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SEA ICE MEIOFAUNA AT SYOWA STATION, ANTARCTICA

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Abstract: Meiofauna composed mainly of copepods, larvae of some invertebrates and occasionally a ciliate in the bottom layer of the sea ice was observed in the vicinity of Syowa Station (69°00′S, 39°35′E), Antarctica. The copepods that appeared were *Paralabidocera antarctica*, three species of harpacticoid, *Ctenocalanus vanus, Oithona similis* and *Oncaea curvata* in the order of abundance. *P. antarctica* and harpacticoid species occurred continuously throughout the winter season. The maximum abundance of copepods was $21.8 \times 10^4/m^2$ in September 1975. The yearly fluctuation of their abundance was remarkable. *P. antarctica* grew in the sea ice possibly feeding on ice algae. The ecological relation of harpacticoid species to the sea ice was not clear but a close relationship was presumed. *C. vanus, O. similis* and *O. curvata* seemed to be temporal constituents of the meiofauna.

1. Introduction

The concept that the sea ice biota which consists of ice flora or ice algal community, ice fauna and sub-ice fauna plays an important role in the marine Antarctic ecosystems is generally accepted. The ice algal community comprising mainly diatoms develops in the interstices between ice platelets in the bottom layer of the sea ice. ANDRIASHEV (1968) defined the ice fauna and the sub-ice fauna as the animals which live at least temporarily within the sea ice and those which do not enter the sea ice but are connected with the ice algal community and/or ice fauna as part of the food web associated with the sea ice, respectively. This definition has been followed by most later workers. He emphasized that "a detailed study is desirable of species composition, biology, productivity and life condition of the ice community members and associated animals". However, the study of the Antarctic sea ice biota since the early 1960's has been mainly concentrated on the investigation of ice algae. Hitherto the species list of ice fauna by GRUZOV *et al.* (1967) is only a report dealing comprehensively with the composition of Antarctic ice fauna. New Zealand scientists carried out a preliminary research on the ice fauna in McMurdo Sound (KNOX, 1986). HOSHIAI (1981) reported the seasonal occurrence of the copepod nauplius in the sea ice of the Syowa Station area, but he did not give information on the other animals which appeared concurrently with the nauplius. It seems that the basic problems on the ecology of the Antarctic ice and sub-ice fauna still remain to be studied as was mentioned by ANDRIASHEV (1968). To complement this gap, we carried out an investigation of the seasonal occurrence of meiofauna in the sea ice in the vicinity of Syowa Station (69°00′S, 39°35′E).

2. Materials and Methods

Sea ice cores were sampled with a SIPRE ice coring auger (8 cm in diameter). Samplings were carried out in the three periods of March to December 1970, July to November 1975 and September to December 1982. Sampling sites in 1970 and 1975 were in the Kita-no-seto Strait about 500 m north of Syowa Station. They were situated close to each other. The site in 1982 was located about 200 m northwest of the Kita-no-seto Strait. A successive sampling of each year was made within a small area selceted on the first year ice.

A sea ice core was sectioned into several subsections of 3 to 15 cm in length in the field. Each subsection was thawed at about 20°C in the laboratory of the Station and preserved with buffered formalin. Enumeration of animals contained in the subsection was done later in Japan. Although all subsections were examined in the 1970 samples, only bottom subsections of 3 cm were examined in the 1975 and 1982 samples because the distribuion of animals was generally limited to a few centimeters of bottom layer of the sea ice. Individual number of animals was expressed as the number per square meter of ice field.

3. Results

3.1. Sea ice condition

In 1970, the sea ice thickness was 30 cm in late March and it increased continuously to about 150 cm by early October. Thereafter it stopped growing. In 1975 the sea ice thickness was not recorded in July but it reached 185 cm by September. The sea ice thickness during the sampling period in 1982 was 161 to 169 cm. In the bottom few centimeter layer of sea ice there were interstices of 0.5 to 1.0 mm in width between ice platelets which were parallelly arranged and grew downwards. Since the interstices were filled with sea water, the ice algae can grow and such small animals as copepods are able to penetrate into there. Because part of interstitial water flowed out when an ice core was drawn up, the individual number of animals recorded may indicate an underestimated figure. Snow accumulated temporarily at the sampling sites and the maximum snow depth was about 40 cm.

3.2. Occurrence of meiofauna in sea ice

On the basis of observation of animals in the fixed samples from surface through bottom of the sea ice collected in 1970 it was confirmed that the distribution of animals was usually confined to the bottom layer of a few centimeters. Occasional and sporadic occurrences of animals were observed up to 20 cm from the sea ice bottom. They seemed to have been entrapped in the intersticies between ice platelets as the freezing advanced.

In 1970, the animals in the bottom layer were a species of ciliate, copepods comprizing nauplius, copepodite and adult, benthos larvae including tadpoles of ascidians and unidentified eggs (Table 1). The ciliate was observed only in late March with an individual number of $36.0 \times 10^4/m^2$. Copepods appeared continuously from late March to late November but disappeared in December. Their individual number reached a high level of $8.0 \times 10^4/m^2$ in mid-winter, July and August. The unidentified eggs seemed

Table 1. Occurrence of meiofauna in the sea ice ($\times 10^4$ individ./m^2).

	1970									
	Mar.	Apr.		May		June	July	Aug.	Sep.	
	27	9	23	1	22	28	22	18	1	18
Ciliata	36.0	—	—	—	—	—	—	—	—	—
Polychaeta larvae	—	—	—	—	—	—	—	—	—	—
Copepoda	0.1	2.6	3.2	4.4	3.4	5.2	7.9	8.0	3.6	5.1
Benthos larvae	—	<0.1	—	—	—	—	—	—	—	—
Egg	52.5	1.7	14.3	30.3	1.5	0.8	0.2	—	—	—
Total	88.6	4.3	17.5	34.7	4.9	6.0	8.1	8.0	3.6	5.1

	1970					1975					
	Oct.		Nov.		Dec.	July			Aug.		
	10	29	14	28	12	3	17	28	11	21	31
Ciliata	—	—	—	—	—	—	—	—	—	—	—
Polychaeta larvae	—	—	—	—	—	<0.1	—	—	—	—	—
Copepoda	4.1	4.0	1.4	<0.1	—	13.1	6.2	11.7	7.9	5.3	16.0
Benthos larvae	—	—	—	—	—	—	—	—	<0.1	—	—
Egg	—	—	—	—	—	—	—	—	<0.1	—	—
Total	4.1	4.0	1.4	<0.1	0.0	13.1	6.2	11.7	7.9	5.3	16.0

	1975						1982			
	Sep.		Oct.			Nov.	Sep.	Oct.	Nov.	Dec.
	11	22	2	18	31	7	18	10	10	13
Ciliata	—	—	—	—	—	—	—	—	—	—
Polychaeta larvae	—	—	—	—	—	—	—	—	—	—
Copepoda	14.9	21.8	14.1	7.4	1.5	1.2	8.3	18.0	2.9	—
Benthos larvae	—	—	—	<0.1	—	<0.1	—	—	<0.1	—
Egg	—	—	—	—	—	—	—	—	—	—
Total	14.9	21.8	14.1	7.5	1.5	1.3	8.3	18.0	2.9	0.0

to be of copepods. They were generally abundant in late autumn and decreased toward winter. The period in which larvae of benthic animals appeared was confined to autumn.

In 1975 copepods, larvae of polychaetes, larvae of benthic animals and unidentified eggs were observed. The dominant components were copepods as in 1970. In general the copepods were more abundant than in 1970. The maximum was 21.8×10^4/m^2 in September. Larvae of polychaetes appeared in early July. The identification of larvae of other animals in August, October and November was difficult. Most eggs seemed to be of copepods as in 1970.

The observation of 1982 was carried out after late winter and the sampling interval was about one month (Table 1). However, the results obtained were consistent with those of the other years. Dominant components were copepods and their maximum abundance was 18.0×10^4/m^2 in October. The larvae of benthic animals in November comprised mainly the tadpoles of ascidians. No animals were found in December.

3.3. Copepods in sea ice

Copepods that appeared in the sea ice were *Ctenocalanus vanus*, *Paralabidocera*

Table 2. Numerical composition of copepod species in the sea ice ($\times 10^4$ individ./m^2).

	1970									
	Mar.	Apr.		May		June	July	Aug.	Sep.	
	27	9	23	1	22	28	22	18	1	18
Ctenocalanus vanus	—	0.1	—	—	0.1	0.1	0.1	—	—	—
Paralabidocera antarctica										
copepodite	—	—	—	—	—	—	—	—	—	0.1
nauplius	0.1	2.3	3.2	4.3	2.9	4.7	7.1	6.9	3.0	2.6
Oithona similis	—	0.1	—	0.1	0.1	0.1	0.1	—	—	—
Oncaea curvata	—	—	—	—	—	—	—	—	—	—
Harpacticoida spp.										
adult	—	—	—	0.1	—	—	—	—	—	—
copepodite (CI-CV)	0.1	—	—	—	—	0.1	—	0.1	0.1	0.8
nauplius	—	0.1	—	—	0.4	0.2	0.6	0.9	0.5	1.6
Unidentified nauplius	—	0.1	0.1	0.1	—	—	—	0.1	—	—
Total	0.2	2.7	3.3	4.6	3.5	5.2	7.9	8.0	3.6	5.1

	1970					1975					
	Oct.		Nov.		Dec.	July			Aug.		
	10	29	14	28	12	3	17	28	11	21	31
Ctenocalanus vanus	—	—	—	—	—	—	—	—	—	—	—
Paralabidocera antarctica											
copepodite	0.4	0.2	0.3	—	—	—	—	—	—	—	—
nauplius	1.1	0.5	0.1	—	—	13.1	5.9	10.6	6.9	5.2	12.6
Oithona similis	—	—	—	—	—	—	—	—	<0.1	—	—
Oncaea curvata	—	—	—	—	—	—	—	—	<0.1	—	—
Harpacticoida spp.											
adult	—	0.1	0.1	—	—	—	<0.1	<0.1	—	<0.1	0.1
copepodite (CI-CV)	1.8	1.5	0.4	0.1	—	—	<0.1	—	<0.1	<0.1	—
nauplius	0.8	1.8	0.5	—	—	<0.1	0.3	1.1	0.9	0.1	3.3
Unidentified nauplius	—	—	0.1	—	—	—	—	—	—	—	—
Total	4.1	4.1	1.5	0.1	0.0	13.1	6.2	11.7	7.9	5.3	16.0

	1975						1982			
	Sep.		Oct.			Nov.	Sep.	Oct.	Nov.	Dec.
	11	22	2	18	31	7	18	10	10	13
Ctenocalanus vanus	—	—	—	—	—	—	<0.1	—	—	—
Paralabidocera antarctica										
copepodite	—	<0.1	0.3	0.6	0.3	0.3	<0.1	0.9	1.9	—
nauplius	9.2	15.5	6.8	1.6	0.4	0.3	5.4	6.3	0.2	—
Oithona similis	—	<0.1	—	—	<0.1	—	—	—	0.2	—
Oncaea curvata	—	—	—	—	—	—	<0.1	—	—	—
Harpacticoida spp.										
adult	<0.1	—	—	<0.1	<0.1	<0.1	—	0.1	—	—
copepodite (CI-CV)	0.1	0.2	0.7	1.6	0.4	0.4	0.3	1.9	0.6	—
nauplius	5.6	6.0	6.3	3.5	0.3	0.1	2.6	8.8	—	—
Unidentified nauplius	—	0.1	—	—	—	—	—	—	—	—
Total	14.9	21.8	14.1	7.4	1.5	1.2	8.3	18.0	2.9	0.0

antarctica, *Oithona similis*, *Oncaea curvata*, possibly at least three species of harpacticoids and unidentified nauplii (Table 2). The most abundant species was *P. antarctica* followed by harpacticoid species. They appeared continuously from autumn to early summer. The occurrence of *C. vanus*, *O. similis* and *O. curvata* was rather temporal. In 1970 the three copepods tended to appear in the winter months but any definite tendency in their appearance was not observed in 1975.

The nauplius of *P. antarctica* appeared in the sea ice in late March and reached the maximum number of $7.1 \times 10^4/m^2$ in July 1970 (Table 2). Thereafter it decreased with the progress of season and disappeared from the sea ice in December. However, the yearly difference in abundance and the seasonal fluctuation pattern of this species were remarkable. The maximal abundance in 1975 was $15.5 \times 10^4/m^2$ in late September (Table 2). The *P. antarctica* population was composed only of nauplius till early September but thereafter copepodite was included in the population. This suggests that the individuals of *P. antarctica* can grow in the sea ice habitat. To examine this possibility the age composition of this species was studied (Fig. 1). In 1970 the growth of nauplius was observed from May to June. Although the growth of nauplius was obscure between July and September in 1970 and 1975, the growth of nauplius and copepodite occurred from October to November in all the three years.

As mentioned above, harpacticoids were the second dominant constituent of sea

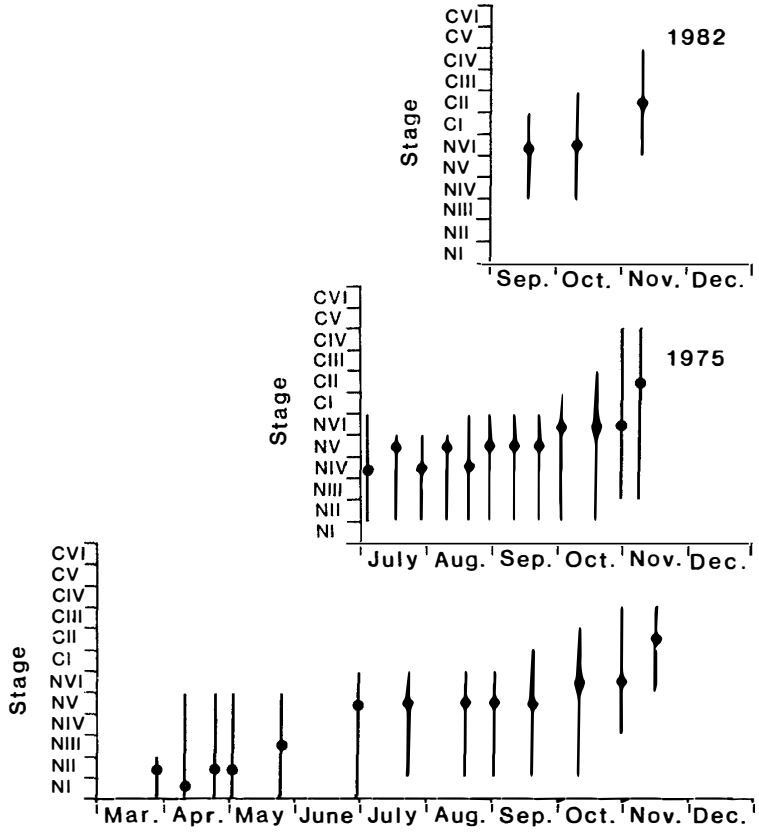

Fig. 1. Age composition of P. antarctica. *Vertical bar denotes the range of developmental stages and solid circle indicates the most abundant stage in a population.*

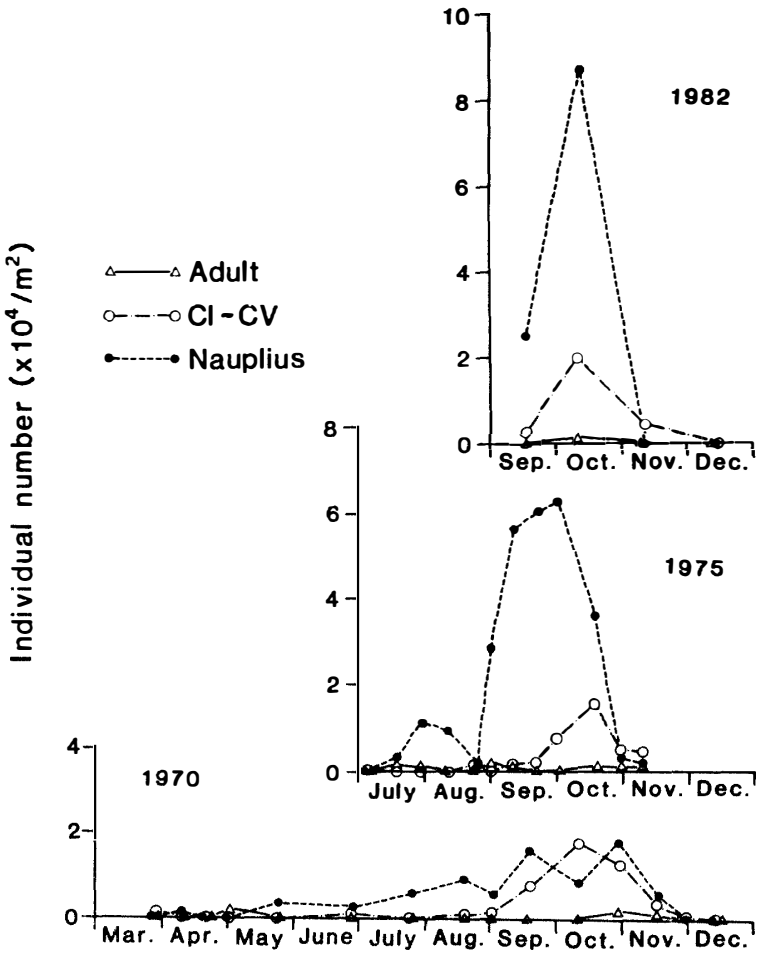

Fig. 2. Age composition of harpacticoid species.

ice meiofauna. Although the yearly fluctuation of population was large, harpacticoids occurred in all the three periods. Their abundance was high between September and November (Fig. 2). The harpacticoid populations were composed of nauplius, copepodite and adult throughout the three observation periods. Due to taxonomic difficulties in the Antarctic harpacticoids, it is difficult at present to make specific analysis of seasonal sequence of their population.

4. Discussion

As the constituents of ice fauna, GRUZOV *et al.* (1967) mentioned polychaetes, *Harmothoe* sp., *Pionosillis* sp.; possible one species of calanoid copepod; cyclopoid copepod, *Oithona* sp.; harpacticoid copepods, *Tisbe* sp., *Harpacticus* sp., *Dactylopodia* sp.; amphipods, *Orchomenopsis* sp., *Bovallia walkeri*; fish, *Trematomus borchgrevinki* fry in the Davis Sea in December 1965 and January 1966. They noted that the occurrence of polychaetes seemed to be accidental. The present samples did not contain polychaetes and neither amphipods nor fish fry. Amphipods temporarily attach to the undersurfaec of sea ice and fish fry usually swim beneath the ice and occasionally enter the pits of the sea ice bottom. Therefore, this difference in the species composition was brought

about by the difference in the sampling method used in the two studies. The samples of GRUZOV and his co-workers were collected by scratching the sea ice bottom with a toothed net, whereas our samples were taken with an ice auger.

GRUZOV *et al.* (1967) stated that the number of copepods was small in their samples. KNOX (1986) mentioned that there were several species of protozoa, a nematoda and a mite in the sea ice cores taken with SIPRE auger in McMurdo Sound in summer. He did not mention the presence of copepods. The present results show that the abundance of copepods was high in winter, diminished toward summer, and after December they disappeared from the sea ice. It is suggested that the winter observation is essential to estimate the biomass of copepods associated with sea ice and to assess their ecological role in the coastal Antarctic ecosystem.

Possibly the sea ice meiofauna is classified into two groups, the temporal group and the permanent one. Ciliate, larvae of benthic animals, *C. vanus*, *O. similis* and *O. curvata* belong to the former and *P. antarctica* and harpacticoid species the latter. TANIMURA *et al.* (1986) reported that *O. similis* and *O. curvata* were abundant in the water column during winter. *C. vanus* was also a constituent of winter zooplankton community. However, the appearance of these copepods in sea ice was temporal and their abundance in the sea ice was extremely low in comparison with that in the water column. On the contrary, the occurrence of *P. antarctica* in the sea ice was lengthy and its abundance was ten times that in the water column. The sea ice seems to be important for the winter life of *P. antarctica* because it grew in and just beneath the sea ice bottom in May to June and October to November. Usually the ice algal concentration in the sea ice bottom is high in the above seasons (HOSHIAI, 1981) in spite of the poverty of phytoplankton in the water column (FUKUCHI *et al.*, 1985). It seems that *P. antarctica* grows feeding mainly on the ice algae. Frustules of sea ice diatoms and/or their fragments are frequently detected in the alimentary duct of nauplii and copepodites of this species (TANIMURA, unpublished). As to the harpacticoids the similar situation is suspected because they are also permanent constituents of ice meiofauna. However, the relationship between the temporary group and the sea ice is not clear at this stage of our investigation.

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