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Feeding ecology of monkfish *Lophius gastrophysus* in the south-western Atlantic Ocean

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The diet of the monkfish Lophius gastrophysus *is described based on the analysis of stomach contents, for the south-western Atlantic from samples landed in the fishing port of Niteroi, Rio de Janeiro state, Brazil, from April 2004 to March 2006. Feeding intensity, measured as the presence or absence of contents in stomachs, and differences in the items' composition were analysed by sex, size-class and season. High feeding intensity predominated for females >32 cm and for males <31 cm. There was no seasonal pattern in the occurrence of full or empty stomachs. The most important category in the diet was fish with 25 identified species.* Dactylopterus volitans *showed the highest alimentary index value, mainly because of the feeding of juvenile monkfish. The second most important category was Mollusca, represented mainly by squid. No relationships between predator- and prey-lengths and weights were observed; but there was a tendency to consume light and small prey independently of the size of the monkfish.*

Keywords: *Lophius*, stomach content, diet, temporal variation, size-classes variation, predator–prey relationship, Brazil

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INTRODUCTION

The monkfish *Lophius gastrophysus* occurs in the western Atlantic Ocean from North Carolina, USA, to Argentina (Figueiredo *et al*., 2002). It is the only species of *Lophius* off the Brazilian coast, where it is known as 'tamboril' or 'toad-fish'. Recently the species became the principal target of the fishing fleet that operates in depths of more than 200 m off the south-eastern and southern Brazilian coast (Perez & Wahrlich, 2005). It is much in demand because of its increasing value in the international fish market. The species is both a target of the deepwater gillnet fishery (Wahrlich *et al*., 2004) and a bycatch component of the shrimp-trawler fishery (Vianna & Almeida, 2005). Despite its economic importance and the increasingly intense fishing pressure (Perez *et al*., 2005), biological data on this species are sparse and urgently needed.

The family Lophiidae is known for the presence of the illicium, the modified first ray of the dorsal fin, which has on its distal end an esca, a pendulous fleshy structure similar to a bait. This feature, together with a flat, deep body, benthic habit, large mouth, and small recurved teeth, suggest that these fish use an ambush strategy to attract and capture prey. The Lophiidae embraces four genera and 25 species (Caruso, 1983), of which *Lophius* is the most important genus because of the commercial value of its seven species. The lophiid predator habit, suggested by the anatomical lure device, has been confirmed by analysis of stomach contents (e.g. Crozier, 1985). *Lophius gastrophysus* was classified as a piscivore and benthic feeder in studies on feeding relationships of demersal fish off south-eastern and southern Brazil (Soares *et al*., 1993; Muto *et al*., 2005).

The aim of the present study was to contribute to knowledge of the feeding ecology of this species, using fish obtained from commercial trawlers that operate off the coast of Rio de Janeiro. We analysed the feeding intensity, diet composition, and its variation among size-classes and during periods of three months. The prey items and the relationships between predator–prey length and weight were investigated.

MATERIALS AND METHODS

From April 2004, over a period of two years, 22 samples of *L. gastrophysus*, totalling 454 individual fish, were obtained consistently from the same commercial trawlers in the fishing port of Niteroi, Rio de Janeiro state. Total length (L_T-cm) and total weight (W_T-g) of each specimen were recorded. Each fish was dissected to identify the sex, the intestine length was measured, in cm, and the stomach was removed and fixed in 10% formalin. Prey items were identified to the lowest taxonomic level whenever possible. Whole prey items were measured and weighed; the others were only weighed. Items such as sciaenids otoliths were considered evidence of Sciaenidae prey; vertebrae and bones were considered as digested fish.

To evaluate ontogenetic variation in feeding activity, the frequency of stomachs containing some contents (%F) and empty stomachs (%E) among the length-classes for males (<31; 32–36; 37–47; >48 cm) and females (<31; 32–49; 50–67; >68 cm) were computed. Length-groups were established based on the length at first maturity of males and

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females (Valentim, unpublished). Males over 37 cm (L_T) and females over 50 cm (L_T) were considered adults; when the sexes were grouped, adults had an L_T over 43 cm. To evaluate temporal variation in feeding activity, (%F) and (%E) were compared among periods of months. For both cases, the χ^2 non-parametric test (Zar, 1996) was performed at the 95% significance level ($\alpha = 0.05$). The intestinal quotient (IQ) was calculated dividing the intestine length and fish total length. Values of IQ were determined for each size-class combining both sexes (<31; 32–42; 43–49; 50–64; >65 cm) and tested using a one-way analysis of variance (F; $P < 0.05$).

The food items found in the mouth cavity and/or oesophagus were not considered in the diet analysis, following Crozier (1985) and Laurenson & Priede (2005). Frequency of occurrence and percentage weight as given by Hyslop (1980) were applied to characterize the diet. They were combined in the alimentary index (IAi) proposed by Kawakami & Vazzoler (1980). The IAi was modified to percentage weight (%W) instead of percentage volume (%V), according to the equation: $(\text{IAi}) = (\%\text{FO} \times \%\text{W})/\Sigma\ (\%\text{FO} \times \%\text{W}) \times 100$, where %FO is the percentage frequency of occurrence of the food item, and %W is the percentage weight of the feeding item. Similarity analyses using the Bray–Curtis index were performed relating the IAi percentage of the food items to both the size-classes (for both sexes together) and to the fish capture months. The values obtained were entered in a similarity matrix for cluster analysis, using the Past Statistics Program (Hammer *et al.*, 2003) with a 0 to 1.0 variation. Length and weight of prey related to predator were evaluated using linear regression analyses (Zar, 1996).

RESULTS

The total lengths of the individual fish ranged from 8.9 to 76.0 cm (mean ± SD $L_T = 48.2 \pm 13.2$ cm). Of 454 stomachs analysed, 61.5% (279) contained some prey items ('full stomachs') and 209 were females (52.9 ± 12.4 cm) and 70 were males (37.0 ± 10.7 cm). The rate of full stomachs (F) differed significantly in males below 31 cm, in females over 32 cm and in the total analysed sample (Table 1). Empty stomachs (E) were recorded during the entire sampling period. The lowest rate of empty stomachs was recorded in the quarter January–February–March, 2005 (Table 2), with significant difference ($\chi 2 = 11.92$; $P < 0.05$).

We identified 40 food items, grouped into four categories: fish, Mollusca, Crustacea and others. Fish was the principal category in the diet (IAi = 91.5%), followed by Mollusca (IAi = 7.7%), Crustacea (IAi = 0.5%) and others (IAi = 0.3%) (Table 3). In the fish category, the digested fish item predominated both in occurrence and in weight (20.4%), reaching the highest IAi value (56.3%). Among the 25 identified species distributed in 20 families, *Dactylopterus volitans* (flying gurnard) showed the highest IAi rate. The most important families in respect to frequency of occurrence were Dactylopteridae (11.2%), followed by Carangidae (6.2%) and Paralichthyidae (4.2%). In weight, the most important was Sciaenidae (15.1%), followed by Dactylopteridae (10.8%) and Merlucciidae (7.7%). The other fish showed IAi values down to 1.1%. In the Mollusca category, squids were present in 10.2% of the stomachs, with a high IAi value (IAi = 7.7%). The categories Crustacea and others, such as starfish, sponges, and cnidarians showed IAi values down to 0.3% (Table 3).

Table 2. Proportion of full stomachs (%F) and empty stomachs (%E) of *Lophius gastrophysus*, per period of three months. Numerical frequency in parentheses; χ2 test; * indicates significant difference ($P < 0.05$).

Quarterly	%F	%E	χ2
Apr–May–Jun-04	68.1 (47)	31.9 (22)	9.06*
Jul–Aug–Sep-04	39.4 (37)	60.6 (57)	4.26*
Oct–Nov–Dec-04	73.0 (27)	27.0 (10)	7.81*
Jan–Feb–Mar-05	78.4 (29)	21.6 (8)	11.92*
Apr–May–Jun-05	70.0 (21)	30.0 (9)	4.80*
Jul–Aug–Sep-05	55.3 (21)	44.7 (17)	0.42
Oct–Nov–Dec-05	47.5 (29)	52.5 (32)	0.15
Jan–Feb–Mar-06	77.3 (68)	22.7 (20)	26.18*
Total	61.5 (279)	38.5 (175)	23.82*

The diet composition in the different length-classes of *L. gastrophysus* is shown in Table 4. In the fish category, *D. volitans*. *Merluccius hubbsi*, *Raneya fluminensis*, *Trachurus lathami* and the digested fish were the main items and occurred in all size-classes. Paralichthyids were observed in all size-classes, despite the small percentage of occurrence and weight. *Dactylopterus volitans* showed the largest percentage in juveniles (<31 and 32–42 cm). The Mollusca category was the second most important, being present in all size-classes (Table 4).

Cluster analysis of diet composition related to length (Figure 1A) indicated two main groups, associated with <31 and 32–42 cm and with 43–53 and 54–64 cm plus >65 cm. Considering that length at first maturity for both sexes combined was about 42 cm, the first two size-groups obtained in the dendrogram (<31 and 32–42 cm) corresponded to juveniles, and the larger fish, in the other size-group, to adults. The similarity was high, among juvenile and adult groups.

Table 1. Proportion of full stomachs (%F) and empty stomachs (%E) of *Lophius gastrophysus* per total length-class. Numerical frequency in parentheses; χ2 test; * indicates significant difference ($P < 0.05$).

Males				Females			
L_T-cm	%F	%E	χ2	L_T-cm	%F	%E	χ2
<31 (J)	69.4 (25)	30.6 (11)	5.44*	<31 (J)	51.7 (15)	48.3 (14)	0.03
32–36 (J)	42.9 (3)	57.1 (4)	0.14	32-49 (J)	66.7 (46)	33.3 (23)	7.67*
37–47 (A)	50.0 (33)	50.0 (33)	–	50-67 (A)	67.5 (135)	32.5 (65)	24.50*
>48 (A)	29.0 (9)	71.0 (22)	5.45*	>68 (A)	81.3 (13)	18.7 (3)	6.25*
Total	50.0 (70)	50.0 (70)	–	Total	66.6 (209)	33.4 (105)	34.45*

J, juveniles; A, adults

Table 3. Frequency of occurrence (%FO), percentage weight (%W) and alimentary index (%IAi) of items in the diet of *Lophius gastrophysus*. N, numerical frequency.

Order	Family	Species	%FO	%W	%IAi
Anguilliformes			3.13	1.76	0.62
	Ophichthidae	*Ophichthus* sp.			
Aulopiformes	Synodontidae	*Saurida caribbaea*	0.63	0.15	0.01
Batrachoidiformes	Batrachoididae	*Porichthys porosissimus*	1.25	2.32	0.32
		Thalassophryne montevidensis	0.42	0.23	0.01
Gadiformes	Merlucciidae	*Merluccius hubbsi*	4.17	7.83	3.65
Ophidiiformes	Ophiididae	*Raneya fluminensis*	3.13	3.03	1.06
Perciformes	Carangidae	*Trachurus lathami*	6.25	3.53	2.47
	Haemulidae	*Orthopristis ruber*	0.21	2.08	0.05
	Mullidae	*Mullus argentinae*	2.08	3.60	0.84
	Percophidae	*Bembrops heterurus*	1.67	0.77	0.14
		Percophis brasiliensis	0.63	2.66	0.19
	Pinguipedidae	*Pinguipes brasilianus*	0.21	0.26	0.01
	Sciaenidae		4.58	15.24	7.83
		Cynoscion sp.			
		Umbrina canosai			
	Serranidae	*Dules auriga*	2.92	1.75	0.57
	Sparidae	*Pagrus pagrus*	2.92	1.69	0.55
Pleuronectiformes	Paralichthyidae		4.12	3.35	1.56
		Etropus longimanus			
		Paralichthys isosceles			
		Paralichthys orbignyanus			
Rajiformes	Rajidae	*Rioraja agassizii*	0.21	0.08	0.00
Scorpaeniformes	Dactylopteridae	*Dactylopterus volitans*	11.25	10.87	13.71
	Scorpaenidae	*Scorpaena isthmensis*	0.21	0.07	0.00
	Triglidae	*Prionotus nudigula*	1.46	0.27	0.04
Syngnathiformes	Syngnathidae	*Hippocampus erectus*	0.21	0.03	0.00
Tetraodontiformes	Monacanthidae	*Stephanolepis hispidus*	2.08	3.08	0.72
Digested fish			24.38	20.06	56.27
Non-identified fish			2.92	2.70	0.88
Total of fish category (N = 578)			80.9	87.1	91.5
Archaeogastropoda	Fissurellidae	*Fissurellidea megatrema*	0.21	0.20	0.00
Neogastropoda	Buccinidae	*Metula anfractura*	0.21	0.01	0.00
Teuthida	Loliginidae		9.79	7.05	7.74
Total of Mollusca category (N = 75)			10.2	7.2	7.7
Decapoda			2.92	0.58	0.19
	Hippolytidae	*Exhippolysmata oplophoroides*			
	Penaeidae	*Metapenaeopsis* sp.			
	Scyllaridae	*Scyllarus ramosae*			
	Galatheidae	*Munida flinti*			
Stomatopoda	Hemisquillidae	*Hemisquilla braziliensis*	0.83	0.73	0.07
Brachyura	Portunidae	*Portunus spinicarpus*	2.71	0.79	0.24
Total of Crustacea category (N = 31)			6.4	2.1	0.5
Asteroidea	Astropctinidae	*Astropecten cingulatus*	0.21	0.04	0.00
		Coral of remains	1.04	0.05	0.01
		Sponge of remains	0.83	2.60	0.24
Platyasterida	Luidiidae	*Luidia* sp.	0.21	0.04	0.00
Total of others category (N = 11)			2.5	3.6	0.3

Variations in the predominance of consumed prey occurred. Anguilliformes, *D. volitans*, *Dules auriga*, *M. hubbsi*, Sciaenidae, *Stephanolepis hispidus* and *T. lathami* occurred in almost all samples in 2004; sciaenids reached the highest IAi value. In 2005, Paralichthyidae and *T. lathami* reached high IAi values (Table 5). The largest number of items occurred in 2004, but the feeding spectrum was more diverse in the quarter January–February–March, 2005. The second most consumed category was Mollusca; the squid item occurred in almost all the quarters of the year, mainly in summer and autumn of both years. Crustacea was not an important item in the diet, but decapods were the most consumed.

The cluster analysis of the IAi percentage of items consumed by *L. gastrophysus* in each quarterly sampling is shown in Figure 1B. The dendrogram showed two separate groups: 2005 samples and 2004 samples. Both groups had IAi values exceeding 27% for digested fish (Table 5). The highest similarity was observed between April–May–June, 2005 and July–August–September, 2005 (coefficient of about 0.7), as a consequence of high IAi values for digested

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Table 4. Frequency of occurrence (%FO), percentage weight (%W) and alimentary index (%IAi) per total length-class of items in the diet of *L. gastrophysus*. (Number of the samples containing prey in parentheses.)

Total length-classes (cm)	**<31**			**32–42**			**43–53**			**54–64**			**>65**		
Food items	**%FO**	**%W**	**%IAi**	**%FO**	**%W**	**%IAi**	**%FO**	**%W**	**%IAi**	**%FO**	**%W**	**%IAi**	**%FO**	**%W**	**%IAi**
Anguilliformes	3.5	2.6	0.6				4.8	2.7	1.4	3.1	1.8	0.7	2.5	0.9	0.2
Bembrops heterurus				4.6	5.2	2.0	0.8	0.4	0.04	2.1	0.6	0.1			
Dactylopterus volitans	24.6	33.0	50.4	16.9	29.9	43.5	10.3	11.7	12.9	7.8	8.9	8.3	2.5	1.4	0.3
Dules auriga				3.1	2.0	0.5	2.4	2.8	0.7	4.2	1.9	0.9	2.5	0.2	0.04
Hippocampus erectus							0.8	0.1	0.01						
Merluccius hubbsi	1.8	2.1	0.2	3.1	8.0	2.1	5.6	11.0	6.5	4.2	5.4	2.7	5.0	12.0	4.7
Mullus argentinae				1.5	2.1	0.3	2.4	3.7	0.9	2.6	3.8	1.2	2.5	4.4	0.9
Orthopristis ruber										0.5	4.2	0.3			
Pagrus pagrus	7.0	2.5	1.1	1.5	1.3	0.2	3.2	2.1	0.7	2.6	2.0	0.6			
Paralichthyidae	1.8	4.4	0.5	6.2	2.6	1.4	4.0	2.6	1.1	4.2	3.1	1.5	5.0	5.3	2.1
Digested fish	29.8	13.8	25.6	27.7	8.6	20.4	27.0	18.8	54.5	20.8	23.3	57.5	20.0	22.2	34.9
Non-identified fish							2.4	1.3	0.3	4.2	3.6	1.8	7.5	4.0	2.4
Percophis brasiliensis							2.4	11.3	2.9						
Pinguipes brasilianus							0.8	1.1	0.1						
Porichthys porosissimus							0.8	0.8	0.1	2.6	4.3	1.3			
Prionotus nudigula				1.5	0.2	0.03				3.1	0.5	0.2			
Raneya fluminensis	8.8	17.3	9.5	4.6	15.0	6.0	4.0	3.5	1.5	0.5	0.3	0.02	2.5	1.7	0.3
Rioraja agassizi				1.5	1.1	0.2									
Saurida caribbaea							0.8	0.2	0.02	0.5	0.1	0.01	2.5	0.2	0.04
Sciaenidae							2.4	8.4	2.2	6.3	15.1	11.2	17.5	36.5	50.1
Scorpaena isthmensis										0.5	0.1	0.01			
Stephanolepis hispidus				1.5	1.2	0.2	1.6	1.3	0.2	3.6	5.5	2.4			
Thalassophryne montevidensis										0.5	0.3	0.02	2.5	0.4	0.1
Trachurus lathami	10.5	10.7	7.0	6.2	4.0	2.1	7.1	6.2	4.7	4.7	2.2	1.2	5.0	1.8	0.7
Fissurellidea megatrema										0.5	0.4	0.02			
Loliginidae	7.0	11.1	4.9	13.8	17.6	20.9	9.5	8.7	8.8	9.9	5.6	6.6	7.5	3.1	1.8
Metula anfractura				1.5	0.1	0.01									
Decapods	1.8	1.1	0.1	3.1	1.0	0.3	3.2	0.3	0.1	3.6	0.8	0.3			
Hemisquilla braziliensis										1.6	0.4	0.1	2.5	3.2	0.6
Portunus spinicarpus	1.8	0.7	0.1				3.2	1.0	0.3	3.6	0.9	0.4	2.5	0.4	0.1
Astropecten cingulatus													2.5	0.3	0.0
Luidia sp.													2.5	0.3	0.1
Coral of remains	1.8	0.4	0.04	1.5	0.04	0.005	0.8	0.04	0.004	1.0	0.05	0.01			
Sponge of remains										1.0	4.7	0.6	5.0	1.7	0.7
Total number of preys	66(40)			87(45)			192(70)			300(88)			51(36)		

Table 5. Alimentary index (%) of items consumed by *Lophius gastrophysus*.

Quarterly	2004			2005			2006	
food items	AMJ	JAS	OND	JFM	AMJ	JAS	OND	JFM
Anguilliformes	0.41	3.08	1.46	1.16			0.61	0.002
Bembrops heterurus		0.10	0.09	0.11		0.09	6.34	
Dactylopterus volitans	7.76	0.15	3.60	0.05			10.80	71.45
Dules auriga	0.03	0.13	0.70	0.99			0.12	1.58
Hippocampus erectus								0.01
Merluccius hubbsi	5.28	2.84	6.40	0.07	7.74	8.10		0.68
Mullus argentinae	0.88	2.74		0.39	1.60	5.26		0.05
Orthopristis ruber				2.36				
Pagrus pagrus	0.21	0.37		0.24		0.46		2.18
Paralichthyidae	0.90	2.74		0.27	8.82	0.92	2.59	0.48
Digested fish	43.24	30.54	27.21	48.0	55.82	79.06	61.23	15.99
Non-identified fish	0.01	1.28	0.09	2.46	17.45	0.12		
Percophis brasiliensis		3.35		0.91			0.27	
Pinguipes brasilianus	0.12							
Porichthys porosissimus	0.12	10.08		0.67				
Prionotus nudigula	0.18		0.10			0.33	0.05	
Raneya fluminensis	2.74	13.41			0.31	0.22	2.30	
Rioraja agassizi								0.02
Saurida caribbaea	0.01					0.16		0.01
Sciaenidae	36.09	16.56	26.15	0.04		0.38		0.70
Scorpaena isthmensis								0.02
Stephanolepis hispidus	0.11	4.25	13.10	0.20				
Thalassophryne montevidensis			0.25		0.15			
Trachurus lathami	0.27	2.11	1.62	0.16	7.01	4.31	10.75	0.58
Fissurellidea megatrema		0.37						
Loliginidae	1.19	0.72	17.85	37.89	0.71	0.00	1.75	6.13
Metula anfractura	0.00							
Decapods	0.11	0.69		0.05	0.30		2.93	
Hemisquilla braziliensis				2.37				0.01
Portunus spinicarpus	0.32	0.55		0.33	0.08	0.60		0.10
Astropecten cingulatus				0.05				
Luidia sp.				0.05				
Coral of remains			0.08				0.25	
Sponge of remains		3.94	1.28	0.12				
Total number of preys	128	70	76	73	49	44	55	**201**
Total number of samples containing prey	47	37	27	29	21	21	29	68

AMJ, April–May–June; JAS, July–August–September; OND, October–November–December; JFM, January–February–March

fish and *M. hubbsi*. In general, the diet of *L. gastrophysus* was quite similar among the quarterly samples, promoted by the constant presence of fish items. The feeding habit with a tendency to piscivory was evident in all length-classes and throughout the two-year sampling period, varying only in the relative importance of the different items in the diet. The IQ was significantly different among the five length-classes ($F = 9.54$; $P < 0.05$; $N = 443$) (Figure 2).

The linear regression analysis showed no correlation between total lengths of predator and prey items ($N = 342$; $r = 0.13$; $P = 0.001$), or the total weights of predator and prey items ($N = 497$; $r = 0.22$; $P = 0.000001$). On the other hand, the dispersion graphs in Figure 3 show that, regardless of its size, *L. gastrophysus* consumed mainly prey items of small size and low weight.

DISCUSSION

The sample size of *Lophius gastrophysus* was larger than that taken on the inner continental shelf by Soares *et al.* (1993), but similar to the sample size reported by Muto *et al.* (2005) on the outer continental shelf and upper slope. These are the areas exploited by commercial trawlers based in the state of Rio de Janeiro, from which the samples analysed in the present study were obtained. The proportion of empty stomachs was similar to that recorded by Olaso *et al.* (1982) and Crozier (1985) for congeneric species. The high proportion of empty stomachs among individuals of *L. gastrophysus* can be explained by their exclusively fish-based diet. According to Nikolsky (1978), the high nutritional value of this kind of diet reduces the need to ingest food continuously. On the other hand, Zavala-Camin (1996) noted that a large number of empty stomachs might result from regurgitation of stomach contents, providing misleading information about the population behaviour. We have no records of the frequency of regurgitation in *L. gastrophysus* taken by the commercial trawlers that constituted our sample, but some stomachs were flaccid (5%), enlarged and filled with liquid. Crozier (1985) suggested that, despite the lack of studies on the subject in *Lophius piscatorius*, the degree of digestion and the high rate of remains of non-identified fish indicate that the digestive

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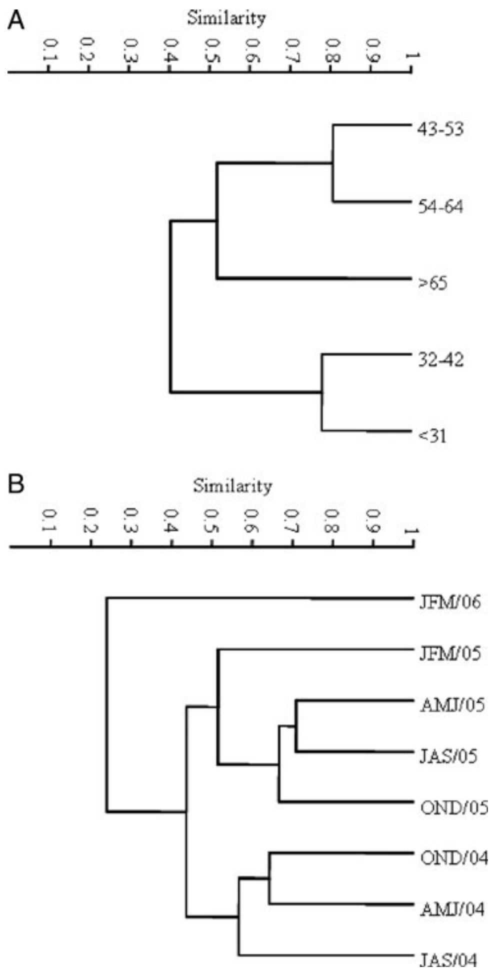

Fig. 1. Dendrogram based on the Bray–Curtis similarity index among (A) length-classes (by cm), and (B) among quarterly samples, based on the alimentary index (%) of items consumed by *Lophius gastrophysus*. JFM, January–February–March; AMJ, April–May–June; JAS, July–August–September; OND, October–November–December.

process is slow. The same may hold true for *L. gastrophysus*, although some regurgitation may occasionally occur.

The possibility of incidental digestion of prey by fish caught in trawls poses a problem for the evaluation of their diet. Laurenson & Priede (2005) observed that prey were ingested during the tow in *L. piscatorius*, in addition to the stomach contents. The same was observed during our study, and these prey items were not considered in the diet analysis.

Lophius gastrophysus is essentially piscivorous, with a wide spectrum of prey, as previously demonstrated in other studies (Soares *et al.*, 1983; Muto *et al.*, 2005). Armstrong *et al.* (1996), Laurenson *et al.* (2004) and Preciado *et al.* (2006) classified different species of *Lophius* as opportunists that take both benthic and pelagic prey, and even seabirds (Bigelow & Schroeder, 1953). Based on this criterion, the presence of pelagic, benthopelagic and demersal prey in the stomachs of *L. gastrophysus* allows it to be classified similarly, although demersal prey predominate.

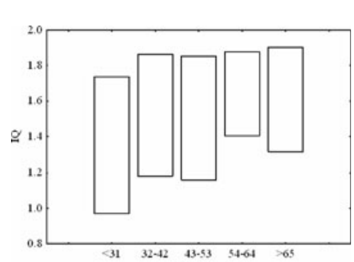

Fig. 2. Intestinal quotient (IQ) values of *Lophius gastrophysus* per length-class; bars indicate standard deviation (N, sample size).

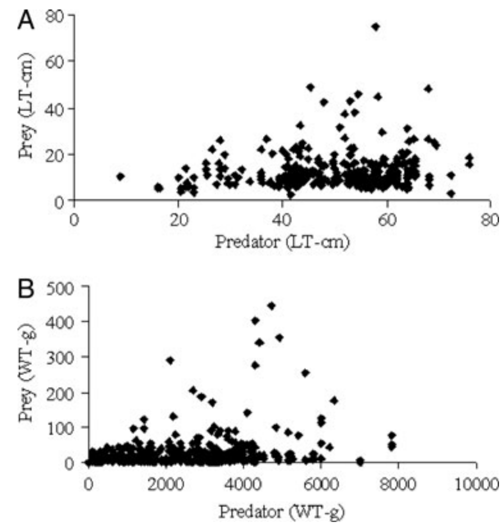

Fig. 3. Relationship between (A) total lengths of *Lophius gastrophysus* and total lengths of prey items consumed and (B) between total weights of *L. gastrophysus* and total weights of prey items consumed.

The stomach contents might reflect the spatial and temporal availability and abundance of the prey, as fisheries were carried out in similar areas and depths in both years. Muto *et al.* (2005) reported that in *L. gastrophysus* from south–south-eastern Brazil, *Merluccius hubbsi* and squid predominated in the stomach contents. Both of these resources are abundant in that area (Haimovici *et al.*, 2002). Squid were also the second most important resource. However, among the items of the fish category, *Dactylopterus volitans* was the most important. The predominance of *D. volitans* in the stomach contents of juveniles of *L. gastrophysus* probably reflects the distribution of predators in shallower areas near the shore. Figueiredo & Menezes (1978) and Soares *et al.* (1993) characterized *D. volitans* as a coastal benthic species that mainly eats crustaceans, molluscs and small benthic fish. It is recognized by commercial trawler fishermen as an indicator species of the presence of pink shrimp (*Farfantepenaeus* spp.). The life habit of *D. volitans* and the bathymetric stratification of *L. gastrophysus*, with smaller and immature individuals in shallower areas and larger and adult individuals in deeper areas (Perez *et al.*, 2002), explains the importance of this prey in the diet of juveniles of *L. gastrophysus*. A similar bathymetric stratification was observed by Laurenson *et al.* (2005) for *Lophius piscatorius*, with juveniles occurring in coastal areas and swimming to deeper waters as they grow. In *L. gastrophysus*, the juveniles consumed smaller quantities and variety of prey than did the adults, in contrast to the behaviour of *L. piscatorius* (Laurenson & Priede, 2005) and *Lophius americanus* (Armstrong *et al.*, 1996; Scharf *et al.*, 2000). The higher prey diversity in the diet of adults, however, might be a bias caused by the different sampling size. The prey-capture strategy of *Lophius* involves, besides attracting the prey by wiggling the illicium, a large and quite protractile mouth combined with a strong bone structure and a developed musculature, which forms an efficient suction mechanism (Paxton & Eschmeyer, 1998). Through the extreme expansion of the mouth and the gill cavity, the rapid opening of the mouth easily sucks in the prey (Paxton & Eschmeyer, 1998). Thus, the smaller size of the mouth of juveniles and, consequently, the amplitude of the oral cavity might explain the pattern observed. In fact, in *L. americanus*, the mouth opening increases about four times as fast as the fish grows (Scharf *et al*., 2000). On the other hand, it is noticeable that *L. gastrophysus*, despite capturing a larger variety and quantity of prey when adult, takes mainly small prey in spite of its large mouth.

The similarity among size-classes indicated gradual changes in diet composition during the growth of *L. gastrophysus*. Crozier (1985) recorded the same pattern for *L. piscatorius*, and the importance of a crustacean (*Nephrops*) for the latter fish led him to suggest that lophiids may be the principal predator of this commercial fishing resource of Northern Ireland. However, the presence of *D. volitans* in stomachs of juveniles of *L. gastrophysus* and their capture by commercial trawlers indicates that this shrimp fishery may be having an impact on *L. gastrophysus* juveniles.

In fish, the dietary composition may vary seasonally because of alterations in food availability caused by changes in habitats available for forage, changes due to biological patterns of organisms and changes caused by feeding activity of the fish themselves (Wooton, 1990). The diet of *L. gastrophysus* showed some seasonal changes, as evidenced by the clustering of the same periods in both sampling years. Squid, for example, were more intensively consumed during summer. Some climatic differences occurred in the Equatorial Pacific Ocean during the two years of the study (www.cptec.inpe.br), which may have been reflected in fish communities of the Atlantic (Sánchez *et al*., 2000).

In the relationship between feeding habit and digestive tract morphology of fish, carnivores tend to have shorter intestines compared to herbivores (Zavala-Camin, 1996). The low values of the IQ of *L. gastrophysus* confirm its carnivorous habit with a tendency to piscivory. Zavala-Camin (1996) noted that fish which keep the same diet show a decrease in IQ as they grow, because daily consumption is relatively smaller in larger-sized individuals. In *L. gastrophysus* the length of the intestine did not follow the growth of the fish, despite the fact that both juveniles and adults are fish eaters.

In general, the size of the prey has a direct relationship with the size of the predator (Gerking, 1994); however, for *L. gastrophysus*, the linear regression between the predator length and the lengths of the prey items indicated only a slight correlation. Small, light prey tended to be consumed independently of the size of the predator, suggesting that *L. gastrophysus* shows low selectivity for prey. Thus, it consumes any prey of handling size and/or weight that it can attract, as observed by Crozier (1985) for *L. piscatorius*. Therefore, considering that *L. piscatorius* juveniles and adults feed in the same area, intra-specific competition may occur. However, competition among different sized individuals in *L. gastrophysus* would be minimized by the dietary segregation observed between juveniles and adults.

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