Swarm of *Paralabidocera antarctica* (Calanoida, Copepoda) under Sea Ice near Syowa Station, Antarctica

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昭和基地近くの海氷下で観察された *Paralabidocera antarctica* (橈脚類) の集群について

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要旨: 1982 年 1 月 22 日から 23 日にかけて，昭和基地近くの北の瀬戸 (水深約 10 m) の海氷下において，*Paralabidocera antarctica* (橈脚類) の濃密な単一群が観察された．出現した本種の大部分は成体であった．昼間，*P. antarctica* は海氷下面に集群を形成し，およそ $2\text{–}6\times10^4$ 個体/m^3 の密度で，海氷下面付近のきわめて狭い層に平板状に分布していたものと推定された．成体雌の大部分に精包の付着がみられ，集群が生殖行動と関連していることが示唆された．また，集群は海氷下面の明るさに誘引されることによって生じたものと思われた．夜間，本種の集群は全水柱から消失した．この夜間の集群の消失は，個体群の大部分が海氷中に入りこんだために起こった可能性があることが示唆された．

Abstract: A monospecific swarm of a calanoid copepod *Paralabidocera antarctica* was observed under the fast ice in the Kita-no-seto Strait near Syowa Station, Antarctica. During the day on January 22 to 23, a swarm appeared just beneath the undersurface of the fast ice. It was primarily composed of adults. *P. antarctica* seemed to have aggregated horizontally in an extremely narrow layer against the undersurface of the sea ice with density of roughly $2\text{–}6\times10^4$ ind./m^3. Swarming may be associated with reproduction because almost all of adult females were carrying the spermatophores. *P. antarctica* was probably attracted to the undersurface brightness of the sea ice. At night, a swarm disappeared from the whole water column and the zooplankton composition differed from that during the day. It was assumed that the disappearance of the swarm was due to *P. antarctica's* entering into the loose lower part of the fast ice.

1. Introduction

Paralabidocera antarctica is a calanoid copepod belonging to the family Acartiidae. This species was first described by THOMPSON (1898) from the South Shetland Islands as *Paracartia antarctica*. Several works (cf. WOLFENDEN, 1908, as *Paralabidocera hodgsoni*; FARRAN, 1929; VERVOORT, 1951, 1957; SENO *et al.*, 1963; TANAKA, 1964) have reported this species from the Antarctic waters. Recently, *P. antarctica* has been recovered under the fast ice near McMurdo Station (BRADFORD, 1971) and Molodezhnaya Station (ZVEREVA, 1975) in Antarctica. Around Syowa Station, *P. antarctica* was a predominant species in number at the Kita-no-seto Strait in the summer season

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of 1975 (FUKUCHI and TANIMURA, 1981). Moreover, the dense population was also observed just beneath the fast ice near the Station in the summer season of 1979 (FUKUCHI and SASAKI, 1981).

P. antarctica is endemic to the waters around Antarctica and may play an important role in secondary production under the fast ice area in the summer season. However, available information on the ecological aspects of this species is very scarce.

During the 23rd Japanese Antarctic Research Expedition in 1981–1983, a year-round biological investigation under the fast ice was performed as part of the Japanese national BIOMASS programme. This paper deals with the diurnal distribution and some ecological aspects of *P. antarctica* during the summer season in 1982 when a swarm of this species was observed just beneath the fast ice near Syowa Station (69°00'S, 39°35'E).

2. Materials and Methods

During the period from 10^{h} on January 22 to 10^{h} on 23, 1982, a zooplankton sampling at 3-hour intervals was carried out through a hole bored into the fast ice at Stn 1 in the Kita-no-seto Strait, close to Syowa Station (Fig. 1). The depth at Stn 1 changed from almost 10 m to 8 m by tide. The thickness of the sea ice was 94 cm.

Zooplankton samples were taken from five discrete layers at 0 (just beneath the sea ice), 2, 4, 6 m depths and near bottom (0.5 m above the bottom) with a "NIPR-I" sampler. Mesh size of the net attached to the sampler was 0.11 mm. Detailed description of the "NIPR-I" sampler and its operation was reported by FUKUCHI *et al.* (1979). Five minutes sampling was carried out at each layer. A total of 45 samples was obtained.

Samples were preserved in 5% formalin-buffered sea water. The number of

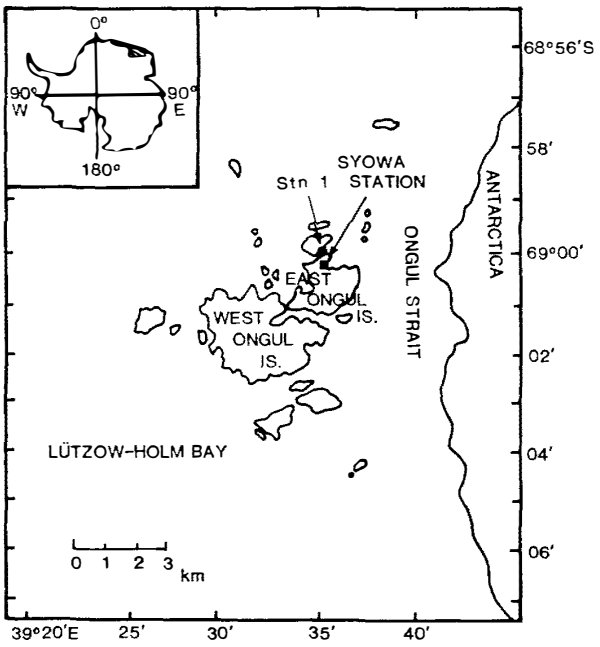

Fig. 1. Location of sampling station. Circle and square indicate Stn 1 and Syowa Station, respectively.

individuals of *P. antarctica* from a whole sample or subsample was counted. Each subsample was from 1/10 to 1/40 of a whole sample. As the flowmeter was not equipped to the "NIPR-I", it was difficult to estimate exactly the filtered volume of water. Zooplankton abundance was expressed as the individual number per five minutes sampling. However, the flow rate within the sampler is roughly estimated at 0.5 m^3/min (unpublished data).

The solar radiation data referred to in this study were obtained by the routine meteorological observation at Syowa Station.

3. Results

Figure 2 shows the solar radiation and each sampling period. The duration of sunshine was very long and the solar radiation reached a peak at noon. The duration of dusky condition was only a few hours around midnight. So we defined the period between 22^h to 04^h as the nighttime and the rest as the daytime.

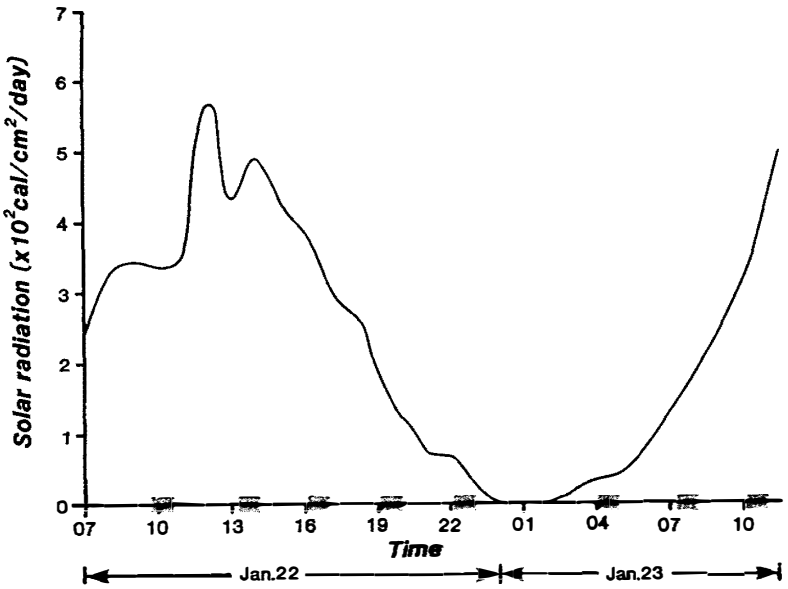

Fig. 2. Diurnal change of solar radiation at Syowa Station during the period from January 22 to 23, 1982. Hatched area shows the sampling period.

Data of individual numbers of *P. antarctica* per five minutes sampling are summarized in Table 1. Most of individuals occurred in the 0 m layer throughout nine samplings. In the 0 m layer, the dense population more than 5×10^4 ind. was found during the day between 10^h to 19^h on January 22 and 07^h to 10^h on January 23, occupying more than 99% of the total number. The density in the 0 m layer was roughly estimated to be $2\text{–}6\times10^4$ ind./m^3. The number in the 0 m layer sharply decreased at night from 22^h to 04^h, but the population more than 60% of total the number was seen in the 0 m layer during this period. Throughout the subsurface layers below 2 m depth, the population size was quite small, being less than 300 ind. (mostly less than 100 ind.). Any distinct changes in numbers between the day and the night were not recognized for the subsurface layers. Dense population which was formed in the 0 m layer during the day disappeared from the whole water column at night.

Table 1. Individual number of Paralabidocera antarctica per five minutes at each layer collected with a "NIPR-I" at Stn 1. Numerals in parentheses are the percentage to total number.

Depth (m)	January 22, 1982					January 23, 1982			
	0948 -1053	1322 -1400	1611 -1648	1914 -1948	2209 -2243	0111 -0147	0406 -0439	0723 -0757	1009 -1043
0	60040	67400	95080	52560	568	245	2180	140120	92320
	(99.4)	(99.8)	(99 9)	(99.1)	(84 1)	(59.6)	(91.7)	(99 8)	(99.8)
2	232	67	48	123	9	7	67	83	82
	(0 4)	(0.1)	(0.1)	(0 2)	(1 3)	(1.7)	(2.8)	(0.1)	(0.1)
4	75	23	25	300	35	45	105	56	33
	(0.1)	(<0.1)	(<0.1)	(0 6)	(5.2)	(10 9)	(4.4)	(<0.1)	(<0.1)
6	26	27	9	22	21	66	13	78	18
	(<0.1)	(<0.1)	(<0.1)	(<0 1)	(3.1)	(16.1)	(0.5)	(0.1)	(<0.1)
Near bottom	18	25	19	12	42	48	12	21	56
	(<0.1)	(<0.1)	(<0.1)	(<0.1)	(6.2)	(11 7)	(0.5)	(<0.1)	(0.1)
Total number	60391	67542	95181	53017	675	411	2377	140358	92509
	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)

P. antarctica collected were mostly adults (99.3% of total number) and the 5th copepodite stage occupied only 0.7%. The majority of adult females had one or two spermatophores attached to their genital segments, which a few females had several spermatophores.

In the 0 m layer, the sex ratio of adults (female/male) was 1.06 as an average though it largely changed from 0.45 to 1.62. The number of females was larger than that of males between 10^h and 16^h (Fig. 3). In spite of a sharp decrease in number of fe-

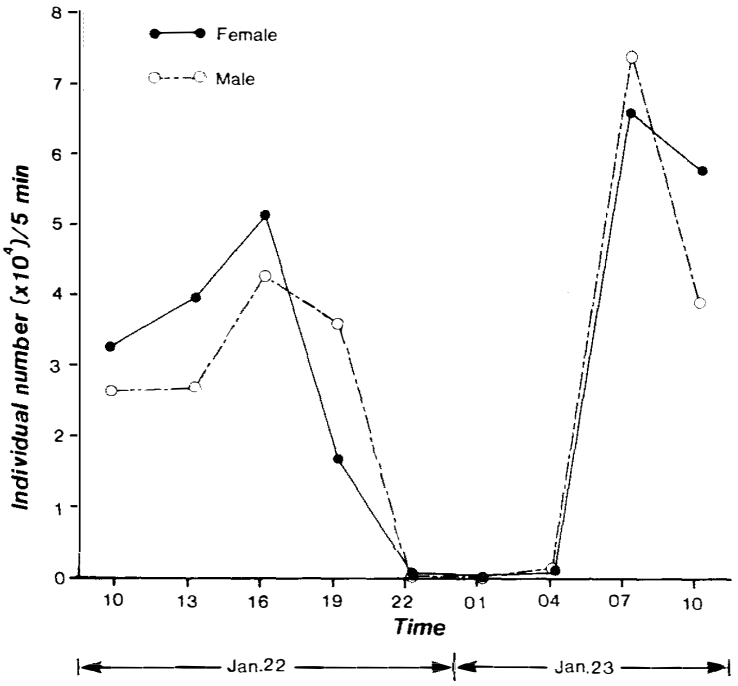

Fig. 3. Diurnal change of individual number of adult male and female of Paralabidocera antarctica collected with a "NIPR-I" at 0 m layer just beneath the sea ice at Stn 1.

males at 19[h], a large number of males remained and the inversion in sex ratio occurred. At 07[h] on January 23, males also outnumbered females.

Numerous fecal pellets were observed in the samples together with *P. antarctica*. The fecal pellets were considered to be produced by *P. antarctica* as those were comparable with the shape of thier guts. Length of fecal pellets was 350–450 μm (Fig. 4A). Microscopic examination revealed that undigested pennate diatoms were packed numerously in the feces (Fig. 4B).

As listed in Table 2, *P. antarctica* occupied more than 98% of total zooplankters in the 0 m layer during the day and *P. antarctica* formed a monospecific aggregation. A few remainders were other copepopds including nauplii and eggs and polychaete larvae. At night the zooplankton composition considerably changed; copepodites and nauplius stages of *Oithona similis* and *Oncaea curvata* occupied 61.1–84.8% of the total number. The total number of zooplankton at night was less than one-tenth of that during the day.

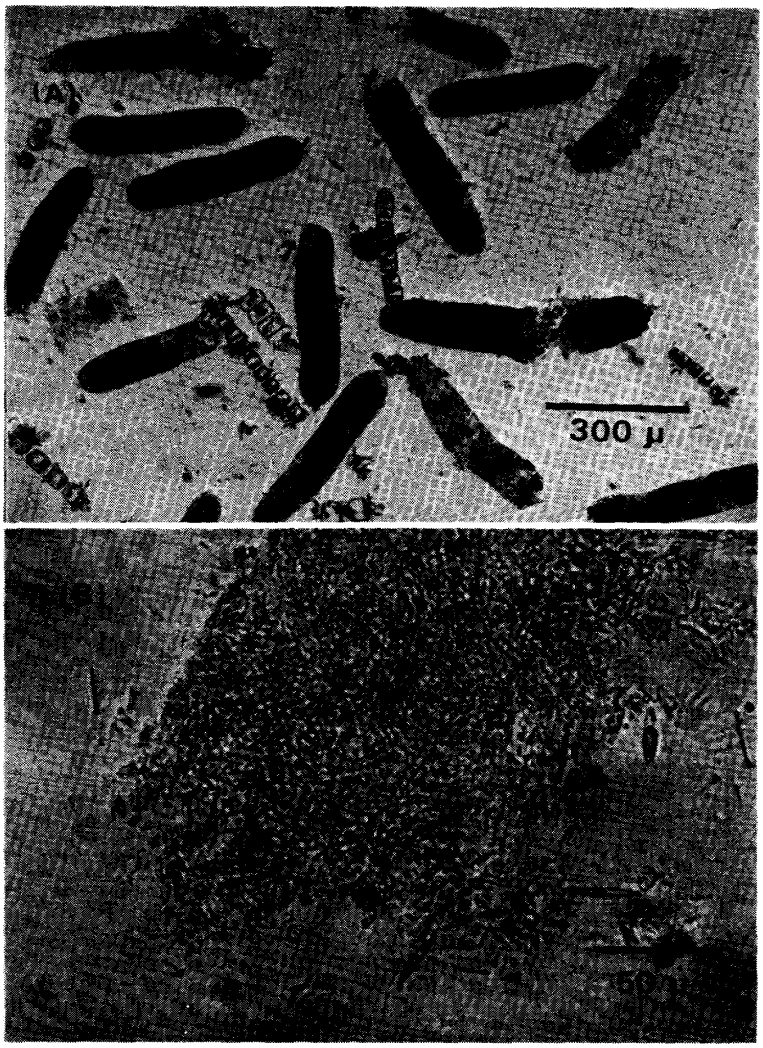

Fig. 4. Microscopic photographs of fecal pellets of Paralabidocera antarctica. A. Fecal pellets collected just beneath the sea ice at Stn 1. B. Pennate diatoms found in fecal pellets.

Table 2. Percent composition of zooplankton collected with a "NIPR-I" at 0 m depth just beneath the sea ice at Stn 1.

Zooplankton	January 22, 1982					January 23, 1982			
	0948 –0953	1322 –1327	1611 –1616	1914 –1919	2209 –2214	0111 –0116	0406 –0411	0723 –0728	1009 –1014
Paralabidocera antarctica	99.8	99.6	99.5	97.8	15.4	13.1	34.5	98.4	98.5
Other calanoid copepods				0.1	1.1		0.3		
Oithona similis	0.1	0.2	0.3	1.0	35.8	39.5	14.1	0.4	0.4
Oncaea curvata	0.1	0.2	0.3	0.4	35.8	38.9	11.4	0.4	0.8
Harpacticoid copepods					3.3	2.1	1.1		0.1
Copepods nauplii				0.1	2.7	4.3	34.2	0.2	0.1
Polychaete larvae			<0.1		2.7	1.6	0.2	0.1	0.1
Chaetognaths					<0.1				
Planktonic larval forms						0.5	0.8		
Eggs				0.7	3.3		3.0	0.5	
Unidentified specimens							0.5		
Total number	60160	67680	95600	53760	3689	1875	6320	142400	93760

4. Discussion

It was evident that *P. antarctica* swarmed just beneath the sea ice during the day. FUKUCHI and SASAKI (1981) observed, by means of the pumping collection, that *P. antarctica* is distributed mainly within an upper 0–15 cm depth under the fast ice near Syowa Station. It is considered that *P. antarctica* aggregated horizontally in an extremely narrow layer against the undersurface of sea ice. Therefore, the density in the 0 m layer mentioned before was possibly underestimated.

HAMNER and CARLETON (1979) reported copepod swarms by diving observation. Coral reef copepods, such as *Acartia australis*, *A. bispinosa*, *Oithona oculata* and *Centropages orsinii*, usually swarmed during the day over a bright sandy substrate, while these swarms dispersed throughout the water column at night. They indicated that the visual organ would contribute to swarming behavior. HEBERT *et al.* (1980) also observed experimentally that adult *Heterocope septentrionalis*, which is an Arctic fresh water calanoid copepod, was aggregated over the area of a pale substrate.

P. antarctica possesses an eye and seems to respond to the light sensitively. *P. antarctica* might be attracted to the undersurface brightness of the sea ice and form a swarm there. Swarming mechanism of *P. antarctica* may be fundamentally the same as that of coral reef copepods and *H. septentrionalis*. In addition, swarming behavior may be associated with reproduction because adult females carry the spermatophore.

The disappearance of swarms at night would not be caused by dispersion throughout the water column but would result from their entering into interstitial water in a loose lower part of the sea ice. Pennate diatoms are the main constituent of ice algae and extremely abundant in the bottom layer of the sea ice in the summer season

(HOSHIAI, 1977, 1981). The fact of abundant pennate diatoms in feces possibly suggests that *P. antarctica* would enter into the sea ice and actively feed on ice algae at night.

Existence of characteristic fauna associated with sea ice was suggested already by ANDRIASHEV (1968). There is a strict ice fauna which is at least temporarily in the lower part of the sea ice and a sub-ice fauna whose members never enter directly into the loose ice but are to some degree in a trophic connection with the ice community. Also, BRADFORD (1978) reviewed animals associated with ice community.

The phenomena observed in this study would presumably occur commonly in the Antarctic coastal water covered with fast ice. It is expected that *P. antarctica* plays an important role as energy transferrers that utilize a primary production of ice algae. Undersurface of sea ice may be significant as feeding and reproductive sites in the life-span of *P. antarctica*. Furthermore, biological information of this species is necessary for clarifying the character of fast ice ecosystem.

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