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Feeding ecology of *Lutjanus analis* (Teleostei: Lutjanidae) from Abrolhos Bank, Eastern Brazil

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Diet and feeding ecology of the mutton snapper *Lutjanus analis* were investigated in the Abrolhos Bank, Eastern Brazil, the largest and richest coral reefs in the South Atlantic, where about 270 species of reef and shore fishes occur. To evaluate seasonal and ontogenetic shifts in the diet, specimens of *L. analis* were obtained through a fish monitoring program in four cities in southern Bahia State, from June 2005 to March 2007. Stomachs from 85 mutton snappers that ranged in size from 18.1 to 74.0 cm TL were examined. Prey were identified to the lowest possible taxon and assessed by the frequency of occurrence and volumetric methods. Variations in volume prey consumption were evaluated using non-metric multi-dimensional scaling ordination, analysis of similarity, and similarity percentage methods. Significant differences in diet composition among size classes were registered, whereas non significant differences between seasons were observed. Considering size-classes, food items consumption showed important variations: juveniles (<34.0 cm TL) fed mostly on crustaceans, sub-adults (34.1-50.0 cm TL) showed a diversified diet and adults (>50.1 cm TL) consumed basically fish, mostly Anguiliformes. *Lutjanus analis* is an important generalist reef predator, with a broad array of food resources and ontogenetic changes in the diet. This snapper species plays an important role on the trophic ecology of the Abrolhos Bank coral reefs.

Foram avaliadas a dieta e a ecologia alimentar da cioba *Lutjanus analis* no Banco dos Abrolhos, Leste do Brasil. O Banco dos Abrolhos abrange os maiores e mais diversos recifes de corais do Atlântico Sul, onde cerca de 270 espécies de peixes recifais e costeiros ocorrem. Para a avaliação das variações sazonais e ontogênicas na dieta, exemplares de *L. analis* foram obtidos através de um programa de monitoramento em quatro cidades do extremo sul da Bahia, entre junho de 2005 e março de 2007. Estômagos de 85 exemplares com comprimento total variando entre 18,1 e 74,0 cm foram examinados. Os itens alimentares foram identificados até o menor nível taxonômico possível e avaliados através dos métodos de frequência de ocorrência e volumétrico. Variações no consumo das presas foram avaliadas através do método de escalonamento multidimensional não-métrico e métodos de análise de similaridade e percentagem de similaridade. Diferenças significativas na dieta foram observadas entre as classes de tamanho, porém estas não foram detectadas entre as estações do ano. Considerando as classes de tamanho, os itens consumidos apresentaram importantes variações: os juvenis (<34,0 cm CT) alimentaram-se preferencialmente de crustáceos, os subadultos (34,1-50,0 cm CT) apresentaram uma dieta diversificada e os adultos (>50,1 cm CT) consumiram basicamente peixes, principalmente Anguiliformes. *Lutjanus analis* é um importante predador recifal generalista, que consome um amplo espectro de presas, apresentando mudanças ontogênicas na dieta. Esse lutjanídeo desempenha um importante papel na ecologia trófica dos recifes de corais do Banco dos Abrolhos.

Key words: Diet, Mutton snapper, Ontogenic variations, Seasonal.

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Introduction

The diets and trophic relationships of top predators and mesopredators are important for understanding their ecological roles. Addressing this lack of data has become more important with the increasing recognition that fish mesopredators may be important in transmitting indirect effects of top predators (*e.g*. Myers *et al*., 2007; Heithaus *et al*., 2008; Baum & Worm, 2009; Ferretti *et al*., 2010). In coral reefs this role is represented by sharks, jacks (Carangidae), groupers (Serranidae), and snappers (Lutjanidae) (Polovina, 1984; Meyer *et al*., 2007).

Fishes from family Lutjanidae are among the most important fishery resources in tropical and subtropical regions (Grimes, 1987; Duarte & Garcia, 1999). They are heavily exploited by commercial fisheries in Northeastern and Central Brazil since the introduction of "pargueiras" (hook and line) by Portugueses during the 1950's and 1960's as a consequence of declining stocks of tuna fishery (Resende *et al*., 2003).

The mutton snapper *Lutjanus analis* (Cuvier, 1828) is found in the tropical Western Atlantic, from Massachusetts (USA) to Southeastern Brazil, with relatively high abundances recorded in Florida, Bahamas, and the Antilles (Figueiredo, 1980; Allen, 1985; Menezes & Anderson, 2003). Sub-adults and juveniles are found in a variety of habitats, such as sand bottoms, seaweed dominated reefs, bays, mangroves, and estuaries (Allen, 1985; Claro & Lindeman, 2004). Adults are found on hard substrates, generally on offshore deep reefs and less commonly on coastal environments (Cocheret de la Morinière *et al*., 2003; Frédou & Ferreira, 2005).

Despite its ecological and commercial importance (Claro & Lindeman, 2004; Moura & Lindeman, 2007) there is little information on its feeding ecology. Available evidences indicate that the diet of *L. analis* include fishes, shrimps, crabs, gastropods, and cephalopods (Allen, 1985; Heck & Weinstein, 1989; Claro & Lindeman, 2004; Pimentel & Joyeux, 2010), a general pattern for the family Lutjanidae (Duarte & Garcia, 1999; Santamaría-Miranda *et al*., 2003; Lee & Szedlmayer, 2004; Rojas *et al*., 2004; Rojas-Herrera *et al*., 2004; Molina *et al*., 2005). Although snappers are generally considered nocturnal predators (Claro & Lindeman, 2004), *L. analis* fed diurnally (Watanabe, 2001), showing a high variability in foraging styles, according to fish size and time of day (Mueller *et al*., 1994).

In order to understand the role that *L. analis* plays in the trophic food web of the Abrolhos Bank, the present study examined the diet and feeding ecology of specimens obtained through a fish monitoring program. Emphasis was placed on the assessment of seasonal and ontogenetic shifts on feeding habits. This dietary information is critical for modeling trophic pathways and assessing the implications of predator removal from a system (Farmer & Wilson, 2010), and combined with fisheries data, information on predator/prey abundance and consumption rates of predators can be used to assess the magnitude of trophic fluxes.

Material and Methods

This study was carried out in the Abrolhos Bank, Bahia State, which includes a wide portion (42,000 km^2) of the continental shelf, with depth rarely exceeding 30 m and a shelf edge at about 70 m depth (16º40'-19º40'S; 39º10'-37º 20'W) (Fig. 1). The region comprises the largest and richest coral reefs in the South Atlantic, as well as an extensive mosaic of algal bottoms, mangrove forests, beaches, and vegetated sandbanks (Leão, 1999; Leão & Kikuchi, 2005). About 270 species of reef and shore fishes occur at the Abrolhos Bank (Moura & Francini-Filho, 2006). Despite its importance, with nearly 10.000 artisanal fishermen operating in the area, the region's reef fisheries are still poorly known and were not included in Frédou *et al*. (2006) revision of Northeastern Brazil reef fisheries.

Specimens of *L. analis* were obtained through a fish landing monitoring program that target fleets on hand line, longline and spear fishing in the Cities of Nova Viçosa, Caravelas, Alcobaça, and Prado (Fig. 1) between June 2005 and March 2007, together with the communities where they landed the craft caught. Morphometric data and weight were recorded to the nearest centimeter and decigrams respectively. Stomach were removed and immediately fixed in 10% formalin solution for 24 h and subsequently transferred and stored in 70% alcohol.

Stomach contents were examined in the laboratory using a stereomicroscope. The identification of food items was performed as refined as possible according to literature data (Melo, 1996; Amaral *et al*., 2005) and consultation with experts. The frequency of occurrence (*i.e*., percentage of stomachs in which a food item occurs considering all stomachs examined) and the proportion by volume (*i.e*., percentage participation of each item in the total food) of a given food item were determined (Hyslop, 1980; Bowen, 1996).

For temporal analysis, the seasons were defined as follow: winter (June - August), spring (September - November), summer (December - February), and autumn (March - May).

For ontogenic diet shift, individuals were divided into seven size classes according to the total length (TL cm) in: Class 1 =18.1-26.0; Class 2 = 26.1-34.0; Class 3 = 34.1-42.0; Class 4 = 42.1-50.0; Class 5 = 50.1-58.0; Class 6 = 58.1-66.0, and Class 7 = 66.1-74.0 cm, defined following the sturges formulation (Silva & Souza, 1987). Juvenile (<34.0 cm TL), sub-adult (34.1-50.0 cm TL), and adult (>50.1cm TL) stages were also used to assess ontogenetic diet changes. Stages classification was performed using the study carried out by Freitas *et al*. (2011), which indicate that the L_{50} of *L. analis* in the Abrolhos Bank occurs at around 38.0 to 40.0 cm TL, close to the results registered for the Cuban shelf (García-Cagide *et al*., 2001; Sierra *et al*., 2001; Claro & Lindeman, 2004).

Differences in prey consumption using quantitative data (volume prey) among seasons and sizes classes were tested with cluster based on Bray-Curtis similarities and hierarchical agglomerative group-average clustering was constructed with the PRIMER program (ver. 6.0, Plymouth Marine Laboratory, Plymouth, England). Data was investigated using analysis of similarity (ANOSIM) and similarity percentage (SIMPER) methods.

A Non-metric Multi-Dimensional Scaling (NMDS) ordination was performed in order to better visualize the similarities between seasons and size classes. Samples in the NMDS plot were grouped according to the results of the cluster analysis using the single linkage method (Clarke & Warnick, 2001). An analysis of similarity percentages (SIMPER) considering the different food items was conducted to examine potential differences in the diet. This latter method helps in determining which food item is responsible for differences recorded.

Results

A total of 85 stomachs of *Lutjanus analis* were analyzed. The food items were grouped into four main categories: Gastropoda, Stomatopoda, Decapoda, and Fish. The category that showed the greatest diversity (*i.e*. Crustacea) was further refined to Stomatopoda, Decapoda Dendrobranchiata (shrimps), and Decapoda Brachyura (crabs and soft crab) (Table 1).

Crustaceans, particularly Decapods, were by far the most common and representative food item recorded, followed by Fish. Decapoda Brachyura (crabs and soft-crabs), had a great abundance in the analysis and was represented by five families. Gastropods were represented only by Fissurellacea. Stomatopods could not be identified to more refined taxonomic categories due to the high degree of digestion. Only one family (Sergestoidea) of Dendrobranchiata Decapoda (shrimps) was recorded. Fishes most commonly recorded were, in decreasing order: Anguilliformes, Perciformes, and Gobiesociformes.

The NMDS ordination and similarity analysis (ANOSIM) showed no significant differences between the seasons of the year in the diet of the species (Global R = 0.056, P=10.6%). On the other hand, the composition of the diet between the classes of length (ontogenic) showed significant differences (Global R = 0.308, P = 2.7%) (Fig. 2). Considering the main life stages (juvenile, sub-adult, and adult), some food items were determinant for the resulting ordination, such as Decapoda (Fig. 3) and Fish (Fig. 4).

The SIMPER analysis showed that the most of dissimilarities among size classes was produced by the food items: Decapoda remains, Dendobranchiata, Portunidae, Fish, and Xanthidae (Table 2). In class 1, Decapoda remains

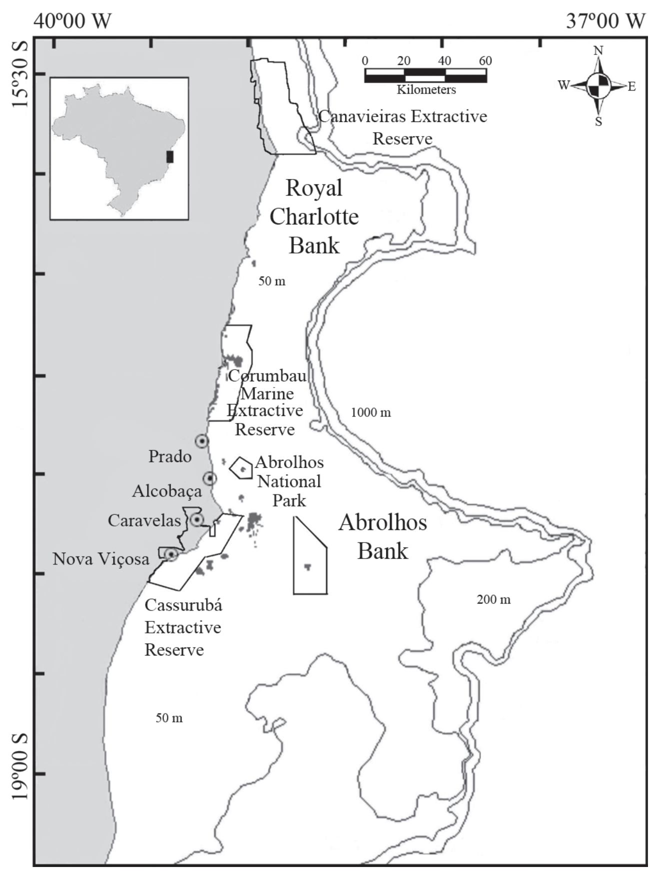

Fig. 1. Map of the study region showing the Abrolhos Bank coral reefs, Eastern Brazil, as well as the marine protected areas and shallow (<50 m) coral reefs.

Table 1. Diet composition showing frequency of occurrence (% FO) and relative volume (V%) of the food items consumed by *Lutjanus analis* from Abrolhos Bank coral reefs, Eastern Brazil, between June 2005 and March 2007.

FOOD ITEMS	%FO	%V
MOLLUSCA		
Gastropoda - Fissurellacea	0.93	0.28
CRUSTACEAN		
Total	65.42	50.53
Stomatopoda	7.47	2.96
Decapoda		
Total - Decapoda	64.48	47.57
Decapoda - Dendrobranchiata (Sergestoidea) - “shrimps”	10.28	1.03
Decapoda - Brachyura - “Crabs and soft crabs”		2.11
Calappidae (*Callapa angusta*)	0.93	1.58
Majidae (*Microphrys* sp.)	1.86	0.37
Majidae (*Mithraculus forceps*)	2.80	1.13
Portunidae (*Callinectes* sp.)	11.21	3.36
Portunidae (*Cronius ruber*)	1.86	0.85
Portunidae (*Scylla serrata*)	0.93	0.28
Xanthidae (*Eurypanopeus abbreviatus*)	2.80	0.37
Xanthidae (*Hexapanopeus schmitti*)	1.86	0.23
Xanthidae (*Hexapanopeus* sp.)	2.80	1.50
Xanthidae (*Panopeus* sp.)	1.86	0.56
Xanthidae (*Tetraxanthus rathbunae*)	2.80	0.42
Goneplacidae (*Eucratopsis crassimanus*)	0.93	1.41
Goneplacidae (Rhizopinae)	0.93	0.06
Decapoda remains	53.27	32.32
TELEOSTEI		
Total	21.49	49.19
Perciformes		
Labrisomidae (*Malacoctenus* sp.)	0.93	0.28
Serranidae (*Epinephelus* sp.)	0.93	0.56
Gobiidae	0.93	0.11
Monacanthidae (*Stephanolepis* sp.)	0.93	0.28
Gobiesociformes		
Gobiesocidae	0.93	1.69
Anguilliformes		
Ophichthydae (*Ophichthus parilis*)	4.67	19.70
Fish remains	14.01	26.55

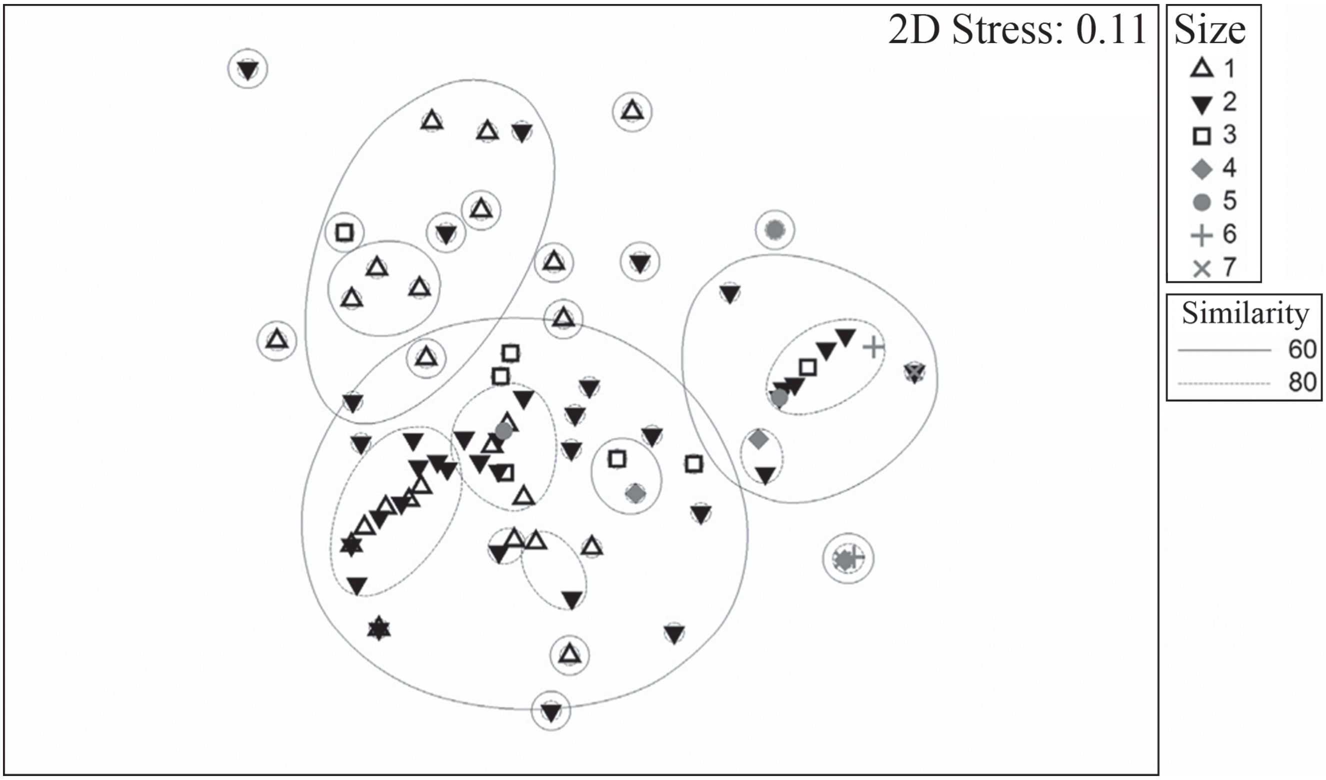

Fig. 2. Ordination resulting from Non-metric Multi-dimensional Scaling analyses (NMDS) with cluster overlay (volume prey) among sizes classes of *Lutjanus analis* from Abrolhos Bank coral reefs, Eastern Brazil, between June 2005 and March 2007.

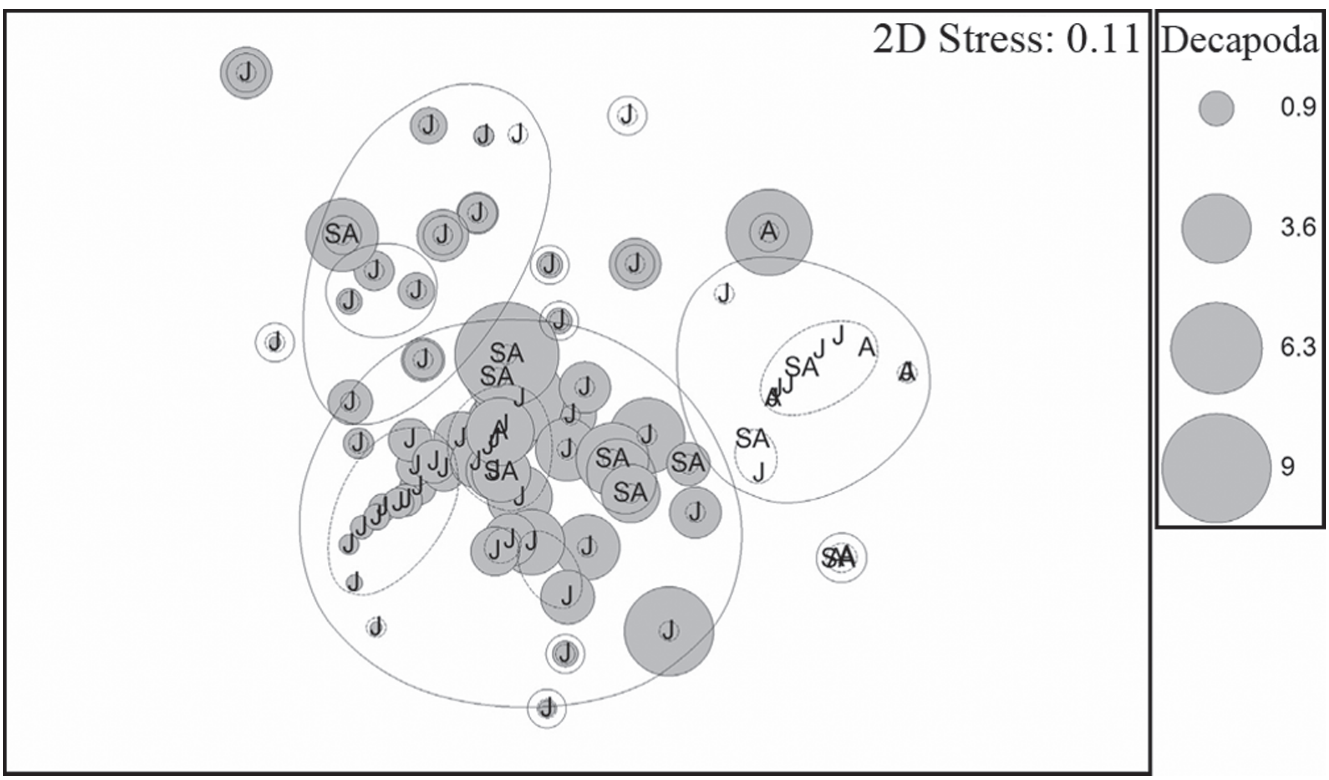

Fig. 3. Contribution of the food item Decapoda to *Lutjanus analis* diet, from Abrolhos Bank coral reefs, Eastern Brazil, between June 2005 and March 2007. The larger the bubble, the greater the percent participation of volume. J = juveniles; SA = sub-adults; A = adults.

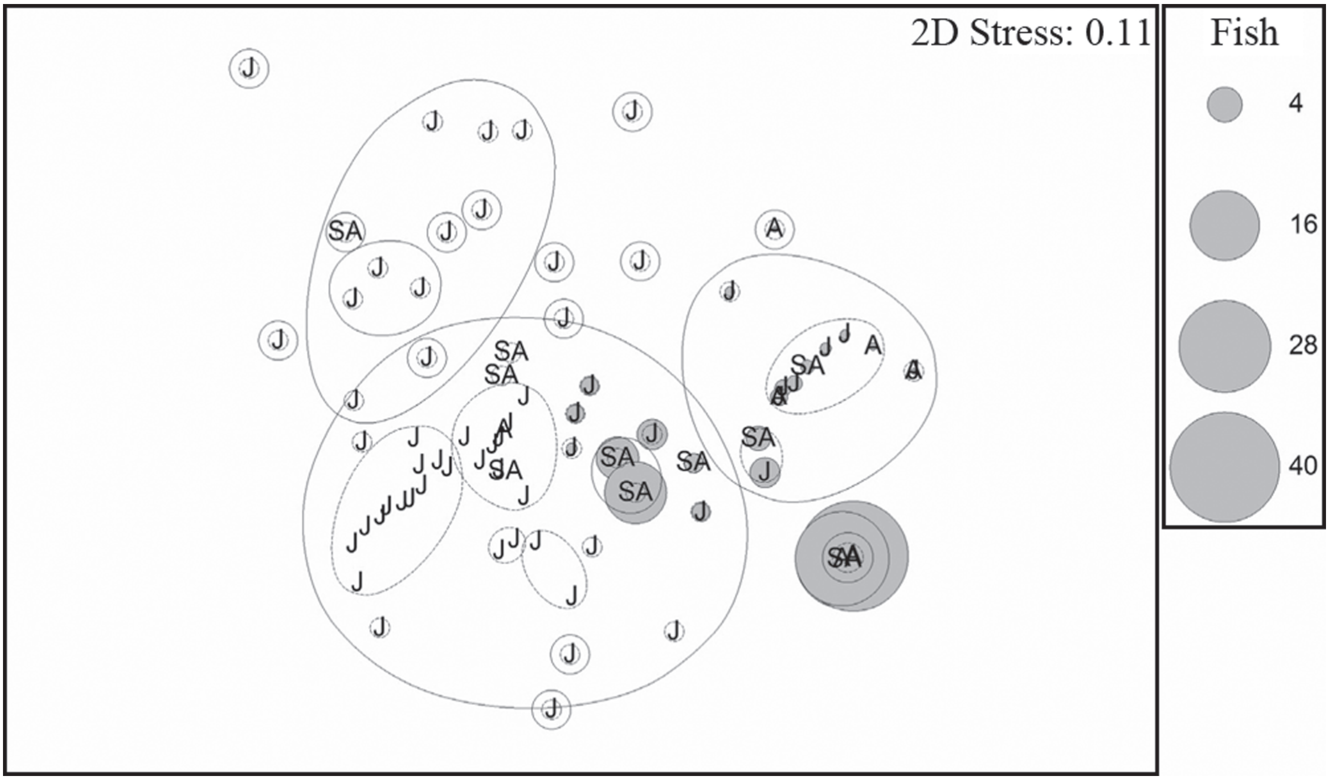

Fig. 4. Contribution of the food item Fish to the *Lutjanus analis* diet, from Abrolhos Bank coral reefs, Eastern Brazil, between June 2005 and March 2007. The larger the bubble, the greater the percent participation of volume. J = juveniles; SA = sub-adults; A = adults.

contributed with 64.73%, followed by Dendobranchiata and Portunidae (18.93% and 7.85%, respectively). In Class 2, Decapods remains was also the most representative food item (70.78%) followed by Fish (19.60%). In Class 3, besides Decapoda remains (66.34%) were also important Fish (19.43%) and Xanthidae (6.03%). In classes 4, 5, 6, and 7 Fish was the predominant food, corresponding to 100% of the diet.

Discussion

Decapod crustaceans and Fish were the most important food items in the carnivorous diet of *L. analis* in the Abrolhos Bank. Several studies have already reported the importance of these food items for *L. analis* (Randall, 1967; Claro, 1981; Guevara *et al*., 1994; Sierra & Popova, 1997; Duarte & Garcia, 1999; Sierra *et al*., 2001; Claro & Lindeman, 2004; Pimentel & Joyeux, 2010), and also for other congeners as *L. synagris* (Linnaeus, 1758) (Duarte & Garcia, 1999; Pimentel & Joyeux, 2010), *L. campechanus* (Poey, 1860) (Lee & Szedlmayer, 2004), *L. guttatus* (Steindachner, 1869) (Rojas *et al*., 2004; Rojas-Herrera *et al*., 2004), *L. peru* (Nichols & Murphy, 1922) (Santamaría-Miranda *et al*., 2003), *L. argentiventris* (Peters, 1869), and *L. colorado* Jordan & Gilbert, 1882 (Molina *et al*., 2005).

The diet based mostly on pelagic crustaceans (specially Decapod) and Fish may reflect the prey availability and abundance in the environment (Wootton, 1990; Moyle & Cech, 1996; Claro & Lindeman, 2004), or are related with the Lutjanidae ability to exploit it (Claro, 1981; Heck & Weinstein, 1989; Duarte & Garcia, 1999; Claro & Lindeman, 2004; Rojas *et al*., 2004; Molina *et al*., 2005). For *L. analis* we believe that this ability can be related to morphological changes during the ontogenetic development (*e.g*. mouth gap), affecting prey size selectivity, a result already recorded for *L. apodus* (Roocker, 1995). In the other hand, it is important to consider that juveniles and adults of *L. analis* display different foraging styles, where small individuals displayed proportionally higher picking and midwater strikes during morning and evening, whereas individuals large winnowed proportionally more often than small or medium fish during evening (Mueller *et al*., 1994).

Despite the fact that Monteiro *et al*. (2009) and Pimentel & Joyeux (2010) suggested temporal changes in the diet composition of snappers in the Brazilian coast, we did not observe seasonal variation for *L. analis*. We believe that this variation is related with the local changes in prey availability (Randal, 1967). In fact, Monteiro *et al*. (2009) and Pimentel & Joyeux (2010) worked in mangrove environments, which are often subjected to more acute environmental changes than are reef faunas (Sierra *et al*., 2001).

Considering size-classes analyses, food items consumption showed important variations: juveniles consumed preferentially crustaceans, sub-adults showed a diversified diet, and adults feed basically on fish. Even though

Table 2. SIMPER analysis of similarity between classes of length of the *Lutjanus analis*, captured in the Abrolhos Bank coral reefs, Eastern Brazil, between June 2005 and March 2007. (Crust, Den, Por, Xan, corresponds respectively to Crustacea remains, Dendrobranchiata, Portunidae, and Xanthidae).

Classes	Average abundance					Average	Contribuition
	Crust	Den	Por	Fish	Xan	similariy	cumulative (%)
1 (N = 27)	0.58	0.17	0.29			17.02	91.50
2 (N = 39)	0.76			0.35		17.25	90.38
3 (N = 7)	2.29			1.11	0.23	16.64	91.80
4 (N = 3)				15.40		29.79	100
5 (N = 3)				0.37		1.00	100
6 (N = 2)				20.10		1.00	100
7 (N = 4)				14.65		0.68	100

few stomachs of larger individuals were analyzed, similar feeding pattern was also observed for *L. analis* in the West Indies (Randall, 1967), in the Caribbean coast of Panama (Heck & Weinstein, 1989) in the Cuban platform (Claro, 1981; Sierra *et al*., 2001) and Southeastern Brazil (Pimentel & Joyeux, 2010). This adaptation probably aims to reduce the competition for food or meet physiological needs that the fish may have during its ontogenetic development in terms of migration, sexual maturation and/or reproduction (Braga & Braga, 1987; Gerking, 1994; Sierra *et al*., 2001).

On the other hand, ontogenetic shifts in the diet can also occur when juveniles and adults occupy different regions (Zavala-Camin, 1996; Bertoncini *et al*., 2003; Machado *et al*., 2008). Allen (1985), Lindeman *et al*. (1998), and Claro & Lindeman (2004) have noted two basic types of habitat selection for snappers: the juveniles of some species are usually found on shallow estuaries, while adults inhabit bays, estuaries, and reef environments of shelf waters. Starck (1970), for example, observed changes in diet of juveniles and adults of *Lutjanus griseus* (Linnaeus, 1758) related with the migration from estuarine areas to deeper waters. Our data generally agree with this statement, because juveniles and sub-adults of *L. analis* occur in estuarine and marine coastal environments (Randall, 1967; Allen, 1985; Claro & Lindeman, 2004; Pimentel & Joyeux, 2010), while adults inhabit hard substrates in offshore waters and reef environments (Cocheret de la Morinière *et al*., 2003; Frédou & Ferreira, 2005).

According to our data, this mesopredator plays an important role on the trophic ecology of the Abrolhos Bank coral reefs, because it is an important reef predator with a wide range of food resources. Despite classified as vulnerable in the IUCN red list of endangered species (Huntsman, 1996), *L. analis* is a commercially important species in the Brazilian Northeastern coast, and previous stock assessments in the study region (Klippel *et al*., 2005) indicated that it is moderately overfished. Impacts of chronic overfishing are evident in population depletions worldwide, and the removal of predatory fishes is also likely to have significant indirect effects on marine ecosystems (Farmer & Wilson, 2010), influencing a range of ecological processes (Babcock *et al*., 1999; Pinnegar *et al*., 2000; Willis & Anderson, 2003).

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