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

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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.


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 helsgolencus* 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. naga, 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.
Eukrohnia fowleri examined) at different maturity stages and different
examined with a stereomicroscope.

To determine the towing course of the net in the
water and the volume of water filtered, a
solution neutralized by hexamine. In the laboratory,
(1947) and then the gut contents of each individual was
considered.

vertical distance recorder and
tow was carried out at

the following five maturity stages; juvenile, stage
I, stage II, stage III and stage IV by Thomson's method

organisms in the gut/the total number of
consumption by
SJ. Eucalanus
Sagitta hexaptera
Sagitta lyra
Eukrohnia fowleri

items in their gut, therefore food organisms in the
organisms in the gut were
the predominant food organisms were copepods and
was 71.6 %, 16.2 %, 1.4 %, 1.4 % and 9.4 %,
respectively. The 24 species of copepods, 5 of chaeto­
10.000
1500
1000
500
Day Night
Wind: m/100m²
ST H10
0
1500
Depth (m)

ML

Vertical distribution
Vertical distribution of S. zetesios at Station 223 and
Station H 10 showed the same pattern. S. zetesios inha­
bited in the deep water layers between about 200 m and
1 700 m, and juveniles had different distributions from
maturating 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 concen­
trations 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.

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 Hakuhô Maru and Tan­
sei Maru of the Ocean Research Institute, University of
Tokyo. Samples were obtained with horizontal or obli­
que tows by a 160-cm ORI net with 1 mm or 0.33 mm
mesh-opening (Omorî, 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 obli­
que 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 number 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.

RESULT

Vertical distribution
Vertical distribution of S. zetesios at Station 223 and
Station H 10 showed the same pattern. S. zetesios inha­
bited in the deep water layers between about 200 m and
1 700 m, and juveniles had different distributions from
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located in the upper 500 m during both day and night.
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trations 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.

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.
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, Eupha­
usiacea, 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 chaeto­
ghnaths and 1 of ostracods were identified and 20 species
are 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
nega and the major prey of adults were large-sized
meso- and bathypelagic copepods. There was also can­
nibalism 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 compa­
red with maturing and adult animals.

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

<table>
<thead>
<tr>
<th>Species</th>
<th>Preys</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eukrohnia fowleri</td>
<td>Diatoms, Radioralians Copepods</td>
<td>Tchindonova (1959)</td>
</tr>
</tbody>
</table>

Figure 1
Sampling stations of Sagitta zetesios by horizontal tow (solid circles) and oblique tow (open circles) in the North Pacific and Sagami Bay.
Table 2
List of the food organisms found in the gut of Sagitta zetesios collected from Sagami Bay.

<table>
<thead>
<tr>
<th>Food organisms</th>
<th>Juvenile</th>
<th>Stage I</th>
<th>Stage II</th>
<th>Stage III</th>
<th>Stage IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copepoda</td>
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<tr>
<td>Calanus cristatus</td>
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<tr>
<td>C. plumchrus</td>
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<tr>
<td>C. pacificus</td>
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<tr>
<td>* Undinula vulgaris</td>
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<tr>
<td>Eucalanus bungii</td>
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<tr>
<td>* E. crassus</td>
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<td>* E. subtenus</td>
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<tr>
<td>Rhincalanus nasutus</td>
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<td>R. ornatiss</td>
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<tr>
<td>* Clausocalanus araucicorns</td>
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<tr>
<td>Aetideus armatus</td>
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<tr>
<td>Gaetanus armiger</td>
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<tr>
<td>* Euchaeta concinna</td>
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<tr>
<td>Parecheta russelli</td>
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<tr>
<td>P. scaphula</td>
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<td>P. rubra</td>
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<tr>
<td>Scaphocalanus echinatus</td>
<td>+</td>
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<tr>
<td>* Scolopithrix danae</td>
<td>+</td>
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<tr>
<td>* S. nicobarica</td>
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<tr>
<td>Scolopithrix valida</td>
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<td>Pleurostomum abdominalis</td>
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<tr>
<td>Heterorhabdus pacificus</td>
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<tr>
<td>* Candacia bipinnata</td>
<td>+</td>
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<tr>
<td>Ocnophaea sp.</td>
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<tr>
<td>Chaetognatha</td>
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<tr>
<td>Sagitta nagae</td>
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<tr>
<td>S. tyra</td>
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<tr>
<td>S. neodicipiens</td>
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<tr>
<td>S. macrocephala</td>
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<tr>
<td>S. zetesios</td>
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</tr>
<tr>
<td>Ostracoda</td>
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<tr>
<td>Conchoecia elegans</td>
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</tr>
</tbody>
</table>

* 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).

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.

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

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

<table>
<thead>
<tr>
<th>Maturity stage</th>
<th>Number of S. zetesios containing food organisms in the gut (A)</th>
<th>Total number of S. zetesios examined (B)</th>
<th>A/B × 100 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juvenile</td>
<td>26 (2)*</td>
<td>168</td>
<td>15.5</td>
</tr>
<tr>
<td>Stage I</td>
<td>82 (15)</td>
<td>396</td>
<td>20.7</td>
</tr>
<tr>
<td>Stage II</td>
<td>51 (7)</td>
<td>383</td>
<td>13.2</td>
</tr>
<tr>
<td>Stage III</td>
<td>2 (2)</td>
<td>137</td>
<td>1.5</td>
</tr>
<tr>
<td>Stage IV</td>
<td>2 (2)</td>
<td>63</td>
<td>3.2</td>
</tr>
</tbody>
</table>

* Figures in the brackets show 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 H10.

<table>
<thead>
<tr>
<th>Station</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>223</td>
<td>153</td>
<td>118</td>
</tr>
<tr>
<td>10</td>
<td>223</td>
<td>118</td>
</tr>
<tr>
<td>Mesopelagic layer</td>
<td>22.6%</td>
<td>18.9%</td>
</tr>
<tr>
<td>Bathypelagic layer</td>
<td>5.9%</td>
<td>3.2%</td>
</tr>
</tbody>
</table>

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

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

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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*.

Acknowledgements

The authors would like to thank Dr. O. Tanaka for his kind identification of copepod species contained in the gut of *Sagitta zetesios*. Thanks are also due to officers and crews of the R/V Hakuho Maru and Tansui Maru of the Ocean Research Institute, University of Tokyo for their cooperation during the cruises.

References


