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Feeding behavior of the poecilostomatoid copepods *Oncaea* spp. on chaetognaths

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Abstract

Feeding behaviors of the poecilostomatoid copepods *Oncaea venusta*, *O. mediterranea* and *O. conifera* were examined in the coastal area of Cheju Island, south of the Korean Peninsula, from April 1993 to November 1995. Late copepodid stages (CV, adult female and male) showed a high frequency of association with larger zooplankton such as *Sagitta* spp. (Chaetognatha), *Oikopleura* spp. (Appendicularia), and *Salpa* spp. (Thaliacea) in a coastal upwelling zone and around the small Munsum Island. Attack behaviors on *Sagitta* observed under the microscope and in the field showed that *Oncaea* approached *Sagitta* using their swimming legs, and then crawled chiefly to the neck regions and caudal septum (around the tail) of *Sagitta* spp. using their second antennae. They pierced the body of *Sagitta* with their sharp maxillipeds, and moved their maxillae and mandibles repeatedly. Midgut contents of *Oncaea* spp. consisted mainly of unidentified fine particles, and the greater part of the gut was empty. Their mouthpart structure is remarkably different from other pelagic copepods. Such differences of the mouthpart structures and the feeding habits in the genus *Oncaea* around Cheju Island are discussed in terms of feeding behavior and ecology in this coastal upwelling area.

Keywords: Feeding behaviour; Oncaea; Cheju Island; chaetognaths; Copepoda

1. Introduction

The poecilostomatoid copepod genus *Oncaea* has 80 known species and occurs frequently in marine ecosystem from the surface to the deep sea (Malt et al., 1989; Böttger-Schnack, 1994). The copepods are very common in the epipelagic layers around the sea of Cheju Island, south of the Korean Peninsula. It was found all year round and was particularly abundant in late spring (May–June) and late autumn (October–November) (Go et al., 1994). In this area, *Oncaea* is the main foods for the subtropical damsel fish *Chromis notatus* (Go and Jeon, 1983) and for various other fishes (Govoni et al., 1986).

Although the genus *Oncaea* is numerically very important in the marine ecosystem (e.g. Böttger-Schnack, 1994), the food habits of these copepods have not been clarified to date. The question of feeding in the genus *Oncaea* raises special problems. The poicilostomatoid copepods are all associates of gelatinous zooplankton, such as appendicularians and

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salps (Huys and Boxshell, 1991). The older stages *Oncaea* are often attached to larger particles (e.g. Ohtsuka and Kubo, 1991). Recently Ohtsuka et al. (1996) found chaetognaths in the guts of large *Oncaea* species. Data on the feeding of tropical Oncaeidae to understand their role in the ocean are scarce and do not reveal many details (Pasternak, 1984; Petipa, 1985; Ohtsuka and Kubo, 1991).

The mouthparts of Oncaeidae are not adapted for mastication or suction, but more properly for collecting particles from the surface or body wall (Sars, 1918). *Oncaea* spp. collected from the Pacific coast of Japan utilized discarded larvacean houses as part of their food (Ohtsuka and Kubo, 1991). And they attach themselves to the body of macrozooplankton such as *Sagitta* spp., *Oikopleura* spp. (Go et al., 1996) and *Salpa* spp. (present study) in a coastal upwelling area.

This paper examines the food habits and feeding behavior in genus *Oncaea* on the basis of gut content analysis, field sampling, and in situ behavioral observations, and discusses their feeding strategy.

2. Materials and methods

Zooplankton were collected by horizontal surface tows and oblique tows from the bottom to the surface using a conical net (mesh size: 330 μm, 56 cm in diameter). A flowmeter was set on each net ring to measure the volume of water filtered. The material was collected in coastal waters around Cheju Island (126°10′E–126°58′E, 33°10′N–33°35′N) from March 1993 to November 1995. The feeding behavior of *Oncaea* was observed mainly in June and November. The sampling sites were described in detail by and Go et al. (1996) and the environmental data by Pang and Kim (1993) and Kang et al. (1996).

The collected specimens were fixed with 10% neutralized formaldehyde-seawater. Some female and male adult *Oncaea* collected during night and day were first fixed in 4% glutaraldehyde and later in 1% osmic acid for SEM observations. The procedures of guts contents analysis with a SEM (Hitachi 2460N) were based on Ohtsuka (1985), Turner (1986, 1987), Ohtsuka et al. (1987) and Ishimaru et al. (1988).

In the field feeding behaviors were observed visually by SCUBA diving at the coast of Munsum Island (126°34′E, 33°14′N) during night in November 1995. Direct underwater observations were performed by using the transparent class box attached a magnification and scale. In addition short (ca 0.5–1 min.) tows were made in the surface layer using a net with a large cod end (ca. 2000 ml) for observations of a video-supported microscope. The drawing of the attacking behaviors on *Sagitta* were based on the direct underwater observations in the field and the images of a video-supported microscope.

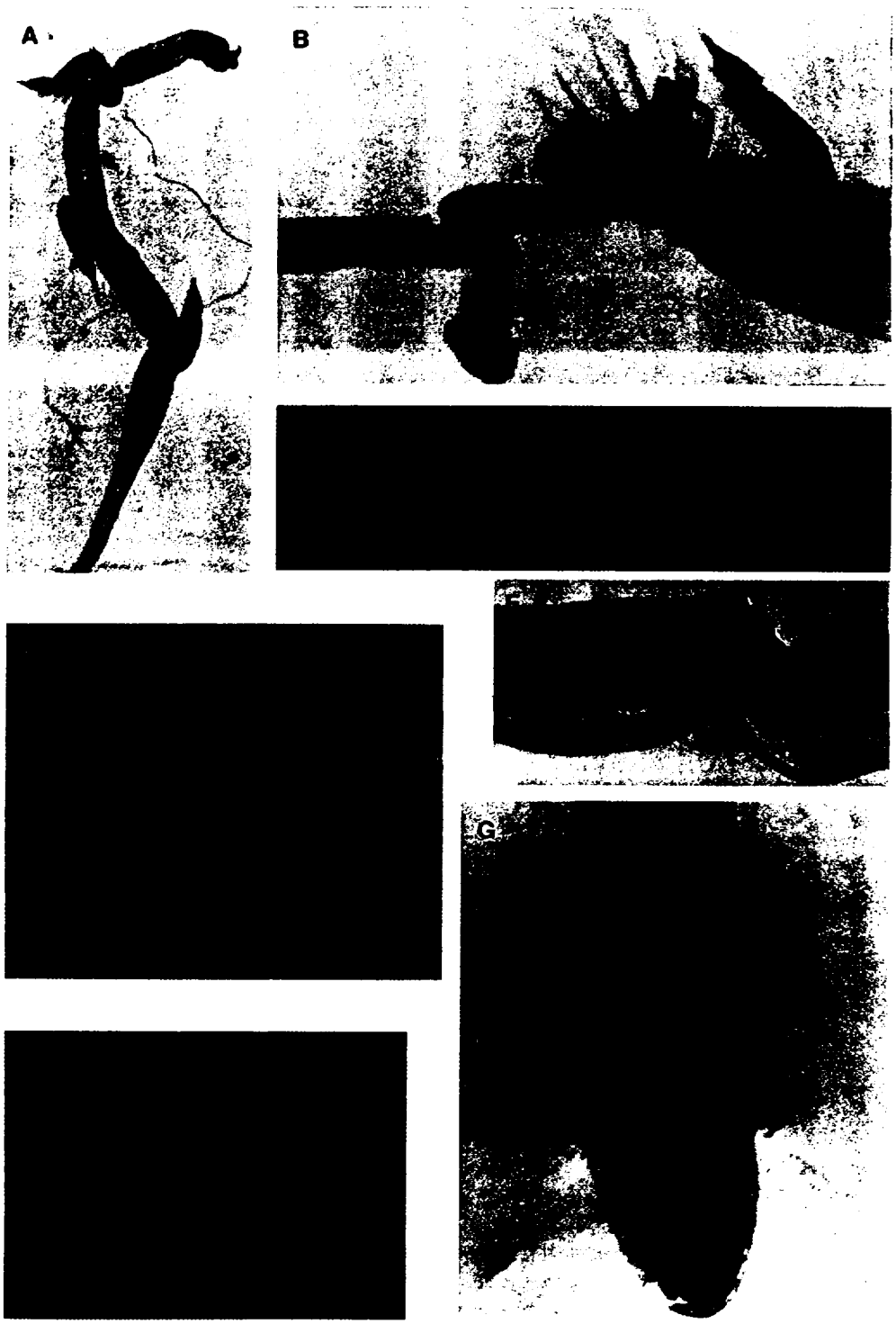
3. Results

3.1. Laboratory observations of Oncaea feeding

High densities of *O. venusta* Philippi and *O. mediteranea* Claus occurred in surface collections and of *O. conifera* Giesbrecht in oblique collections in the present study. These three *Oncaea* species were found in association with macrozooplankton such as *Sagitta* spp., *Oikopleura* spp., and *Salpa* spp. around the coastal upwelling area of Cheju Island (Figs. 1 and 2A, B).

Oncaea species attached themselves to various zooplankton texa, such as Siphonophora, Chaetognatha, Amphipoda, Decapoda, Euphausiacea, Pteropoda, Appendicularia, Thaliacea, fish larvae and other Copepoda. Of these, gelatinous macrozooplankton such as Chaetonatha (9.8–74.8%), Appendicularia (6.5–15.8%) and Thaliacea (1.4–5.6%), showed a high frequency of attachment rate (Table 1). The early *Oncaea* copepodid stages (CI–CIV) and adult female with egg sac attached on *Sagitta* were not found during the survey. And the possibility of being attached in the cod end was slight, as indicated by the high attachment frequency and by very short sampling time (0.5–1 min.) using a large volume cod end.

Fig. 1. Micrographs of *Oncaea* spp. in association with *Sagitta* spp. and *Oikopleura* sp. (A–C) Attached to *Sagitta* spp. (D) *Oncaea* sp. in foregut of *Sagitta* sp. (E) Marks of *Oncaea* maxilliped. (F) Attached to *Oikopheura* sp. (G) Tail of *Sagitta* sp.


A
B
G

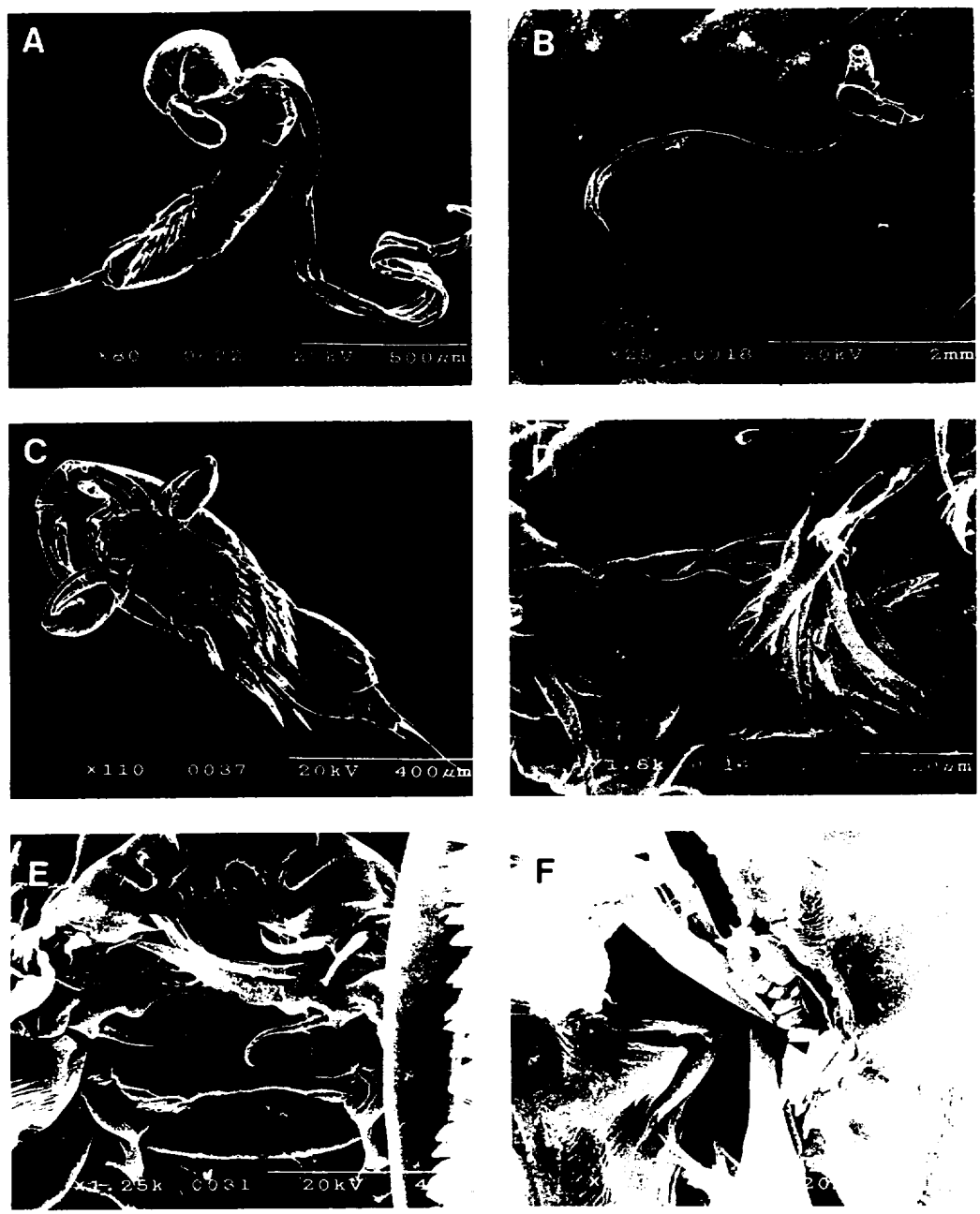


Fig. 2. SEM micrographs of *Oncaea* spp. A. *O. "enusta* Philippi attached to *Oikopleura* sp. B. *Oncaea* sp. attached to tail of *Sagitta* sp. C–F. Mouthparts of *Oncaea "enusta*.

The location of attacks was more frequently at the tail near the seminal vesicles posterior part of caudal septum, and neck anterior to the ventral ganglion, while the body trunk between ventral ganglion and caudal septum was attached to a lower degree Table 2. And the frequency of attack side

Table 1
Frequency of the various zooplankton to which *Oncaea* spp. attached in the coastal upwelling area

Zooplankton	Frequency (%)	*n*
Siphonophora	c	68
Chaetognatha	9.8–74.7	175
Copepoda	c	77
Amphipoda	c	20
Decapoda	c	34
Euphausiacea	0.2–2.4	89
Pteropoda	0.3–1.2	95
Appendicularia	6.5–15.8	169
Thaliacea	1.4–5.6	134
Fish larvae	0.2–3.7	31

n: no. of observations; c: less than 0.05%.

on *Sagitta* was higher on ventral side than on the dorsal side (Table 3). This phenomenon was not clear when they attached themselves to the tail part of *Sagitta*.

3.2. Field observations of the attacking behavior on chaetognaths

Direct underwater observations with SCUBA were performed at night. The attack behavior of *Oncaea* started mostly from below the stationary *Sagitta* in the field. The attack distance at which *Oncaea* spp. approached *Sagitta* spp. from below was about 5–6 cm. The attacking behavior from the upper side of *Sagitta* was observed only occasionally, and the attack distance was about 1–3 cm in this case. This behaviour suggests that *Oncaea* is not a touch feeder. After *Oncaea* reached the surface of *Sagitta*, they crept directly to the chaetognath tail or the head region using their second antennae (Fig. 3). Occasionally they moved along the part of the *Sagitta*

Table 2
The body regions of *Sagitta* spp. where *Oncaea* spp. were attached. A total 253 individuals of *Sagitta* with *Oncaea* examined

Final attack region	Frequency (%)
Around neck (near the ciliary loop)	39.2
Around tail (near the seminal vesicles)	48.7
Body trunk (region between ventral ganglion and caudal segment)	12.1

Table 3
The attachment sites of *Oncaea* spp. on the body of *Sagitta* spp. A total of 320 individuals of attached *Oncaea* examined

Attack site of *Oncaea*	Frequency (%)
Ventral side of *Sagitta*	56.3
Lateral side	32.8
Dorsal side	10.9

body trunk that lacks fins (Fig. 4). The first antennae of *Oncaea* were expanded while swimming in the water. They were folded ventro-laterally after *Oncaea* reached, attached, and pierced *Sagitta* (Fig. 4).

Oncaea pierced the body of chaetognaths with the long claw of the maxilliped, and moved maxillae and mandibles repeatedly under the microscope in the field. The chaetognaths did not move at all when this copepod was crawling on the body. When *Sagitta* were pierced by the maxilliped, they wiggled or moved slightly, and some chaetognaths disappeared from the field of vision.

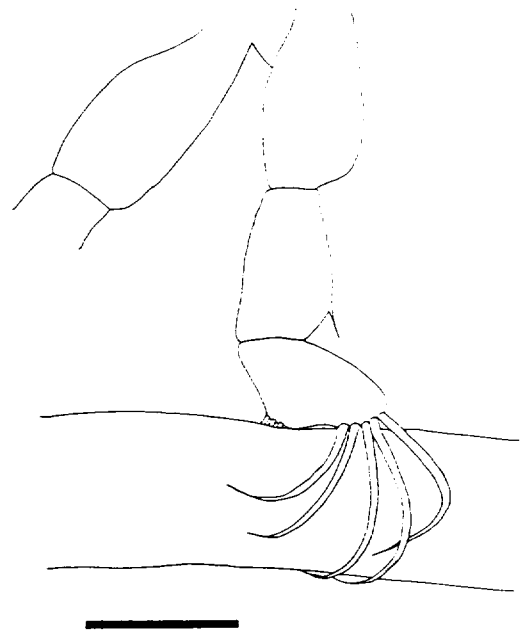


Fig. 3. Left second antenna of *Oncaea mediterranea* Claus on the body of a larval *Sagitta* sp.

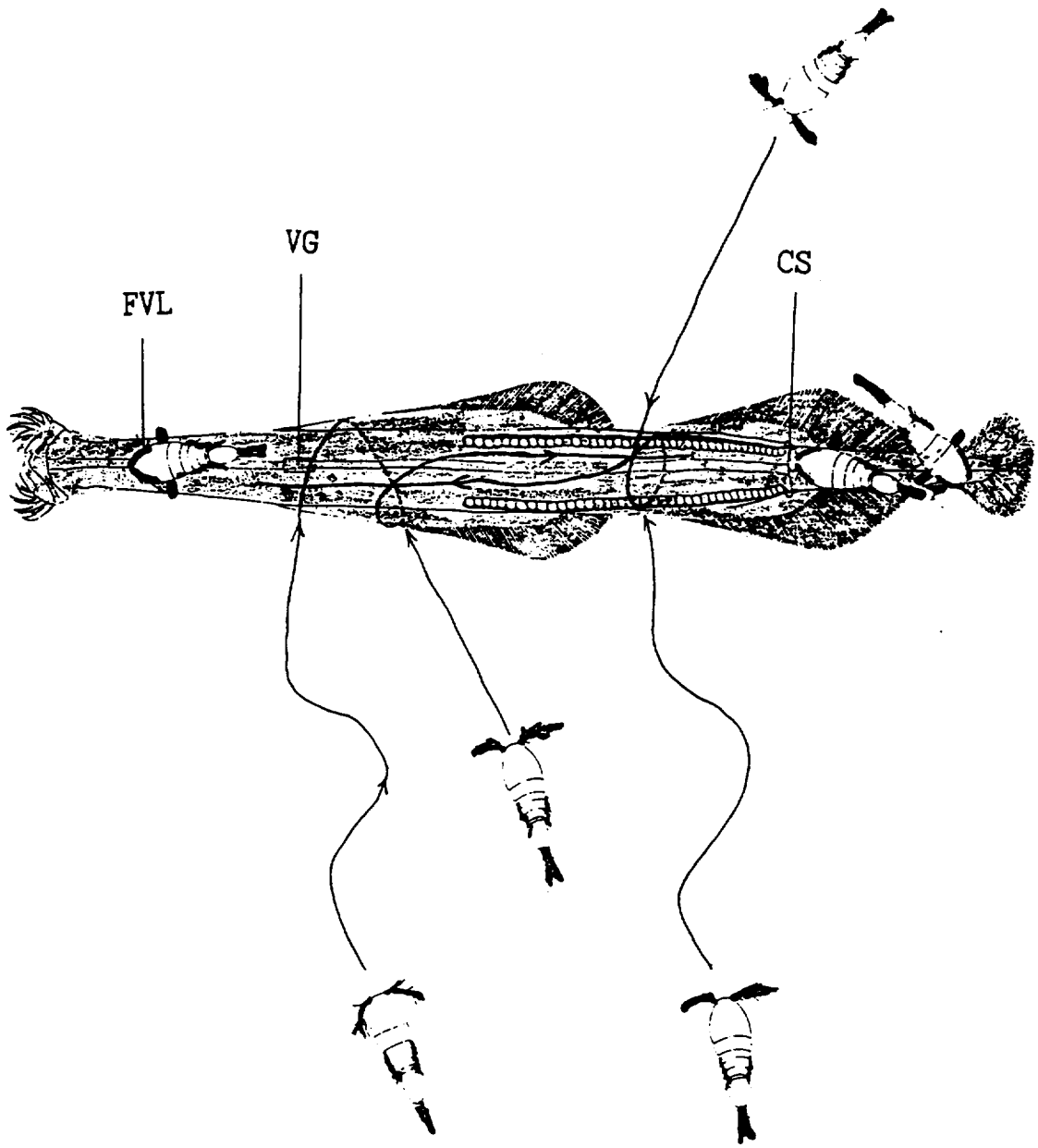


Fig. 4. Attacking behaviors of *Oncaea* on the body of *Sagitta*. *VG*s ventral ganglion; *CS*s caudal septum.

3.3. Gut content analysis and mouthpart of Oncaea

The first antennae of *Oncaea* can be folded backward just along the ventro-lateral cuticular ridge Fig. 2C. The mandible and maxilla seem better suited to scrape food particles rather than to hold and crush macrozooplankton Fig. 2D–F. The sharp and large maxillipeds of these copepods seem to work at a very rapid rate, to tear the body of macrozooplankton such as Chaetognatha and Appendicularia.

Table 4
Occurrence frequency (%) of food items detected in the guts of *Oncaea* spp. collected in coastal waters of Cheju Island. A total of 50 individuals were examined

Food items	Day	Night
Diatoms	2	4
Diatom fragments	4	2
Coccoliths	4	4
Dinoflagellates	0	2
Crustacean fragments	2	4
Unidentified fine particles	36	30
Unidentified remains	22	28
Empty	62	54

Midgut contents of *Oncaea* spp. sampled during both day and night were examined by SEM. The greater part of the midgut of these copepods collected at both periods was empty, and the contents consisted mainly of unidentified fine particles, and occasionally larvacean houses, diatoms, diatom fragments, coccoliths, dinoflagellates, crustacean fragments and unidentified remains (Table 4).

4. Conclusions

The Oncaeidae is a widespread family of typically small species which are abundant at all depths in the water column, especially in subtropical and tropical waters (Huys and Boxshell, 1991). We suggest that the *Oncaea* species studied here are nonvisual predators and utilize a variety of prey organisms. *Oncaea* feed on surfaces and tend to be associated with macrozooplankton, especially *Sagitta*, *Oikopleura* and *Salpa*, although their food and feeding habits vary depending on time, season, locality, sex, stages and environmental factors (Alldredge, 1976; Pasternak, 1984; Petipa, 1985; Paffenhöfer, 1991).

The maxilliped seems to be move at a very rapid rate, to scrape and tear the integument of *Sagitta* and *Oikopleura*. Aspects of feeding were described for *Oncaea* and deep-sea copepods by Wickstead (1962). His conclusion was that the Oncaeidae attach themselves to a host with the maxilliped and feed on particulate matter on the host, or on the body wall of the host, and pierce the body wall and feed on body fluids. We observed similar behaviours in an upwelling environment in the present study.

During the present study *Oncaea* spp. approached *Sagitta* spp. from a distance of 1–6 cm in the field. This implies that *Oncaea* use sense organs or sensory capability other than vision, since they lack an image-forming eye. Predators and omnivores must detect and orient themselves to their prey at a distance. In most copepods mechanoreceptors and chemoreceptors are the dominant sensory structures (Gophen, 1981).

Most part of the midgut contents of this *Oncaea* spp. were empty or unidentified fine particulate matters, and other contents such as larvacean house or phytoplankton and crustacean fragments were found on occasion. These gut contents may be derived indirectly from the surface of macrozooplankton or larger particles. Therefore we suggest that this copepod feeds chiefly on surface materials such as fine particles, bacteria, or the integument or fluid of gelatinous macrozooplankton. The phytoplankton and larvacean houses in the midgut of *Oncaea* spp. imply that they feed on houses and body wall of *Oikopleura* spp. (Ohtsuka and Kubo, 1991).

Early *Oncaea* copepodid stages and adult females with egg sacs were not found attached to *Sagitta* spp. in the present study. We need further studies of attacks by these copepods, the mechanics of ingestion, food requirements at different copepodid stages, and on the relationship between parasitic and gelatinous zooplankton.

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