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ABUNDANCE AND VERTICAL DISTRIBUTION OF THE CHAETOGNATH *PARASAGITTA ELEGANS* (VERRILL) UNDER THE SEA ICE IN SAROMA KO, A LAGOON ON HOKKAIDO, JAPAN

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Abstract: Abundance, vertical distribution and maturity of the chaetognath *Parasagitta elegans* under the sea ice in a shallow lagoon (the depth of bottom, <20 m) on Hokkaido in the daytime in February 1986, were examined. The abundance was estimated to be about 10–30 individ. m^{-3}. This is approximately half of the maximum densities previously reported in inshore open waters. Vertically, the maximum abundance was observed at a depth of 2 m beneath the undersurface of the ice. The size ranged 15.40–27.05 mm in body length, and most *P. elegans* were adult forms of Stage II in ovary maturity. These findings suggest that in the boreal waters *P. elegans* occurs commonly under the sea ice, and that the maturing adult forms appear in proximity of the ice even in the daytime.

1. Introduction

The chaetognath *Parasagitta elegans* (VERRILL) is one of the commonest planktonic invertebrate carnivores living in the boreal seas of the world, playing an important role in the energy flow in the sea (KOTORI, 1979; CONWAY and WILLIAMS, 1986). It has been suggested to be a typical indicator species for the Subarctic Water (BIERI, 1959; TOKIOKA, 1959; FURUHASHI, 1961). It appears rather constantly throughout the year in the epipelagic layer of the Subarctic Water in the northern North Pacific Ocean (KOTORI, 1985; TERAZAKI and MILLER, 1986). Although *P. elegans* appears less abundantly in the Arctic Water than in the Subarctic Water (BIERI, 1959; KASSATKINA, 1982), it also occurs commonly in the Bering Sea and the Okhotsk Sea (TAKEUCHI, 1972; KOTORI, 1976).

P. elegans, therefore, has been well investigated so far (*e.g.*, KOTORI, 1976; KING, 1979; SULLIVAN, 1980; SWEATT, 1980; TANDE, 1983; ØRESLAND, 1985; WILLIAMS and COLLINS, 1985; TERAZAKI and MILLER, 1986; CONWAY and WILLIAMS, 1986; etc.). However, knowledge on the distribution, abundance and life history has been mostly confined to the open waters of the seas, and little is known in the waters under the sea ice.

In this paper, we present some aspects of the abundance, vertical distribution, and

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maturity conditions of *P. elegans* under the sea ice in Saroma Ko, a lagoon on Hokkaido facing the Okhotsk Sea.

2. Material and Methods

The collections with a NIPR sampler and Norpac nets were made at two stations (Stns. 3 and 11) in Saroma Ko (the approximate location, 44°10'N, 143°45'E; the deepest bottom, 20 m), a lagoon on the northeast coast of Hokkaido, Japan, connected with the Okhotsk Sea through two channels (Fig. 1). Samplings were carried out in the daytime of February 22 to 24, 1986 (Table 1). The thickness of sea ice was 29.5 cm at Stn. 3, and 24.7 cm at Stn. 11 with snow cover of 10.5 cm. The depth of the bottom was 11 m at Stn. 3, and 7 m at Stn. 11. The sea surface temperature was −1.5°C during the investigation. No data on salinity, light intensity and water movement under the ice were available in the present study. The plankton samplings of 10-min periods with a NIPR sampler were made at four layers, 0.3, 2, 5, and 10 m beneath the undersurface of the ice, at Stn. 3 on February 23, and the samplings of 5-min periods at four layers 0.3, 2, 5, and 6.5 m at Stn. 11 on February 24. A flowmeter was used on a standard Norpac net for estimating the volume of water filtered. No flowmeter was employed in the NIPR sampler and a modified Norpac net.

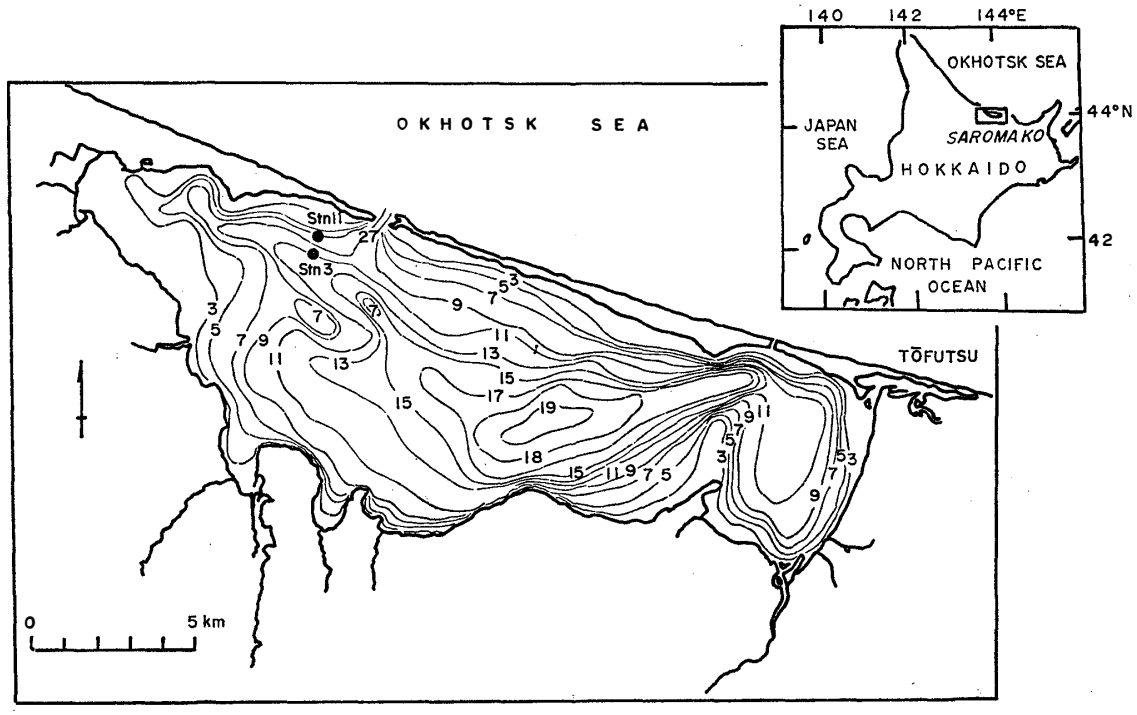

Fig. 1. Locations of Stns. 3 and 11 in Saroma Ko, a lagoon on the northeast coast of Hokkaido, connected with the Okhotsk Sea through two channels.

Fifty-four zooplankton samples were collected and used in the present study (Table 1). Of them, 33 samples were collected with a NIPR sampler, which is slightly modified from the prototype "NIPR-I" described by FUKUCHI *et al.* (1979), having a conical net (20 cm in mouth diameter, 105 cm in side length) made of one of three

Table 1. Sampling records on zooplankton collections under the sea ice in Saroma Ko, February 1986.

Station No.	Sampling			Mesh size of nets (μm)	Duration of sampling (min)	Depth of collection (m)	Sample No.
	Gear*	Date in February	Time				
3	NOR	22	1407	100	—	11–0	1–3
3	M-NOR	22	1425	100	—	11–0	4–6
3	NOR	22	1447	330	—	11–0	7–9
3	NOR	22	1512	505	—	11–0	10–12
3	NIPR	22	1419	100	5, 10, 15	0.3	13–15
3	NIPR	22	1340	330	5, 10, 15	0.3	16–18
3	NIPR	22	1502	505	5, 10, 15	0.3	19–21
3	NIPR	23	1027	100	10	0.3, 2, 5, 10	22–25
3	NIPR	23	1128	330	10	0.3, 2, 5, 10	26–29
3	NIPR	23	1221	505	10	0.3, 2, 5, 10	30–33
11	NOR	24	0939	100	—	7–0	34–36
11	NOR	24	1005	330	—	7–0	37–39
11	NOR	24	1028	505	—	7–0	40–42
11	NIPR	24	0937	100	5	0.3, 2, 5, 6.5	43–46
11	NIPR	24	1017	330	5	0.3, 2, 5, 6.5	47–50
11	NIPR	24	1047	505	5	0.3, 2, 5, 6.5	51–54

* NOR, Standard Norpac net; M-NOR, Modified Norpac net; NIPR, NIPR sampler (see text, p. 139–140, for more detail).

different mesh sizes (100-, 330-, and 505-μm). The other 21 samples were obtained by vertical hauls from the near bottom to the surface of water with a standard Norpac net and a modified Norpac net. The modified Norpac net is designed for use under the sea ice, and its mouth ring is made of flexible rubber, so that it can be run out or taken in through a small ice hole for sampling (A. TANIMURA, unpublished). The two types of Norpac nets were also made of one kind of the three different mesh sizes in the net attached to the NIPR sampler.

All samples were preserved in a 10% neutral formalin seawater solution. In the laboratory, chaetognaths were separated from other zooplankters, and species were identified under a microscope and counted. All chaetognaths found in this study were *Parasagitta elegans* (VERRILL). Body length, from the tip of the head to the end of the tail excluding tail fin, was measured for 71 individuals of *P. elegans* from 4 layers at Stn. 3 (Sample Nos. 22–25, Table 1). Ovary maturity stages were determined for the individual specimens after staining with a solution of neutral red according to DUNBAR (1962), MCLAREN (1969) and KOTORI (1976). The ovaries of Stage I are minute and no visible ova under a stereo microscope of low magnification. Stage II ova are small and of about the same size. In Stage III, some of the ova were evidently larger than the others.

3. Results and Discussion

3.1. *Abundance of* P. elegans *under the sea ice*

The abundance of *P. elegans* (number of individ. m^{-3}) was estimated in triplicate

vertical hauls with Norpac nets having different mesh sizes at Stns. 3 and 11 (Table 2). The results indicate that the coefficient of variance (CV) of the number of individuals with 100-μm mesh size was smallest. If the mean values with the smallest coefficient of variance are most reliable, the abundance of *P. elegans* under the sea ice found using a 100-μm mesh size net is about 10–30 individ. m^{-3} at these stations.

Table 2. Range, mean, standard deviation (SD) and coefficient of variance (CV) of number of individuals of P. elegans *per m^3 in triplicate vertical hauls with Norpac nets in three mesh sizes at two stations in Saroma Ko (Sample Nos. 1–3, 7–12, and 34–42, see Table 1), February 1986.*

Mesh size (μm)	Station 3				Station 11			
	Range	Mean	SD	CV(%)	Range	Mean	SD	CV(%)
100	11–15	13.0	1.8	13.5	23–34	28.0	5.5	19.6
330	9–22	14.8	6.9	46.7	26–39	32.8	6.8	20.6
505	8–24	14.9	8.3	55.7	14–31	25.1	9.4	37.3

The abundance of *P. elegans* has been well investigated in open waters. According to the data given by several authors (SULLIVAN, 1980; SWEATT, 1980; TANDE, 1983; WILLIAMS and COLLINS, 1985; TERAZAKI and MILLER, 1986), the maximum abundance of *P. elegans* does not exceed 100 individ. m^{-3} in the boreal waters of the world. SWEATT (1980) observed the seasonal change of abundance of this species, and recorded the maximum densities of the chaetognath to be about 100 m^{-3} in the outer parts of Narragansett Bay (depths, 22–35 m), and about 50 m^{-3} in the inner parts of the bay (depths, 9–19 m) during April through May. Therefore, it seems that the densities (10–30 m^{-3}) found under the sea ice in the present study are approximately half of the maximum ones previously found in inshore waters. This finding suggests that numerous *P. elegans* occur even under the sea ice in the boreal waters.

Meanwhile, *P. elegans* was completely absent in 14 zooplankton samples collected by vertical hauls from the near bottom to the surface with a Norpac net (330-μm mesh size) from August 8 to 31, 1985, at a station (depth, about 10 m), 2 km south of Stn. 3 (M. KOTORI and Y. MORI, unpublished data). The sea surface temperature ranged from 19.5° to 24.3°C during this summer investigation. Therefore, it seems that the population of *P. elegans* found in this study under the sea ice was not endemic to Saroma Ko but transported incidentally into the lagoon from the Okhotsk Sea.

3.2. Vertical distribution, size, and maturity

The vertical distribution of *P. elegans* at Stns. 3 and 11 is illustrated in Fig. 2. The maximum abundance was observed at a depth of 2 m beneath the sea ice at the two stations. The size ranged between 15.40 and 27.05 mm in body length at Stn. 3 (Fig. 3). Stages of ovary maturity (Fig. 3) indicate that *P. elegans* were all adult forms, most of them being in Stage II of maturity. No individuals in Stage I were found. The smallest individual in Stage III was 20.95 mm. The maximum diameter of the ovarian eggs found in the animals at Stage III reached about 150 μm. The minimum one in Stage II animals was 30 μm. The proportion of Stage III of this population was 7.0%. The occurrence proportion of Stage III was greatest at 10 m depth. Due to small sample size, it is difficult to examine the difference in size range

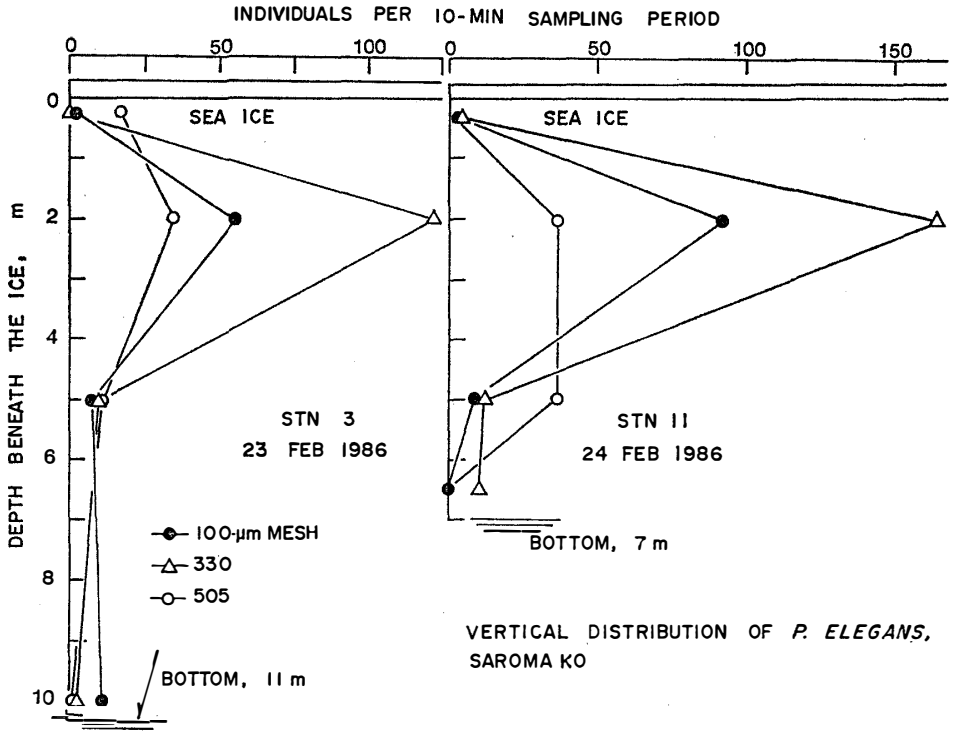

Fig. 2. Vertical distribution of P. elegans *under sea ice with nets of different mesh sizes (Sample Nos. 22–33 and 43–54, see Table 1) at Stns. 3 and 11 in Saroma Ko, February 1986.*

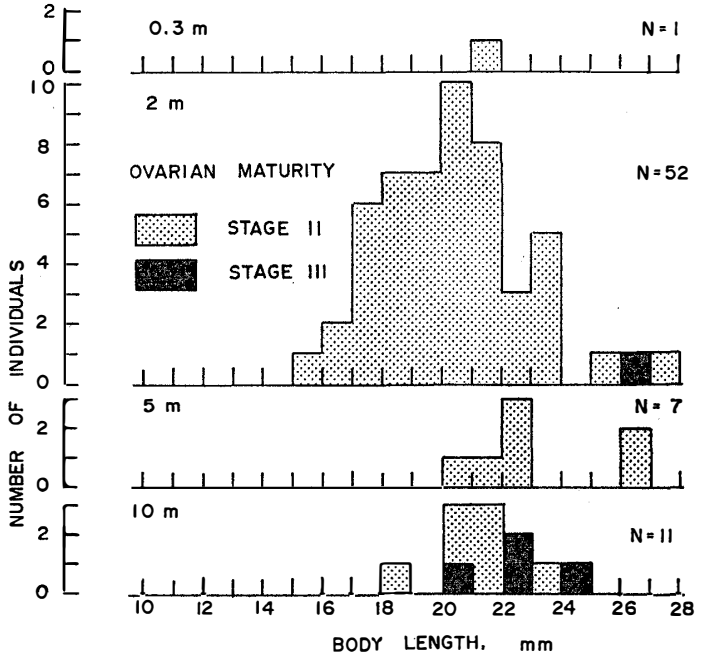

Fig. 3. Size-frequency distribution and stages of ovary maturity of P. elegans *under sea ice at various depths at Stn. 3 (Sample Nos. 22–25, see Table 1), February 23, 1986.*

by depth. However, the size range appears to be similar among the four depth layers. When the four depth layers are combined, the average size is given as 20.90 mm (±2.47 mm, SD), indicating the population consists of a single size group. The stage composition suggests that the ovaries were in progress of development. Therefore, it is unlikely that the egg-laying of the animals will occur during the periods of the present study, since the maximum diameter of fully matured ovarian eggs and the eggs immediately after spawning of *P. elegans* is about 300 μm (HUNTSMAN and REID, 1921; KOTORI, 1975). It is uncertain how many days it takes for eggs of 150 μm within the ovary to reach 300 μm in diameter.

In open waters of the seas, it is well documented that the adult forms of *P. elegans* are restricted to the deeper waters and scarcely distributed in the shallower layers in the daytime (KOTORI, 1972; PEARRE, 1973; KING, 1979; SULLIVAN, 1980; SWEATT, 1980). For instance, SULLIVAN (1980) indicated that in the daytime in July only a few *P. elegans* individuals with mature or maturing ovaries, 18–36 mm long, occurred in the waters shallower than 100 m, whereas they were abundant in the deeper waters, at Ocean Station "P" in the eastern North Pacific. The evidence that adult *P. elegans*, 15–27 mm long, occurred in the near sea surface under the ice even in the daytime in the present study is noteworthy. Their occurrence in the shallow layer is assumed to be related to the existence of the sea ice which reduces irradiance in the sea and serves as a substratum for ice algae (HOSHIAI and FUKUCHI, 1981), but the causes inducing the planktonic carnivore *P. elegans* to aggregate near the sea surface under the ice and related phenomena are unknown.

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