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Feeding Ecology of Juvenile Dog Snapper *Lutjanus jocu* (Bloch and Shneider, 1801) (Lutjanidae) in Intertidal Mangrove Creeks in Curuçá Estuary (Northern Brazil)

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ABSTRACT

The diet and feeding ecology of juvenile dog snapper (Lutjanus jocu) *were investigated in 92 specimens collected in four intertidal mangrove creeks of Curuçá estuary, Northern Brazil, between September 2003 and July 2004. No significant differences in total length were found between the sampling months. Feeding intensity was high as indicated by high stomach fullness index and low vacuity index. The most important prey was Penaeidae, followed by Grapsidae and Porcellanidae. The diet of juvenile dog snapper showed clear seasonal differences. Specimens from dry season (September and November) and dry / wet season transition (January), were specialists feeding exclusively on Penaeidae. However, the specimens from wet season (March and May) and wet /dry season transition (July) that consumed mainly Grapsidae, Penaeidae and Porcellanidae were generalist. These seasonal changes in diet could be related to variations in food availability.*

Key words: estuary; feeding habits; feeding strategy; juvenile fish; *Lutjanus jocu*; intertidal mangrove creek

INTRODUCTION

Mangroves are widely considered to be an important habitat for fishes, including juveniles of commercially important species (e.g. Morton, 1990; Laegdsgaard and Johnson, 1995; Giarrizzo and Krumme, 2008, 2009). This habitat is thought to provide excellent shelter against predators due to water turbidity, the structural complexity of these biotopes (Parrish, 1989; Robertson and Blaber, 1992), as well as provide high food availability for the high productivity of the mangroves and the associated epi and benthic fauna (Odum and Heald, 1972; Laegdsgaard and Johnson, 2001).

The Lutjanidae family comprises medium to large sized demersal predacious fishes which inhabiting mangroves and seagrass beds during their juvenile and sub-adult stages and when adults, they migrate to rocky or coral reefs to take up permanent residence there (Druzhinin, 1970; Cervigón, 1993; Cocheret et al., 2003).

The snappers have high market values and are commercially exploited in the tropical and subtropical coastal waters (e.g. Serrano-Pinto and Caraveo-Patiño, 1999; Luckhurst et al., 2000;

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Sheaves and Molony, 2001; Kiso and Mahyam, 2003; Miranda et al., 2003; Kamukuru and Mgaya, 2004; Rezende and Ferreira, 2004; Rojas et al., 2004).

The dog snapper, *Lutjanus jocu*, is one of the Lutjanidae species targeted by artisanal, small and medium scale fisheries in the Brazilian coastal waters (Rezende et al., 2003). Its distribution extends along the western Atlantic Ocean, from Massachusetts (USA) to the southern Brazilian coast, including Gulf of Mexico and Caribbean Sea (Froese and Pauly, 2006). In spite of its relative abundance and importance to fisheries, few information on biology and ecology of this species are available. In order to understand the role that *L. jocu* plays in the trophic food web, the present study examined the feeding ecology of the juvenile dog snapper in the intertidal mangrove creeks of Curuçá estuary. Emphasis was placed on the assessment of season-related feeding habits, as well as feeding strategy.

MATERIAL AND METHODS

Study area

Sampling was carried out in four intertidal mangrove creeks located in the estuary of the Curuçá River near the city of Curuçá (0° 10´S, 47° 50´W), Pará, Northern Brazil, approximately 160 km north-east of the state capital Belém (Fig. 1). The estuary is a well preserved environment and has been designated by the Ministry of the Environment as a conservation unit (“Reserva Extrativista”). The climate is hot and humid with mean annual rainfall of 2,526 mm (ANA, 2005; n = 16 years, range: 1,085 – 3,647 mm). Salinity changes according to the season, being low during the rainy season, in the first half of the year and attaining values of marine water during the dry season (Giarrizzo and Krumme, 2007). Tides in the region are characterized by a semi-diurnal pattern with tidal range between 4 and 5 m.

Fish sampling

Bimonthly samples of *L. jocu* were obtained using a fyke net in four creeks from September 2003 to July 2004 on four consecutive days, yielding a total of 24 samples. The net was composed by two wings (20 m long, 6 m deep, with 20 mm stretch-mesh) and a hoop-net (with 13 mm stretch-mesh). The fyke net was set at the mouth of the creeks at daytime slack high water (HW) in the waxing of the moon (neap tide). During ebb tide, the fish were collected until total drainage of the creek and kept on ice.

Laboratory analysis

Each fish examined was measured to the nearest 0.1 cm of total length (TL) and weighed to the nearest <0.11 g of wet body weight (WT). Gonadal stages were recorded according to Vazzoler (1996) and stomach contents were dissected out. The relative contribution of the number of empty stomachs was recorded (vacuity index). Stomach contents were identified to the lowest possible taxon (Figueiredo and Menezes, 1978; Menezes and Figueiredo, 1980; 1985; Cervigón et al., 1992; Melo, 1996; 1999). Prey items were counted and weighed to the nearest 0.0001 g after removing the surface water by blotting on tissue paper.

Diet analysis

The feeding activity of fish was evaluated by fullness index (%FI):

$$\%FI = (Wcont / WT) \times 100$$

Where Wcont is the weight of stomach contents calculated from the difference between the weights of pre-washed and washed empty stomachs.

For the qualitative and quantitative analysis of dietary composition were used:

- Frequency of occurrence (F): represents the number of stomachs in which a food item was found, expressed as the percentage of total number of non-empty stomachs.
- Percentage numerical abundance (N): considers the number of individuals in each food category expressed as a percentage of the total individuals in all food categories.
- Percentage gravimetric composition (W) represents the total wet weight of a food category expressed as a percentage of the overall weight of stomach contents.

The main food items were identified using the index of relative importance (IRI) of Pinkas et al. (1971), as modified by Hacunda (1981):

$$IRI = F \times (N + W)$$

This index has been expressed as:

$$\%IRI = (IRI / \Sigma\ IRI) \times 100$$

To assess the feeding strategy along the annual cycle studied, the modified Costello (1990) graphical method (Amundsen et al., 1996) was used. In this method, the prey-specific abundance (%Pi) (y – axis) was plotted against the frequency of occurrence (F) (x - axis). The prey-specific abundance (P_i) has been expressed as:

$$\%P_i = (\sum S_i / \sum S_{ti}) \times 100$$

Where S_i is the number of prey i and S_{ti} is the total number of prey in the stomachs containing prey i.

To assess the bimonthly changes in diet breadth of *L. jocu* we used the Levins' standardized index (B_i) (Hurlbert, 1978; Krebs, 1989):

$$B_i = (1/n - 1) \times (1/\sum_j P^2_{ij} -1)$$

where B_i is the Levins' standardized index for predator i; P_{ij} is proportion of diet of predator i that is made up of prey j, and n is number of prey categories.

This index ranges from 0 to 1; low values indicate the diets dominated by few prey items (specialist predators), high values indicate the generalist diets (Krebs, 1989).

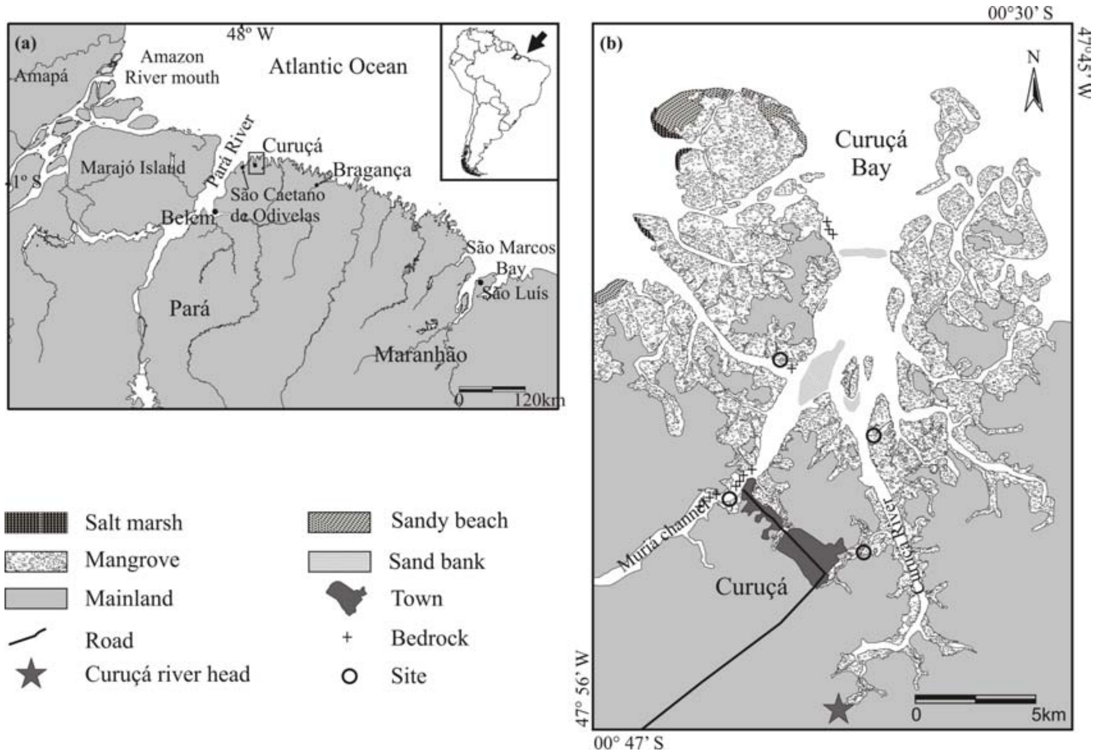

Figure 1 - (a) Coast of the states Pará and Maranhão, north Brazil; (b) location of the Curuçá estuary on the southern edge of the Pará River mouth.

Statistical analysis

The bimonthly variation of TL and %FI were tested using a one-way analysis of variance (ANOVA) (Underwood, 1997). ANOVA assumptions of normality (Kolmogorov-Smirnov test) and homoscedasticity (Bartlett's test) were previously tested. In all the tests, $p < 0.05$ was used for rejecting the null hypothesis.

The data matrix of bimonthly %IRI values of family diet components were square root transformed (Platell and Potter, 2001) and the similarity was calculated using Bry-Curtis similarity (Marshall and Elliott, 1997). A hierarchical agglomerative cluster analysis (using complete linkage) was performed to describe the similarity in feeding habitat among the months.

RESULTS

Sample characterization

A total of 92 individuals of *L. jocu* were captured between September 2003 and July 2004. Catch was highest in July (n = 27) and lowest in March (n = 4). The dog snapper ranged in size from 8.4 to 31.0 cm TL, with a mean value (± SD) of 16.5 cm (± 4.5). Total length did not change significantly over the months (ANOVA: $F = 1.53$, $p > 0.05$),

though mean TL value in March (21.5 ± 2.2 cm) was higher than May value (15.2 ± 5.1 cm).
All the catches were represented only by juveniles.

Feeding activity

Of the 92 stomachs analyzed, 4 (4.3%) were empty. The fullness index (%FI) ranged from 0 to 6% with a mean value (± SD) of 3% (± 1.6%). The values of %FI were not influenced by months sampled (ANOVA, F = 1.31, p > 0.05). However, lowest and highest values occurred in July (2.0 ± 1.7%) and May (3.5 ± 1.8%), respectively.

Overall composition of the diet

A total of 732 prey belonging to 44 taxa were identified, with a average number of prey per stomach of 8.3. Identification to species level was possible in several cases, due to the limited stage of digestion of prey. Frequency of occurrence, percentage of numerical abundance, gravimetric composition and index of relative importance values of different groups, genera and species of prey organisms found in the stomachs are shown in Table 1. Penaeidae and Grapsidae were present in highest abundance (N: 37.8% and 17.8%, respectively) and also had the highest frequency of occurrence (F: 61.4% and 60.2%, respectively) in the dog snapper stomachs. In spite of the numerous Penaeidae ingested, they only represented 15.2% of percentage gravimetric composition. Grapsidae and Porcellanidae dominated in biomass (W: 22.1% and 16.2%, respectively). According to percentage of index of relative importance (%IRI), the most important prey was Penaeidae (36.5%), followed by Grapsidae (27.0%) and Porcellanidae (21.4%).

Table 1 - Frequency of occurrence (F), numerical abundance (N), gravimetric composition (W) and Index of Relative Importance (IRI) of the stomach contents of 88 juvenile dog snapper collected bimonthly between September 2003 and July 2004 in four macrotidal creeks of the Curuçá estuary. Abbreviations for major categories of food items are shown in brackets.

Prey item	F	N	W	IRI%
CRUSTACEA				
Decapoda				
Alpheidae [Alp]	15.9	2.3	8.6	3.1
Alpheus sp.	15.9	2.3	8.6	3.1
Diogenidae [Dio]	1.1	0.1	0.1	<0.1
Clibanarius sp.	1.1	0.1	0.1	<0.1
Goneplacidae [Gon]	6.8	1.0	0.8	0.1
Nanoplax xanthiformis	6.8	1.0	0.9	0.3
Grapsidae [Gra]	60.2	17.9	22.1	27.0
Aratus pisonii	10.2	1.8	1.5	0.6
Goniopsis cruentata	14.8	4.0	3.8	2.0
Pachygrapsus gracilis	45.5	11.1	16.5	22.0
Grapsidae n.i.	4.5	1.0	0.3	0.1
Ocypodidae [Ocy]	22.7	3.0	1.6	1.2
Uca cumulanta	11.4	1.4	1.0	0.5
Uca mordax	1.1	0.1	<0.1	<0.1
Uca rapax	4.5	0.8	0.2	0.1
Uca n.i.	5.7	0.7	0.4	0.1
Palaemonidae [Pal]	8.0	1.6	2.8	0.4
Macrobrachium amazonicum	1.1	0.1	0.3	<0.1
Macrobrachium surinamicum	5.7	1.4	1.5	0.3
Macrobrachium n.i.	1.1	0.1	1.0	<0.1
Penaeidae [Pen]	61.4	37.8	15.2	36.5
Farfantepenaeus subtilis	19.3	13.9	8.6	7.7
Litopenaeus schmitti	6.8	2.3	2.3	0.5
Penaeidae n.i.	45.5	21.6	4.3	20.7
Porcellanidae [Por]	60.2	15.4	16.2	21.4
Petrolisthes armatus	60.2	15.4	16.2	33.6
Portunidae [Port]	38.6	8.6	9.2	7.7

(Cont. ...)

(Cont. Table 1)

Prey item	F	N	W	IRI%
Callinectes bocourti	18.2	4.4	5.4	3.1
Callinectes danae	3.4	1.0	0.5	0.1
Callinectes n.i	17.0	3.1	3.2	1.9
Portunus rufiremus	1.1	0.1	<0.1	<0.1
Xanthidae [Xan]	22.7	4.4	4.0	2.1
Eurytium limosum	17.0	3.0	3.5	2.0
Pilumnus quoyi	2.3	0.3	0.1	<0.1
Xanthidae n.i.	5.7	1.1	0.3	0.1
Isopoda				
Sphaeromidae [Sph]	5.7	1.4	<0.1	0.1
MOLLUSCA				
Gastropoda				
Nassaridae [Nas]	2.3	0.3	0.4	<0.1
Nassarius n.i.	2.3	0.3	0.4	<0.1
TELEOSTEI				
Batrachoidiformes				
Batrachoididae [Bat]	1.1	0.1	0.4	<0.1
Thalassophryne nattereri	1.1	0.1	0.4	<0.1
Clupeiformes				
Engraulidae [Eng]	9.1	2.5	3.5	0.6
Anchovia clupeoides	2.3	1.0	2.6	0.1
Engraulidae n.i.	6.8	1.5	0.9	0.3
Cyprinodontiformes				
Poecilidae [Poe]	2.3	0.4	0.9	<0.1
Poecilia vivipara	2.3	0.4	0.9	0.1
Perciformes				
Carangidae [Car]	2.3	0.3	2.9	0.1
Oligoplites saurus	2.3	0.3	2.9	0.1
Gobiidae [Gob]	6.8	1.4	6.5	<0.1
Ctenobius smaragdus	1.1	0.1	0.8	<0.1
Gobionellus oceanicus	2.3	0.3	4.2	0.2
Gobionellus sp.	1.1	0.1	0.1	<0.1
Gobiidae n.i.	4.5	0.8	1.3	0.2
Haemulidae [Hae]	2.3	0.3	0.9	<0.1
Genyatremus luteus	2.3	0.3	0.9	<0.1
Sciaenidae [Sci]	1.1	0.1	0.2	<0.1
Cynoscion n.i.	1.1	0.1	0.2	<0.1
Pleuronectiformes				
Paralichthyidae [Par]	1.1	0.1	0.8	<0.1
Citharichthys spilopterus	1.1	0.1	0.8	<0.1
Siluriformes				
Ariidae [Ari]	3.4	0.8	3.0	0.1
Cathorops sp.	2.3	0.5	2.9	0.1
Ariidae n.i.	1.1	0.3	0.1	<0.1
Unidentified vegetal material [Veg]	1.1	0.1	<0.1	<0.1

Temporal variation of the diet and feeding strategy

Cluster analysis carried out on IRI data differentiated two groups at a similarity of 55% (Fig. 2a). The first group (A) was composed of specimens from dry season (September and November) and dry / wet season transition (January), with their diet dominated by Penaeidae (Fig. 2b). The second (group B) contained specimens from the wet season (March and May) and wet / dry season transition (July) that consumed mainly Grapsidae, Penaeidae and Porcellanidae (Fig. 2b).

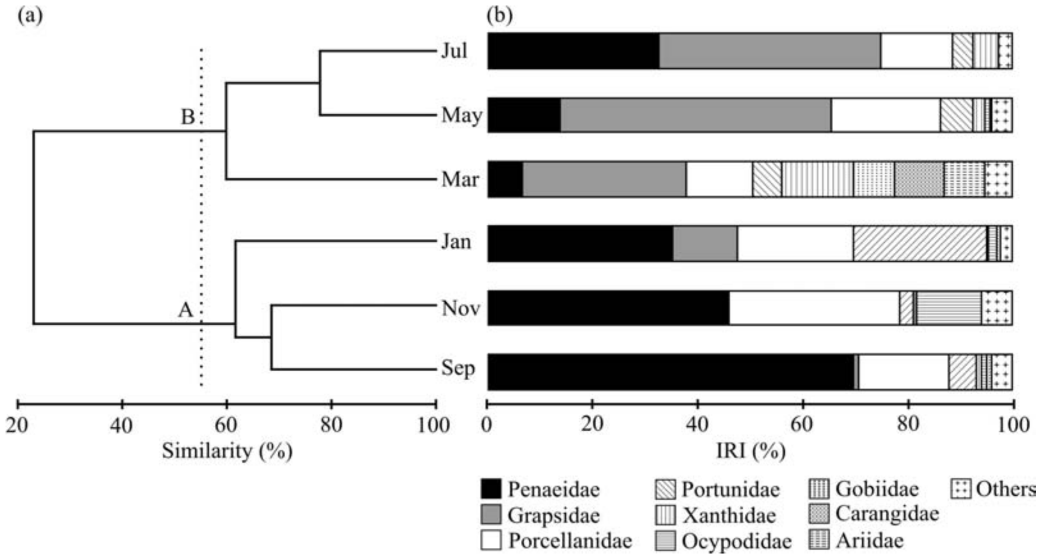

Figure 2 - (a) Dendrogram of cluster analysis of similarity in feeding habitat among the months of *L. jocu* collected between September 2003 and July 2004 in four macrotidal mangrove creeks in the Curuçá estuary (north Brazil). (b) Percent of the index of relative importance (%IRI) of main prey items.

The interpretation of the diagrams of the modified Costello graphical method (Amundsen et al., 1996) is shown in Figure 3a. The plot of prey-specific abundance (%Pi) and frequency of occurrence (F) of the main components of the diet between September 2003 and July 2004, showed a strong specialization towards Penaeidae to have been eaten by more than half the individuals (F = 61%) and to have high contribution in specific abundance (Pi = 54%) (Fig. 3b). However, some teleost prey (e.g. Sciaenidae, Poecilidae, Haemulidae, Ariidae and Carangidae) presented a low F and a low P_i (lower left quadrant), displaying evidence of a generalist strategy.

The independent analysis of feeding strategy between the temporal groups identified by cluster analysis showed for the group A, a similar tendency to that observed in the total population being Penaeidae the dominant prey component (P_i = 62% e F = 80%) (Fig. 3c). The dog snappers of group B (March, May and July) presented most prey with lower contribution in abundance, indicating a generalized feeding strategy (Fig. 3d). The most representative prey families were Grapsidae (P_i = 31% and F = 83%), Penaeidae (P_i = 42% and F = 55%) and Porcellanidae (P_i = 23% and F =58%).

The Levins' standardized index (B_i) was lower in September (B_i = 0.1) and November (B_i = 0.2) indicating a selective diet and narrow niche width (Fig. 4). A higher value of B_i recorded in March (B_i = 0.7) showed a wide trophic niche. Similar patterns were found in the interpretation of the diagrams of the modified Costello graphical method for each month (no shown).

DISCUSSION

Population characteristics

The small size of *L. jocu* specimens caught in intertidal mangrove creeks of Curuçá estuary supported the hypothesis that the mangroves are a nursery ground habitat for juveniles and sub-adults snapper species (Sheaves, 1995; Nagelkerken et al., 2000; Cocheret de la Moriniére et al., 2003). The highest abundances of dog snapper in dry season suggested that the salinity variations and the hydrodynamic regime established by the seasonal changes in freshwater runoff, have been important control factors in the use of mangrove habitat by this species.

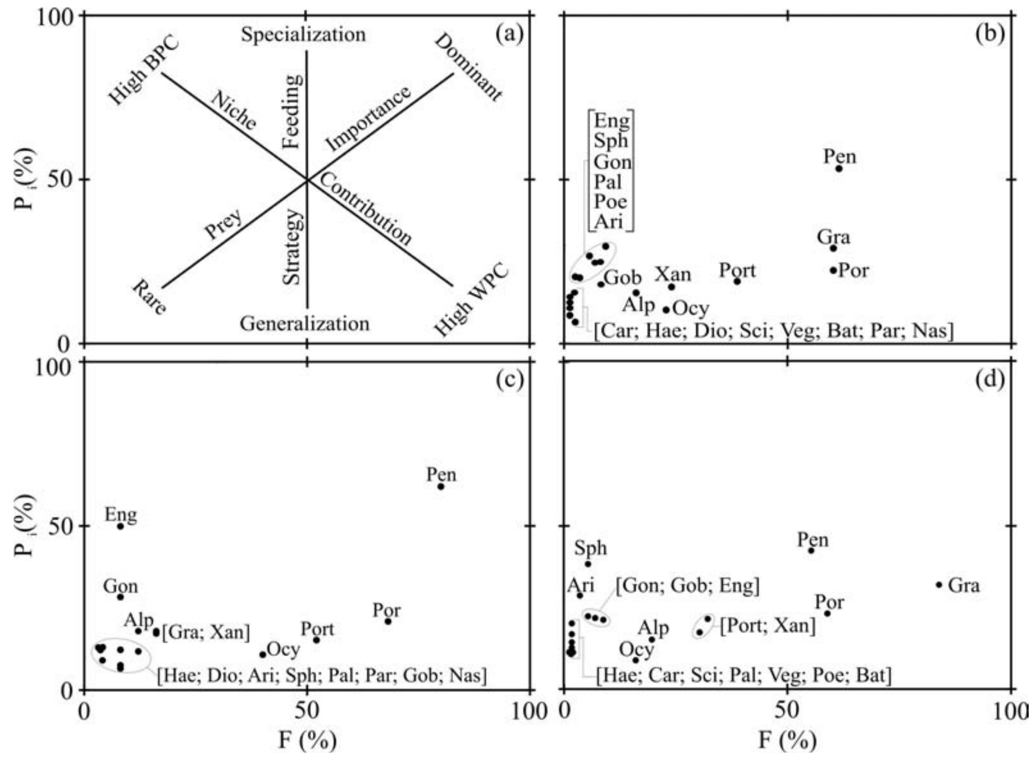

Figure 3 - (a) Explanatory diagram of the modified Costello method (F: frequency of occurrence; P_i: prey-specific abundance; BPC: between-phenotype component; WPC: within phenotype component). (b)Variation of feeding strategy of *L. jocu* analysed for all months; (c) cluster group A; (d) cluster group B. Refer to Table 1 for abbreviations of major food categories.

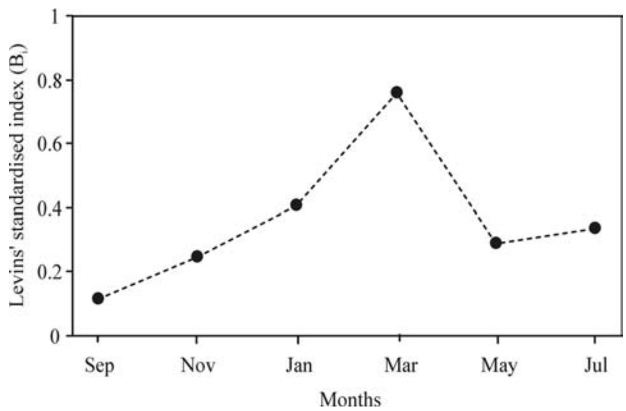

Figure 4 - Bimonthly values of Levins' standardised index (B_i) for *L. jocu* collected between September 2003 and July 2004 in four macrotidal mangrove creeks in the Curuçá estuary (north Brazil).

Feeding activity

Juvenile dog snapper showed a feeding activity similar to other estuarine fishes (Krumme et al., 2005; Giarrizzo and Saint-Paul, 2008). The high %FI and the limited stage of digestion of prey indicated that the feeding activity started at high tide. The low vacuity index and the no significant changes in %FI during the year emphasized the importance of the intertidal zone as a feeding ground for dog snapper.

Diet

Several studies have been carried out on the dietary habits of snappers (e.g. Hiatt and Strasburg, 1960; Guevara et al., 1994; Rooker, 1995; Kiso and Mahyam, 2003; Kamukuru and Mgaya, 2004; Szedlmayer and Lee, 2004). These studies suggested that Lutjanidae species were demersal predacious fishes with a broad diet dominated by crabs, shrimps, stomatopods, fish and other motile invertebrates.

According to the obtained data, the diet of *L. jocu* included a wide range of prey taxa related to the high diversity and abundance of food sources in the intertidal mangrove habitat. Similar results were reported for *L. johnii* (Bloch, 1792) in the Matang mangrove estuary (Malaysia) by Kiso and Mahyam (2003) and for *L. campechanus* (Poey, 1860) in Gulf of Mexico (USA) by Szedlmayer and Lee (2004).

According to Kamukuru and Mgaya (2004), while the range of prey consumed by *L. jocu* was large, comparatively few prey items dominated the diet. In this study, the analysis of stomach contents showed that the most frequent and dominant item was Penaeidae. In terms of biomass, the Grapsidae crabs presented a significant contribution in diet given the higher body mass. Our data are in agreement with the finding of Stark (1971) where juveniles of *L. griseus* (Linnaeus, 1758) from Florida, displayed a diet dominated by crustacea mainly crabs and shrimps (Penaeidae).

According to the %IRI values, Penaeidae, Grapsidae and Porcellanidae were the most important prey families of the juvenile dog snapper diet. Similar findings were reported for congeneric species such as the sub-adult of *L. fulviflama* (Forsskal, 1775) from Tanzânia showing a diet dominated by crustacea, with shrimps accounting for 40% of %IRI (Kamukuru and Mgaya, 2004).

During the sampling period, clear changes were observed in the diet composition of *L. jocu*. Dog snapper, reflected in the dried months a specialist diet, mainly consuming Penaeidae shirmps, and in the wetted months a generalist diet displaying a widening of the trophic spectrum consuming Grapsidae, Porcellanidae, Portunidae, Penaeidae and Xanthidae. Nevertheless, the occurrence of several prey items with lower contribution in abundance indicated that *L. jocu* was also an opportunistic predator. A possible cause for the observed intra-annual difference in diet of the juvenile dog snapper can be related to the distribution, abundance and availability of prey in each season (Guevara et al., 1994, Rooker, 1995, Sierra and Popova, 1997).

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RESUMO

A dieta e a ecologia alimentar de juvenis de *Lutjanus jocu* foram verificadas em 92 espécimes coletados em quatro canais de maré do estuário do rio Curuçá, Norte do Brasil, entre setembro de 2003 e julho de 2004. O comprimento total dos peixes coletados não apresentou diferenças significativas entre os meses amostrados. A intensidade alimentar foi elevada conforme indicado pelos altos valores do índice de repleção estomacal e os baixos valores do índice de vacuidade. A presa mais importante foi Penaeidae, seguida por Grapsidae e Porcellanidae. A dieta de juvenis de *L. jocu* apresentou diferenças sazonais evidentes. Os espécimes da estação seca (setembro e novembro) e transição seca/chuvosa (janeiro) foram considerados especialistas alimentando-se exclusivamente de Penaeidae. No entanto, os espécimes da estação chuvosa (março e maio) e da transição chuvosa/seca (julho), que alimentaram-se principalmente de Grapsidae, Penaeidae e Porcellanidae, foram considerados generalistas. Esta mudança sazonal na dieta poderia estar relacionada com a disponibilidade do alimento.

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