

Stratification of zooplankton in the northwestern Indian Ocean

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Abstract - Study on stratification of zooplankton in the northwestern Indian Ocean was carried out with special reference to its relative abundance and distribution. Samples were collected using a multiple plankton net, during the first cruise of *ORV Sagar Kanya*. Sixty samples from 12 stations were collected from the northwestern Indian Ocean, between latitudes 10°N and 4°S and longitudes 52° - 63°E (Fig. 1) from 5 depth zones (1000 - 800 m, 800 - 600 m, 600 - 400 m, 400 - 200 m and 200 m to 0 m) during the latter part of the southwest monsoon from 25th July to 30th August, 1983. Biomass, number of taxa and numerical abundance of zooplankton at a station varied from 3.00 to 28.00 ml/100 m³, 8 to 26 and 376 to 25284 no./100 m³ respectively. In most of the samples, the dominant groups in the order of their numerical abundance were copepods, chaetognaths, foraminiferans, ostracods and decapods (Fig. 4). The maximum number of organisms was in the surface/subsurface layer (200-0 m) and the minimum was between 600 - 400 m. This is the first report on stratification of the zooplankton from the northwestern Indian Ocean. The study has revealed a pronounced diurnal vertical migration in almost all areas, showing a two-fold increase in numerical abundance in night collections (10755/100 m³) compared to day collections (5688/100 m³). The equatorial region was found to be relatively rich in total numbers of organisms (8405/100 m³) and taxa (16) when compared to the areas between latitudes 5° N - 10° N. It was also noticed that collections made between 800 - 600 m depth were mostly constituted by organisms of larger size and of mesopelagic habitat. Another important phenomenon was that the lowest number of taxa was observed in the 600 - 400 m stratum.

INTRODUCTION

Information on stratifications of the zooplankton in the Indian Ocean is scant, mainly because suitable gear for quantitative sampling of known, discrete depths is unavailable. Some collections were made using closing nets, but they were all from a particular depth zone (stratum) in a water column. With the introduction of a multiple plankton net, which can be operated at five successive depths in a single haul through a water column, studies on stratification of zooplankton have become very easy and meaningful. Studies made earlier using the multiple net have shown the vertical distribution of calanoid copepods in the southeastern Arabian Sea (MADHUPRATAP and HARIDAS, 1990); and the distribution, abundance and development of copepods in the SE Bering Sea (SMITH and VIDAL, 1986). The abundance of zooplanktonic organisms from the middle and southwestern Arabian Sea (NW Indian Ocean) and their vertical migration are dealt with in this paper. Special mention is made of the decapod larvae, which include the larvae of the penaeid prawns of commercial importance, though they constitute only a small fraction of the zooplankton. An assemblage of over 26 different groups was present in the samples. The most abundant groups were in the order of Copepoda, Chaetognatha, Foraminifera, Ostracoda and Decapoda.

MATERIALS AND METHODS

The samples were collected during the first cruise of *ORV Sagar Kanya* from 11 July to 25 August 1983, in the northwestern Indian Ocean, between latitudes 10°N - 4°S and longitudes 52° to 63° E and from depths of 1000 - 0 m. Sampling was done

at 12 stations (Fig. 1) with a multiple opening/closing plankton net (Hydrobios No. 438100). The net is made of a Stainless Steel frame with a motor unit for the opening and closing of the net bags; a canvas part with zip fasteners for the 5 net bags. The mouth area is 50 x 50 cm. There is a power supply of 6 V from 4 batteries. Each net bag has a zip fastener, opening of 50 x 50 cm, a standard length of 2.5 m and with nylon netting of 300 micron mesh size. A flow meter is attached at the mouth, in the centre of the frame and the net is hauled vertically at a speed of 40 m/minute. Five samples were collected from each station from 5 depths (1000 - 800 m, 800 - 600 m, 600 - 400 m, 400 - 200 m and 200 - 0 m) bringing the total number of samples to 60. The biomass was determined as displacement volume. Groups are listed in the order of their abundance. The total number of organisms in each group was calculated for 5 strata in all the 12 stations. The percentage of organisms of each group is also calculated (Table 2). A standard subsample of 10 ml was taken for sorting wherever possible; in other cases the entire sample was sorted. The numerical abundance of each taxon was calculated to number/100 m³ and the major 6 groups are given (Fig. 4). The occurrence, abundance and vertical migration of the zooplankton are studied and illustrated in this paper.

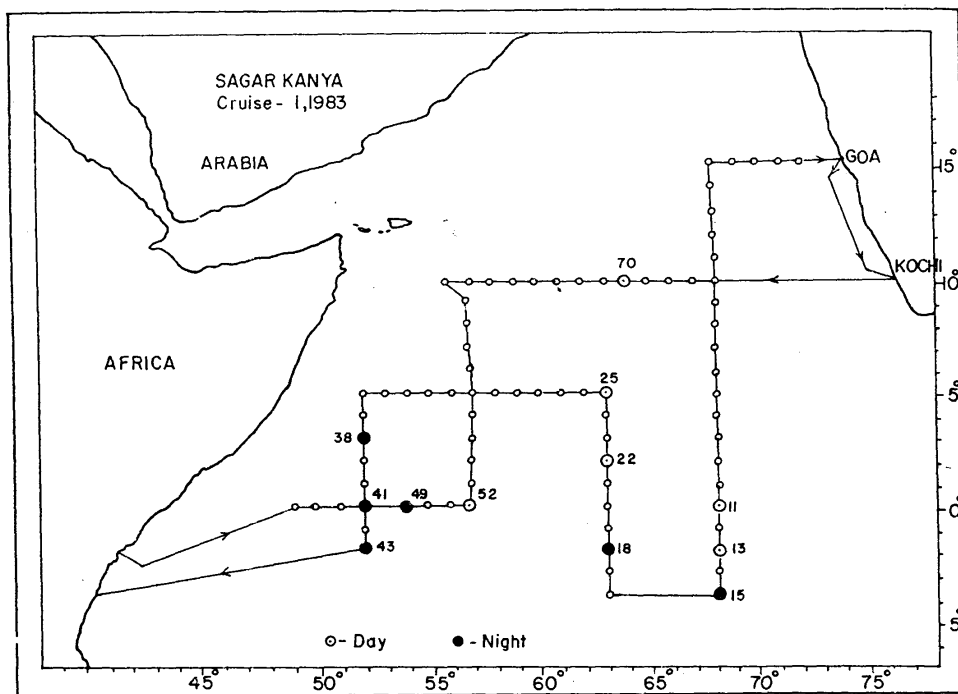


Fig. 1. Station position. (Day and Night stations)

RESULTS

Studies on stratification of the zooplankton are scant and hence, this is an important, unique study from this region. All 12 stations had representatives from all major groups of zooplankton (Table 1) at all depths but their numbers varied. In deeper layers, large bathypelagic copepods such as *Eucalanus*, *Pleuromamma*, *Rhincalanus* (STEPHEN *et al.*, 1987), Chaetognaths (*Sagitta*) and the decapod *Aristeus alcocki* were often collected. Twenty six taxa of zooplankton were collected in the samples. The numerical abundance

Table 1. The presence of various taxa at 5 depths

Sl. No.	Taxa	DEPTHS (m)									
		1000 - 800		800 - 600		600 - 400		400 - 200		200 - 0	
		Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
1.	Copepoda	+	+	+	+	+	+	+	+	+	+
2.	Chaetognatha	+	+	+	+	+	+	+	+	+	+
3.	Foraminifera	+	+	+	+	+	+	+	+	+	+
4.	Ostracoda	+	+	+	+	+	+	+	+	+	+
5.	Euphausiacea	+	+	+	+	+	+	+	+	+	+
6.	Appendicularia	+	+	+	-	-	-	+	+	+	+
7.	Siphonophora	+	+	-	-	+	+	-	+	+	+
8.	Decapoda	+	+	+	+	+	+	+	+	+	+
9.	Salps & Doliolids	-	+	-	+	+	+	+	+	+	+
10.	Cyphanautes	-	-	-	-	-	-	+	-	-	-
11.	Fish eggs & lar.	+	+	+	+	+	+	+	+	+	+
12.	Gastropoda	-	+	+	+	+	+	+	+	+	+
13.	Amphipoda	+	+	+	+	-	+	-	+	+	+
14.	Lamellibranchs	-	-	-	-	+	-	-	-	+	+
15.	Pteropoda	+	+	+	-	+	+	-	-	+	+
16.	Heteropoda	-	-	-	-	-	-	-	-	+	+
17.	Mysidacea	-	+	-	+	-	+	-	+	+	+
18.	Polychaeta	+	+	+	+	+	+	-	-	+	+
19.	Hydrozoa	-	+	+	-	+	+	+	-	+	-
20.	Anthozoa	-	-	+	-	+	+	-	-	+	+
21.	Phyrosoma	+	-	-	+	-	-	-	-	+	-
22.	Brachyura	-	-	-	+	-	-	-	-	+	-
23.	Scyphozoa	-	-	-	-	+	-	-	-	-	-
24.	Cladocera	+	-	-	-	-	-	+	-	-	-
25.	Tornaria	+	-	+	-	+	-	-	-	+	-
26.	Isopoda	-	-	-	-	-	-	+	-	-	-

+ = Present; - = Absent

Table 2. Group assemblage, numerical abundance and percentage occurrence in 1000 - 0 m.

Sl. No.	Taxa	No./M ²	Percentage (M ²)
1.	Copepoda	89,3840	77.73
2.	Chaetognatha	9,7900	8.50
3.	Foraminifera	5,3630	4.70
4.	Ostracoda	2,9220	2.54
5.	Euphausiacea	1,6440	1.43
6.	Appendicularia	1,4640	1.30
7.	Siphonophora	8680	0.75
8.	Decapoda	8400	0.73
9.	Salps & Doliolids	5120	0.45
10.	Cyphanautes	4080	0.35
11.	Fish eggs & Larvae.	2770	0.24
12.	Gastropoda	2580	0.23
13.	Amphipoda	2560	0.22
14.	Lamellibranchs	2280	0.20
15.	Pteropoda	2080	0.18
16.	Heteropoda	1480	0.13
17.	Mysidacea	1360	0.12
18.	Polychaeta	980	0.09
19.	Hydrozoa	760	0.07
20.	Anthozoa	340	0.03
21.	Pyrosoma	260	0.02
22.	Brachyura	220	0.02
23.	Scyphozoa	120	0.01
24.	Cladocera	120	0.01
25.	Tornaria	80	0.01
26.	Isopoda	40	0.00

of different taxa and their percentages are given (Table 2). The maximum biomass (22.00 ml/100m³) in a stratum was recorded in the uppermost layer (200 - 0 m) at station No. 41 (Fig. 2 A) during night. The stratum between 600 - 400 m was found to be relatively non-productive in the area of study. The surface/subsurface layer (200 - 0 m) had 85% of the total biomass, while the 1000 - 800 m layer had only 2% (Fig. 2 A). The largest total biomass was observed at station No.49, a night station (Fig. 2 B). Copepods were the dominant group at station 49. Their maximum number (21180/100m³) was observed in a night collection in the 200 - 0 m stratum of stn. No. 43. The 2nd and 3rd most abundant groups were Chaetognatha and Foraminifera. Their maximum numbers were 2960/100 m³ and 2020/100 m³ respectively at station No. 11, also from 200 - 0 m. Other dominant groups were ostracods, euphausiids, fish larvae, amphipods and decapods (Fig.3).

The percentage occurrence of organisms in each taxon in the 5 different depth strata were calculated (Table 4). The more important and most abundant groups are represented in the form of histograms (Fig. 4). The total number of each group of zooplankton organisms in the entire water in all the stations together was also calculated (No./m², Table 2).

While considering the occurrence and abundance of the zooplankton, night collections exceeded day collections both in number of taxa and numerical abundance of organisms. There were six day and six night stations (Fig. 1). The average numerical abundance in night collections was 10755/100 m³ and that of day was 5688/100 m³. Most individual groups also showed similar results (Fig. 3). Thus, on an average, night collections had 17 taxa, whereas day collections had only 14. Both night and day collections had the maximum number of organisms at the 200 - 0 m stratum.

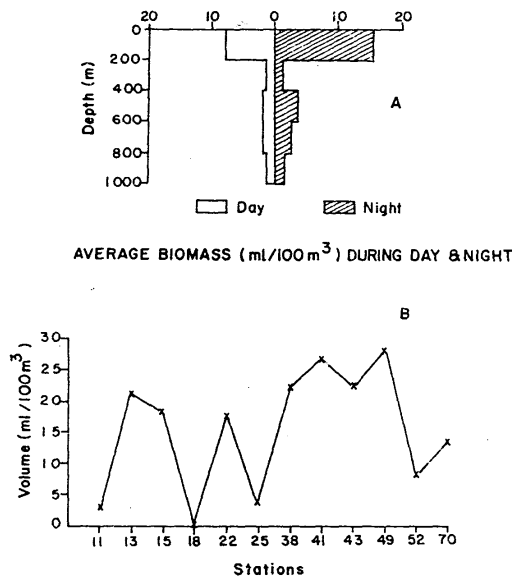


Fig. 2. A - Average biomass (ml/100 m³) during day and night, B - Biomass (ml/100 m³) at 12 stations

DISCUSSION

Earlier studies in deep waters suggest that at great depths, at the order of 2000 m, the diversity of zooplankton decreases and the number of species declines (LEAVITT, 1935). However, it cannot always be assumed that the maximum concentration is

towards the surface. The results of the Expeditions like that of *H.M.S. CHALLENGER* (1873 - 1876) suggested that at depths of a few hundred metres there was probably a greater diversity of zooplankton than at the surface. The depth distribution of zooplankton and the pattern appears to change in different oceanic areas. In the present collections mostly from a mid oceanic, equatorial region, the organisms were very few at greater depths. The deeper zones were represented by deep water species like *Aristeus* (Penaeidae), *Sagitta* (Chaetognatha) and *Parapandalus* (Caridea). Chaetognaths are generally abundant in the sea and constitute an important part of marine plankton. They are highly predaceous and carnivorous, eating mainly copepods. They can also be indicators of water masses and other hydrographical conditions. The abundance and scarcity of chaetognaths may correspond to the pattern of distribution of copepods.

The biomass (Fig. 2 A & B) as well as the number of individuals in each taxon (Table 2) was not found to be very high. The north and northwestern Arabian Sea is 4 to 10 times richer in zooplankton biomass (280 ml/100 m³) than that of the entire Indian Ocean (PAULINOSE and ARAVINDAKSHAN, 1977). The present collections are mainly from the open ocean, away from the coasts where depths normally exceed 3000 to 5000 m. Two stations from the equatorial region (Stn. Nos. 22 and 25; Fig. 1) were rich in zooplankton (Chaetognatha and Foraminifera). This supports the findings of PANIKKAR and RAO (1973) that some areas along the equator support very rich zooplankton populations. The foraminiferans belonged to nearly 17 species. The most abundant species are *Globigerinella aequilateralis*, *Globigerinoides ruber*, *G. sacculifer* and *Globorotalia tumida* (RAO *et al.* 1988). Of all the factors influencing their distribution and abundance, such as salinity, temperature and dissolved oxygen; temperature is the most important factor controlling the distribution pattern of planktonic foraminifera (RAO *et al.* 1988).

Table 3. Percentage of various taxa at 5 strata against total number of all groups.

Sl. No.	Animal Taxa	DEPTHS (m)				
		1000-800	800-600	600-400	400-200	200-0
1.	Copepoda	77.77	78.83	74.33	81.45	77.50
2.	Chaetognatha	4.09	3.09	3.86	9.88	8.86
3.	Foraminifera	9.66	7.42	4.15	1.43	4.72
4.	Ostracoda	3.20	5.49	3.28	1.50	2.49
5.	Euphausiacea	0.26	1.07	3.11	1.15	1.44
6.	Appendicularia	0.30	0.06	-	0.53	1.45
7.	Siphonophora	0.97	-	0.40	0.03	0.85
8.	Decapoda	0.78	0.57	0.49	0.60	0.75
9.	Salps & Doliolids	0.14	0.38	0.35	1.38	0.38
10.	Cyphanautes	-	-	2.36	0.05	0.33
11.	Fish eggs & Larvae	0.67	1.52	2.54	0.90	0.05
12.	Gastropoda	0.07	0.13	0.58	0.08	0.23
13.	Amphipoda	0.59	0.44	0.06	0.28	0.21
14.	Lamellibranchs	-	-	2.99	-	0.13
15.	Pteropoda	0.14	0.06	0.12	-	0.20
16.	Heteropoda	-	-	-	-	0.15
17.	Mysidacea	0.07	0.13	0.12	0.50	0.09
18.	Polychaeta	0.59	0.38	0.23	-	0.06
19.	Hydrozoa	0.14	0.06	0.35	0.18	0.05
20.	Anthozoa	-	0.06	0.23	-	0.02
21.	Pyrosoma	-	0.19	-	-	0.02
22.	Brachyura	-	0.07	-	-	0.02
23.	Scyphozoa	-	-	0.29	-	0.02
24.	Cladocera	0.37	-	-	0.03	-
25.	Tornaria	0.07	0.06	0.06	-	0.02
26.	Isopoda	0.12	-	-	0.03	-

The total biomass in a station was on average 28.00 ml/100 m³ in the upper 200 m and almost an equal amount of biomass was present in the deeper layers (1000-600 m). The percentage occurrence of each taxon in a given stratum was separately estimated and showed that the most abundant groups were copepods, foraminiferans and chaetognaths in 1000 - 800 m; copepods, foraminiferans and ostracods in 800 - 600 m; copepods, foraminiferans and chaetognaths in 600 - 400 m; copepods, chaetognaths and ostracods in 400 - 200 m and copepods, chaetognaths and foraminiferans in 200 - 0 m (Table 3). Other groups were present in lesser numbers or absent (Table 3). The percentage occurrence of the common groups of zooplankton in the five different strata are also given (Table 4). Copepods are the most abundant group among the zooplankton in the entire column (1000 - 0 m) and also in the different strata studied.

Table 4. Percentage of individual of a taxon at 5 strata.

Sl. No.	Animal Taxa	DEPTHS (m)					Total No. per m ²
		1000-800	800-600	600-400	400-200	200-0	
1.	Copepoda	2.35	2.79	2.89	7.29	84.68	894800
2.	Chaetognatha	1.12	1.00	1.37	8.07	88.44	94020
3.	Foraminifera	4.85	4.38	2.69	2.13	85.95	52880
4.	Ostracoda	2.94	5.95	3.90	4.11	83.10	29220
5.	Euphausiacea	0.43	2.07	6.57	5.60	85.33	8540
6.	Appendicularia	0.55	0.14	-	2.87	96.44	13200
7.	Siphonophora	2.29	-	1.64	0.23	85.84	7940
8.	Decapoda	2.50	2.14	2.02	5.71	87.63	7700
9.	Salps & Doliolids	0.78	2.34	2.34	21.48	73.06	4780
10.	Cyphanautes	-	-	20.10	0.98	78.92	1660
11.	Fish eggs & Larvae	6.79	32.85	24.56	29.50	19.25	2780
12.	Gastropoda	0.78	1.55	7.75	2.33	87.59	2680
13.	Amphipoda	6.25	5.47	0.78	8.59	78.91	1900
14.	Lamellibranchs	-	-	45.61	-	54.39	2280
15.	Pteropoda	1.17	0.60	2.00	-	92.87	2560
16.	Heteropoda	-	-	-	-	100.00	90
17.	Mysidacea	1.47	2.94	2.94	29.41	63.24	1340
18.	Polychaeta	16.32	12.24	8.16	-	63.28	2160
19.	Hydrozoa	5.26	2.63	15.75	18.42	57.90	860
20.	Anthozoa	-	5.88	23.53	-	70.59	340
21.	Pyrosoma	-	23.08	-	-	76.92	260
22.	Brachyura	-	9.09	-	-	90.91	220
23.	Scyphozoa	-	-	83.33	-	16.67	120
24.	Cladocera	83.33	-	-	16.67	-	120
25.	Tornaria	25.00	25.00	25.00	-	25.00	80
26.	Isopoda	50.00	-	-	50.00	-	40

They show a stratumwise distribution in species. Thus sp. of Paracalanidae, Calanidae and Eucalanidae are abundant in the 200 - 0 m whereas sp. of Eucalanidae and *Pleuromamma* sp. in 400 - 200 m stratum. Clausocalanidae, Aetideidae, Lucicutiidae and Augaptilidae dominated in the 600 - 400 m stratum but *Megacalanus* sp. dominated in the 800 - 600 m stratum. The deeper most stratum was occupied with more of *Calanoides* sp. *Disseta* sp. and *Mesorhabdus* sp. (Stephen R et al. 1987).

The total of the general zooplankton taxa are shown in Table 2. More than 77% of the plankton population comprised copepods which form the primary consumers in the food chain. Chaetognaths which formed the second abundant group had a wider vertical distribution in the ocean (Fig. 3) being present in the entire 1000 - 0 m water column. They mainly feed on copepods. The foraminiferans, the third abundant group, also were present in deeper waters (Tab. 3). Compared to the variety of taxa present in coastal waters, the 26 different taxa observed in the present investigation

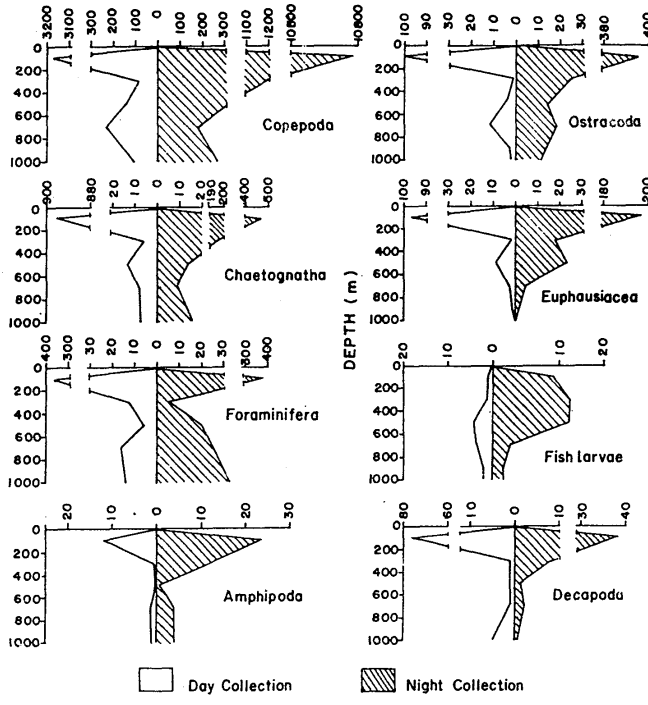


Fig. 3. Vertical distribution of major taxa (no./100 m³)

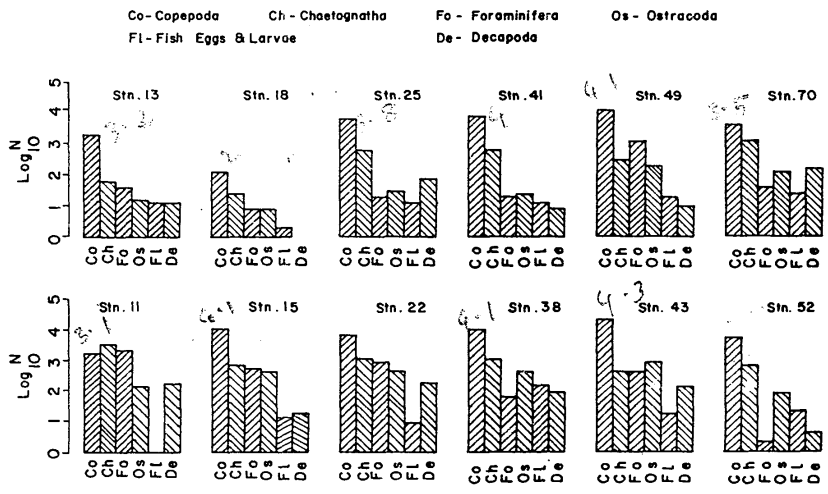


Fig. 4. Numerical abundance of major groups of zooplankton in the upper 1000-0 m.

are small. MENON *et al.* (1977) noticed a reduction in the standing crop of zooplankton, both at surface and throughout the water column as a function of depth. However, the present investigation establishes the fact that in the northwestern Indian Ocean, zooplankton are present in fair numbers, at least, up to a depth of 1000 m.

An interesting feature was observed in the stratum of 600 - 400 m, it had the lowest number of zooplankton compared to all other strata, in all 12 stations. MADHUPRATAP and HARIDAS (1990) also found this layer as the minimum for abundance of calanoid copepods. The scarcity of organisms in this stratum cannot be fully explained. However, vertical migration may add slightly to this phenomenon. The largest total number of specimens and the maximum concentration of copepods were found at stn. 43 during night. The second maximum of copepods was at station 38 which also was sampled at night. Each major component of zooplankton has different periods of abundance as reported by Menon *et al.* (1967). As all these samples were collected within a period of 2 months; July and August, the spawning periods of all the groups might not have commenced, which could be another reason for the lower abundance. As for the vertical migration of most of these organisms, nothing could be clearly stated as the samples were not collected for this purpose. Only through detailed work in future in the same line, more light can be thrown on the zooplankton at greater depths; their behaviour in vertical migration at different depths, latitudes and at various regions during day and night, and also, about the micro-layerings of zooplankton organisms.

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