed by DUARTE and GARCIA (1999) for *L. synagris*, by MONTEIRO *et al*. (2009) for *Lutjanus jocu* and by PIMENTEL and JOYEUX (2010) for *Lutjanus analis*. These changes occur mainly due to alterations in the availability of the items, which are associated with reproductive pulses and physical-chemical alterations in aquatic ecosystems (PLATELL *et al*., 1997). In this study, the season with higher temperatures seems to be related to the substantial increase in consumption of Amphipoda by juveniles of *L. synagris*. DUBIASKI-SILVA and MASUNARI (1995) mention that high temperatures should favor the abundance and reproduction of this small crustacean. Studies suggest that factors such as temperature do not seem to influence the distribution and abundance of Mysidacea (RAPPÉ *et al*., 2011). However, the pluviometric historical of last ten years (*i.e.* that preceded the study period, see Figure 2) showed low rainfall in the cold/dry season. Rainfalls influence the volume of freshwater discharge on coastal ecosystems and may increase or decrease the fluvial input at these sites, interfering with the salinity and influencing the biota (GONZÁLEZ-ORTEGÓN and DRAKE, 2012). The dominance of Mysidacea in the diet of *L. synagris* coincided with the period of lowest rainfall. According to SUZUKI *et al*. (2009), the distribution patterns of Mysidacea can be linked to salinity tolerance of the respective life stages.

Although seasonality can influence the diet composition, it also undergoes continuous alterations during the growth of the fish, either in composition or item size (UCHIKAWA and KIDOKORO, 2014). It was possible to detect significant differences related to the size of the items consumed for each size class, suggesting a food pattern in which the size of the item increases proportionally with the size of the juveniles of *L. synagris*. Furthermore, small deviations in the amplitude of items size (0.5 to

1.0 mm) indicate a strong choice of *L. synagris* for items of specific sizes in the tree size classes. Similar results were reported for the species by FONSECA (2009) in Abrolhos bank, Bahia state. According to PARRISH (1987), lutjanids have a tendency for an increase in the rate of consumption of larger items and a decrease in the rate of consumption of smaller items, with the increase in age. It is consistent with the optimal foraging theory, which predicts the predators consume preys with higher energetic value to maximize their fitness (GERKING, 1994). Other factors can also be important, including age-specific changes in the use of habitats (MARTINO and HOUDE, 2012) like nursery-to-coral reef migrations by snappers (MCMAHON *et al*., 2012).

The diet of *L. synagris* on Ilha do Frade is consistent with their congeners and corroborates studies carried out in other Brazilian states (*e.g*. FONSECA, 2009; PIMENTEL and JOYEUX, 2010), as well as in other countries in Central and North America (*e.g*. DUARTE and GARCIA, 1999; FRANKS and VANDERKOOY, 2000). Lutjanid juveniles feed mainly on benthic and planktonic invertebrates, while adults may invest mainly in fish or in benthic invertebrates (DUARTE and GARCIA, 1999). The use of crustaceans by fish of the genus *Lutjanus* has been documented for a number of species, such as *L. analis* (FREITAS *et al*., 2011b), *L. jocu* (MONTEIRO *et al*., 2009), *Lutjanus argentiventris* and *Lutjanus guttatus* (ORTEGA *et al*., 2010), *Lutjanus griseus* (YEAGER *et al*., 2014).

The relevance of peracarid crustaceans in the diet composition of juvenile lane snappers is associated with the opportunistic feeding habits of the species and the environment investigated. In intertidal and subtidal rock shores, peracarids, manly Amphipoda, Isopoda and Mysidacea, have an important trophic role as food for juveniles and adults of several commercially important fish species (HERRERA *et al*., 2014). Additionally, the accumulation of macroalgae such as *Sargassum* and *Ulva* on the sandy beach of Ilha do Frade contributes to an increase in the availability of items such as Amphipoda, which, according to several studies (DUARTE *et al*., 2010; POORE and GALLAGHER, 2013), are predominant in this type of substrate. Nevertheless, the results indicate that peracarids were important component in the environment studied playing a key role in the food web as food items, thereby contributing to the nursery function that Ilha do Frade sandy beach provide for many fish species.

Although the result of the PERMANOVA for size classes did not show significant alterations in the relative biomass of the items, a significant interaction between seasonality and body size was observed, indicating that the differences between the seasons did not occur in every class. Notably, there was a greater availability of items in the hot/rainy period. However, possible morphological restrictions present in the smaller fish (≤ 40 mm) seemed to have made the capture of Isopoda and Penaeidae (larger items) more difficult. In this way, the factors availability and morphology, combined to the recognized opportunist character of *L. synagris*, may explain the differentiated use of the food items among the juveniles in the studied environment. Within a species, differences in the diet composition at different life-history stages or between populations can be a result of morphological differences (DAVIS *et al*., 2012). Such differences have important consequences in recruitment because they reduce the intensity of competitive interactions (BRANSKI and DORN, 2013; DUKOWSKA *et al*., 2013).

CONCLUSIONS

The results indicate that *L. synagris* exhibits a carnivore-opportunist food habit, shifting their diet based on the seasonality. Increased consumption of Amphipoda shows the diet flexibility of juveniles and suggests greater availability of this small crustacean during the hot/rainy season in the Ilha do Frade. Furthermore, the results suggest that juvenile lane snapper are of great importance in regulating epifaunal populations. The information that has been obtained highlights the important functional role of *L. synagris* in the trophic dynamics of the community inhabiting the sandy beach investigated.

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