Diel feeding pattern and diet of rough scad *Trachurus lathami* Nichols, 1920 (Carangidae) from the Southwestern Atlantic

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Diel changes in feeding activity and dietary composition of the rough scad *Trachurus lathami* were investigated through the analysis of stomach contents of 307 fish sampled over a 24-h period on the continental shelf off Ubatuba (23º 35´S 45ºW). Stomach contents were analyzed by frequency of occurrence (O%), percent number (N%), percent mass (M%), and feeding index (FI% = O% * M%). Rough scad fed on mollusks (Gastropoda, Crepidula sp.), crustacean (Ostracoda, Copepoda, decapod larvae), chaetognat and teleostean fish. The main items were calanoid copepods (*Eucalanus* sp*.* and *Centropages* sp*.*). According to the analysis of the stomach fullness and prey digestion, *T. lathami* is both a diurnal and nocturnal feeder, showing some seasonal variation in feeding time. According to the Chronobiology concept, it was raised the hypothesis of circadian rhythm in feeding of this fish, probably synchronized by light/dark cycle.

O estudo da dieta e do padrão diário e sazonal de atividade alimentar do chicharro *Trachurus lathami* foi realizado através de análises dos conteúdos estomacais de 307 peixes amostrados em estações fixas de coleta de 24 horas na plataforma continental ao largo de Ubatuba (23º 35´S 45ºW). Os conteúdos estomacais foram analisados através da freqüência numérica (N%), massa porcentual (M%) e freqüência de ocorrência (O%) dos itens alimentares, e índice alimentar (O% * M%). A espécie caracterizou-se por ingerir principalmente copépodes calanóides (ex. *Eucalanus* sp*.* e *Centropages* sp.), além de outros crustáceos (Ostracoda, larva de decápodes), moluscos (Gastropoda: *Crepidula* sp.), quetognatos e peixes teleósteos. De acordo com o grau de repleção estomacal e grau de digestão das presas, *T. lathami* ingeriu alimento tanto na fase clara quanto na fase escura do dia, apresentando variação sazonal no horário de tomada de alimento. De acordo com os conceitos da Cronobiologia foi levantada a hipótese de ritmo circadiano na atividade alimentar, provavelmente sincronizado pelo ciclo claro/escuro.

Key words: Food Habits, Feeding Ecology, Stomach Contents, Rhythms, Southeast Brazil.

Introduction

The critical and limiting resources for all animals are food and time. Food provides energy and nutrients for reproduction, and to develop, maintain, and protect the somatic body. Time is necessary for foraging, as well as for other activities, such as resting and reproduction (Wootton, 1990). According to chronobiologists, the majority of organisms present a circadian rhythm in their activities and this organization is the result of an evolutionary process that expresses a synchronicity among geophysical, environmental and biological events (Marques & Menna-Barreto, 2003). Among marine, estuarine, and freshwater fishes, there are several records of feeding activity with circadian rhythm (see Neilson & Perry, 1990; Boujard & Leatherland, 1992, Sánchez-Vázquez *et al*., 1997, Gerkema *et al*., 2000).

Studies on diel feeding in the natural environment are basic tools to understand the autoecology of fish species. And studies on diet composition may contribute to clarify prey-predator relationships, and to elaborate trophic models for the assessment of stocks (Christensen & Pauly, 1992).

Most species of *Trachurus* are widely distributed in both temperate and tropical coastal waters. Fifteen species are recognized (Suda *et al*., 1995). Only *Trachurus lathami* Nichols 1920 occurs in the south-western Atlantic from the Gulf of Maine (United States of America) down to the north of Argentina. It is a demersal-pelagic species, with maximum size about 40 cm of length and 0.5 kg of mass (Menezes & Figueiredo, 1980), occurring in waters from 50 to 100m in depth, at temperatures between 15º and 17º C and salinity between 35.5 and 35.8 (Saccardo & Katsuragawa, 1995; Mello *et al*., 1992).

Trachurus lathami is an abundant species on the southeastern Brazilian coast and represents a potential fishing resource (Saccardo & Katsuragawa, 1995).

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Considering that there are few studies on diet composition of *T. lathami* (Pedreira, 1997; Crispino, 1995) and there are no studies about diel feeding of this species, we proposed to identify its pattern of daily feeding activity, and to describe the variation of its diet composition during the course of the day.

Study area. The study site is located on the continental shelf of the coastal system off Ubatuba (23°35'S, 45°00'W), Brazil, southwestern Atlantic (Fig. 1).

Different water masses are present in this area during summer and winter. During summer, there is a two-layer vertical stratification due to the seasonal thermocline: the upper layer consists of warmer and less saline Coastal Water – CW (T=22-24°C; S=35-35.4) and the lower of colder South Atlantic Central Water – SACW (T=14-15°C; S=35.6-35.8). During the winter, only Coastal Water is present on the inner shelf (Castro & Miranda, 1998).

Materials and Methods

Sampling. Rough scad were sampled during the periods 22-24 July 1988 and 4-6 December 1988 on the continental shelf off Ubatuba, São Paulo State, Brazil (Fig. 1). On each cruise, samples were collected in two consecutive 24-hour periods at 3-hour intervals, through 30 min trawls.

From the total catch, a sample of at least 30 specimens were randomly separated for biological analysis, size considered suitable for this type of study (*eg*. Livingston, 1982); all available individuals were collected from the small samples. A total of 307 stomachs were considered in this study (Table 1).

The specimens were frozen, and the total length and total mass of each individual were measured in the laboratory. The stomachs were removed and preserved in 10% buffered formalin solution.
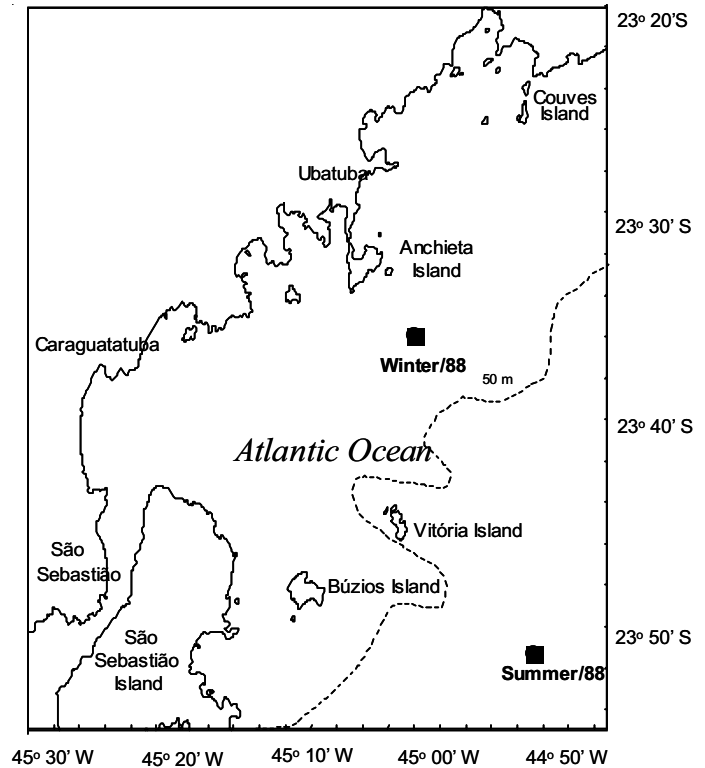
Regional samples of this species are deposited in Museu

Fig. 1. Sampling area on the southeastern Brazilian shelf and the trawl stations location.

de Zoologia da Universidade de São Paulo (MZUSP 65886, MZUSP 65888, MZUSP 25887).

Laboratory methods. A fullness level was assigned for each stomach: empty, half full and full (Hyslop, 1980). The stomach content was sorted taxonomically and the degree of digestion (1-fresh prey; 2- partially digested prey; 3- digested

Table 1. Sampling information for *Trachurus lathami* from Brazilian shelf off Ubatuba.

Winter	time (h)	phase	stomach (n)	size range (mm)	<115mm (n)	>115mm (n)	mean mass (g)
22/07/88	15:13 to 15:43	afternoon	17	104-128	8	9	16.69
22/07/88	18:17 to 22:15	night	37	110-157	3	34	22.31
23/07/88	00:10 to 00:40	night	6	111-136	1	5	16.74
23/07/88	10:46 to 11:16	morning	26	104-153	5	21	17.99
23/07/88	15:23 to 15:53	afternoon	2	112-114	2	0	14.25
Total			88	104-157	19	69	17.60

Summer	time (h)	phase	stomach (n)	size range (mm)	<115mm (n)	>115mm (n)	mean mass (g)
12/4/1988	14:06 to 17:37	afternoon	36	53-92	36	0	3.11
12/4/1988	23:04 to 23:34	night	1	149	0	1	31.80
12/5/1988	02:43 to 03:13	night	5	65-155	1	4	22.12
12/5/1988	05:11 to 05:41	dawn	29	79-175	4	25	30.07
12/5/1988	08:55 to 11:40	morning	35	56-154	33	2	4.93
12/5/1988	15:05 to 17:39	afternoon	37	54-167	17	20	22.20
12/5/1988	20:01 to 20:31	night	10	56-168	3	7	32.68
12/6/1988	02:05 to 02:35	night	9	53-170	5	4	15.99
12/6/1988	05:13 to 05:43	dawn	28	55-170	15	13	19.56
12/6/1988	08:00 to 08:30	morning	29	48-97	29	0	3.38
Total			219	53-175	143	76	18.58

prey) was assigned for individual items, according to Soares & Apelbaum (1994). The state of digestion of the total stomach content was assigned based on the proportion of prey in a particular state in the content: fresh, more than 75% of the prey in a fresh state; partially digested, 25-75% of fresh content and digested, less than 25% of fresh prey.

Data analysis. Diel feeding activity was analyzed according to data on stomach's fullness levels (%), stomach index of fullness (BM% = mass of the stomach content X mass of the fish^{-1} X 100), state of digestion of the stomach content (%), and number and frequency of fresh prey.

The samples were joined into a single 24-hour cycle per sampling period; the midpoint of each hauling period was used as a reference point in time. Sampling times that were less than half an hour apart were brought together into a single sample, and the midpoints averaged (Table 1). Variations in the BM% and number of fresh prey between sampling periods of the day were tested by Kruskall-Wallis' nonparametric test variance analysis (Zar, 1996) to assess the influence of the sampling time on feeding activity.

The stomach contents were analyzed using: frequency of occurrence (O%), percent number (N%), percent mass (M%) (Hyslop, 1980), and a feeding index (FI% = O%* M%) (Kawakami and Vazzoler, 1980). Cluster analysis (UPGMA method), using Shoener's percent similarity index (PS), was used to analyze the diel changes in prey composition (Magurran, 1988; Linton *et al*., 1981). Values of PS vary from 0, when no food is shared, to 1, when there are the same proportional food resources. As suggested in literature (*eg*. Wallace, 1981; Cabral, 2000) values PS ≥ 60% should be considered similar.

Results

Oceanographic conditions. In this study, during the winter, water temperature ranged from 19 to 21°C and salinity from 32 to 35, presenting a homogeneous profile throughout the day. In the summer, two water masses were present, one of them with temperatures between 21 and 23°C and salinity between 35.3 and 35.9, and the other with temperatures between 15 and 19°C and salinity between 35.5 and 36. The temperature profiles are shown in Fig. 2.

Diel feeding activity. The stomach's fullness levels and index of fullness showed the same diel pattern during the winter and summer (Figs. 3-4). Full stomachs occurred in the afternoon and at night. Empty stomachs occurred only in the summer, in the early morning and at dawn. Data on index of fullness revealed a pattern of daytime feeding, attaining maximum values during the afternoon in the winter (Kruskall-Wallis test: c²=47,09; P<0.0001) and summer (Kruskall-Wallis test: c²=138.93; P=0).

The index of fullness presented the same tendency along the day, in winter and summer, when fishes were divided in adults (≥115 mm) and juvenile (<115 mm), following the estimative of the size of first maturity (Saccardo & Katsuragawa, 1995) (Fig. 5).

The proportion of stomachs containing fresh prey was highest in the afternoon (15:33h) and at night (18:32h) in the winter. During the summer, stomachs with fresh or partially digested prey were highest at afternoon (15:20h, 17:23h) and at night (20:16h) just stomachs with partially digested prey occurred (Fig. 6).

Diet. The diet of *T. lathami* was composed of Mollusca, Crustacea, Chaetognatha, and Teleostei fish (eggs and larvae.

Among Arthropoda there was a greater abundance of Crustacea, represented by Ostracoda and Copepoda (Tab. 2).

The diet composition was similar over the feeding activity time (afternoon and night) during the winter and summer, and consisted mainly of calanoid copepods (*Eucalanus* sp. and *Centropages* sp.) and decapod larvae (Tab. 3).

Two similar groups of length class were detected based on diet composition. Specimens of the classes of 50 to 90mm presented similar diet composition, mainly cumaceans, and the classes of 100 to 130 mm ingested essentially calanoid copepods (Tab. 4).
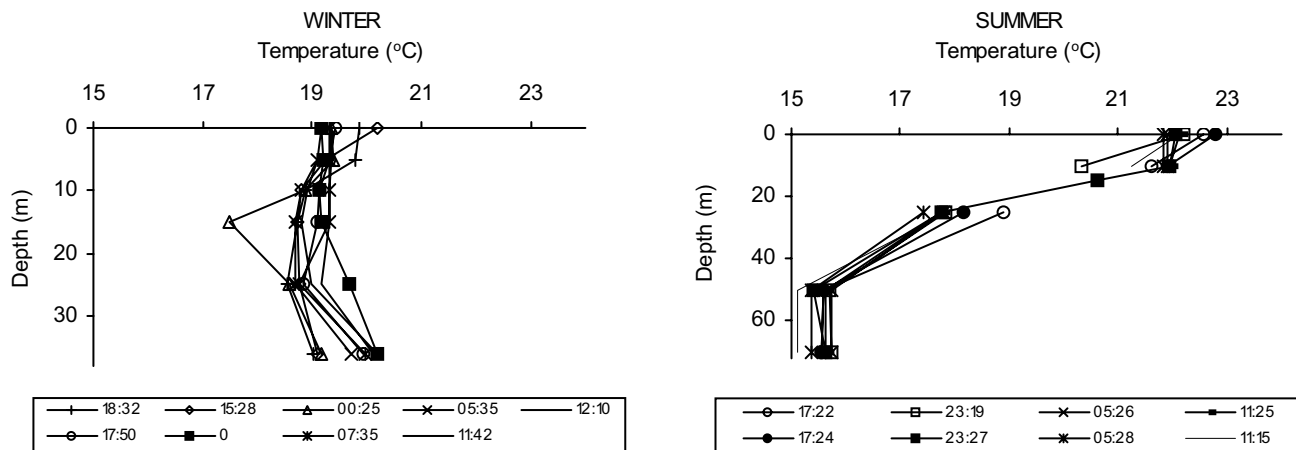

Fig. 2. Fluctuation of water temperature at different times of the day, in winter (23º 35.6´S/ 44º 59´W) and summer (23º 51.3´S/ 44º 47.6´W) 1988, on the shelf off Ubatuba.

Table 2. Frequency of occurency (O%), percent mass (M%), and feeding index (FI%) of food items of *Trachurus lathami* collected in winter and summer from Brazilian shelf off Ubatuba.

Food items	Winter (n=88)			Summer (n=219)		
	O%	M%	FI%	O%	M%	FI%
Gastropoda	22.730	0.179	0.558			
Crustacea	48.860	23.034		67.480	34.522	
Ostracoda	15.910	0.179	0.552	18.400	0.334	2.282
Copepoda	48.860	16.167				
Calanoides sp.	29.550	0.974	3.681	7.980	0.223	1.224
Calanopia americana	2.270	0.038	0.028	0.610	0.008	0.071
Candacia sp.	3.410	0.090	0.050	11.040	0.485	3.073
Centropages sp.	38.640	3.228	17.984			
Ctenocalanus sp.	2.270	0.013	0.009	0.610	0.008	0.002
Eucalanus sp.	32.950	5.840	26.400	14.720	12.160	83.218
Paracalanus sp.	3.410	0.038	0.042	1.230	0.645	0.326
Temora stylifera	43.180	2.729	12.450	14.110	0.183	1.004
Hemicyclops sp.	1.140	0.013	0.005			
Corycaeus sp.	31.820	0.167	0.780	5.520	0.048	0.152
Oncaea sp.	25.000	0.128	0.394	8.590	0.088	0.277
Decapoda (larvas)	30.680	5.790	35.146	7.980	0.875	2.920
Luciferidae	15.910	0.525	1.131			
Brachyura (zoea)	20.450	0.167	0.540	1.230	0.024	0.012
Brachyura (megalopa)	2.270	0.064	0.047	2.450	0.231	1.353
Mysidacea	1.140	0.013	0.005			
Anchistylis sp.				38.650	0.159	2.845
Campylaspis sp.				0.610	0.008	0.002
Cyclaspsis sp.	2.270	0.013	0.060			
Diastylis sp.	2.270	0.013	0.060	13.500	0.088	1.056
Cyclaspis sp.				1.840	0.024	0.089
Chaetognatha				1.230	0.048	0.024
Teleostei	2.270	0.282	0.096	0.610	0.064	
teleostean egg	3.410	0.038	0.017			
crustacean egg	1.140	0.013	0.003	3.070	0.024	0.030

Discussion

Trachurus lathami presented distinct phases of feeding and nonfeeding time during the 24-hour period, suggesting a circadian rhythm in feeding activity. Evening and nocturnal feeding activity were observed. We can say that even in the summer and in the winter, the feeding activity occurred, mainly, at afternoon and night phases. This similar result can be explained by the fact of the distinct points where the sample was collected (38m in winter and 72m in summer) were located in an intermediate area. This area presents different oceanographic conditions (Castro & Miranda, 1998), but this species in large schools can occupy all of this area, including the different points cited (Almeida, 2001; Saccardo & Katsuragawa, 1995).

The majority of the fish known as "horse-mackerel" (*Trachurus* spp.) present diurnal feeding habits (Shuntov, 1969; Pillar & Barange, 1998). Daily variation in feeding activity is often recorded in other carangids, and they usually present a pattern of feeding activity with greater intensity around twilight (Danemann, 1993; Helmer *et al.*, 1995).
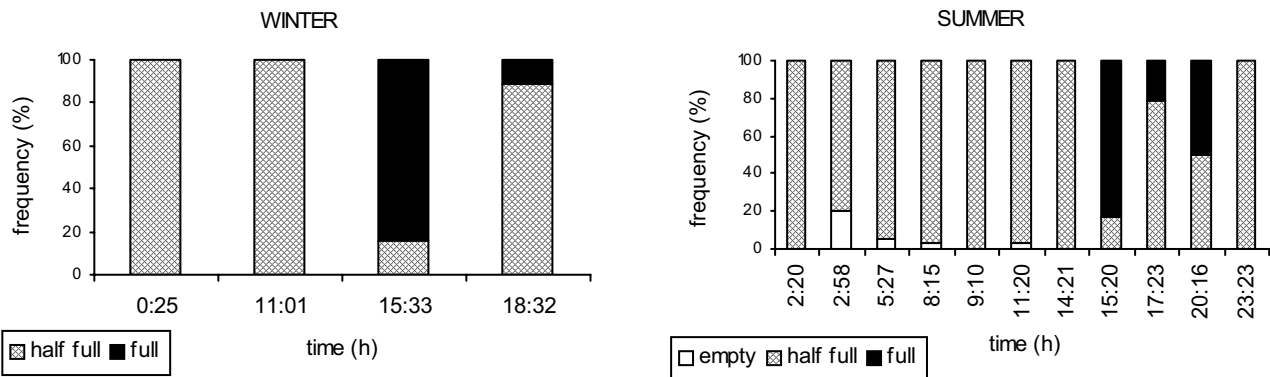

Fig. 3. Proportion of the stomach fullness levels of *Trachurus lathami* from Ubatuba shelf by sampling period in winter (22-24/07/1988 - 23° 35.6′S/ 44° 59′W) and summer (04-06/12/1988 - 23° 51.3′S/44° 47.6′W).

Table 3. Feeding index of food items of *Trachurus lathami* collected in winter and summer from Brazilian shelf off Ubatuba. *and **Percent similarity index (PS) > 60%.

Food items	Winter (n=88)			Summer (n=219)		
	morning	afternoon*	night*	morning	afternoon**	night**
Gastropoda	40.820	0.070	0.640			
Ostracoda		0.670	0.160	11.760	3.370	
Calanoides sp.		3.220	5.400		0.820	1.970
Calanopia americana		0.040				0.200
Candacia sp.	3.060		0.110		2.650	3.940
Centropages sp.		17.550	20.190			
Ctenocalanus sp.		0.010			0.001	
Eucalanus sp.		23.580	37.140	23.530	84.720	83.270
Paracalanus sp.		0.060			0.530	
Temora stylifera	24.490	7.780	27.990	0.980	1.360	0.390
Hemicyclops sp.		0.010				
Corycaeus sp.		0.780	0.800		0.130	0.200
Oncaea sp.	30.610	0.090	0.270	0.980	0.420	
Decapoda (larvas)	1.020	44.250	5.230		3.780	1.570
Luciferidae		1.050	1.470			
Brachyura (zoea)		0.590	0.400		0.020	
Brachyura (megalopa)		0.060			0.110	3.540
Mysidacea		0.010				
Hyperiidae		0.01	0.03			
Gammaroidea		0.07	0.01		0.01	
Isopoda					0.001	
Tanaidacea				0.98		
Anchistylis sp.				43.140	1.750	2.950
Campylaspis sp.					0.001	
Cyclaspsis sp.			0.030	0.980	0.001	0.200
Diastylis sp.			0.030	17.650	0.210	1.770
Cyclaspis sp.				0.98	0.001	0.2
Chaetognatha					0.040	
Teleostei		0.110	0.050		0.030	
teleostean egg		0.010	0.050			
crustacean egg			0.010		0.050	
P.S	*60%			** 91%		

The circadian rhythms in fish may be associated with various factors such as light, temperature, salinity, and availability of prey or with association of these factors. The light has been suggested as a strong and universal influence, acting powerfully in the synchronization of these physiological and behavioral rhythms (McFarland, 1986; Boujard & Leatherland, 1992; Marques & Menna-Barreto, 2003). Diurnal and nocturnal feeding activity must be related to the difference in the intensity of light, which brings alternation in the period of time of the light and dark phases of the day (Boujard & Leatherland, 1992).

Hunter (1968) suggested, however, that with adequate light, as when there is a full moon, some fish are able to feed at the surface at night. In the present study, data were collected during periods of the waxing or waning of the moon, therefore without interference of moonlight in the feeding activity of the
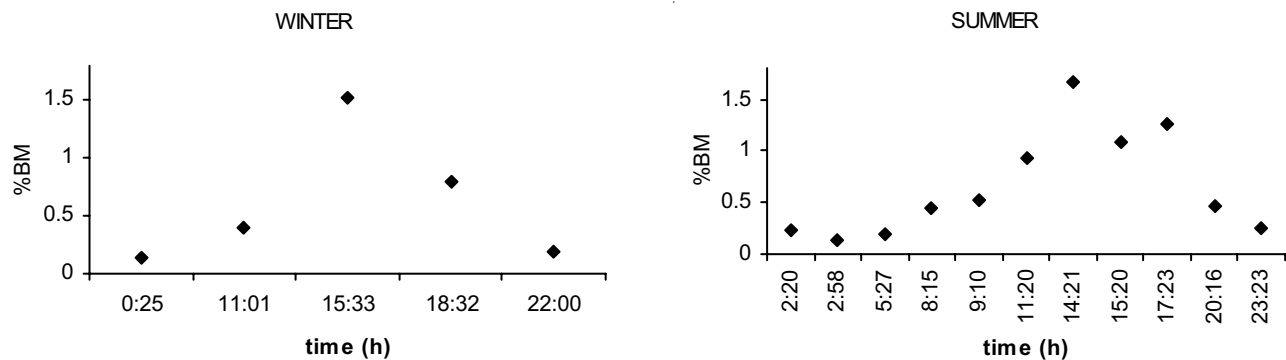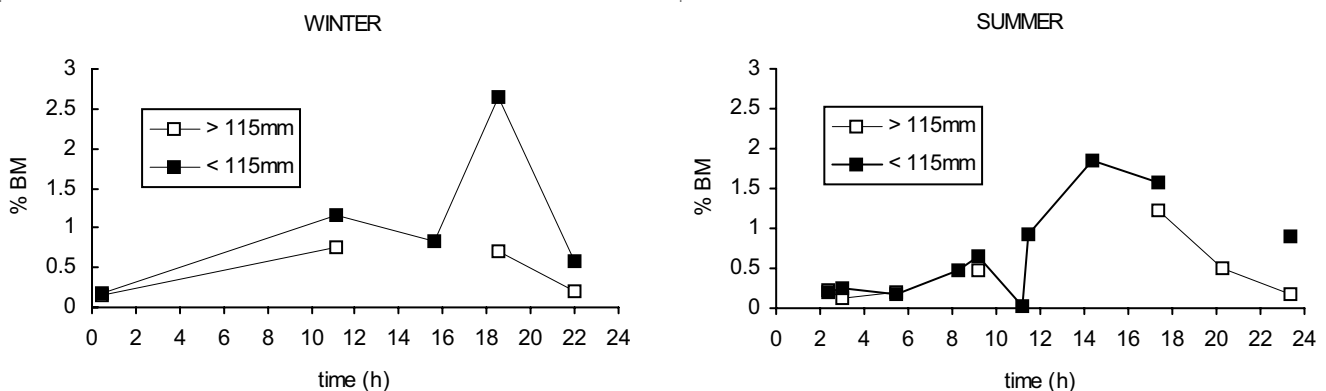
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Fig. 4. Stomach index of fullness expressed as BM% (mass of the stomach content x mass of the fish $^{-1}$ x 100) of *Trachurus lathami* by sampling period from Ubatuba shelf, in winter (22-24/07/1988 - 23° 35.6′S/ 44° 59′W) and summer (04-06/12/1988 - 23° 51.3′S/44° 47.6′W).

Table 4. Diet composition of *Trachurus lathami* expressed by feeding index (FI%) according of lenght classes (mm) of fish collected in winter and summer on Brazilian shelf off Ubatuba. * and ** Percent similarity index (PS) > 60%.

Food items	50-60*	60-70*	70-80*	80-90*	90-100*	100-110**	110-120**	120-130**	130-140**	140-150	150-160	160-170
Mollusca												
Gastropoda						0.28	0.11	0.49	1.36	0.14		
Ostracoda	0.22	4.98	1.82	25.00	7.14	0.56	0.10	0.10	0.03	0.26	0.34	0.21
Calanoides sp.			0.36			3.94	3.18	1.47	2.98	2.93	0.63	0.31
Calanopia americana							0.00			0.00		0.05
Candacia sp.	1.99	0.06				0.28	0.01	0.02	0.03	0.28	1.78	1.67
Centropages sp.						32.68	22.34	19.84	23.67	18.97		
Ctenocalanus sp.	0.22						0.01			0.01		
Eucalanus sp.		0.06	0.36	2.78		43.38	32.37	29.64	36.84	36.15	91.66	41.78
Paracalanus sp.							0.02	0.02		0.91	0.96	49.61
Temora stylifera	0.22	0.06	1.09			12.39	8.16	37.04	27.37	9.42	3.18	3.13
Hemicyclops sp.							0.00			0.00		
Corycaeus sp.	0.22	0.51	0.73	2.78	14.29	4.23	1.96	3.72	5.19	1.87		0.21
Oncaea sp.	0.22	1.02		2.78	7.14	0.28	0.17	1.91	1.30	0.34	0.02	
Decapoda (larvas)	0.22	0.06	0.36			1.69	30.61	5.39	0.58	24.94	0.50	2.51
Luciferidae							0.40	0.10	0.39	0.32		
Brachyura (zoea)	0.22					0.28	0.50	0.20	0.06	0.41		
Brachyura (megalopa)							0.00			0.02	0.08	0.05
Mysidacea							0.00			0.00		
Anchistylis sp.	92.92	90.84	88.89	66.67	71.43					2.79	0.59	0.21
Cyclaspsis sp.	0.44	0.23							0.03	0.01	0.02	
Diastylis sp.	0.88	1.13	5.74							0.14	0.19	
Campylaspsis sp.	0.22									0.00		
Tanaidacea		0.06								0.00		
Isopoda			0.55							0.01		
Amphipoda		0.06								0.01		0.26
Hyperiidea								0.02	0.03	0.00		
Gammaroidea	0.22	0.06					0.01	0.02		0.01		
Chaetognatha	0.22						0.04			0.04	0.02	
Teleostei	0.22						0.00			0.01	0.02	
teleostean egg		0.06					0.00		0.13	0.01		
crustacean egg	1.33	0.85	0.09				0.00			0.02		
n	27	62	33	15	4	6	39	19	13	35	32	11
P.S	*73%					**70%						

fish. Fluctuations in temperature and salinity during the day were not reflected in the daily cycle. It may be conjectured, however, that the light, during the photoperiod must act as an abiotic factor responsible for the synchronization between the environmental events and the feeding activity of *T. lathami*. The vertical migration shown by the species, which migrates to the surface layer during the night and remains at the bottom during the morning (Saccardo, 1987), may also be synchronized by the cycle of availability of prey. Beyond this fact, the migration of prey may also occur in such a way as to synchronize it to the light/dark cycle (Neilson & Perry, 1990). The feeding phase of *T. lathami* is the same of those that have been registered in the main catches of this species, denoting the higher vulnerability on these times (Almeida, 2001).

Fig. 5. Mean of stomach index of fullness expressed as BM% (mass of the stomach content x mass of the fish $^{-1}$ x 100) of adult (≥ 115mm) and juvenile (< 115mm) *Trachurus lathami* by sampling period from Ubatuba shelf, in winter and summer.

Overall, the diet of *T. lathami* was similar in the two phases of feeding activity, being mainly composed of calanoid copepods, which are the most abundant copepod in the study area (Veja-Pérez, 1993). In relation to Eucalanidae copepods, they are abundant along the year (Hernandez, 1999; Oliveira, 1999), which might explain their occurrence over all the 24-hours cycle, both in winter and in summer.

Difference as the occurrence of decapod larvae only at the twilight and nocturnal phases in the winter, for instance, may be related to the phase in the development of these organisms. In the case of the ingestion of cumaceans mainly in summer, it must be associated with their greater abundance in this season, related to the penetration of the cold water of the SACW (Santos, 1992). In the summer the penetration of the SACW leads to the nutrient enrichment of the euphotic zone water, causing an increase in the production of phytoplankton. This primary production sustains a larger biomass of herbivorous zooplankton and offers better conditions for the survival of fish larvae and benthic animals (Pires-Vanin & Matsuura, 1993). Cumaceans present the same pattern of daily vertical migration (Santos & Pires-Vanin, 1999) as *T. lathami* (Saccardo, 1987), moving upward during the night and descending during the morning. This co-existence explains the prey-predator relationship between cumaceans and *T. lathami*.

Trophic interactions are complex relationships that involve food, fish, predators, biological process and displacement in water (Manteifel *et al.*, 1978). The vertical migration of many species of crustaceans is due to endogenous rhythm synchronized by light/dark cycle (Neilson & Perry, 1990) that produces the synchronicity between the movement of the prey and predators.

We may point out that there are clear evidences of temporal organization in the feeding activity of *T. lathami* in the daily cycle. Based on the evening and nocturnal activity, we can suggest the hypothesis of a circadian rhythm for this species, synchronized by the light/dark cycle and/or by the cycle of availability of food. However, to know if this rhythm is endogenous or exogenous, free-running laboratory experiments are needed in order to study the origin of the rhythm. If this feeding rhythm would be detected in constant condi-

tions, without any environmental cycle, it could be considered an endogenous rhythm, characterized by an anticipation of cyclic changes, if not, exogenous rhythm is related with a direct answer to an environmental cycle.

The results related with feeding activity pattern of this study can improve the fisheries resolutions for management of this increasing economical resource.

Acknowledgements

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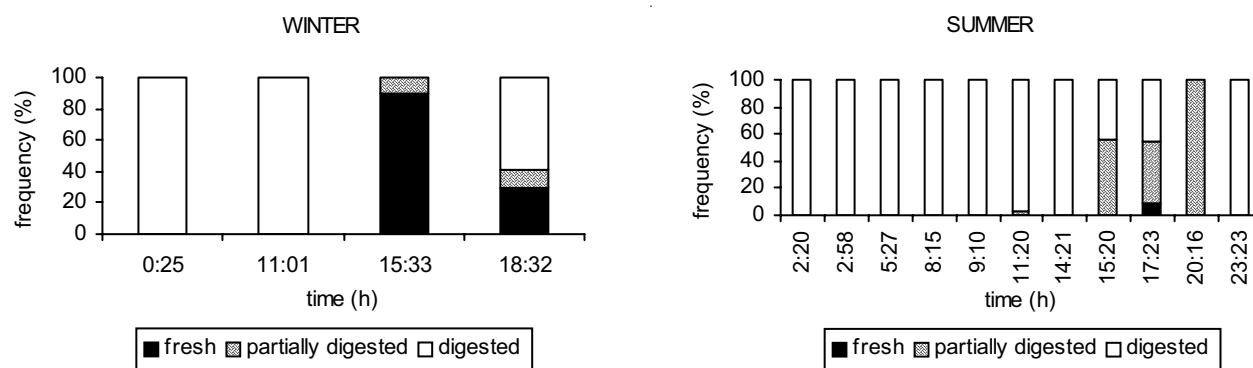

Fig. 6. Proportion of the state of digestion of stomach content of *Trachurus lathami* by sampling period from Ubatuba shelf, in winter (22-24/07/1988 - 23º 35.6´S/ 44º 59´W) and summer (04-06/12/1988 - 23º 51.3´S/44º 47.6´W).

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