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Latitudinal Distribution of Zooplankton in the Southern Ocean with Special Reference to Euphausiids

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ABSTRACT

The oceans are subjected to great variations in space and time with regard to their physico-chemical and biological features. These changes are more pronounced latitudinally than longitudinally. In order to understand how these changes were reflected in the occurrence and abundance of zooplank ton as a whole and the various groups in particular a series of zooplankton samples were collected during the Third Indian Expedition to Antarctica from the edge of the pack ice upto 20°S along an oblique course between 22°56 E and 56°53 E. The area included the Antarctic Sub Antarctic and Sub tropical zones where the surface water temperature ranged from 1 5°C to 27 5°C with striking variations at the Antarctic and Sub tropical convergences. The zooplankton obtained was subjected to volumetric and numerical analyses. For euphausiids besides the above gravimetric analys s was also done. The zooplankton was found especially more in the Antarctic waters where an average value of 105 64 cc per 1000 m^3 of water was obtained. The plankton at the various stations fluctuated between 29 41 cc and 329 34 cc per 1000 m^3 of water. When considered numerically the highest density of 199 zooplankton organisms per m^3 of water were present at the station at the Antarctic Circle.

The euphausiids constituted 13 67% of zooplankton by volume. A gravimetric estitmation revealed that the euphausiids were relatively more in the Antarctic and Sub Antarctic waters which to gether claimed for 89 30% of the total euphausiids obtained. When considered numerically the maximum abundance of euphausiids (4 347/1000 m^3 of water) was at 53°21 S 48°04 E.

Altogether 20 groups of zooplankters were present with the maximum numerical abundance of copepods. The zooplankton groups showed differential distribution in each latitudinal zones. Seven groups namely euphausiids copepods chaetognaths appendicularians ostracods siphonophores and foraminiferans occurred at all the stations sampled.

INTRODUCTION

The zooplankton is an important tool in the study of biological oceanography. It changes its pattern of distribution and abundance in accordance with the changes in the environmental factors and consequent variations in the availability of food materials. These changes however, are more pronounced latitudinally than longitudinally. A north south course traverses through the main surface boundaries of the ocean and follow the principal temperature gradients. In view of these facts a latitudinal study of the occurrence and abundance of zooplankton with particular reference to euphausiids was taken up during the Third Indian Expedition to Antarctica in which the senior author was a participant.

Based on the *'Discovery'* collections Baker (1965) made a study on the latitudinal distribution of species of the genus *Euphausia* (Crustacea) from the very edge of the pack-ice in the Antarctic Ocean upto the equator along the 90°E meridian in the Indian Ocean sector. Another study made on the latitudinal abundance of zooplankton was that of Goswami (1983) based on collections made during the First Indian Expedition to Antarctica between 67°13 S and 39°25'S in a diagonal manner.

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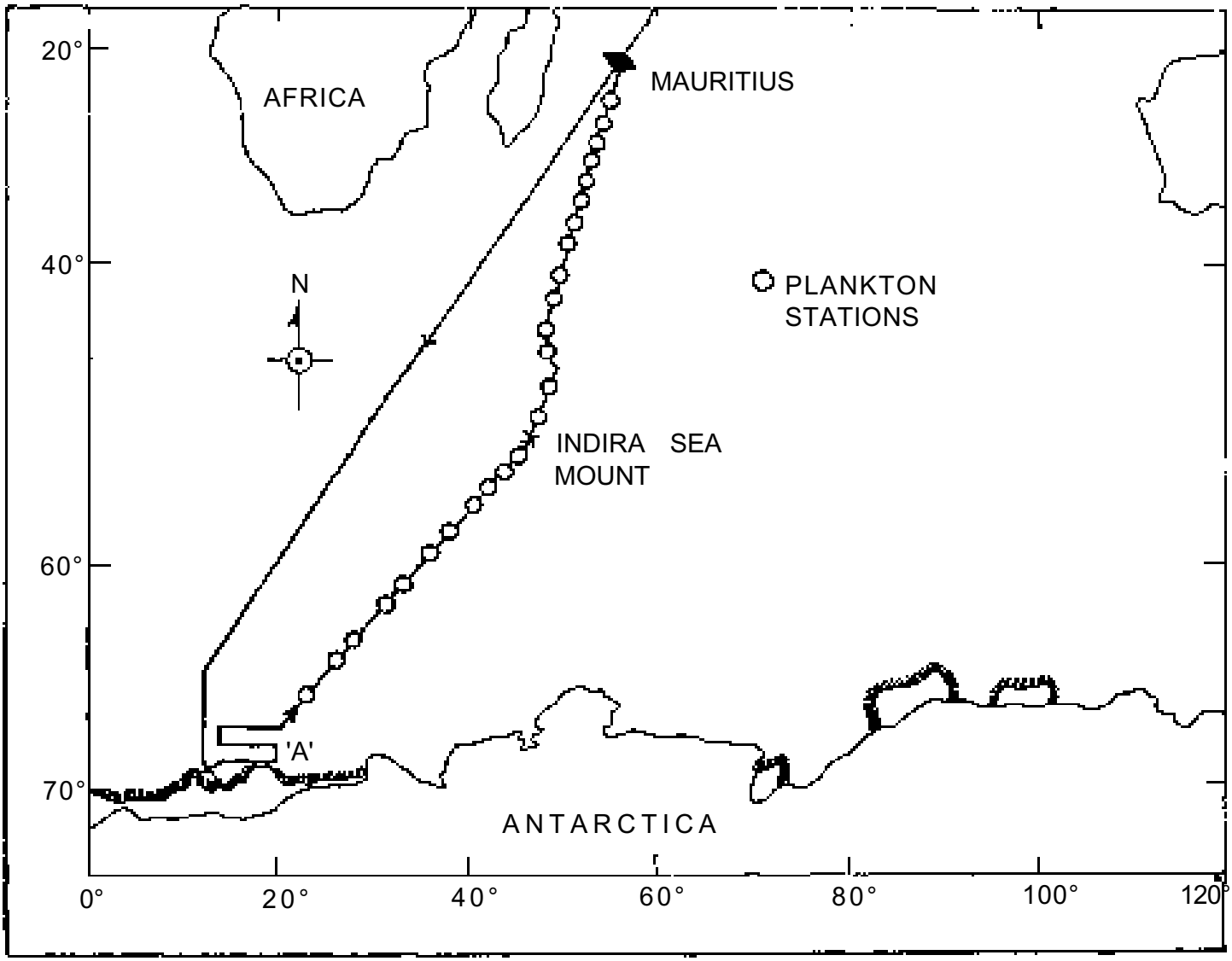
MATERIAL AND METHODS

26 stations were occupied for the collection of zooplankton between 61°31 S and 21°34 S in a diagonal manner extending from 22°56 E to 56°53 E covering the Antarctic, Sub Antarctic and Sub tropical zones (Fig 1). A Bongo net of 60 cm mouth diameter and 4 mm mesh size was used for the collection of the plankton at 0730 hrs and 1800 hrs on every day from 5-3-84 to 17-3-84. However the last collection on 18-3-84 was made at 0430 hrs. The zooplankton samples were collected from a depth of 150 m to the surface as open vertical hauls while the ship was moving in one knot speed A T S K flow meter was attached in a manner to keep itself in the centre of one of the collars of the net. The samples were preserved in 3% formalin. The atmospheric as well as surface water temperature were noted during each sampling.



F g 1 Sampl ng stations fo t e study of latitud nal d str but on of zooplankton

In the laboratory the volume of the plankton was estimated by displacement method after which the various groups of zooplankton were sorted out from an aliquot sample of minimum 5 cc and esti mated for 1000 m^3 of water based on the method followed by Gopalaknshnan and Bnnton (1969)and Bnnton and Gopalakrishnan (1973) The details for the sampling stations are presented in table 1

TABLE 1

Station details for the samples collected and total plankton obtained

Gear used: Bongo-60; Depth of haul : 150-0 m; Type of haul: Oblique

Sl. No.	*Date*	*Time (hrs)*	*Position*		*Depth at stn. (m)*	*Displ. volume (cc)*
			lat. °S	*long. °E*		
1.	05-3-'84	1800	66°31'	22°56'	4525	38.8
2.	06-3-'84	0730	64°40'	27°36'	5068	60.5
3.	06-3-'84	1800	63°37'	30°00"	4900	94.8
4.	07-3-'84	0730	61°32'	34°27'	5104	169.0
5.	07-3-'84	1800	61°07'	35°28'	5086	192.4
6.	08-3-'84'	0730	58°59'	39°27'	5158	25.2
7.	08-3-'84	1800	58°00'	41°10'	4977	43.0
8.	09-3-'84	0730	55°57'	44°33'	4344	21.7
9.	09-3-'84	1800	54°28'	46°41'	4579	25.2
10.	10-3-'84	0730	53°21'	48°04'	3982	71.3
11.	10-3-'84	1800	52°22'	49°15'	4163	19.2
12.	11-3-'84	0730	49°44'	48°07'	4050	22.7
13.	11-3-'84	1800	48°09'	46°41'	3800	54.1
14.	12-3-'84	0730	45°59'	48°06'	2600	67.0
15.	12-3-'84	1800	44°41'	48°48'	2550	40.2
16.	13-3-'84	0730	42°02'	49°56'	2850	5.7
17.	13-3-'84	1800	40°48'	50°51'	3500	19.0
18.	14-3-'84	0730	37°49'	51°58'	3000	2.5
19.	14-3-'84	1800	36°31'	52°22'	3600	23.6
20.	15-3-'84	0730	33°49'	53°18'	3100	4.2
21.	15-3-'84	1800	32°25'	53°41'	4200	3.0
22.	16-3-'84	0730	29°43'	54°37'	4100	7.1
23.	16-3-'84	1800	28°07'	55°04'	5050	5.2
24.	17-3-'84	0730	25°32'	55°57'	4900	1.5
25.	17-3-'84	1730	23°42'	56°28'	4550	7.9
26.	18-3-'84	0430	21°34'	56°53'	3900	5.5

RESULTS AND DISCUSSION

Environmental features

The area of investigation was latitudinally very extensive, covering the Antarctic, Sub-Antarctic and Sub-tropical waters. The Antarctic zone extends from the Antarctic continent upto the Antarctic convergence (around 52°S) and from there the Sub-Antarctic waters stretch upto the Sub-tropical convergence (around 40°S). The basic structure of the Antarctic and Sub-Antarctic waters have been studied by Deacon (1937, 1963, 1964). During the present studies temperature of the sea surface waters and the atmosphere were analysed. The behaviour of the surface water temperature clearly indicated the different water masses from the higher to the lower latitudes. It showed a gradual increase from 1 5°C at the two southern-most stations to 6°C around the Antarctic convergene (St 11) (Fig 2). In this zone the average temperature was calculated as 3 0°C.

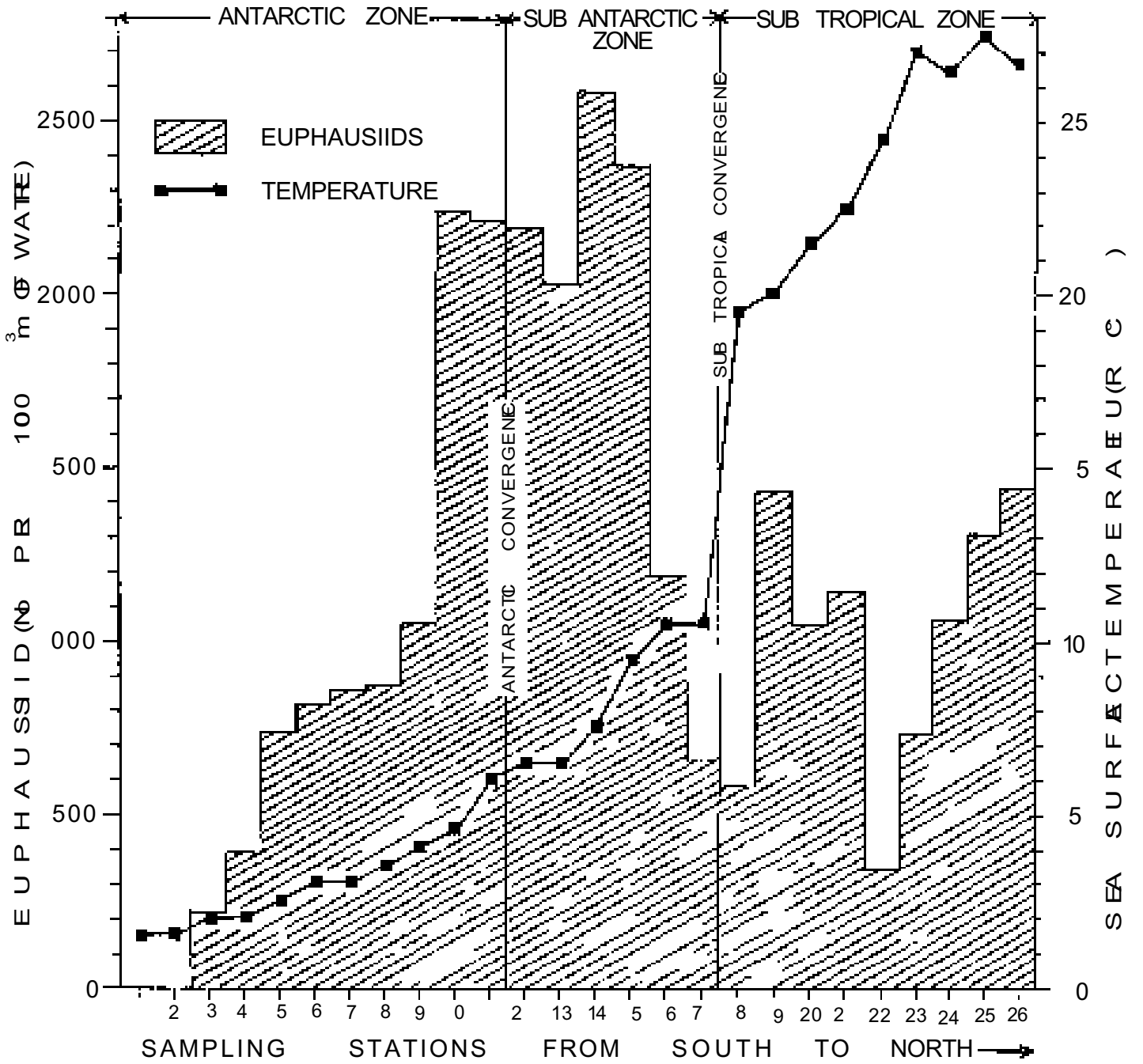


Fig 2 Abundance of euphausiids (No /1000 m^3 of water) in the various latitudes plotted against sea surface temperature (°C)

Between the Antarctic convergence and the Sub tropical convergence there was a rather steep increase in surface temperature. It rose from 6 5°C to 10 5°C within this narrow zone (Fig 2). The average temperature of this zone was worked out to be 8 5°C. At the border between the Sub Antarctic and Sub tropical waters striking variation in surface water temperature was noticed. From a minimum of 10 5°C at 40°48 S the temperature rose to 19 5°C at 37°49 S. Within the Sub tropical zone also the temperature showed marked increase from the south to the north. The maximum tern perature of 27 5°C was observed at 23°42 S. The average value of surface water temperature in this zone was estimated as 24°C. An almost similar result was obtained by Raju and Somayajulu (1983) who analysed the temperature data collected during the First Indian Expedition to Antarctica.

With regard to the atmospheric temperature, four hourly readings were taken for the entire period of observation and the results obtained are presented in Fig 3. As in the case of surface water temperature, a steady increase from south to north was noticed for the atmospheric temperature also but without any striking fluctuations. From a minimum of -10°C in the southern-most station it rose to about 7 0°C at the Antarctic convergence from where it increased to 15°C at the sub-tropical convergence. At the northern-most station at 21°34'S the atmospheric temperature reached upto 28°C which was almost equal to the surface water temperature there.

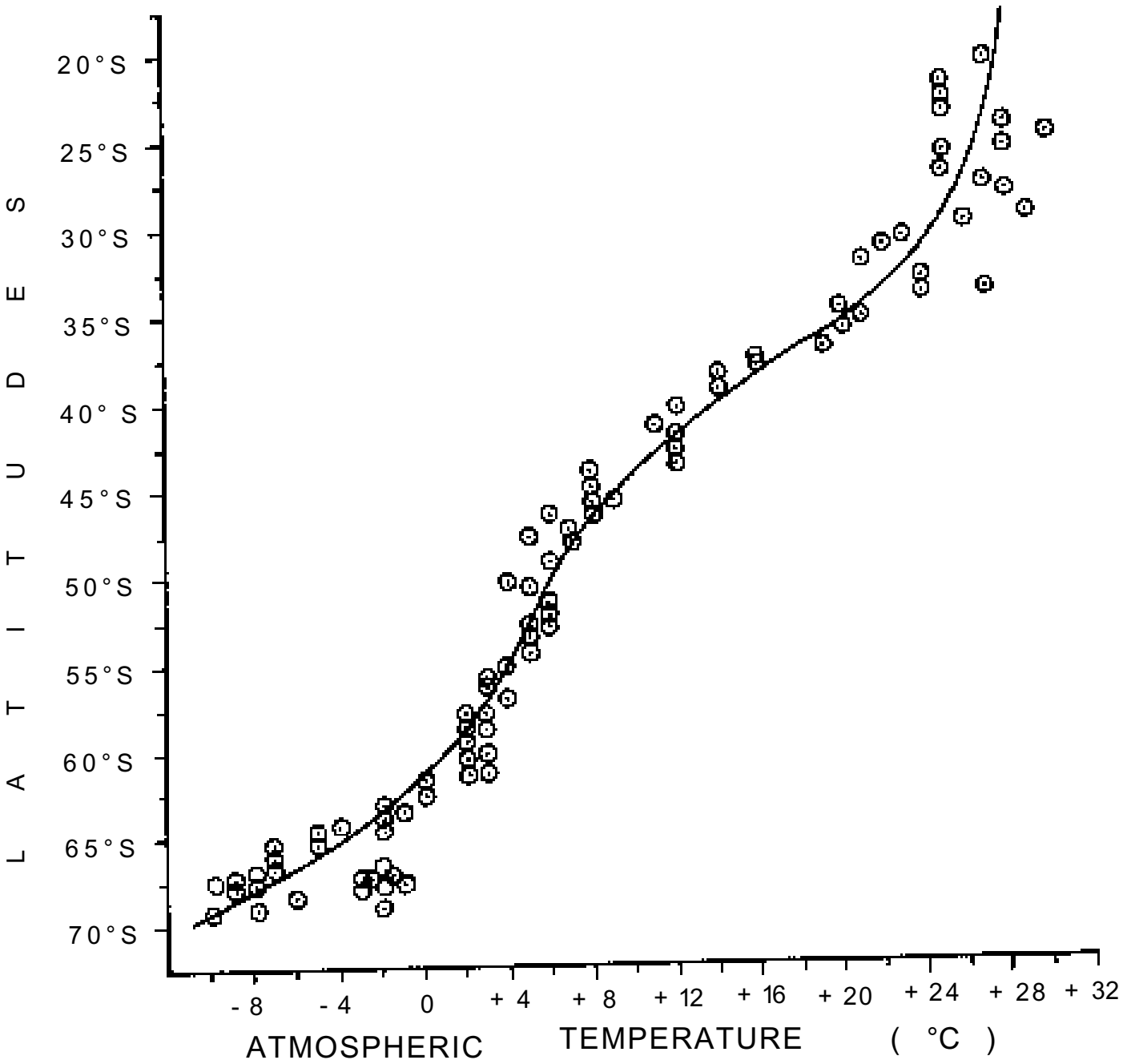


Fig 3 Atmospheric temperature in the course of the zooplankton sampling stations

Thus the present material of zooplankton was collected along a course with widely fluctuating environmental features. It will be interesting to see how far these differences were reflected in the zooplankton biomass and the occurrence and abundance of various zooplankton groups.

Zooplankton biomass

Generally considering the zooplankton biomass was richer in the Sub Antarctic and Antarctic waters (Fig 4). It was especially more towards south of the Antarctic convergence where the average biomass value obtained was 105 64 cc per 1000 m^3 of water. The plankton at the various latitudinal stations fluctuated between 29 41 cc and 329 34 cc per 1000 m^3 of water. The maximum quantity of plankton collected was from 61°07S where the surface water temperature was 2 5°C. During the First Expedition Goswami (1983) also recorded the highest density of plankton at the Antarctic convergence. However he obtained a still higher biomass of 624 cc per 1000 m^3 of water.

In the Sub Antarctic waters (between the Antarctic and Sub tropical convergences) an average of only 58 71 cc of plankton per 1000 m^3 of water were present. The biomass values at the various stations in this zone varied from 10 80 cc to 114 38 cc per 1000 m^3 of water. The zooplankton biomass was rather poor north of the Subtropical convergence. The average value obtained for this zone was13 13 cc per 1000 m^3 of water. At the various stations the values fluctuated between 4 55 cc and 38 08 cc per 1000 m^3 of water.

From the zooplankton point of view the most productive area was found to be south of the Antarctic Circle where the maximum abundance was noticed at 61°07 S 35°28 E where a total of 1 99 247 organisms per 1000 m^3 of water were taken which means that for every m^3 of water there were 199 zooplankton organisms at this station. Of this the major contribution was by copepods which occurred at a rate of 1 77 364 individuals per 1000 m^3 of water.

Euphausiid biomass

The euphausiids formed a major constituent of the zooplankton with the dominance of krill *(Euphausia superba)* in the southern ocean south of the Antarctic convergence. A volumetric estimate was done for the abundance in the various latitudes and the results obtained are given in comparison with the total zooplankton in Fig 4. Volumetrically the euphausiids were relatively more in the 10° belt between latitudes 46°S and 56°S where the quantity ranged from 1 6 cc to 29 67 cc per 1000 m^3 of water with the average value at 14 07 cc. The average volume obtained for zone south of 60°S upto 66°31 S (Antarctic waters) was 8 92 cc while that obtained for areas north of 46°S upto 21°34 S (Sub tropical zone) was 4 51 cc only per 1000 m^3 of water.

However a more precise picture emerged when a gravimetric estimate of the euphausiids was made which removed the possible errors that would have occurred while finding out the volume of such smaller organisms. The values obtained indicated that the euphausiids had a major representation in the Antarctic and Sub Antarctic zones with 41 43% (2 397 gm/1000 m^3 of water) and 47 87% (2 770 gm/1000 m^3 of water) respectively of the total euphausiids obtained while the Sub tropical zone claimed only 10 70% (0 619 gm/1000 m^3 of water). The highest values of 8 57 and 8 51 gm per 1000 m^3 of water were obtained at station 4 in the Antarctic zone and station 13 in the Sub Antarctic zone respectively.

Numerically speaking the maximum abundance observed was at 53°21 S and 48°04 E (4347/ 1000 m of water). A three point moving average values were worked out for the numerical abundance of euphausiids at the different latitudes and a correlation was made with the surface water temperature (Fig 2). Thus it was seen that from a minimum of 214 euphausiids per 1000 m^3 of water in the southern areas it rose gradually to a maximum of 2 592 at the Antarctic convergence.

Euphausiid - zooplankton relationship

When all the samples were considered together the euphausiids constituted 13 67 % of the zooplankton by volume. In the Antarctic zone of the total plankton collected only 8 44% was consti-

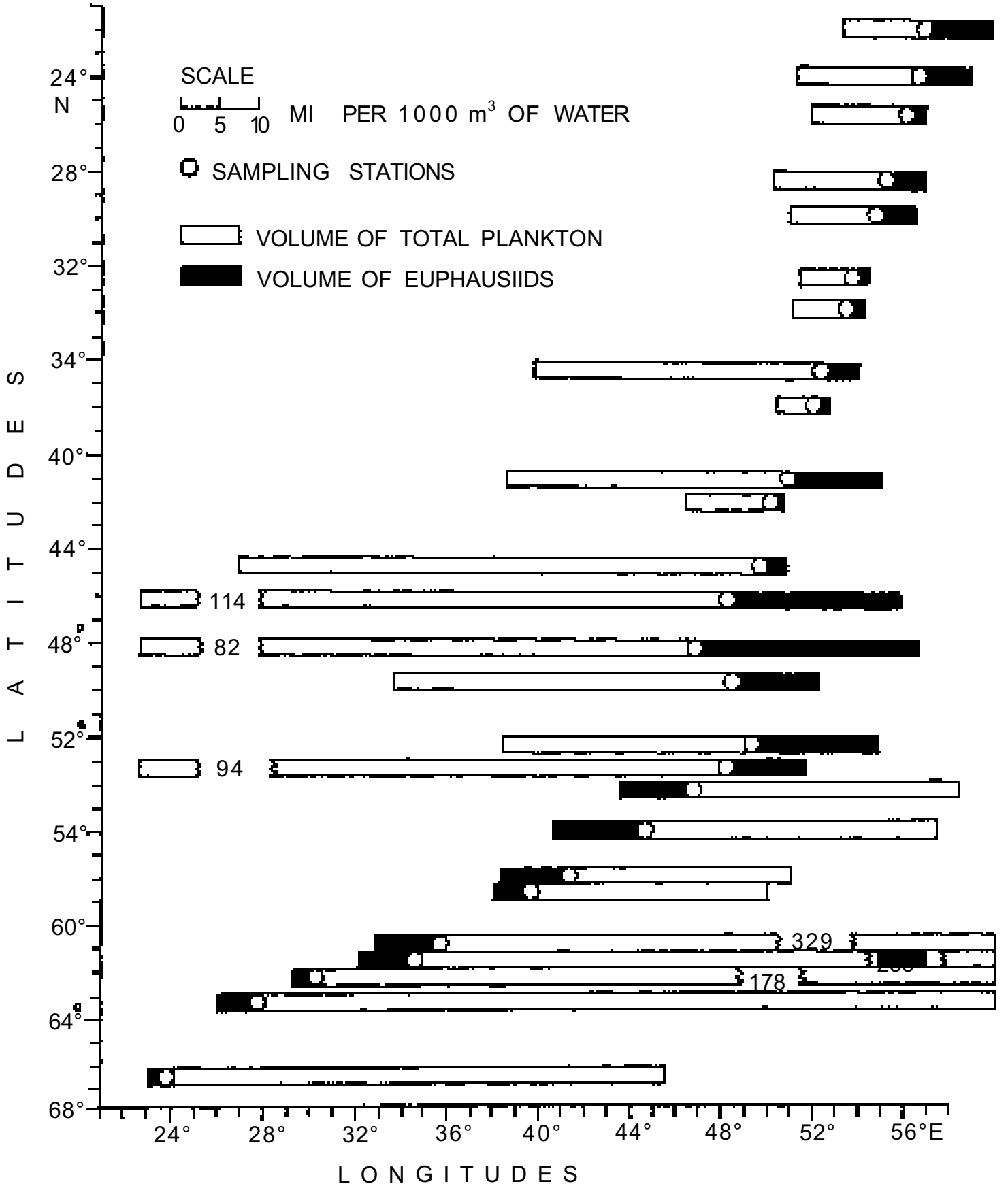


Fig 4 Volume of total zooplankton in relation to that of euphausiids at the respective stations (cc/1000m^3 of water)

tuted by euphausiids, whereas in the Sub-Antarctic and the Sub-tropical zones the percentage composition of euphausiids against total zooplankton was 23 97 and 34 36 respectively.

The relationship between total volumetric biomass of zooplankton (other than euphausiids) and the euphausiids at each station was also studied and the results are given in Fig 5. The share of euphausiids in zooplankton (excluding euphausiids) varied from 1 40% at station 6 to 84 17% at station 26. In general the proportion of euphausiids increased from south to north. However striking zonal peaks were also observed. Thus the euphausiids were found at a higher rate on either side of the Antarctic convergence (between latitudes 58°00 S and 45°59 S) where they formed 20 10 to 50 83% of the total zooplankton (Fig 5). The rather high dominance of euphausiids over the rest of the plankton was particularly observed at the Antarctic convergence (Station 11). The second peak in volume of euphausiids was found on either side of the Sub tropical convergence (Fig 5) between latitudes 44°41 S and 33°49 S with the maximum at the Sub tropical convergence (Station 17). Proportionally more euphausiids occurred in the Sub tropical zone north of 32°25 S where 24 83 to 84 17% of zooplankton was constituted by euphausiids. The main reason for obtaining higher percentage values for euphausiids at the northern stations was the proportionate decrease in the quantity of other zooplankton obtained.

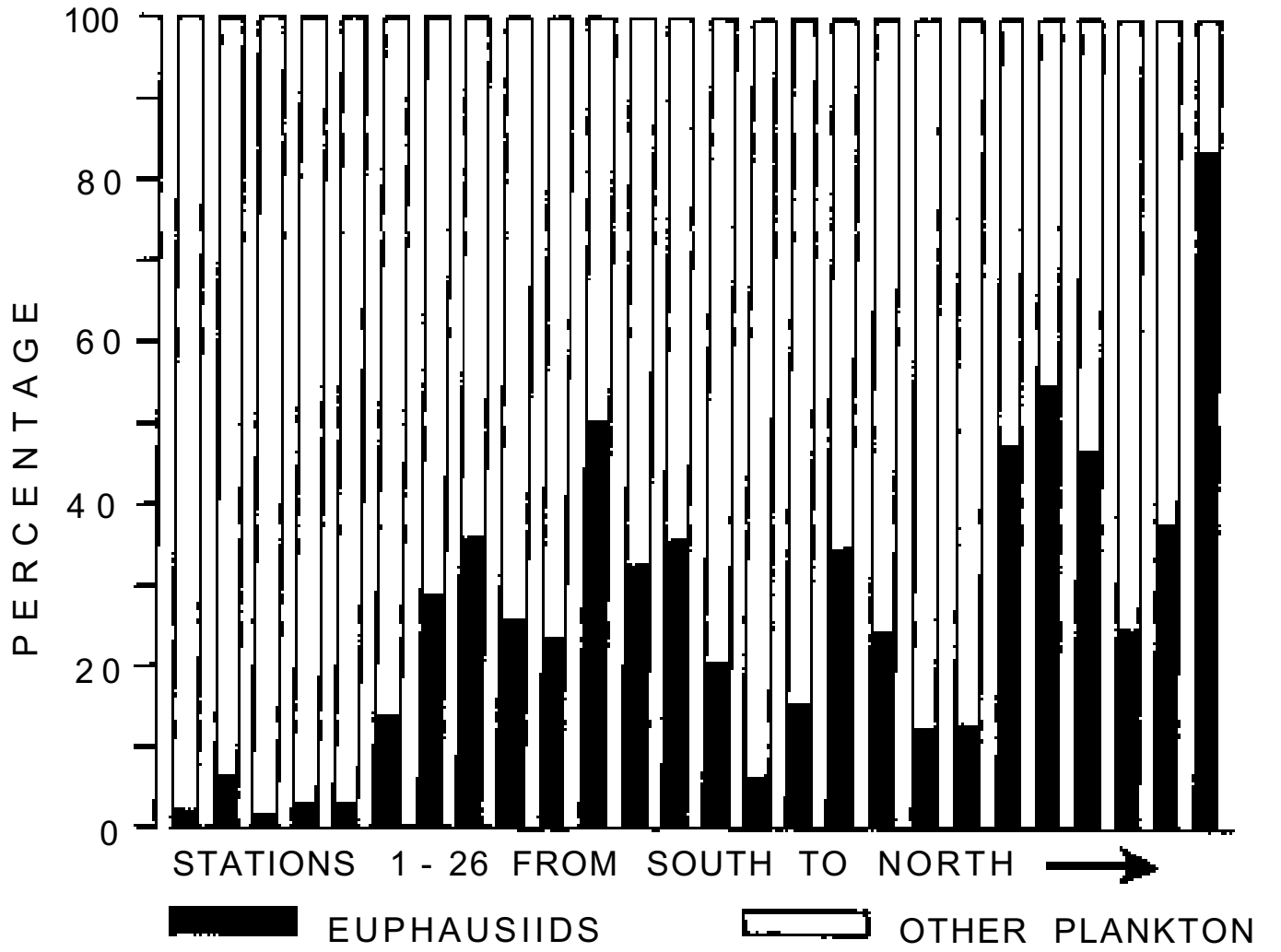


Fig 5 Percentage composition by volume of euphausiids and other zooplankton in the various latitudes

Latitudinal abundance of other zooplankters

Altogether 20 groups of zooplankters including euphausiids were collected during the investigation. Of these copepods sharing 82 83% was numerically the most abundant and they were followed by chaetognaths (4 89%) foraminifera (2 28%) euphausiids (1 69%) ostracods (1 58%) appendicularians (1 52%) amphipods (1 15%) planktonic gastropods (1 02%) and others (4 62%). Out of the 20 groups the first named six groups and siphonophores were present at all the stations. Planktonic gastropods and amphipods were absent at two stations only Lucifer medusae doliolids and decapod larvae occurred only north of the Sub tropical convergence. The salps were present more frequently north of this limit.

The numerical abundance of various groups of zooplankters is presented in Fig 6 as log values. Numerically the copepods were the most abundant and ranged from 5 205 in the Antarctic zone to 177 364 in the Sub tropical zone per 1000 m^3 of water. The zooplankton including copepods was poor in the 10° latitudinal belt between 30° and 40°S. The chaetognaths even though ranked next to copepods were numerically not in any way near to the latter. They ranged from a minimum of 571 to 21 741 per 1000 m^3 of water. However in bulk probably the large sized chaetognaths would have surpassed the copepods. The foraminiferans has a relatively good population in the Sub Antarctic and Antarctic waters and they ranged between 295 and 9202 per 1000 m^3 of water. The appendicularians ostracods siphono phores crustacean eggs and planktonic gastropods were also well distributed at almost all the stations and their numerical abundance are also presented in Fig 6. Others had only a meagre representation in the plankton.

Relative abundance in three major latitudinal zones

Eventhough most of the zooplankton groups occurred in all the major latitudinal zones their number varied considerably in each zone. This shows their close association with the principal surface water masses. However certain groups showed independence of the hydrographic boundaries.

As mentioned earlier within the area of investigation three distinct water masses can be identified Sub tropical Sub Antarctic and Antarctic. The relative abundance of various groups in the different latitudinal zones is presented in table 2. From the table it is seen that out of the 19 groups considered five namely copepods appendicularians polychaetes and forainiferans had more representation (about or more than 50% of the total) in the Antarctic zone. Six groups namely euphausiids chaetognaths amphipods ostracods planktonic gastropods and bivalves were relatively more in the Sub Antarctic zone. Siphonophores fish larvae and salps were particularly more in the sub tropical zone. While three groups namely medusae lucifer and decapod larvae were confined to the sub tropical zone doliolids were absent in the Antarctic zone. Fish eggs enjoyed almost equal dominance in the Antarctic and Sub Antarctic zones as was the case with planktonic bivalves in the Sub Antarctic and Sub tropical zones.

Relative abundance within zooplankton groups in 10° latitudinal zones

A further grouping of stations was done so that each group included a 10° latitudinal zone. Thus five such groups were identified each embrasing the following zones 20°-30°, 30°-40°, 40°-50°, 50°-60°, and 60°-70°S. The pattern of occurrence of each zooplankton group was also worked out as percentages and the results emerged are given in Fig 7. In most of the groups a rhythmic increase or decrease was noticed from south to north. Those showed a definite increase towards south included copepods appendicularians polychaetes crustacean eggs and foraminiferans and those indicated an increasing trend towards north were ostracods siphonphores fish larvae and pteropods. All others behaved in a rather irregular manner. However a tew groups namely chaetognaths amphipods ostracods planktonic gastropods and bivalves were comparatively more abundant in the mid zone between 40° and 50°S. Thus three distinct groups could be identified depending upon whether the planktonic groups showed an abundance towards the south north or in the middle latitudes.

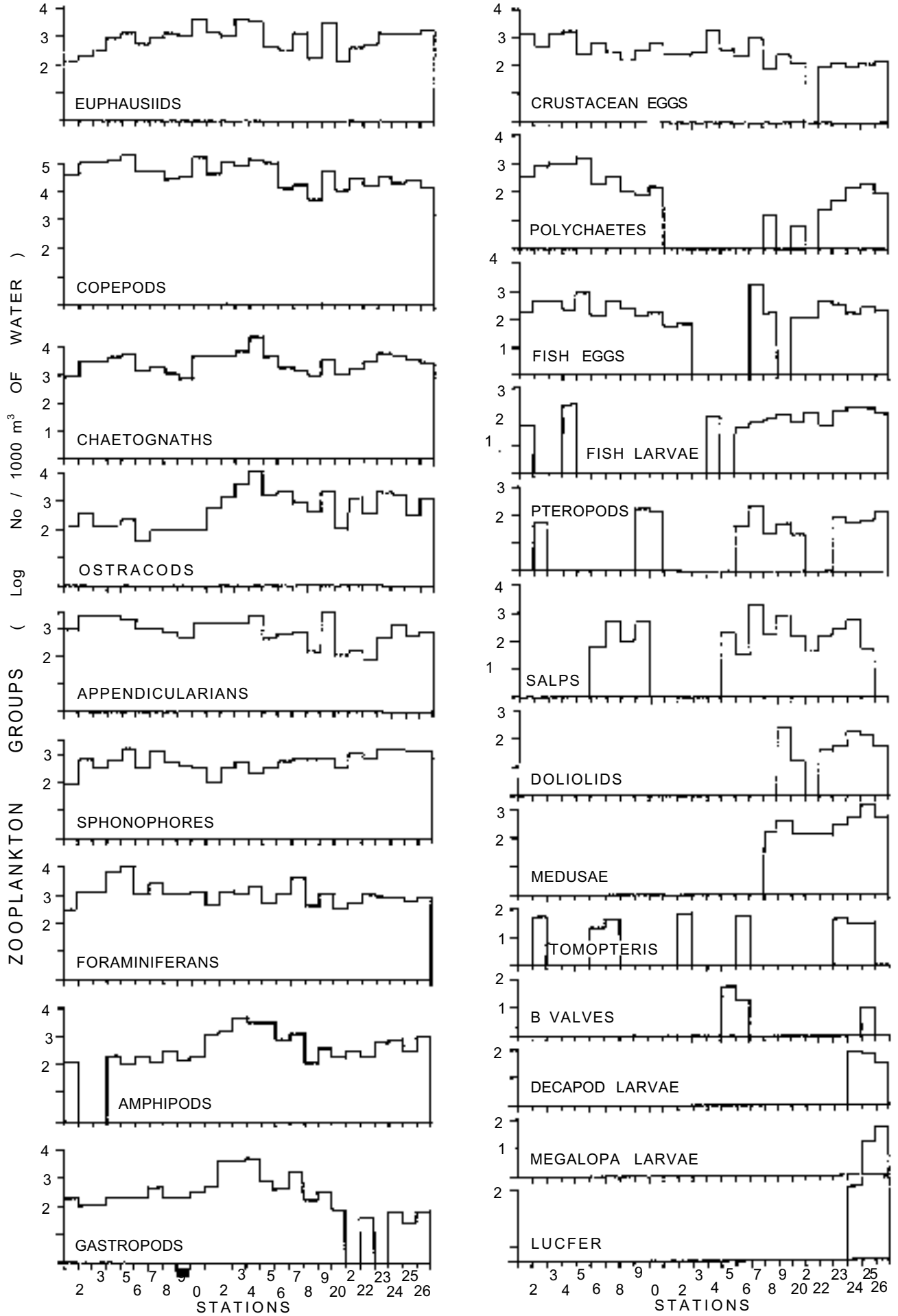


Fig 6 Station wise numerical abundance of various groups of zooplankton expressed as log values

TABLE 2

Relative abundance of zooplankton groups in the various latitudinal zones expressed as No /1000m^3 of water (percentage of occurrence is given in paranthesis)

Sl No	Zoopln groups	Antarctic	Sub-Antarctic	Sub tropical
1	Euphausiids	1075 (28 47)	1,625 (43 03)	1,076 (24.50)
2	Copepods	83 546 (48 00)	67,673 (38 88)	28,824 (13.12)
3	Chaetognaths	2 581 (20 00)	6,525 (50 54)	3,805 (29.47)
4	Appendicularians	1 386 (43 58)	1,108 (34 84)	686 (21.57)
5	Amphipods	236 (07 55)	2,461 (78 78)	427 (13.67)
6	Ostracods	163 (03 85)	3 053 (72 12)	1,017 (24.03)
7	Polychaetes	518 (88 10)	17 (02 89)	53 (09.01)
8	Siphonophores	530 (24 48)	441 (22 86)	958 (49.56)
9	Foraminiferans	2 381 (50 78)	1,603 (34 19)	704 (15.02)
10	Pl gastropods	253 (08 75)	2,555 (88 38)	83 (02.87)
11	Fish eggs	278 (40 70)	287 (42 02)	118 (17.28)
12	Fish larvae	29 (15 03)	36 (18 65)	128 (66.32)
13	Crustacean eggs	843 (50 97)	692 (41 84)	119 (07.19)
14	Pteropods	32 (22 54)	38 (26 76)	72 (50.70)
15	Pl bivalves	—	11 (91 67)	1 (08.33)
16	Salps	104 (17.69)	251 (42 69)	233 (39.63)
17	Doliolids	—	—	77
18	Medusae	—	—	371
19	Lucifer	—	—	696
20	Decapod larvae	—	—	19

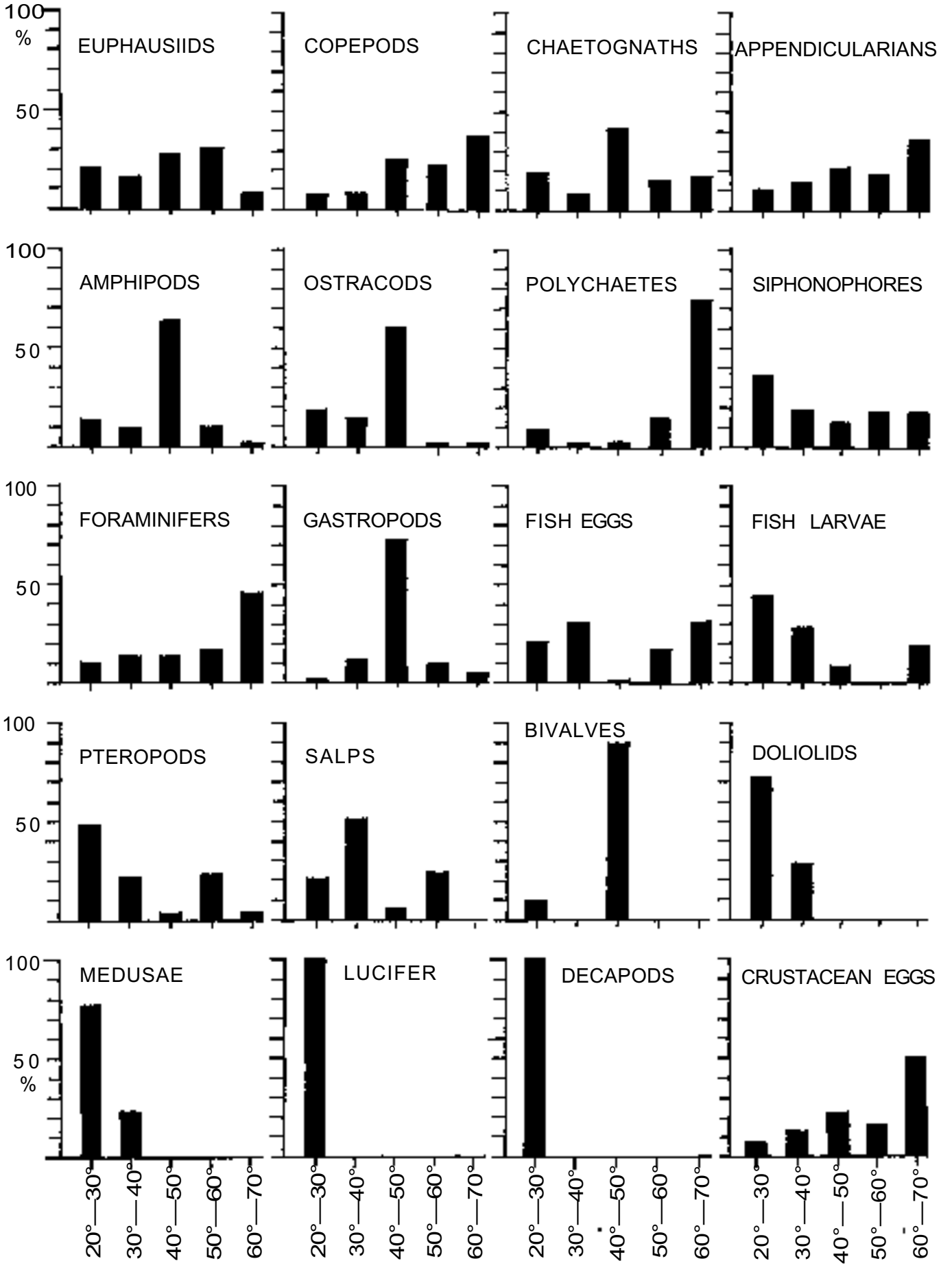


Fig 7 Relative abundance (in percentage) within each zooplankton group in every 10° latitudinal zones

Relative abundance among zooplankton groups

The relative abundance in number among different groups of zooplankters in each 10° latitudinal zone from south to north was also made to understand the degree of dominance by the groups and the results are given in table 3. Copepods ranging from 65 38 to 89 56% was the most dominant group in all the latitudinal zones. Chaetognaths ranging between 2 39 and 10 56% took the second place in all except the zone between 60° and 70° latitude where it was pushed down to the third place by the foraminifers. The third place was taken up by various groups in the different latitudinal zones. Thus while the chaetognaths claimed it in the southern most zone the euphausiids got it in the zone ahead of this the ostracods between 40° and 50°S the foraminifers in the 30° to 40° zone and the siphonophores in the northern most zone. Similarly the 4th place was claimed by the euphausiids in the two northern zones the gastropods in the 40° to 50° zone the foraminiferans and the appendicularians respectively in the two southern most zones. The ostracods had the fifth position in the two northern zones the euphausiids in the middle zone the appendicularians in the 50° to 60° zone. Crustacean egg were dominant enough to claim the fifth position in the southern most zone. The above study shows that there is striking north south variations in the occurrence and abundance among various zooplankton groups and this can be attributed to variations in the environment which are also more significant latitudinally.

TABLE 3

Relative abundance (in percentage) of zooplankters in 10° latitudinal zones

Sl No.	*Zooplankton groups*	*Latitudinal zones*				
		60°-70°	*50°-60°*	*40°-50°*	*30°-40°*	*20°-30°*
1	Euphausiids	0.41	2.30	1.69	3.07	3.85
2	Copepods	89.56	87.92	78.14	74.01	65.38
3	Chaetognaths	2.39	3.31	7.59	4.59	10.56
4	Appendicularians	1.59	1.30	1.21	2.48	1.80
5	Amphipods	0.07	0.54	2.72	1.34	1.82
6	Ostracods	0.15	0.22	3.52	2.64	3.57
7	Polychaetes	0.76	0.23	0.04	0.02	0.35
8	Siphonophores	0.47	0.71	0.41	1.93	3.90
9	Foraminiferans	3.02	1.77	1.20	3.70	2.58
10	Pl gastropods	0.14	0.47	2.74	1.40	0.12
11	Fish eggs	0.31	0.27	0.01	1.26	0.86
12	Fish larvae	0.05	..	0.03	0.29	0.47
13	Crustacean eggs	1.08	0.61	0.63	0.92	0.39
14	Pteropods	0.01	0.08	0.01	0.18	0.21
15	Pl bivalves	..	..	0.01	..	0.01
16	Salps	..	0.28	0.05	1.53	0.59
17	Doliolids	..	..	..	0.17	0.27
18	Medusae	..	..	..	0.48	1.63
19	Lucifer	..	..	..	..	1.51
20	Decapod larvae	..	..	..	..	0.15

The foregoing account throws some light on the latitudinal variations in the production of zooplankton in general and their groups in particular when viewed from various angles. However more works are required to be done with samples taken at frequent intervals for a better understanding in the finer details of latitudinal variations of zooplankton particularly of various species and their association with the changing environmental parameters in the different seasons.

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