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Abundance and distribution of mesozooplankton in Andaman waters during winter monsoon

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Original Article

Abstract

Distribution and abundance of major groups of mesozooplankton of the upper 1000 m of the Andaman waters, during winter monsoon (December 2003–January 2004) is described based on collection made from a ship. Stratified samples were collected from five standard depths using Multiple Plankton Net (MPN). The quantitative and qualitative abundance of mesozooplankton were found to be maximum in the mixed layer. The average zooplankton biomass in the mixed layer was 243 ml per 1000 m^3, which was a high value for the season. Zooplankton abundance and standing stock showed spatial and temporal variations. The average biomass was higher on the eastern side of the Island chain than on the western side. Areas of high zooplankton standing stock were encountered in the 12°N latitude area. Copepods (84.5%) formed the dominant group, followed by chaetognaths (6.9%), ostracods (2.5%), decapods (1.9%) and copelates (1.6%). Distribution and abundance of zooplankton were influenced by various hydrographical characteristics. Comparatively higher values of dissolved oxygen, primary production and chlorophyll-a were noticed in the mixed layer on the western side.

Keywords: *Meso-zooplankton, Andaman sea, winter monsoon, Mixed Layer Depth.*

Introduction

Andaman Sea in the Indian EEZ forms the eastern part of the northeastern Indian Ocean with a partial separation by Andaman–Nicobar Island chain. It is one of the important biodiversity hotspot (Nair and Gireesh, 2010) and the richness of marine biota of these islands is mainly linked with the renowned coral reefs and the extensive mangroves of these islands (Pillai *et al*., 2013). Most of the studies in Andaman waters have taken place in the EEZ of Thailand (Janekarn and Hylleberg, 1989; Janekarn and Kiorboe, 1991; Satapoomin, 1999; Munk *et al*., 2004). The oceanographic and biological aspects of the Andaman waters falling in the Indian EEZ were covered only partially, during the International Indian Ocean Expedition (IIOE, 1959-1965) and information on the mesozooplankton community and distribution remains limited (Madhupratap *et al*., 1981a, b; Antony *et al*.,1997; Madhu *et al*., 2003; Satapoomin *et al*., 2004). The Andaman waters contain a relatively extensive basin with a maximum depth of 4360 m and uneven bottom topography. The surface circulation of the region is controlled by the monsoon systems of the northern Indian Ocean (Bhattathiri and Devassy, 1981). The northeastern part receives a considerable amount of river run-off and the southeastern side is connected to the Pacific Ocean through Malacca Strait. Corresponding to these physical and topographical characteristics of Andaman waters, the hydrodynamic and biological properties showed significant variations from other parts of Indian EEZ. The physical environment affects the composition and structure of plankton communities, and therefore modulates ecosystem function and dynamics (Paffenhofer, 1980; Landry *et al.*, 2001).

The mesozooplankton community plays a vital role in the marine food chain and contributes to the flux of biogenic material through their daily vertical excursions in the water column. So their distribution and biomass is related to ocean productivity and biogeochemical processes. Understanding the spatial and temporal variability of zooplankton biomass and the factors controlling their distribution is important in assessing the marine ecosystem functions. The aim of the present study is to describe the spatial variation and abundance of mesozooplankton biomass of the Andaman waters using the vertical profile up to a depth of 1000 m in relation to the prevailing physico-chemical features during winter monsoon.

Material and methods

Study area

The study is based on the data and samples collected as a part of Marine Living Resource Programme (MLRP) of Ministry of Earth Sciences, Government of India, on board FORV *Sagar Sampada* (Cruise No. 220) in the Andaman waters during December 2003 to January 2004. Sampling was done at 24 hydrographic stations along 8°N, 10°N, 12°N and 13°50' N transects (Fig. 1).

Sampling procedure

A Sea Bird CTD was used to collect the temperature-salinity

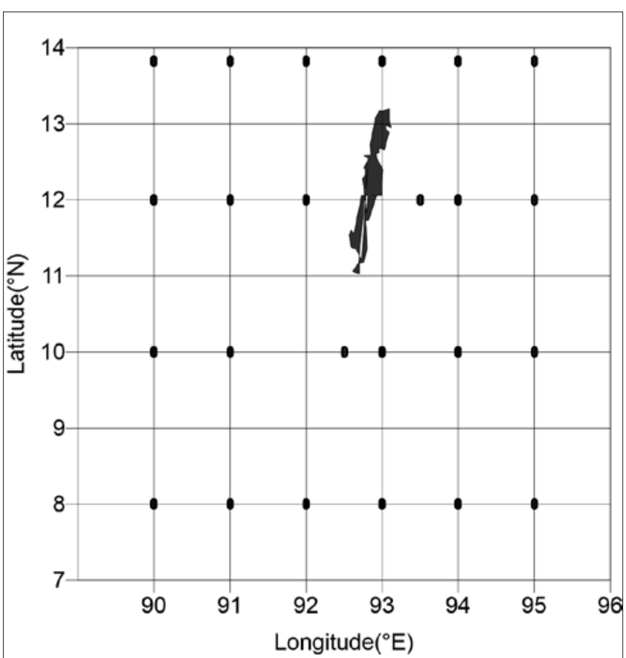

Fig. 1. Station positions of the study area

profiles. Salinity values from CTD were corrected against the values obtained from the Autosal (Guildline 8400). Surface meteorological parameters were collected at all stations and along track by the ship–borne weather station. The sea surface temperature (SST) was measured using a Bucket thermometer. Water samples were collected using Rosette sampler fitted with Niskin water bottles from 14 standard depths and dissolved oxygen estimation was done by Winkler method. For measuring primary production and chlorophyll *a*, water samples were collected from seven discrete depths (surface, 10, 20, 50, 75, 100, 120m). Primary productivity was measured following *in-situ* C^{14} technique (Strickland and Parsons, 1972). Chlorophyll *a* (chl–a) was estimated by filtering 1L of water through GF/F filters (0.7), extracted using 90% acetone and measured using spectrophotometer (Strickland and Parsons, 1972).

Mesozooplankton samples were collected from five different depth strata *viz.* 1000-500 m, 500-300 m, 300 m-bottom of thermocline (BT), BT-top of thermocline (TT) and TT-surface (Mixed layer) using multiple closing plankton net (MPN Hydro-Bios, Mouth area-0.25 m^2, mesh size-200 μm). The net was retrieved at a speed of 1m s^{-1}, the samples from each depth were filtered, and the biomass was estimated as displacement volume (ml per 1000 m^3). They were preserved in 4% formaldehyde for enumeration and identification of different zooplankton taxa.

Results

Weather and hydrographic parameters

The wind pattern during the observation period was northeasterly with an average speed of 3.5 m s^{-1}. The sea surface temperature ranged from 27.1°C to 28.6°C with an increasing trend from north to south, on both the western as well as eastern sides of the Island chain. In the northern region, sea surface temperature was low due to fresh water influx from rivers. The upper isothermal layer is treated as the mixed layer (ML) and was taken as the subsurface depth where the temperature was 1°C less than that at the surface using CTD profiles. The mixed layer depth varied between 40 m and 99 m during the study period (Fig. 2). Comparatively deeper mixed layer depth was observed on the western side. Sea surface salinity on the eastern side ranged from 31.6 psu to 33.5 psu and 32.7 psu to 33.7 psu on the western side. Relatively low sea surface salinity was observed at the northern region and was increasing towards the south. The depth of bottom of thermocline ranged from 150 m to 215 m on the western part and 140 m to 205 m on the eastern part. In the mixed layer the values of nitrate ranged between 0.5-1.5 μM in the west and 0.5-1 μM in the east. Dissolved oxygen values ranged between 4.4 and 4.9 ml L^{-1} in the mixed layer. Comparatively higher value of surface dissolved oxygen was found on the western side.

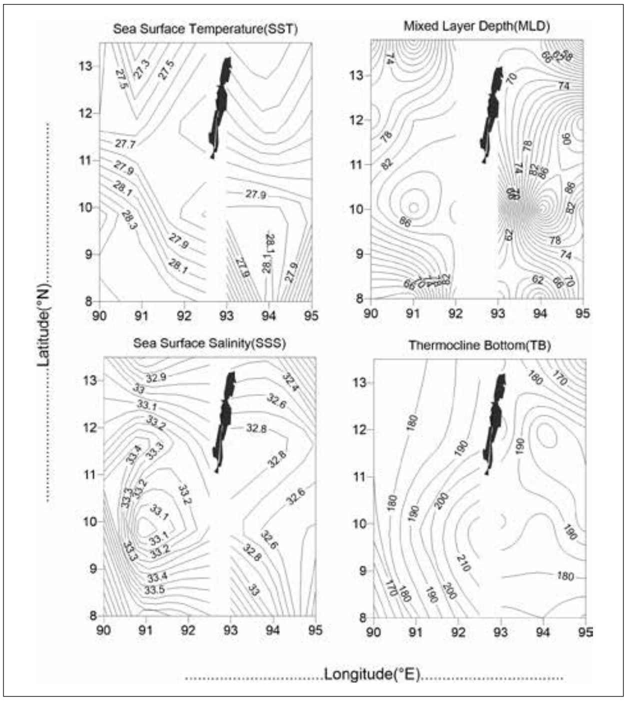

Fig. 2. Distribution of Sea Surface Temperature (°C), Mixed Layer Depth (m), Sea Surface Salinity (psu) and Thermocline Bottom (m) in the Andaman waters during winter monsoon.

The Oxygen Minimum Zone (OMZ) showed a distinct gradient between east and west (Fig. 3). The oxygen concentration was very low in the 100-500 m water column (0.05-0.2 ml L^{-1}) on the western side, but the layer became thinner and the values increased to 0.2-0.5 ml L^{-1} on the eastern side.

Primary productivity and Chlorophyll a distribution

The maximum value of surface primary production (16.79 mg C m-3 d^{-1}) was recorded at 13° 50' N, 92° E in the northwestern region and minimum (0.69 mg C m-3 d^{-1}) was recorded at 7° 59' N, 95° E in south-eastern region. The average surface and column chl-a was 0.3 mg m^{-3} and 25.06 mg m^{-2} respectively. Average column primary productivity of 235.54 mg C m^{-2} d^{-1} was obtained from the oligotrophic waters of Andaman, with maximum production in the northwestern region (391.8 mg C m^{-2} d^{-1}) and minimum production in the southeastern region (77.2 mg C m^{-2} d^{-1}). Similarly, maximum and minimum column chl-a (44.8 mg m^{-2} and 8.8 mg m^{-2}) were obtained from the same locations, respectively, with an average value of 25.07 mg m^{-2}.

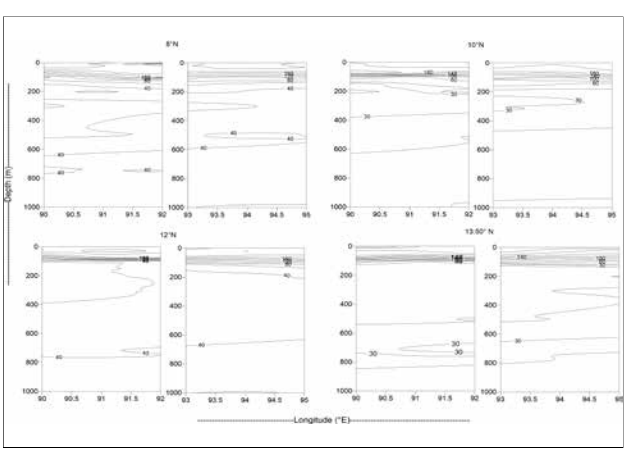

Fig. 3. Latitudinal distribution of dissolved oxygen (ml L^{-1}) in the Andaman waters during winter monsoon

Mesozooplankton biomass and distribution

Biomass and diversity of zooplankton taxa were maximum in the mixed layer. Fifty eight percent of the total biomass occurred in the mixed layer (Fig. 4). The total mesozooplankton biomass ranged between 85 and 530 ml per 1000 m^3 and the average biomass was 243 ml per 1000 m^3 in the mixed layer (85 ml per 1000 m^3 up to 1000 m). The average biomass was higher on the eastern side of the sea (318 ml per 1000 m^3) than on the western side (167 ml per 1000 m^3). The maximum biomass value (530 ml per 1000 m^3) was recorded towards a coastal station (12° N, 93°20' E), on the eastern side of the sea. The horizontal distribution of biomass showed the maximum value at 12°N (288 ml per 1000 m^3) with a decrease from north to south (12°N–8°N) (Fig. 4). The lowest biomass value in the mixed layer was observed at13° 50' N. Below the mixed layer a steady decrease was noticed downwards up to 1000 m. Across the thermocline layer (TT-BT) and below it (BT-300) the average biomass values were 78 ml per 1000 m^3 and 49 ml per 1000 m^3 respectively. An average biomass of 37 ml per 1000 m^3 occurred at 300-500 m depth. A sharp decline in biomass was observed in the 500-1000 m depth with an average of 2 ml per 1000 m^3.

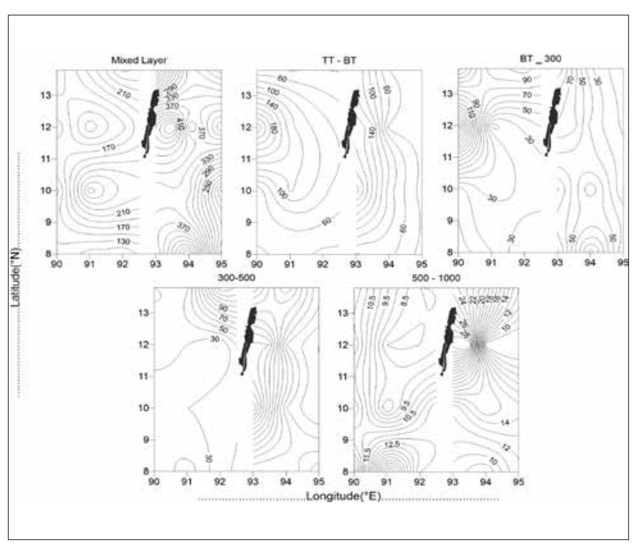

Fig. 4. Latitudinal distribution of zooplankton biomass (ml per 1000 m^3) at different strata in the Andaman waters during winter monsoon

Major mesozooplankton components and their relative abundance

The abundance of all major zooplankton groups indicated a relatively higher density along the eastern side than on the western side (Table 2 and 3). Numerically copepods formed the major component among zooplankton groups accounted for 84.5% (Table 1). The average density of copepods was 222185 ind. per 1000 m^3 in the mixed layer. Their maximum numerical density (385000 ind. per 1000 m^3) was recorded at 12° N, 94° E in the mixed layers (Fig. 5). The percentage contribution of copepods to total zooplankton abundance on the western side was very high (88.8%). Copepods were followed by the carnivorous forms, chaetognaths (6.9%) with an average density of 22069 ind. per 1000 m^3 in the mixed layer. They were fairly abundant at all stations. Their maximum density of 57058 ind. per 1000 m^3 was observed at the coastal station (12° N, 93°20' E). Other zooplankton groups generally accounted for less than 4% of the total abundance. Among them the important contributors were ostracods (2.5%), decapods (1.9%), copelates (1.6%) and euphausiids (1%).

The average numerical density of ostracods in the mixed layer was 3190 ind. per 1000 m^3 with a maximum number of 23628 ind. per 1000 m^3. This group showed an equal population density in the mixed layer as well as the thermocline layer (Fig. 5 and 6). The numerical distribution of decapod larvae and copelates

Table 1. Percentage abundance of major groups of Zooplankton in the study area

Major Groups	Total Study Area	East (%)	West (%)
Copepods	84.5	81.3	88.8
Chaetognaths	6.9	7.4	6.2
Ostracods	2.5	3.2	1.6
Decapods	1.9	2.5	0.9
Copelates	1.6	1.7	0.4
Euphausiids	1	1.1	0.3
Fish Larvae	0.2	0.26	0.1
Fish Eggs	0.05	0.02	0.1

Table 2. Average population density (individuals per 1000 m^3) of common groups of zooplankton at different depths in the eastern Andaman waters

Group	0-TT	TT-BT	BT-300	300-500	500-1000
Copepoda	241375	62873	21620	19225	8877
Chaetognatha	27918	2902	605	427	171
Ostracoda	4945	4610	2983	888	311
Decapoda	6894	476	37	33	73
Copelata	10432	289	-	3	20
Euphausiid	2779	1392	471	230	13
Fish Larvae	915	158	-	25	12
Fish Egg	52	25	3	3	-

- indicate absence

Table 3. Average population density (individuals per 1000 m^3) of common groups of zooplankton at different depths in the western Andaman waters

Group	0-TT	TT-BT	BT-300	300-500	500-1000
Copepoda	202995	50108	19671	6765	4085
Chaetognatha	16219	2664	516	253	122
Ostracoda	1434	1867	1707	145	61
Decapoda	1213	112	25	15	9
Copelata	829	3	-	-	5
Euphausiid	1474	535	656	100	9
Fish Larvae	217	51	-	42	10
Fish Eggs	293	17	4	10	3

- indicate absence

showed that their representation on the western side was comparatively less. The maximum observed value for decapod larvae was 45703 ind. per 1000 m^3, in the mixed layers. A large aggregation of the sergestid shrimp, Lucifer (37333 ind. per 1000 m^3) constituted the bulk of decapods. Copelates sustained relatively very poor representation on the western side. They had the maximum density of 49617 ind. per 1000 m^3. They were almost absent from all the layers except in the mixed layer. Euphausiids showed a relatively high density amounting to 5295 ind. per 1000 m^3. The contributions of fish eggs and larvae were 0.2% and 0.05%, respectively. Maximum density of fish larvae (1647 ind. per 1000 m^3) was recorded at the coastal station (12° N, 93°20' E), and the maximum fish eggs (1687 ind. per 1000 m^3) in the south-west (8°N, 90°E). Abundance of fish larvae was high on the eastern side, but the fish eggs were high on the western side. Apart from these, other organisms such as polychaetes, hydrozoans, siphonophores, gastropods, amphipods, etc. were also encountered at different stations, but their contribution to the total counts was negligible (< 0.05%).

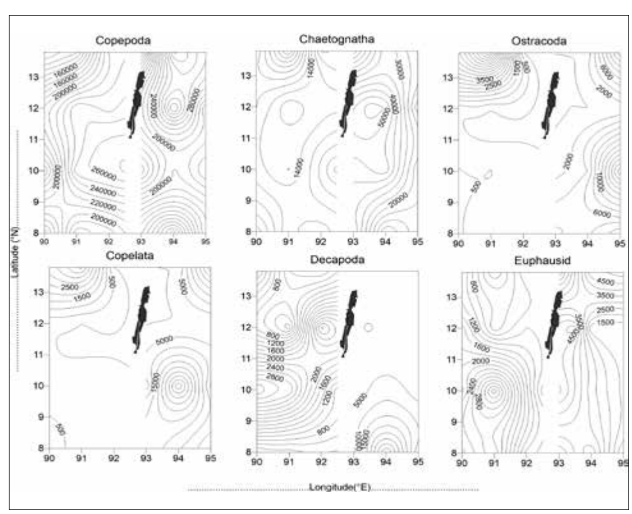

Fig. 5. Latitudinal distribution of major groups of zooplankton (ind. per 1000 m^3) in the mixed layer in the Andaman waters during winter monsoon.

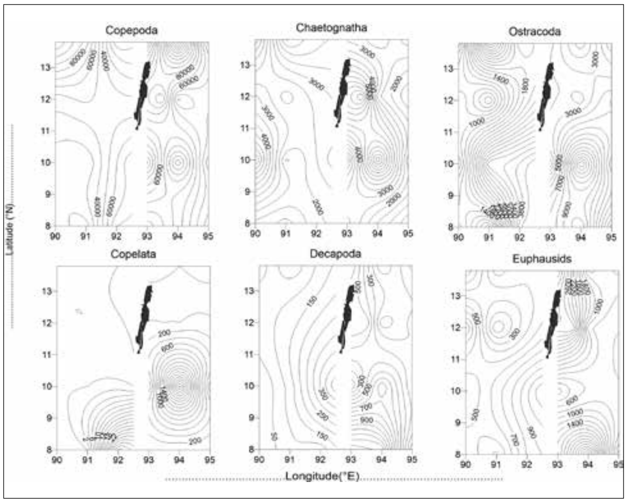

Fig. 6. Latitudinal distribution of major groups of zooplankton (ind. per 1000 m^3) in the thermocline in the Andaman waters during winter monsoon.

Discussion

The hydrography of the Andaman waters is influenced by the monsoon winds and the seasonal variations are prominent. The cycling of north east and south west monsoonal wind systems reverses the atmospheric circulation and the surface currents of the Bay of Bengal and the Andaman Sea from December to April, and June to October with intervening transitional period (Murthy *et al.*, 1981). The mesozooplankton community, a key component of the pelagic food chain, linking the primary producers with the secondary consumers is strongly controlled by the physical environment, which influence their growth, reproduction and distribution (Mauchline, 1998). The zooplankton biomass values obtained in the mixed layer were in general higher than those reported earlier during winter monsoon from the Andaman waters (Madhu *et al.*, 2003; Madhupratap *et al.*, 1981a). This may be due to the fact that most of the earlier studies were conducted during the late winter monsoon- February. Temperature plays an important role in the distribution of zooplankton. Studies by Bhattathiri and Devassy (1981) in the Andaman waters during February 1979 and January 1980 have shown a higher zooplankton biomass during January than February. Maximum zooplankton biomass was reported in December from the Binge Bay, in the Bay of Bengal (Nair, 1978). Nair (1978) reported that September to December period was noted for abundance of fish eggs and larvae with intense breeding in November-December months. Sea surface temperature (SST) has been considered the most important factor controlling concentration of zooplankton in comparison with the food availability (Heinle, 1969). A typical range of 24–26° C water temperature was found preferable for zooplankton production in a bio-physical model developed to estimate zooplankton production by Solanki *et al.* (2015). Temperature alters the rates of various biological processes in copepods, such as their growth, productivity, and mortality (Hirst and Kirboe, 2002). This causes the aggregation of zooplankton to the particular temperature zones. The biomass values generally showed a decrease from north to south on the eastern and western sides, with a maximum production at the 12°N latitude where the surface waters were characterized by low temperature and salinity. The sea surface temperature and salinity showed an increase from north to south. Earlier studies (Marichamy, 1983; Antony *et al.*, 1997) also reported the occurrence of low zooplankton abundance at places of high temperature and salinity.

The general distribution pattern of biomass and abundance showed that the eastern part of the sea is highly productive than the western part. Aggregation of different zooplankton groups evidently contributed to the higher biomass on the eastern side, which is represented in less numbers in the west, especially copelates and decapods. Particulate carbon, coral mucus and zooxanthellae occurring in the northeast coast of the Andaman Islands contribute significantly to the reef productivity in the waters and aid as a source of food to zooplankton (Pillai, 1983). The species composition of the autotrophs and heterotrophs determines the amount of carbon that is either recycled in the euphotic zone or is exported to depth. The hydrography and topography of the eastern and western Andaman waters is different. The Andaman Islands have steeper continental slope on the eastern side compared to the western one, which is very irregular (Murthy *et al.*, 1981). The primary production was higher on the western side (6.56 mg C m^{-3} day^{-1}) than on the eastern side (3.784 mg C m^{-3} day^{-1}). Latitudinally, the surface production showed an increasing trend towards north. Column production and chl-a values also showed the same pattern. The zooplankton may not have built up significant population size to consume the phytoplankton, such that the phytoplankton numbers remained high. This can be a reason for the decrease in the population density of the zooplankton on the western part during the study period. By late winter monsoon, the zooplankton community will build up with a subsequent decrease in the phytoplankton biomass as shown in earlier studies.

A temperature inversion ranging from 0.6 °C to1.3 °C, and low salinity was observed in the upper layers at 40 to 70 m depths at the northern most stations. Low salinity water in the surface layers was largely due to the influence of fresh water discharge through the Irrawady –Salween river system (Janekarn and Hylleberg, 1989). This condition was strong in the northern transect (13°50'N) due to fresh water influx from northern part of the Andaman waters. Zooplankton biomass was least for the northern most stations (13°50'N), which can be attributed to the high fresh water discharge and associated very low salinity of the area. The relatively low nutrients in the mixed layer might be due to the capping of low density water on top preventing vertical mixing from down below (Madhupratap *et* *al*., 1996; Nair *et al*., 1999). Studies by Nair and Tranter (1971) have shown that salinity plays a major role in controlling the faunistic composition of a given area.

The depth-wise zooplankton distribution showed a downward decrease in biomass, up to 1000 m. In the thermocline layer, the biomass was reduced to more than half in the mixed layers on the eastern and western sides. Zooplankton abundance and relation to thermocline suggested a preference for zooplankton to aggregate above the discontinuity layer (Nair *et al*., 1977). Preference of zooplankton to aggregate above the thermocline is attributed to several factors of which the temperature gradient could be considered as the most important one (Peter and Nair, 1978). The further decrease of biomass from the bottom of the thermocline up to 500 m depths can be attributed to the occurrence of an oxygen minimum zone (OMZ). The OMZ and thermocline can have considerable impact on the vertical distribution of species (Sameto, 1986). The layer between 1000 m and 500 m showed low density among all zooplankton groups. Variations in abundances with depth seem to partition the environment vertically between congeners to avoid competition (Madhupratap and Haridas, 1990).

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