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DISTRIBUTION OF CHAETOGNATHS IN THE AUSTRALIAN SECTOR OF THE SOUTHERN OCEAN DURING THE BIOMASS SIBEX CRUISE (KH-83-4)

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Abstract: Studies on pelagic chaetognaths were carried out on the plankton samples collected during the R.V. HAKUHŌ MARU KH-83-4 cruise in the Australian Sector of the Southern Ocean as part of the BIOMASS SIBEX I (1983-1984) investigations. The density of chaetognaths in the epipelagic layer in the Southern Ocean was 2.6-17.3 individuals/m^3 and high values were observed in the northern Antarctic region. *Eukrohnia hamata* and *Sagitta gazellae* were distributed widely in the Southern Ocean. *S. tasmanica* was a dominant species in the Subtropical region. Complicated hydrography in the Subtropical Convergence (STC) and Antarctic Convergence (AC) regions was reflected in the distribution of chaetognaths. The occurrence of *S. minima* in the subsurface layer of the central station of the STC region suggests that the northern warm and saline water mass intruded southward into the depths of 30-70 m. The plural populations of *E. hamata* exist in the AC and STC regions. Vertically segregative distribution of chaetognaths was observed in the Antarctic and AC regions: *S. gazellae* at the depths of 50 to 150 m, *E. hamata* at 100 to 400 m, and *S. maxima* at 200 to 500 m.

1. Introduction

The Chaetognatha is the major zooplankton in the Southern Ocean (HOPKINS, 1971). Some species of this group have been used as biological indicators of hydrographical conditions because there has been recognized a strong connection between water masses. There have been a number of previous studies dealing with the distribution of chaetognaths in the Antarctic and adjacent regions (MACKINTOSH, 1964; DAVID, 1958, 1965; ALVARIÑO, 1965; ALVARIÑO *et al.*, 1983). The chaetognath fauna of the Southern Ocean is made up of seven species, *Sagitta gazellae*, *S. marri*, *S. maxima*, *S. macrocephala*, *Eukrohnia hamata*, *E. bathyantarctica* and *Heterokrohnia mirabilis*. *S. marri*, *S. gazellae* and *E. bathyantarctica* are endemic forms (DAVID, 1965). The basic pattern of distribution is circumpolar, and the Antarctic and Subtropical Convergences act to a greater or lesser extent as geographical boundary regions for the fauna (DAVID, 1965).

In this paper, I deal with the horizontal and vertical distributions of chaetognaths in the Australian sector of the Southern Ocean and discuss the relationship between water masses and chaetognath distribution.

2. Materials and Methods

Chaetognaths were collected in the Australian Sector of the Southern Ocean during the BIOMASS SIBEX cruise (KH-83-4) of the R. V. HAKUHŌ MARU of the Ocean Research Institute, University of Tokyo. Two observation lines were selected along the meridians of 150° and 115°E between 40° and 65°S. The cruise in the Southern Ocean consisted of two legs, from Sydney to Hobart and Hobart to Fremantle. The hydrographic data and chlorophyll-*a* concentration have been presented by the OCEAN RESEARCH INSTITUTE, UNIVERSITY of TOKYO (1985), NAKAI *et al.* (1986) and FURUYA *et al.* (1986). The Subtropical Convergence (STC) was detected at 47°S along 150°E and 43.5°S along 115°E. The Antarctic Convergence (AC) was at 56.5°S along 150°E and 55°S along 115°E (Fig. 1). Three stations were occupied in the STC and AC regions along 150°E, respectively, and two stations in the STC along 115°E. The distances

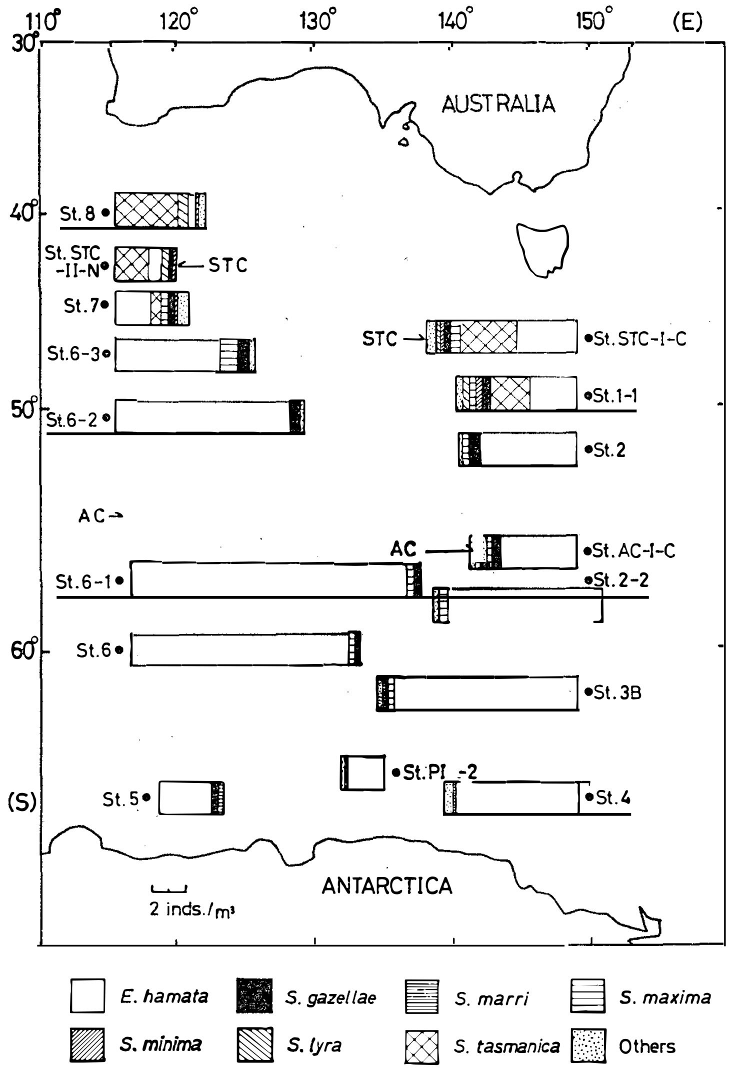

Fig. 1. Horizontal distribution of chaetognaths in abundance, collected with a Norpac net (0–200 m) in the Australian Sector of the Southern Ocean in 1983/84 summer.

between Stn. STC-I-N and Stn. STC-I-S, Stn. AC-I-N and Stn. AC-I-S, and Stn. STC-II-N and Stn. STC-II-S, are about 55.7 km, 48.3 km and 44.6 km, respectively.

Plankton collections were made with a Norpac net (0.33 mm mesh size) by vertical hauls from a 200 m depth to the surface at 16 stations, and with a Motoda horizontal net (MOTODA, 1969; MTD net, 0.33 mm mesh size) which was towed horizontally mostly in 8 different strata at 8 stations in the STC and AC regions, and in 14 strata at Stn. 5 in the Antarctic (Table 1). To determine the towing depth and the volume of water filtered a depth-distance recorder and a flowmeter were set at the mouth of the net. Specimens were preserved in 10% neutralized formalin sea water. The

Table 1. Data on zooplankton samplings during the KH-83-4 cruise.

Stn.	Location (S)	Location (E)	Date	Local time	Net type	Mesh size (mm)	Sampling layer (m)
1-1	44°59.7′	150°00.8′	Dec. 13 1983	2207–2216	Norpac	0.33	0–200
2	52 07.5	150 03.7	Dec. 17 1983	0353–0403	〃	〃	〃
2-2	57 31.6	150 02.9	Dec. 18 1983	1147–1155	〃	〃	〃
4	64 56.4	150 12.8	Dec. 22 1983	1912–1930	〃	〃	〃
3B	61 24.8	150 05.7	Dec. 25 1983	2306–2315	〃	〃	〃
AC-I-C	56 11.5	150 05.2	Dec. 28 1983	1250–1259	〃	〃	〃
STC-I-C	46 45.9	150 00.7	Dec. 31 1983	2038–2048	〃	〃	〃
PL-2	64 16.3	136 06.8	Jan. 16 1984	1434–1445	〃	〃	〃
5	65 00.3	117 59.5	Jan. 18 1984	2225–2236	〃	〃	〃
6	66 00.4	116 02.2	Jan. 21 1984	1553–1604	〃	〃	〃
6-1	57 29.7	115 58.9	Jan. 23 1984	0829–0837	〃	〃	〃
6-2	50 29.7	114 59.3	Jan. 24 1984	1928–1937	〃	〃	〃
6-3	47 29.8	115 00.0	Jan. 25 1984	1106–1115	〃	〃	〃
7	44 49.3	114 54.4	Jan. 26 1984	1902–1910	〃	〃	〃
STC-II-N	43 00.7	114 51.0	Jan. 28 1984	0231–0241	〃	〃	〃
8	39 54.8	114 54.4	Jan. 28 1984	2026–2033	〃	〃	〃
AC-I-N	55 59.1	150 08.5	Dec. 28 1983	0150–0205	MTD	〃	0, 11, 33, 55, 82, 109, 164, 218
AC-I-C	56 12.2	150 00.5	Dec. 28 1983	0542–0557	〃	〃	0, 11, 34, 56, 84, 112, 168, 224
AC-I-S	56 23.2	149 59.5	Dec. 28 1983	2159–2214	〃	〃	0, 10, 31, 52, 78, 104, 155, 207
STC-I-N	46 28.3	149 59.7	Dec. 31 1983	1445–1501	〃	〃	0, 11, 32, 54, 80, 107, 161, 214
STC-I-C	46 45.7	150 02.5	Dec. 31 1983	2156–2210	〃	〃	0, 10, 32, 51, 77, 103, 154, 205
STC-I-S	47 00.4	150 00.4	Jan. 1 1984	0625–0640	〃	〃	0, 11, 34, 56, 84, 113, 169, 225
5	65 03.8	117 54.1	Jan. 19 1984	1625–1837	〃	〃	0, 11, 33, 56, 84, 112, 167, 223, 318, 424, 530, 636, 848, 1060
5	66 00.0	118 00.9	Jan. 19 1984	0045–0240	〃	〃	0, 11, 33, 54, 80, 107, 161, 214, 285, 380, 475, 570, 760, 950
STC-II-S	43 24.0	114 54.7	Jan. 27 1984	2210–2230	〃	〃	0, 15, 43, 73, 109, 145, 218, 291
STC-II-N	43 00.3	114 51.7	Jan. 28 1984	0131–0151	〃	〃	0, 11, 34, 57, 85, 114, 171, 228

number of chaetognaths by each species in each sample was counted. The body length of *Eukrohnia hamata* predominating in the STC and AC regions was measured.

3. Results

3.1. Horizontal distribution

The density of pelagic chaetognaths collected with a Norpac net in the epipelagic layer (0–200 m) of the Southern Ocean was 2.6–17.3 individuals/m^3 and high values more than 10 individuals were observed in the northern Antarctic region between the AC and 61.5°S.

Eleven species, *S. tasmanica*, *S. maxima*, *S. minima*, *S. gazellae*, *S. lyra*, *S. decipiens*, *S. planktonis*, *S. hexaptera*, *Pterosagitta draco*, *E. hamata* and *E. bathypelagica* were collected from the STC. *S. tasmanica* was a dominant species in the Subtropical region. *S. tasmanica*, *S. maxima*, *S. minima*, *S. gazellae*, *S. lyra*, *S. planktonis* and *E. hamata* occurred in the northern Subantarctic region (Stns. 1–1 and 7). Four species, *S. maxima*, *S. gazellae*, *S. marri* and *E. hamata* were distributed in the Antarctic region. *S. gazellae* was collected from all the stations and *E. hamata* was dominant and occupied more than 80 percents of the total number in the southern Subantarctic Water, AC and Antarctic Water.

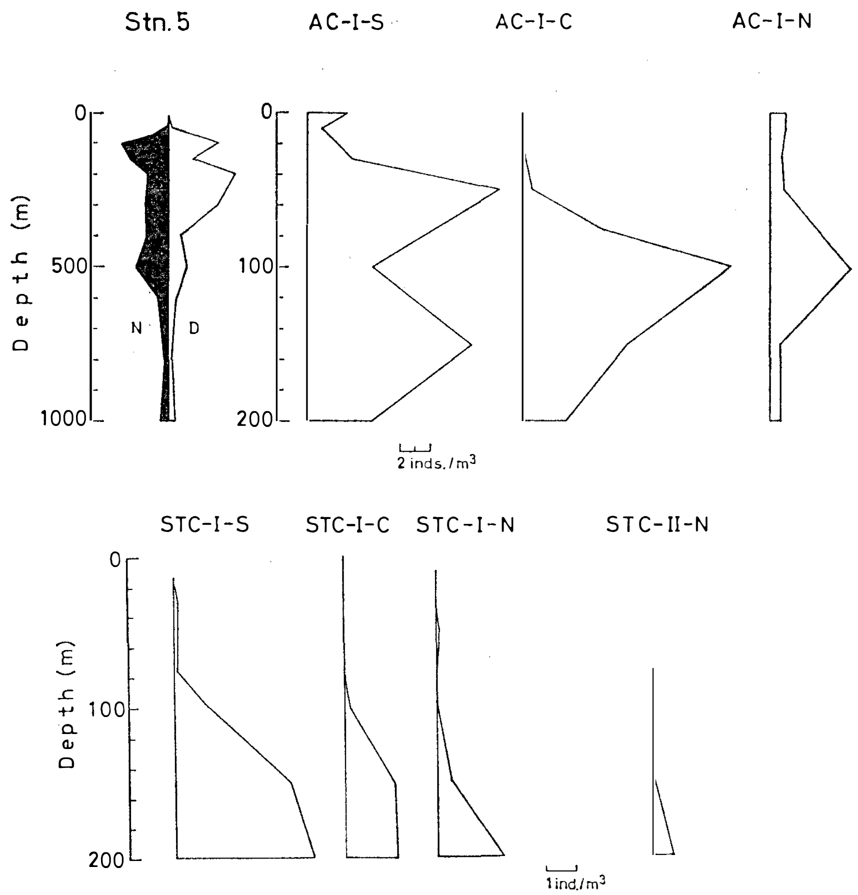

Fig. 2. Vertical distribution of Eukrohnia hamata *in the Antarctic (Stn. 5), AC and STC regions. N, night; D, day.*

A complicated distribution pattern was recognized in the STC regions and the number of species, decreased toward the south along both sections. In the AC region, *S. tasmanica* and *S. planktonis* occurred only at Stn. AC-I-N but no individual was collected from the central and southern stations (Stns. AC-I-C and AC-I-S).

3.2. Vertical distribution

Eukrohnia hamata: Maxima of abundance were found at depths of 200 m in the daytime and 100 m and 500 m in the nighttime at Stn. 5 (Fig. 2). In the AC region along 150°E, the high density (6–13 individuals/m^3) was found at depths of 50 m and 150 m at Stn. AC-I-S while it was in the 100 m layer at Stns. AC-I-C and AC-I-N. The pattern of length-frequency distribution was not similar among these 3 stations. The individuals of middle size (5–15 mm) were abundant in all sampling layers at three stations, and small size (below 5 mm) ones mainly occurred at Stn. AC-I-S. Large size (15–20 mm) ones were collected from the 200 m layer at Stn. AC-I-S and from the 10–50 m layer at Stn. AC-I-C but no mature individual was found (Fig. 3). In the STC region, the density of this species decreased compared with the AC region and the main concentration was found in lower epipelagic layers below 150 m, but no animal was collected from Stn. STC-II-S and the surface at Stns. STC-I-S and STC-I-N. Small size animal in the STC region was less abundant compared with the AC region and mature individuals occurred in the 50 m layer at Stn. STC-I-N.

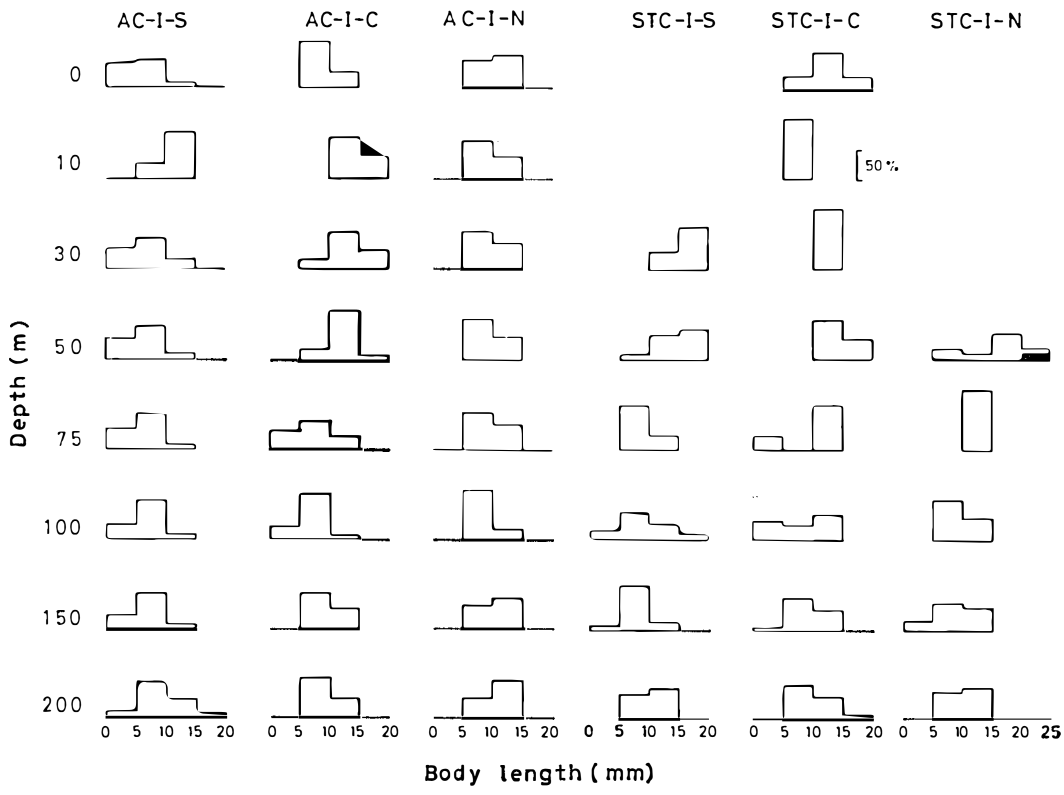

Fig. 3. Length-frequency distribution of Eukrohnia hamata *with depth at six stations in the AC and STC regions. Shaded area represents the proportion of mature individuals.*

Sagitta gazellae: Generally, this species is distributed in shallow layers compared with *E. hamata*. This species inhabited mainly in the 100–200 m layer in the Antarctic Water, 50–75 m layer in the AC region, 50–100 m layer in the STC-I region and 50–150 m layer in the STC-II region, respectively (Fig. 4). The density decreased rapidly toward the north and the maximum distribution layer also became deeper.

Sagitta maxima: This species was distributed mainly at the 200 m layer in the daytime and at the 300 m in the nighttime at Stn. 5 (Fig. 5). *S. maxima* was found in the layer below 100 m in the STC and AC regions except Stn. STC-I-C. There was no difference in the density between the STC-I stations and the AC-I stations. The maximum distribution layer became shallower toward the north.

Sagitta marri: This species was distributed at depths of about 200–700 m at Stn. 5 and there is no sign of the diurnal vertical migration (Fig. 6).

Sagitta tasmanica: This species was collected from all sampling layers at all STC-I stations. *S. tasmanica* was also collected from depths of 10 m, 30 m and 75 m at Stn. AC-I-N, but disappeared in the southern two stations, Stns. AC-I-C and AC-I-S.

Other species: *S. lyra* and *S. planktonis* were distributed in lower epipelagic layers at all STC-I stations. *S. minima* and *S. decipiens* appeared at STC-I-C and STC-I-N. *P. draco* and *E. bathypelagica* occurred at Stn. STC-I-N, and STC-I-C, respectively (Fig. 7).

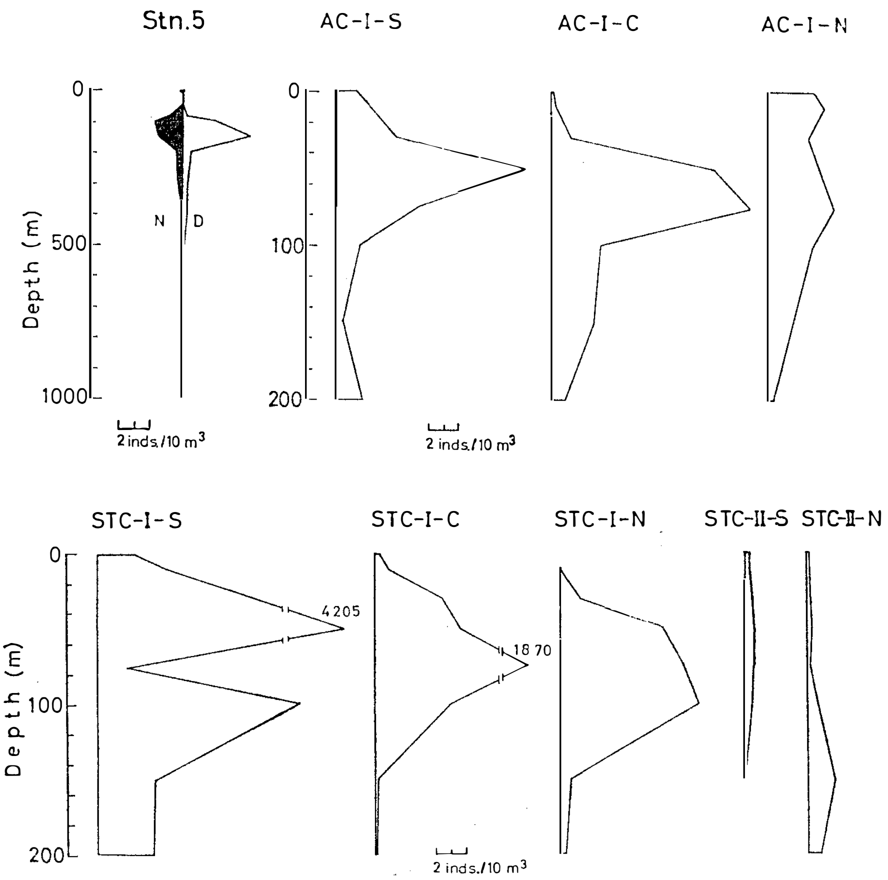

Fig. 4. Vertical distribution of Sagitta gazellae *in the Antarctic (Stn. 5), AC and STC regions. N, night; D, day.*

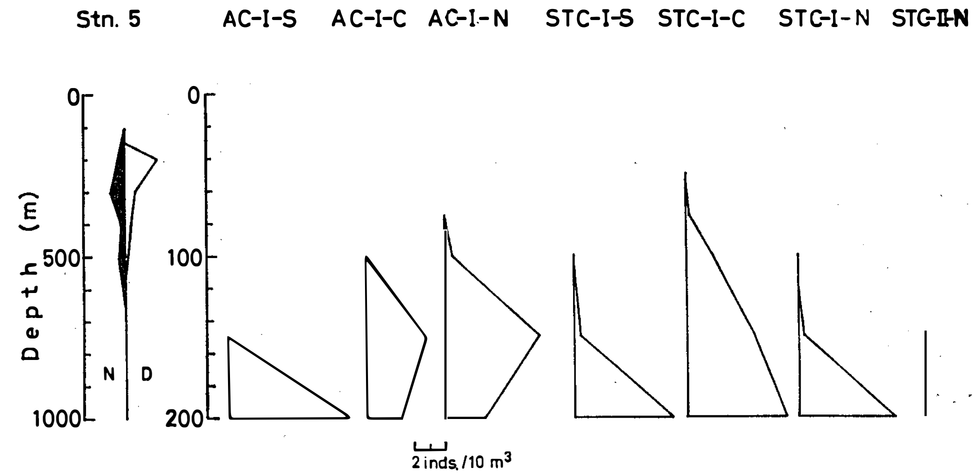

Fig. 5. Vertical distribution of Sagitta maxima *in the Antarctic (Stn. 5), AC and STC regions. N, night; D, day.*

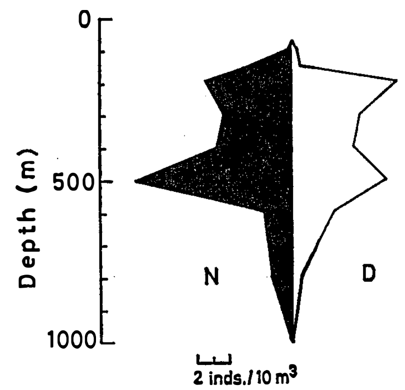

Fig. 6. Vertical distribution of Sagitta marri *in the Antarctic (Stn. 5). N, night; D, day.*

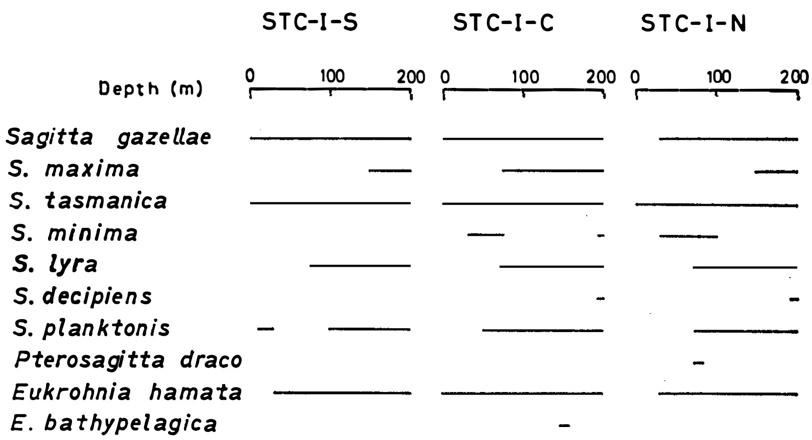

Fig. 7. Vertical distribution of chaetognaths at three STC-I stations.

4. Discussion

The Chaetognatha is the second in biomass to Copepoda among the zooplankton occurring in the Pacific sector of the Southern Ocean (HOPKINS, 1971). Chaetognath biomass was highest in northern Antarctic Water near the Antarctic Convergence. The major food organisms of chaetognaths collected from this region were copepods such as *Rhincalanus gigas*, *Calanoides acutus* and *Calanus simillimus* (TERAZAKI, unpublished). It was also observed that copepod biomass was highest in both density (Fig. 8) and wet weight (KAWAMURA, 1986) at Stns. 6, 6–1 and 3B. Chlorophyll *a* was highest in the upper epipelagic layer of northern Antarctic Water (Fig. 9) where high standing stock of phytoplankton was reported by HOSAKA and NEMOTO (1986). Therefore, the high chaetognath biomass in the northern Antarctic region may be a result of favourable food conditions among phytoplankton-herbivorous copepods-chaetognaths.

E. hamata was most common species in both abundance and frequency occurrences at many Antarctic and Subantarctic stations. In the Antarctic and AC regions, three species, *S. gazellae*, *E. hamata* and *S. maxima* showed segregative distributions vertically: *S. gazellae* in the epipelagic layer (50 to 150 m), *E. hamata* in the epipelagic and upper mesopelagic layers (100 to 400 m), and *S. maxima* in the upper mesopelagic layer

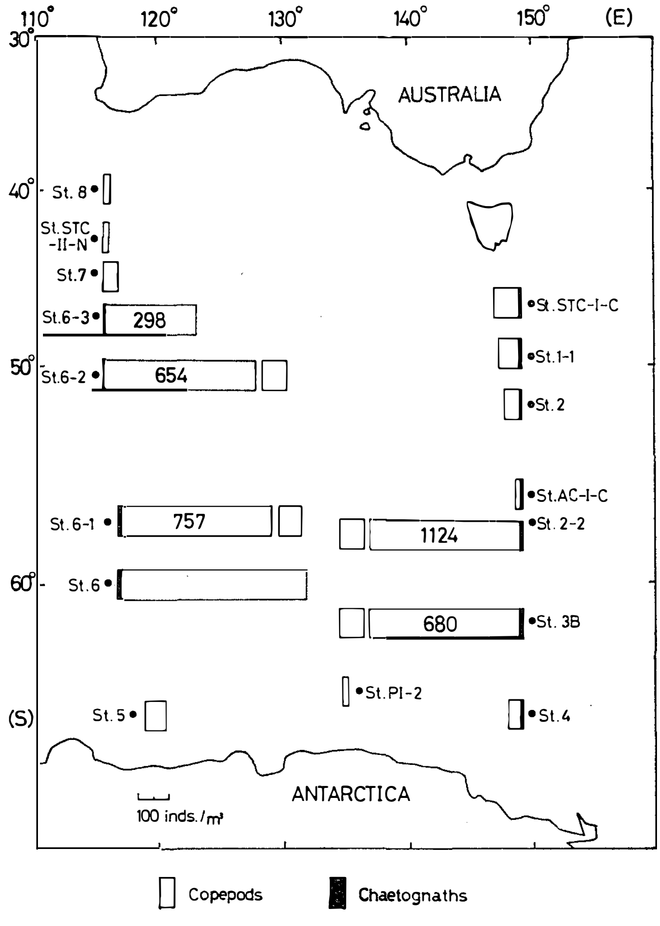

Fig. 8. Abundance of total copepods and chaetognaths collected with a Norpac net in the upper 200 m in 1983/84 summer.

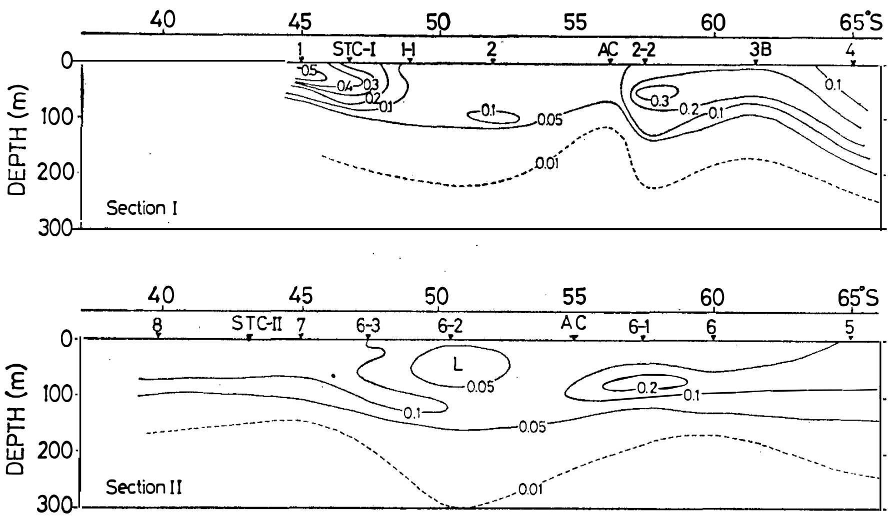

Fig. 9. Vertical sections of chlorophyll-a concentration (μg/l) along 150°E (upper) and 115°E (lower).

(200 to 500 m). Such phenomena were reported at Ocean Station P in the Gulf of Alaska, where five species, *S. elgans*, *E. hamata*, *E. bathypelagica*, *S. macrocephala* and *E. fowleri*, showed distribution peaks in different layers above 2000 m (TERAZAKI and MILLER, 1986).

According to ALVARIÑO *et al.* (1983), population density of *S. gazellae* collected with a Norpac net in an area between 45°S and 50°S along 150°E in the austral summer of 1967 was 0.4–0.7 individuals/m^3. Density of this species in the studied area was 1–10 individuals/m^3 except Stns. STC-I-C and STC-I-S in which the density was more than 100 individuals/m^3. The population density of *S. gazellae* seems to change in this area.

Complicated hydrography in the studied area was reflected in the distribution of chaetognaths. In the STC-I region, three warm water species, *S. minima*, *S. lyra* and *Pterosagitta draco* were not collected from the southern stations. The occurrence of *S. minima* from the subsurface layer of the central station (Stn. STC-I-C) suggests that the northern warm and saline water mass intruded southward into the depths of 30–70 m as mentioned by FURUYA *et al.* (1986). This phenomenon was not clear at STC-II compared with the STC-I judging from the results of the oceanographical observations (NAKAI *et al.*, 1986). But the STC-II represented the southern limit of *S. minima* and *S. hexaptera*.

E. hamata inhabits at temperatures of 0–3°C at Stn. AC-I-S and 5–6°C at Stn. AC-I-C while it was 7–8°C at Stn. AC-I-N. These remarkable differences in water temperature were reflected on the occurrences of juvenile, immature and adult of *E. hamata*. Difference in the length-frequency distribution at the three stations may suggest that the plural populations exist even in this spatially narrow region where the distance between Stn. AC-I-N and Stn. AC-I-S was 48.3 km. Usually, adults of this species inhabit deep layers in the Subantarctic and Subtropical areas (ALVARIÑO, 1965) but they were collected from the subsurface layer of 30–50 m in the STC-I region. It therefore seems that they migrate and/or are transported upward into the subsurface layer from deeper layers in this region.

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