

Feeding of a pelagic chaetognath, *Sagitta friderici* Ritter-Záhony off Ubatuba region (São Paulo, Brazil)

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- **Abstract:** The diet of *Sagitta friderici* off Ubatuba region, São Paulo State, was studied in March, 1989. Specimens were collected with a closing-net during three days at six hours' intervals (00:00; 06:00; 12:00; 18:00 h), at a fixed station of 38 m depth. The population was composed basically by young stages (O-II). A total of 3175 specimens were examined but only 760 contained preys in their guts. Copepods were the main constituent of food eaten (79.86%). There was a preference for the genera *Paracalanus*, *Oncaea*, *Corycaeus* and for crustacean nauplii. Other zooplanktonic groups such as Annelida, Urochordata, and Mollusca were also found in the gut. Cannibalistic behavior occurred in 2.66% of the samples. In *S. friderici* the food was selected by size and was a direct function of the predator size. Younger stages (O-I) selected small prey, whereas older stages (II) preferred larger preys. Specimens collected above the thermocline exhibited higher feeding intensity (FCR) during the night periods.
- **Descriptors:** Feeding, Predation, Zooplankton, Chaetognatha, *Sagitta friderici*, Ubatuba, Brazil.
- **Descritores:** Alimentação, Predação, Zooplâncton, Chaetognatha, *Sagitta friderici*, Ubatuba: SP, Brasil.

Introduction

Chaetognaths constitute a substantial fraction of the macroplankton (Reeve & Walter, 1972). They are considered primary carnivorous and key food species for commercial fishes (Heydorn, 1959).

The studies of their feeding habits have shown that chaetognaths are probably one of the main predation pressures on the copepod community (Alvariño, 1985; Oresland, 1987).

Sagitta friderici Ritter-Záhony (1911) is described as a neritic, epiplanktonic chaetognath, preferring lower salinity water, but also able to tolerate oceanic salinities and temperatures between 13° - 27°C (Furnestin, 1957; McLelland, 1980, 1989). It is a common member of the plankton from coastal waters of the Ubatuba region, where it is numerically dominant during the year. However, little is known about its feeding habits.

The objective of the investigation described below is to study the diet composition of *S. friderici* and determine the existence of selective feeding.

Material and methods

Zooplankton samples were collected off the Ubatuba region (23°35'S ; 44°49'W), São Paulo during March 6-8, 1989 at a fixed station over 38 m depth. Vertical tows above (5-0 m) and below (35-10 m) the thermocline were made with a closing-net (0.5 m mouth diameter and 0.200 mm mesh aperture), every six hours (00:00; 06:00; 12:00; 18:00) during three days. Temperature and salinity data of the water column were obtained simultaneously with Nansen bottles.

The zooplankton samples were preserved with 10 % buffered formalin solution.

In the laboratory, 3175 specimens of *Sagitta friderici* were removed from the samples and their gut contents analyzed by body transparency. The position of the food in the gut was recorded and only the preys localized at posterior region were considered.

The food items were identified as much as possible in species using a Wild M8 stereo microscope. The taxonomy of the copepods prey was based on Björnberg (1981) and chaetognath maturity stages were determined according to Reeve (1970): O-II, young stages; III-IV, adult stages.

Finally, food containing ratio (FCR), i.e., number of chaetognaths containing food/total number of chaetognaths X 100, was calculated.

Results

Sagitta friderici was the most abundant species in Ubatuba region in March, 1989. Their numbers varied from one sample to another suggesting mobility and dispersion of the population. They occurred both above and below the thermocline with a tendency to aggregate in lower layers, where the temperature was cooler (15.5°C) than at the surface (26.5°C).

The population was composed of juvenile stages. Approximately 97.73% of the specimens taken during the different periods of the day were juveniles and 2.27% adults (Table 1).

Analysis of the gut contents of 3175 *S. friderici* showed that 2415 specimens had empty guts and 760 contained food (771 prey items). The guts generally had one prey, but 2-3 items were found in eight specimens. In all cases this species swallowed its prey whole.

The diet was composed basically of Crustacea (88.52%), Annelida (4.71%), Urochordata (3.69%), Chaetognatha (2.66%) and Mollusca (0.41%) (Fig. 1). The specific composition is presented in Table 2. Generally, the diet was composed of a high diversity of items, 28, but in low numbers. The diversity varied with maturity stage of *S. friderici*. In stage I, for example, 25 items were

Table 1. Number, percentage of different stages and food containing ratio of *Sagitta friderici* at the different maturity stages

	Maturity Stages					Total
	0	Young I	II	III	Adult IV	
N ^o of <i>S. friderici</i> examined	1857	956	290	65	7	3175
Percentage	58.49	30.11	9.13	2.05	0.22	100
N ^o of specimens with food	245	420	93	2	-	760
Food containing ratio	13.19	43.93	32.07	3.07	-	23.94

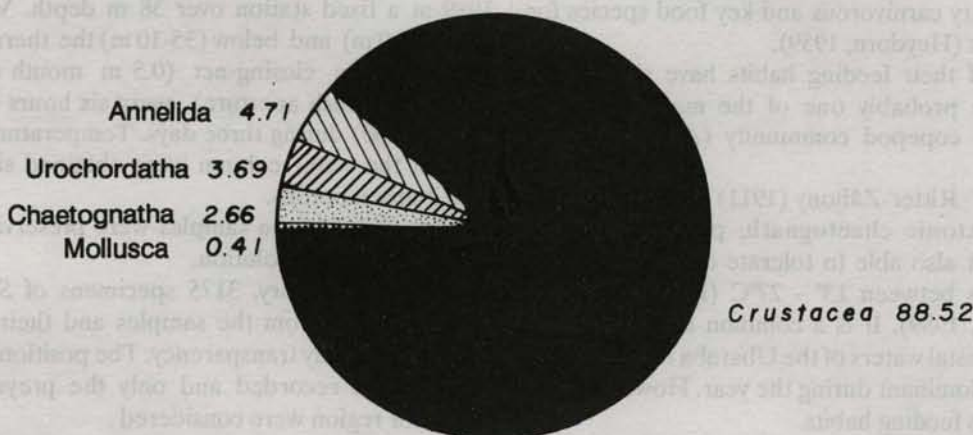
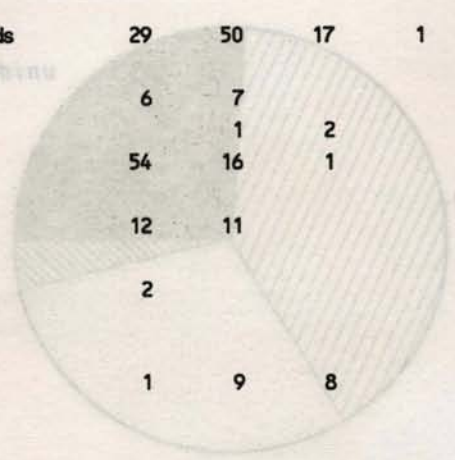


Fig. 1. Percentage of food categories found in the guts of *Sagitta friderici*.

Table 2. The specific composition of the diet of *Sagitta friderici* at different maturity stages

Food item	Maturity		Stages		Total
	Young		Adults		
	0	I	II	III	
Crustacea					
Copepoda					
Calanoida					
<i>Nannocalanus minor</i>		3	3		6
<i>Paracalanus</i> sp	13	28	3		44
<i>P. quasimodo</i>	4	15			19
<i>P. crassirostris</i>		1			1
<i>Clausocalanus furcatus</i>		12			12
<i>Ctenocalanus</i>	5	11			16
<i>Arcatia liljeborgi</i>		3	1		4
<i>Temora stylifera</i>	3	17	7		27
<i>Centropages velificatus</i>			1		1
<i>Pontellopsis</i> sp		1	1		2
Cyclopoida					
<i>Corycaeus</i> sp	1	9	1		11
<i>Corycaeus speciosus</i>		9	2		11
<i>C. amazonicus</i>		2			2
<i>C. giesbrechti</i>	4	10	3		17
<i>Farranula</i> sp		1			1
<i>Oncaea</i> spp	21	34	5		60
<i>Oithona plumifera</i>		1			1
Harpacticoida					
<i>Microsetella norvegica</i>	2	5			7
<i>Macrosetella gracilis</i>			1		1
<i>Euterpina acutifrons</i>	1	4			5
Unidentified copepods	29	50	17	1	97
Cladocera					
<i>Evadne</i> sp	6	7			13
Crustacean nauplii	54	16	1		71
Annelida (larvae)					
Mollusca	2				2
Urochordata					
<i>Oikopleura</i> spp	1	9	8		18
Chaetognatha					
<i>S. friderici</i>		6	6		12
<i>S. tenuis</i>		1			1
Unidentified prey	88	161	33	1	283
Total prey items	246	428	95	2	771



identified, whereas stage O and II showed 14 and 15 items, respectively. We also observed higher diversity of food items in specimens collected below the thermocline than above it.

The most important prey within the global diet were the copepods, specially Calanoida (40.29%), Cyclopoida (29.85%) and Harpacticoida (3.77%). The percentage of unidentified copepods was 26.08% (Fig. 2). In all stages the genera *Paracalanus*, *Oncaea* and *Corycaeus* were the most frequent and significant food items (Fig. 3A-C). Crustacean nauplii were also important food, specially for stage O (Fig. 3A). Appendicularians and Annelida larvae were other important preys of *S. friderici*. Predation on chaetognaths were detected in stage I (2.62%) and it tended to increase during stage II (9.68%) (Fig. 3 B,C).

The percentage of unidentified prey present in the gut of *S. friderici*, during this study was very high (36.70%).

The diet of stage III was not studied here, because only two individuals contained food in their gut. All specimens of stage IV showed an empty gut.

In *S. friderici* prey size changed with the developmental stages. Younger stages (O-I) preferred nauplii and small-sized copepod of the genera *Oncaea* and *Paracalanus*, whereas older stages took larger preys such as *Temora stylifera* and *Corycaeus* spp (Fig. 3C).

The food containing ratio (FCR) showed that the number of guts with prey was higher in specimens collected at night. The period of more intensive feeding was recorded at 18:00-00:00 h in the first day and at 00:00-06:00 h during the second day of sampling. In all cases the time of maximum intensity was not the same (Fig.

4). The diel trends in feeding were more evident in specimens collected above the thermocline than below it.

Discussion

During March, 1989 Ubatuba was dominated by numerous young stages (O-II) of *S. friderici*. Almeida-Prado (1968) also found a dominance of juvenile stages in the Cananéia and Santos regions. She suggested that adult scarcity was due to near-shore sampling and the distribution of the chaetognaths in the deeper layers. Recently, Stuart & Verheye (1991) found more adults than juveniles of *S. friderici* off the west coast of South Africa, in 70 m deep collections.

Temperature is one of the factors which appear to influence the distribution of *S. friderici*. Almeida-Prado (1961) recorded a large temperature range for this species (13°C - 27°C), but according to Heydorn (1959) the species never occurs in large numbers when the temperature of the water is higher than 13°C. *S. friderici* from Ubatuba region was more abundant below the thermocline, where the temperature was 15.5°C. Our results confirm the preference of this species for the lower temperature.

S. friderici was found to have a pattern of feeding habits similar to previously reported studies on other chaetognaths. Copepods were the main constituent of food eaten, representing 79.86% of their diet. It showed preference by copepods of the genera *Paracalanus* and *Oncaea*. This result confirms Stone (1969) and Pearre

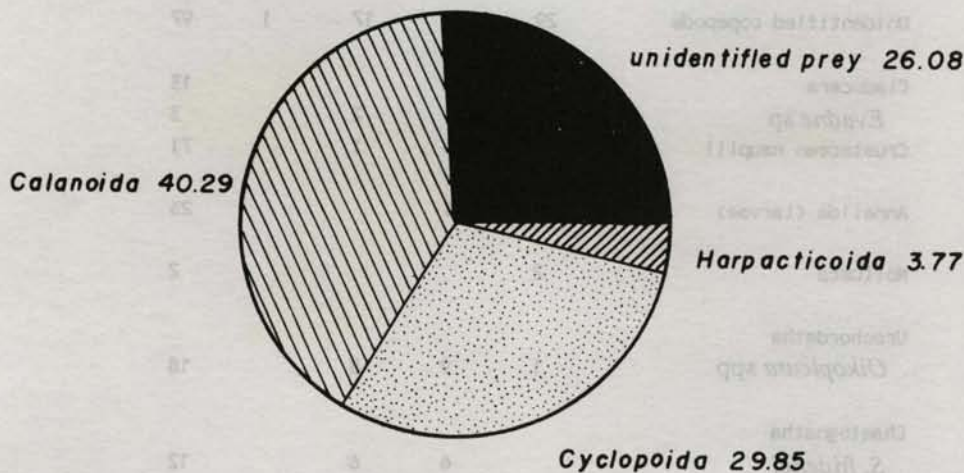


Fig. 2. Percentage of copepods found in the gut of *Sagitta friderici*.

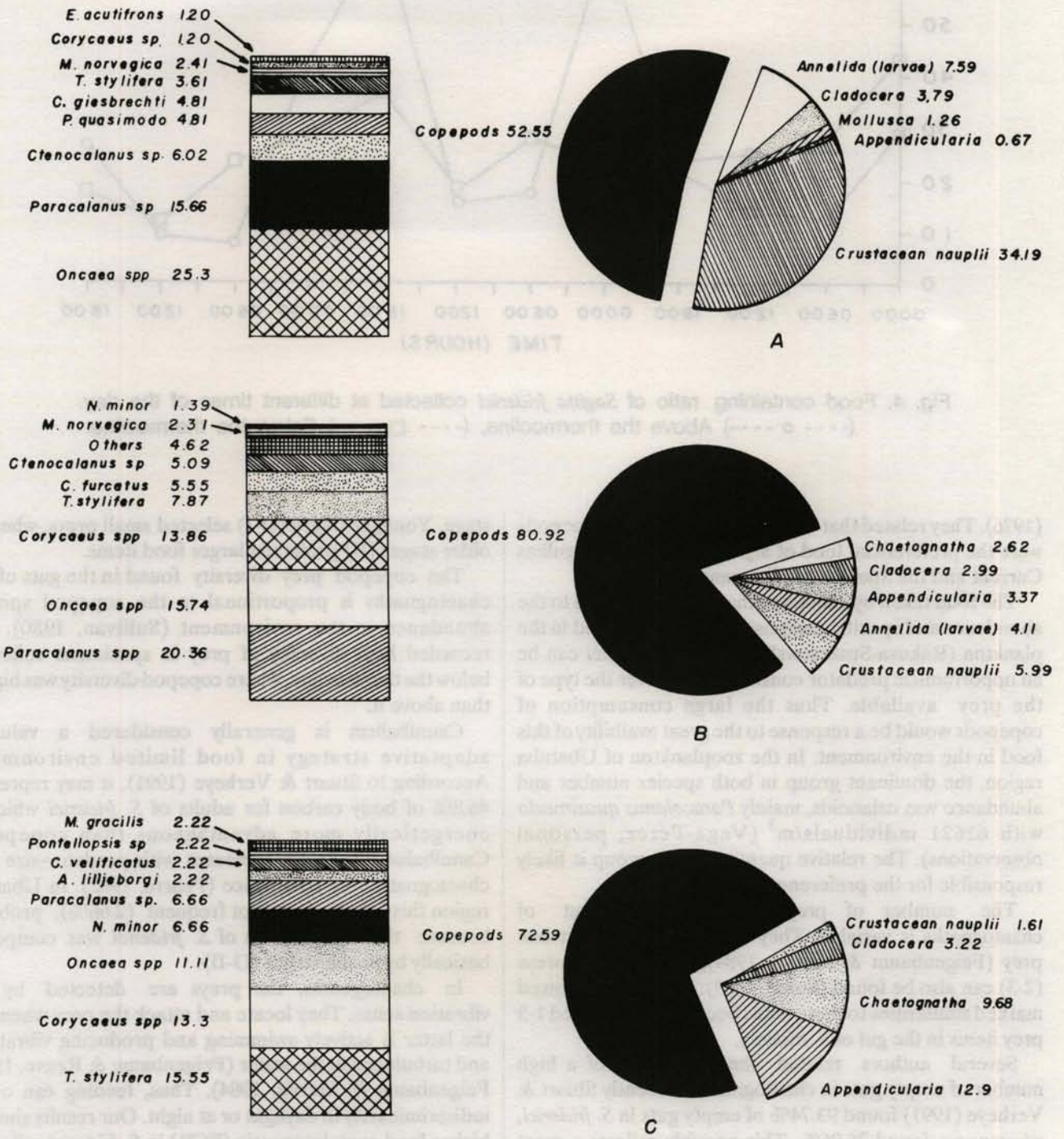


Fig. 3. Main food items of *Sagitta friderici* at different maturity stages. (A) stage O, (B) stage I, (C) stage II.

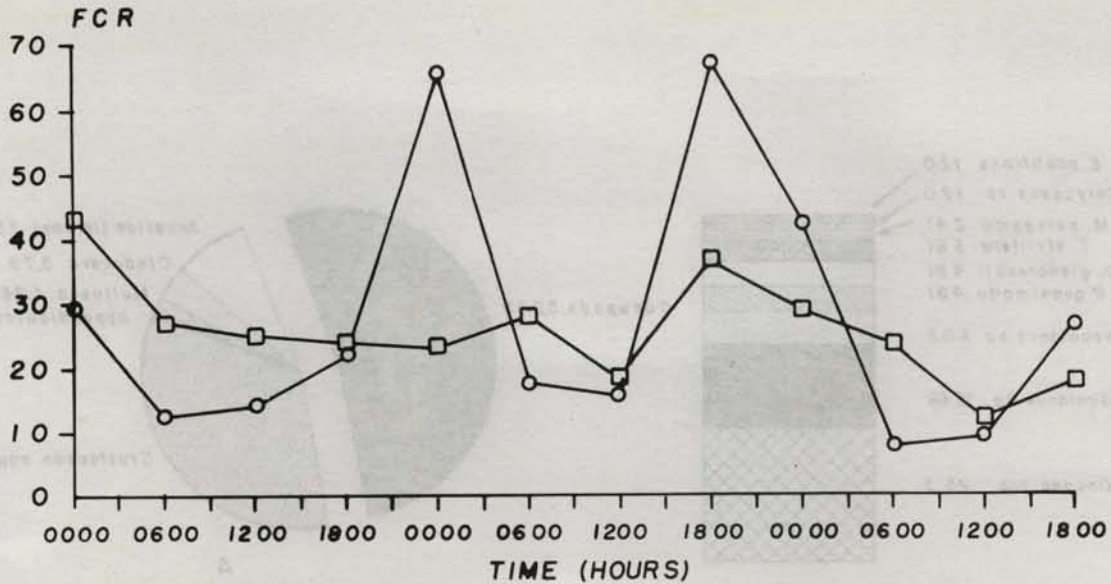


Fig. 4. Food containing ratio of *Sagitta friderici* collected at different times of the day. (---- o ----) Above the thermocline, (---- □ ----) Below the thermocline.

(1976). They related that calanoid and cyclopoid copepods were the preferential food of *S. friderici* from the Agulhas Current and the Spanish Mediterranean coast.

The food taken by chaetognaths is closely related to the abundance and specific composition of the copepod in the plankton (Rakusa-Suszczewski, 1969). *S. friderici* can be an opportunistic predator consuming whatever the type of the prey available. Thus the large consumption of copepods would be a response to the great availability of this food in the environment. In the zooplankton of Ubatuba region, the dominant group in both species number and abundance was calanoids, mainly *Paracalanus quasimodo* with 61621 individuals/m³ (Vega-Pérez, personal observations). The relative quantity of this group is likely responsible for the preference of *S. friderici*.

The number of prey present in the gut of chaetognaths is variable. They contain typically just one prey (Feigenbaum & Marris, 1984), but multiple preys (2-3) can also be found (Stone, 1969). Our results showed marked similarities to these data, because we observed 1-3 prey items in the gut of *S. friderici*.

Several authors related the presence of a high number of empty guts in chaetognaths. Recently Stuart & Verheye (1991) found 93.74% of empty guts in *S. friderici*, whereas we found 76.06%. This possibly reflects a great dependency on soft bodied preys as Annelida, which were not found. On the other hand, *S. friderici* could not be feeding at the depths where they were caught.

It has been demonstrated that the principal feature by which chaetognaths select the prey is the size. According to Pearre (1980) larger specimens and mature stages tend to select larger particles. Our results showed that, in *S. friderici*, the prey-size changed with the developmental

stage. Younger stages (O-I) selected small preys, whereas older stages (II) preferred larger food items.

The copepod prey diversity found in the guts of the chaetognaths is proportional to the copepod species abundance in the environment (Sullivan, 1980). We recorded high diversity of prey in specimens collected below the thermocline, where copepod diversity was higher than above it.

Cannibalism is generally considered a valuable adaptative strategy in food limited environment. According to Stuart & Verheye (1991), it may represent 46.8% of body carbon for adults of *S. friderici* which is energetically more advantageous than copepods. Cannibalistic behavior increases with predator-size and chaetognath prey abundance (Pearre, 1982). In Ubatuba region this behavior was not frequent (2.66%), probably because the population of *S. friderici* was composed basically by young stages (O-II).

In chaetognaths, the preys are detected by the vibration sense. They locate and attack the prey whenever the latter is actively swimming and producing vibrations and turbulence in the water (Feigenbaum & Reeve, 1977; Feigenbaum & Marris, 1984). Thus, feeding can occur indiscriminately in daylight or at night. Our results showed higher food containing ratio (FCR) in *S. friderici* collected during the night period as previously reported by Nagasawa & Marumo (1972, 1976), Szyper (1978) and Øresland (1987) for *S. nageae*, *S. enflata* and *S. elegans*, respectively.

According to Pearre (1973) the smaller feeding by chaetognaths during the light periods can be explained as an adaptation to avoid visual predators. Feeding during daylight can increase their visibility due to undigested food

in their guts, although chaetognaths can more easily detect their preys during the diel migratory movements.

Young stages (O-I) of *S. friderici* tend to show higher FCR than the more mature stages. This may be associated with the higher metabolism that younger and smaller organisms have in response to the growth need.

Further studies on the ecology of *S. friderici* as well as in other species are necessary due to the potential contribution of this group to the secondary production of marine ecosystems.

Conclusions

1. *S. friderici* in Ubatuba region showed high number of specimens with empty guts.
2. The diet was composed basically of Crustacea, Annelida, Urochordata, Chaetognatha and Mollusca.
3. The most important prey of *S. friderici* were the copepods, specially calanoids.
4. The food diversity varied with maturity stage of *S. friderici*.
5. Higher diversity of food items were observed in specimens collected below the thermocline.
6. In *S. friderici* prey size changed with the developmental stages.
7. In Ubatuba region, the cannibalistic behavior was not frequent.

Resumo

Espécimens de *Sagitta friderici* foram coletados numa estação fixa de 38 m de profundidade, ao largo de Ubatuba, Estado de São Paulo, em março de 1989. Arrastos verticais, acima e abaixo da termoclina, foram feitos com rede de fechamento (50 cm de diâmetro de boca e malha de 0.200 mm) durante três dias consecutivos e em intervalos de seis horas.

O estudo de 3175 indivíduos, nos estágios de O-IV, revelou que 2415 apresentaram o trato digestivo vazio e 760 com algum tipo de alimento. Destes últimos, 283 continham material amorfo e os 473 restantes de 1 a 3 presas. Das 488 presas identificadas, 99,74% estavam localizadas na região posterior do trato digestivo e 0,26% na região anterior.

A dieta de *S. friderici* esteve constituída de Crustacea, Annelida, Urochordata, Chaetognatha e Mollusca. Dentre os Crustacea, os Copepoda foram os mais abundantes, predominando os Calanoida e Cyclopoida.

O estágio 0 de *S. friderici* teve preferência pelos náuplios de crustáceos, enquanto que uma maior

diversificação do alimento, incluindo a prática do canibalismo, foi observada a partir do estágio I.

Não houve diferenças significativas na composição da dieta dos indivíduos coletados nos diferentes períodos do dia.

Os espécimens de *S. friderici* coletados acima da termoclina apresentaram maior porcentagem de tratos digestivos (FCR) contendo alimento.

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