Feedings habits of meso- and bathypelagic chaetognatha, *Sagitta zetesios* Fowler

Feeding habits
Chaetognatha
Deep sea
Food containing ratio

Habitudes alimentaires
Chaetognathe
Haute mer
Taux de nutrition

M. Terazaki [a], R. Marumo [b]
[a] Otsuchi Marine Research Center, Ocean Research Institute, University of Tokyo, Akahama, Otsuchi, Iwate, 028-11 Japan.
[b] Ocean Research Institute, University of Tokyo, Minamidai, Nakano, Tokyo, 164 Japan.

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ABSTRACT

The predominant food organisms of meso- and bathypelagic Chaetognatha, *Sagitta zetesios* Fowler, were copepods. The percentages of Copepoda, Chaetognata, Euphausiacea, Ostracoda and unidentified in the gut, was 71.6 %, 16.2 %, 1.4 %, 1.4 % and 9.4 %, respectively. The 24 species of copepods, 5 of chaetognaths and 1 of ostracods were identified and these 20 species were meso- and bathypelagic and another 10 species were epipelagic. Higher day time feeding rates were found, because *Sagitta zetesios* feed on epipelagic food organisms when they migrate from the upper layer during the day.

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RÉSUMÉ

Habitudes alimentaires du Chaetognathe *Sagitta zetosios* Fowler.

Les organismes qui prédominent dans l'alimentation du Chaetognathe méso-et bathypélagique, *Sagitta zetesios* Fowler, sont des copépodes; la proportion de copépodes, chaetognathes, cuphausiacés, ostracodes et éléments non identifiés, observés dans le tube digestif, est respectivement de 71,6 %, 16,2 %, 1,4 %, 1,4 % et 9,4 %. 24 espèces de copépodes, 5 de chaetognathes et 1 d'ostracodes ont été identifées; parmi elles, 20 espèces sont méso- et bathypélagiques, les 10 autres étant épipélagiques. Les taux de nutrition observés sont plus élevés le jour, car *Sagitta zetesios* rencontre les organismes épipélagiques dont elle se nourrit lorsque ceux-ci migrent à partir des couches superficielles durant la journée.

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INTRODUCTION

Chaetognaths are one of the principal predators of the marine plankton. They feed upon young fish, copepods and crustacean larvae which they catch by a rapid grab with the large armature of their jaws.

There are number of references to the food of chaetognaths. *Sagitta enflata* and *S. hispida* were observed to prey on copepods (*Corycaeus, Calanus*), tunicates, fish larvae, siphonophores, *Lucifer,* and more often cannibalistic (Furnestin, 1957). Murakami (1959) has observed *S. crassa* feeding on large copepods (*Centropages* and *Calanus*) and small copepods (*Acartia* and *Paracalanus*) in winter and medium size copepods (*Arcartia erythraea* and *Tortanus*) in summer in Kasaoka Bay, Japan. Elian (1960) observed *Calanus helgolandicus* was always present in the gut contents of *S. euxina.* The feeding habits of other epipelagic chaetognaths such as *S. bipunctata, S. elegans, S. friderici, S. gazellae, S. minima, S. nagae, S. robusta, S. setosa* and *Pterosagitta draco* were reported by David (1955), Tchindonova (1959), Rakusa-Suszczewski (1969), Stone (1969), Nagasawa and Marumo (1972), and Pearre (1974).

In comparison with epipelagic chaetognaths, there is not many knowledges about the feeding habits of meso- and bathypelagic chaetognaths (Table 1), because their sampling takes much time and they are often damaged during net sampling from the deep sea. Fortunately, we have found many good specimens of the meso- and bathypelagic species, *Sagitta zetesios* for study of feeding habits in samples collected from the Pacific Subarctic Water and Sagami Bay.

Table 1
Some records on preys of meso- and bathypelagic chaetognaths

Species	Preys	Authors
Sagitta hexaptera	Copepods *Candacia aethiopica, Corycella, Eucalanus* *Oncaea* Chaetognaths Ostracods	Furnestin (1957) Stone (1969)
S. lyra	Copepods *Oncaea* Chaetognaths Amphipods	Tchindonova (1959) Stone (1969)
Eukrohnia fowleri	Diatoms Radioralians Copepods	Tchindonova (1959)

MATERIALS AND METHODS

Sagitta zetesios for this study was collected from Sagami Bay and Station H 10 (37°-30' N, 150°E) during the period from January 1964 to November 1971 during cruises of the R/V Hakuhō Maru and Tansei Maru of the Ocean Research Institute, University of Tokyo. Samples were obtained with horizontal or oblique tows by a 160-cm ORI net with 1 mm or 0.33 mm mesh-opening (Omori, 1965). In the case of horizontal tows, a net with opening-closing apparatus was towed in 14 different layers from surface to 2 220 m at Station 223 in Sagami Bay and 11 different layers from surface to 1 650 m at Station H 10. A 0 - 2 000 m wire-out oblique tow was carried out at 59 stations in Sagami Bay (Fig. 1). Samples were collected during the day and night. To determine the towing course of the net in the water and the volume of water filtered, a TS depth-distance recorder and RGS flowmeter set in the net ring.

Collections were preserved in 10 % formalin seawater solution neutralized by hexamine. In the laboratory, the preserved specimens of *S. zetesios* were classified into the following five maturity stages; juvenile, stage I, stage II, stage III and stage IV by Thomson's method (1947) and then the gut contents of each individual was examined with a stereomicroscope.

Consumption by *S. zetesios* of other animals in the net could have unnaturally increased the frequency of food items in their gut, therefore food organisms in the mouths were not included in the data. The food containing ratio (number of *S. zetesios* containing food organisms in the gut/the total number of *S. zetesios* examined) at different maturity stages and different layers was obtained.

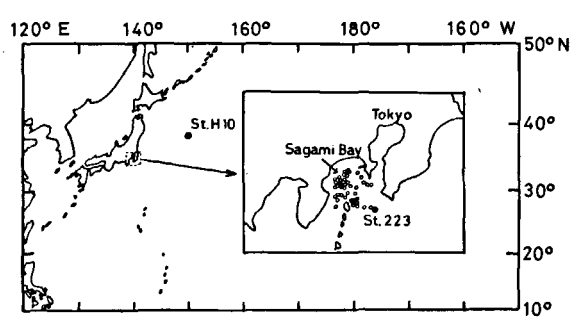

Figure 1
Sampling stations of Sagitta zetesios *by horizontal tow (solid circles) and oblique tow (open circles) in the North Pacific and Sagami Bay.*

RESULT

Vertical distribution

Vertical distribution of *S. zetesios* at Station 223 and Station H 10 showed the same pattern. *S. zetesios* inhabited in the deep water layers between about 200 m and 1 700 m, and juveniles had different distributions from maturing and adults (Fig. 2). Juvenile *S. zetesios* was located in the upper 500 m during both day and night. Stage I and stage II individuals were mainly distributed between 300 and 1 200 m depth. The main concentrations of adults (stage III and stage IV) were found in the layer below 1 000 m. Evidence of diurnal vertical migration was not recognized, because the sampling stratum was too large.

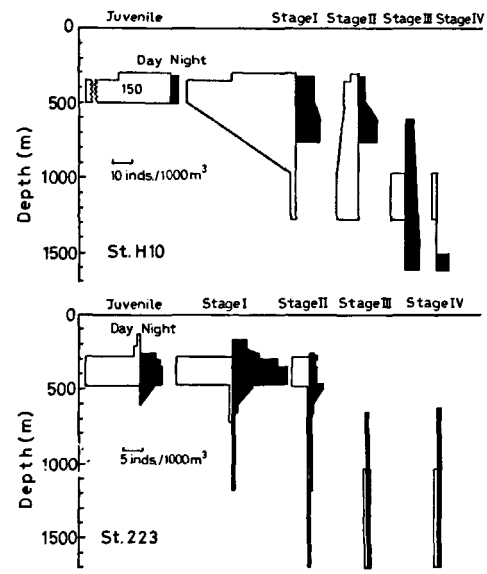

Figure 2
Vertical distribution of each maturity stage of Sagitta zetesios *at stations* 223 *and* H 10.

Food items

A total number of 163 out of the 1 149 *S. zetesios* were found to have one or more food organisms in their gut. Of the 163 animals, 24 had consumed two items, 3, 1 and 1 had consumed 3, 4 and 5 items, respectively.

The predominant food organisms were copepods and the percentages of Copepoda, Chaetognatha, Euphausiacea, Ostracoda and unidentified in the gut of *S. zetesios* was 71.6 %, 16.2 %, 1.4 %, 1.4 % and 9.4 %, respectively. The 24 species of copepods, 5 of chaetognaths and 1 of ostracods were identified and 20 species were meso- and bathypelagic and another 10 species were epipelagic (Table 2).

The food organisms frequently found in the gut were *Calanus pacificus, Pareuchaeta russelli* and *Sagitta nagae* and the major prey of adults were large-sized meso- and bathypelagic copepods. There was also cannibalism in stage II and stage III individuals.

Food containing ratio

The food containing ratio (FCR) of juvenile, stages I, II, III and IV individuals were 15.5 %, 20.7 %, 13.2 %, 1.5 % and 3.2 %, respectively (Table 3). It is clear that the young *S. zetesios* had high FCR compared with maturing and adult animals.

Table 2
List of the food organisms found in the gut of Sagitta zetesios *collected from Sagami Bay.*

Food organisms	Juvenile	Stage I	Stage II	Stage III	Stage IV
Copepoda					
Calanus cristatus			+		
C. plumchrus	+	+			
C. pacificus	+	+	+		+
* *Undinula vulgaris*	+				
Eucalanus bungii	+				
* *E. crassus*		+			
* *E. subtenuis*		+		+	
Rhincalanus nasutus		+	+		
* *R. cornutus*			+		
* *Clausocalanus arcuicornis*	+				
Aetideus armatus		+			
Gaetanus armiger			+		
* *Euchaeta concinna*		+	+		
Pareuchaeta russelli		+	+		+
P. scaphula			+		
P. rubra				+	
Scaphocalanus echinatus			+		
* *Scolecithrix danae*		+			
* *S. nicobarica*		+			
Scolecithricella valida			+		
Pleuromamma abdominalis			+		
Heterorhabdus pacificus		+			
* *Candacia bipinnata*		+			
Oncaea conifera		+			
Chaetognatha					
* *Sagitta nagae*		+			
S. lyra		+			
S. neodicipiens			+		
S. macrocephala			+		
S. zetesios			+	+	
Ostracoda					
Conchoecia elegans		+			

* Epipelagic species

S. zetesios contained food organisms in the gut more frequently at the daytime than during the night, and 16.7-22.3 % of *S. zetesios* collected from the upper 500 m layer had the prey in their gut, but the FCR was under 8.7 % in the deep water layer below 500 m (Table 4).

Size of the food organisms

S. zetesios mainly consumed food organisms ranging from 2 to 3 mm in body length and this size accounted for 43.8 % of all their prey (Table 5). Generally, the large-sized *S. zetesios* have a tendency to consume larger food organisms (Fig. 3).

Table 3
Food containing ratio at different stages of Sagitta zetesios.

Maturity stage	Number of *S. zetesios* containing food organisms in the gut (A)	Total number of *S. zetesios* examined (B)	A/B × 100 (%)
Juvenile	26 (2)*	168	15.5
Stage I	82 (15)	396	20.7
Stage II	51 (7)	385	13.2
Stage III	2 (2)	137	1.5
Stage IV	2 (2)	63	3.2

* Figures in the brackets shows the number of specimens contained more than two items in the gut.

Table 4
Food containing ratio of Sagitta zetesios *collected from the mesopelagic and bathypelagic layers at stations* 223 *and* H 10.

	Station 223 (153)*		Station H 10 (118)	
	Day	Night	Day	Night
Mesopelagic layer	22.6 %	18.9 %	18.1 %	16.7 %
Bathypelagic layer	5.9 %	3.2 %	8.7 %	0 %

* Figures in the brackets show total number of *S. zetesios* examined.

DISCUSSION

Most food organisms in the gut of *S. zetesios* were positioned with their head to its anus. The eyes of chaetognaths (*Sagitta*) are not constructed to give any reliable visual image (Tokioka, 1950; Eakin, Westfall, 1964). However, recently, Ducret (1978) showed that the eyes of *Eukrohnia hamata* (ultrastructural study) are different. Horridge and Boulton (1967) reported that bottom-living the chaetognath *Spadella cephaloptera* would give a positive feeding response and bite a glass probe vibrating between 9 and 20 cycles/sec. and at an amplitude of 100-500 μm if the probe was placed within 1-3 mm, thus confirming the generally accepted theory

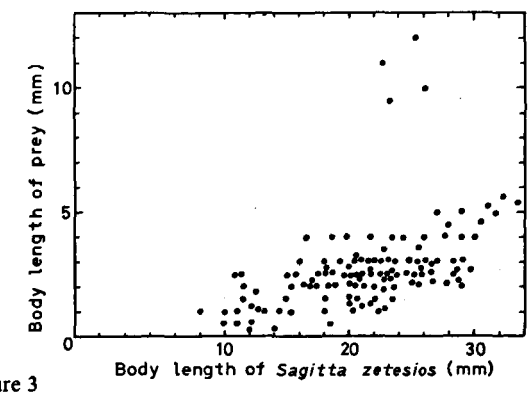

Figure 3
Relationship between body length of Sagitta zetesios *and its food-size.*

Table 5
Percentage of prey size (body length) of Sagitta zetesios.

Size range (mm)	Percentage (%)
less than 1	0.8
1-2	16.5
2-3	43.8
3-4	19.0
4-5	10.7
5-6	5.0
above 6	4.2

that they were sensing the vibrations caused by the swimming movements of their prey. Also, Newbury (1972) suggested that chaetognaths recognized the specific vibration rates produced by swimming copepods and hence can select their food. Therefore, it appears that *S. zetesios* waits in ambush and seizes the prey organisms quickly when their swimming and/or feeding appendages create vibrations in the water in close proximity to the head of *S. zetesios.*

Epipelagic chaetognaths take the food organisms more actively at night than during the day. The FCR of *Sagitta nagae* was 5 to 14 % with a mean of 10.3 % during the day and 16 to 22 % with a mean of 20.2 % at night (Nagasawa, Marumo, 1976). Similar results were obtained for *S. setosa* and *S. elegans* by Mironov (1960) and Rakusa-Suszczewski (1969), and also higher feeding rates at night were found in laboratory experiments with *S. hispida* (Reeve, 1964).

But the meso- and bathypelagic species, *Sagitta zetesios* showed the opposite pattern. In both sampling areas (Sagami Bay and Station 10), *S. zetesios* took the food organisms more actively at day. The juvenile, stage I and stage II individuals of *S. zetesios* consumed fair amounts of epipelagic copepods and chaetognaths which distributed mainly in the layer upper 200 m. On the other hand, *S. zetesios* inhabited in the deep water layers between about 200 and 1 700 m.

Many epipelagic zooplankton show a marked diurnal vertical migration, that is, they appear more abundant in the upper layers at night and in the deep layer during the day (Russell, 1934; Banse, 1964; Foxton, 1970; Terazaki, Marumo, 1979). It therefore appears that the young *S. zetesios,* living in the layer between 300 and 500 m depth, capture epipelagic food organisms when they migrate from the upper layer during the day.

There is a remarkable difference in the FCR of *S. zetesios* between the mesopelagic (upper 500 m) and the bathypelagic (below 500 m). The FCR of *S. zetesios* living in the mesopelagic layer, ranged from 16.7 % to 22.6 %, but it was only under 8.7 % in the bathypelagic layer where adults mainly lived. It may be suggested that the low FCR of adult *S. zetesios* is caused by low density of their food organisms in the deep sea.

Reeve and Walter (1972) showed that the food size preferred by *Sagitta hispida* increased with age. *S. zetesios* had a simillar tendency, but they had no selective grazing like *S. hispida.* Copepods were the predominant food organisms of *S. zetesios* and adult *S. zetesios* consumed bathypelagic copepods such as *Pareuchaeta russelli* and *P. rubra* which had a large body compared with epipelagic copepods, therefore food size increased with size of *S. zetesios.*

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