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# Diurnal variations in the vertical distribution and abundance of zooplankton in the continental shelf waters off Cochin during April 1991

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## ABSTRACT

The present study is based on zooplankton samples collected by vertical hauls from 0-30, 30-60 and 60-90 m depths from a 100 m depth station in the continental shelf (09° 44′ N, 75° 42′E) off Cochin for two days at three hourly interval. The mean displacement volume of zooplankton biomass at these depth zones were 6.24, 6.70 and 6.07 ml/100 $m^3$ water while their numerical counts were 14490, 13355 and 11290 no/100 $m^3$ respectively. The overall mean volume (ml) and number per 100 $m^3$ in the entire water column (0-90 m) were 6.34 and 13045 respectively and were distributed as 5.89 ml and 11715 no/100 $m^3$ in the daytime and 6.79 ml and 14376 no/100 $m^3$ during night hours respectively. The biomass was dominated by copepods (75.6%), decapod larvae (12.2%), chaetognaths (6.5%) and appendicularians (2.4%) in April. In general, copepods, decapod larvae and appendicularians showed increasing trend in number from the bottom (60-90 m) to the surface layer (0-30 m); chaetognaths, medusae, pteropods, heteropods, salps and doliolids were distributed more in the middle zone (30-60 m); while ostracods and planktonic polychaetes were more in the bottom zone (60-90 m). Distribution of amphipods and ostracods indicated significant diurnal vertical migration. The phenomenon of mid- night sinking was noticed in the case of copepods, chaetognaths, appendicularians, medusae, siphonophores, salps and doliolids.

## INTRODUCTION

Although considerable studies on the diurnal vertical migration of zooplankton in the ocean have been made in several parts of the world (Sverdrup *et al.* 1942), similar studies are not available to any significant level from the Indian seas. Majority of the zooplankton groups, which form food of several crustaceans, molluscs, fishes and marine mammals, are known to make extensive diurnal vertical migration in response to light and other physico-chemical characteristics of the environment (Daniel, 1977; Nair, 1977; Peter & Nair, 1978; Madhupratap *et al.* 1981; Gajbhiye *et al.* 1984). In

view of their importance in the marine food-chain and as a fishery associated factor, the present investigation was carried out at a 100 m depth station during April 1991 to study their vertical distribution and diurnal variation in the stable premonsoon season.

## MATERIALS AND METHODS

Hydrographic data and zooplankton samples were collected at three hourly interval for two days during 11-13 April 1991 from a 100 m depth station in the continental shelf off Cochin (09° 44′ N; 75° 42′E). Seawater temperature, salinity and depth were recorded by the micro-computer (MICOM STD Profile) instrument from surface to bottom and the range and mean values of temperature and salinity for 0-30, 30-60 and 60-90 m depth zones were determined. Zooplankton samples were collected by vertical hauls from these three depth zones using a closing type net having a mouth diameter of 110 cm and mesh size of 0.3 mm. The plankton samples thus collected from each 30 m vertical column were preserved separately in 5% formalin; and displacement volumes of the zooplankton and numerical counts of the different zooplankton groups in each sample were estimated. From the diurnal data for two days at three hourly interval, mean values for the respective hours were calculated for the three depth zones. The data for 0600, 0900, 1200 and 1500 hrs were treated for the day and 1800, 2100, 2400 and 0300 hrs for the nighttime. High and low tide phases of the day were determined based on the diurnal fall and rise in water temperature observed in the bottom layer at 90 m depth.

## RESULTS

### Hydrography

The ranges in seawater temperature at 0-30, 30-60 and 60-90 m depth zones were 29° - 31.25°, 28.15° - 30.3° and 22.65° - 28.75 °C showing the variation of 2.25°, 2.15° and 6.1°C respectively while the variation at 0 - 60 m depth was 3.1°C only indicating that the thermocline was prevailing around 60 m depth in April. The ranges in salinity at the three depth zones were 34.6 - 34.8, 34.7-35.3 and 35-35.65 x $10^{-3}$ with the variation of 0.2, 0.6 and 0.65 x $10^{-3}$ respectively; while the variation at 0-60 m water column was 0.7 x $10^{-3}$ which indicated the stability of the marine environment during premonsoon season. The water temperature below 60 m depth showed wide diurnal variation with rhythmic rise and fall in values. At 90 m depth, very low values were recorded between 0900 and 1200 hrs and high values between 1500 and 1800 hrs of the day (Fig.1 ) indicating high and low tide phases of the day respectively in the shelf waters.

### Zooplankton biomass

The displacement volumes of zooplankton biomass in the 30 m vertical haul varied from 3.86 to 8.59 ml/100 $m^3$ at 0-30 m, 5.08 to 8.06 ml/100 $m^3$ at 30-60 m and 5.08

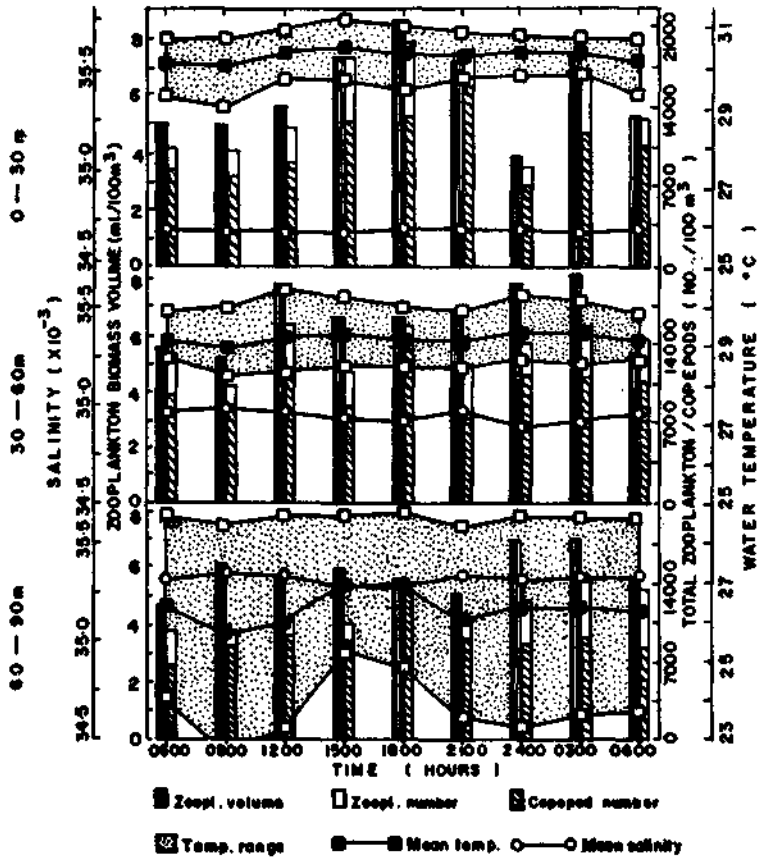


Fig.1 - Dial variation in temperature, salinity and zooplankton biomass dominated by copepods at 0-30, 30-60 and 60-90 m depth zones during April 1991

- 7.01 ml/100 $m^3$ at 60-90 m depth zones; and their mean values were 6.24, 6.70 and 6.07 ml/100 $m^3$ water respectively. The numerical counts of total zooplankton varied from 8780-19292, 10259-15726 and 9414-14158 no/100 $m^3$ respectively (Table 1) and their averages were 14490, 13355 and 11290 no/100 $m^3$ at the respective depth zones. The overall mean volume and numerical count in the entire 0-90 m vertical column of water were 6.34 ml and 13045 no/100 $m^3$ respectively. The volume and number in the three depth zones showed that the density of zooplankton was relatively less in the bottom layer below 60 m (Fig.1).

## Relative abundance

The zooplankton biomass was constituted by copepods (75.6%), decapod larvae (12.2%), chaetognaths (6.5%), appendicularians (2.4%), planktonic molluscs comprising of pteropods, heteropods, other gastropods and bivalves (0.7%), amphipods (0.55%), ostracods (0.45%) and medusae (0.4%). The other groups which contributed

Table 1 - Diurnal variation in zooplankton counts (no/100m$^3$) at 0-30, 30-60 and 60-90 m depth zones

| Time (hrs.) | 0-30m | 30-60m | 60-90m | 0-90m |
|---|---|---|---|---|
| 0600 | 10529 | 11872 | 9414 | 10605 |
| 0900 | 10242 | 10259 | 9537 | 10013 |
| 1200 | 12181 | 15726 | 10659 | 12855 |
| 1500 | 18464 | 11497 | 10200 | 13387 |
| 1800 | 19292 | 15578 | 14158 | 16343 |
| 2100 | 19148 | 12170 | 10263 | 13860 |
| 2400 | 8780 | 14141 | 12184 | 11702 |
| 0300 | 17297 | 15600 | 13906 | 15601 |
| Day average | 12854 | 12339 | 9952 | 11715 |
| Night average | 16129 | 14372 | 12628 | 14376 |

individually to less than 0.4% were salps, doliolids, siphonophores, planktonic polychaetes, mysids, lucifers and fish larvae (totalling 1.2%).

## Vertical distribution

The diurnal variations in the vertical distribution and abundance of different zooplankton groups at 0-30, 30-60 and 60-90 m depth zones are depicted in Fig.2. The mean numerical counts of the different groups at the three depth zones indicated the abundance of copepods, decapod larvae, appendicularians, amphipods, mysids and lucifers in the upper zone (0-30 m); chaetognaths, medusae, salps, doliolids, pteropods, heteropods and euphausiids in the middle zone (30-60 m); and ostracods, planktonic polychaetes, planktonic gastropods (other than pteropods and heteropods) and bivalves in the bottom zone (60-90 m). Their percentages of abundance in the respective zones are given in Table 2. The data further revealed that majority of the groups were abundant in the water column above the thermocline depth (60 m). The mean numerical counts of the zooplankton groups which showed their abundance above and below thermocline depth are given in Table 3.

## Day and night variations

In general, night collections were rich in zooplankton at the three depth zones with their abundance in the upper 0-30 m zone (Table 1); and the increase was contributed chiefly by copepods, decapod larvae, amphipods, planktonic molluscs and fish larvae (Table 4). Chaetognaths were relatively more at night in the upper zone (0-30 m) as compared to the daytime abundance while ostracods and planktonic polychaetes showed their abundance at night in the middle zone (30-60m). Medusae, salps and

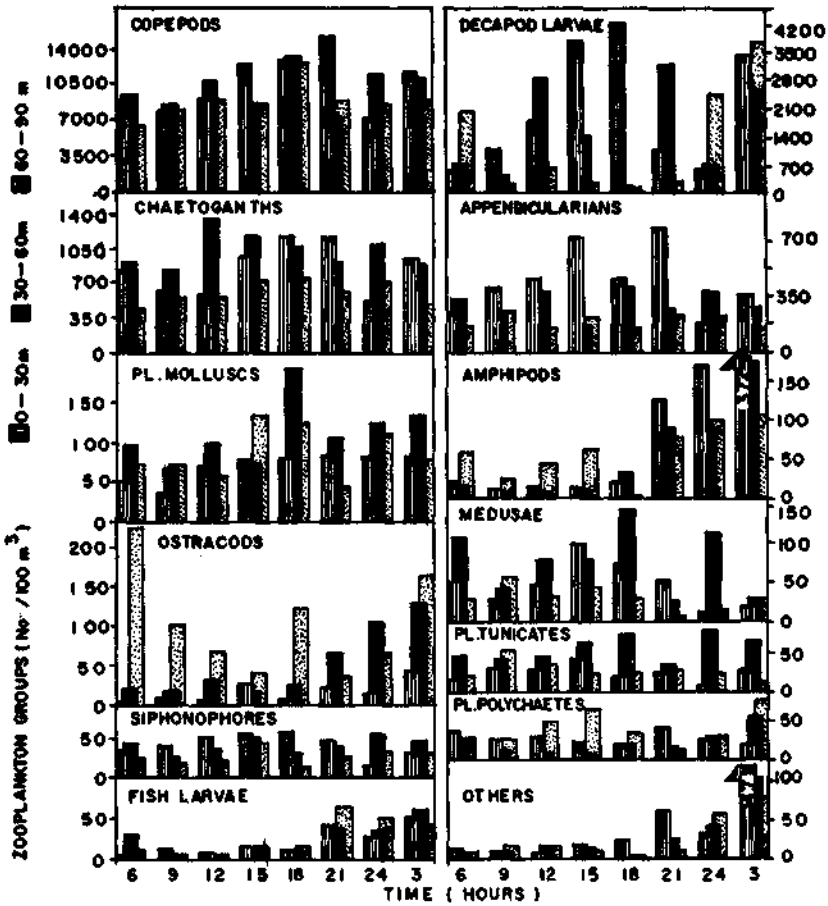


Fig.2 - Dial variation in the distribution of zooplankton groups at 0-30, 30-60 and 60-90 m depth zones

doliolids were relatively more in the upper zone (0-30 m) during the day- time than at night indicating their preference to day light. Among the major groups, appendicularians and siphonophores did not show any remarkable difference between day and night hours.

## Diurnal migration and mid-night sinking

During diurnal observation, most of the dominant zooplankton groups indicated their abundance in the upper 0-30 m water column during night. Among them,

Table 2 - Relative abundance (%) of zooplankton groups at 0-30, 30-60 and 60-90 m depths (Day and night values are pooled together)

| Zoopl. groups | 0-30m (%) | 30-60m (%) | 60-90m (%) |
|---|---|---|---|
| Copepods | 36.26 | 33.88 | 29.86 |
| Decapod larvae | 42.97 | 31.75 | 25.28 |
| Appendicularians | 47.43 | 32.32 | 20.25 |
| Amphipods | 44.39 | 26.17 | 29.44 |
| Mysids | 45.16 | 32.26 | 22.58 |
| Lucifers | 50.00 | 25.00 | 25.00 |
| Siphonophores | 37.50 | 37.50 | 25.00 |
| Chaetognaths | 34.32 | 41.34 | 24.34 |
| Medusae | 31.21 | 49.04 | 19.75 |
| Salps | 22.58 | 45.16 | 32.26 |
| Doliolids | 23.86 | 52.28 | 23.86 |
| Pteropods | 24.07 | 47.53 | 28.40 |
| Heteropods | 29.17 | 41.66 | 29.17 |
| Euphausiids | 29.41 | 41.18 | 29.41 |
| Fish larvae | 32.18 | 32.18 | 35.64 |
| Ostracods | 10.12 | 29.17 | 60.71 |
| Pl. polychaetes | 31.96 | 24.74 | 43.30 |
| Other pl. gastropods | 31.82 | 31.82 | 36.36 |
| Pl. bivalves | 29.41 | 29.41 | 41.18 |

copepods, chaetognaths, appendicularians, medusae, salps, doliolids and siphonophores exhibited a sharp decline in their number at mid-night (2400 hrs) in the upper zone with considerable increase in the middle zone (30-60 m) indicating the phenomenon of mid-night sinking. It was followed by their abundance again in the upper zone (0-30 m) at 0300 hrs with considerable reduction in the middle zone (Fig.3). The amphipods, which were abundant at 60-90 m in the daytime, exhibited their abundance in the upper and middle zones during night hours, while the ostracods, which were distributed more in the bottom zone (60-90 m) during day time, showed their abundance in the middle zone (30-60 m) at night. Further, the amphipods and ostracods indicated their downward movement to the bottom zone in the early morning hours (Fig.3). Decapod larvae did not show any definite trend of dispersal in the present study. Of all the zooplankton groups, amphipods and ostracods exhibited very significant diurnal vertical migration.

## DISCUSSION

The distribution of temperature and salinity at different depths in the diurnal study indicated the existence of thermocline around 60 m depth at this station during April (Fig.4). The temperature showed wide variation than salinity. The variation (differ-

Table 3 - Density (no/100m$^3$) of major zooplankton groups in the water column above and below thermocline (60m) (Day and night values are pooled together)

| Zoopl. groups | 0-60m (no/100m$^3$) | 60-90m (no/100m$^3$) |
|---|---|---|
| Copepods | 10372 | 8832 |
| Decapod larvae | 1799 | 1217 |
| Chaetognaths | 959 | 617 |
| Appendicularians | 380 | 193 |
| Medusae | 63 | 31 |
| Siphonophores | 42 | 28 |
| Salps | 10 | 10 |
| Doliolids | 33 | 21 |
| Pl. molluscs | 98 | 46 |
| Amphipods | 75 | 63 |
| Mysids | 12 | 7 |
| Lucifers | 10 | 7 |
| Euphausiids | 12 | 10 |
| Ostracods | 33 | 102 |
| Pl. polychaetes | 28 | 42 |
| Fish larvae | 28 | 31 |

Table 4 - Day and night variations in the numerical counts of major zooplankton groups (mean values in no./100 m$^3$) at different depth zones

| Zooplankton groups | 0-30m | | 30-60m | | 60-90m | |
|---|---|---|---|---|---|---|
| | Day | Night | Day | Night | Day | Night |
| Total zooplankton | 12854 | 16129 | 12339 | 14372 | 9954 | 12630 |
| Copepods | 9572 | 11872 | 9295 | 10743 | 7991 | 9674 |
| Decapod larvae | 1799 | 2339 | 1353 | 1665 | 775 | 1655 |
| Chaetognaths | 757 | 978 | 1080 | 1017 | 575 | 659 |
| Appendicularians | 459 | 442 | 280 | 303 | 200 | 186 |
| Medusae | 56 | 42 | 77 | 77 | 39 | 21 |
| Siphonophores | 42 | 39 | 39 | 42 | 28 | 24 |
| Salps & doliolids | 32 | 17 | 49 | 46 | 24 | 24 |
| Pl. Molluscs | 60 | 84 | 88 | 140 | 70 | 91 |
| Amphipods | 14 | 172 | 14 | 98 | 49 | 74 |
| Ostracods | 14 | 21 | 21 | 81 | 109 | 98 |
| Pl. Polychaetes | 32 | 28 | 14 | 32 | 46 | 39 |
| Fish larvae | 14 | 39 | 17 | 39 | 10 | 49 |

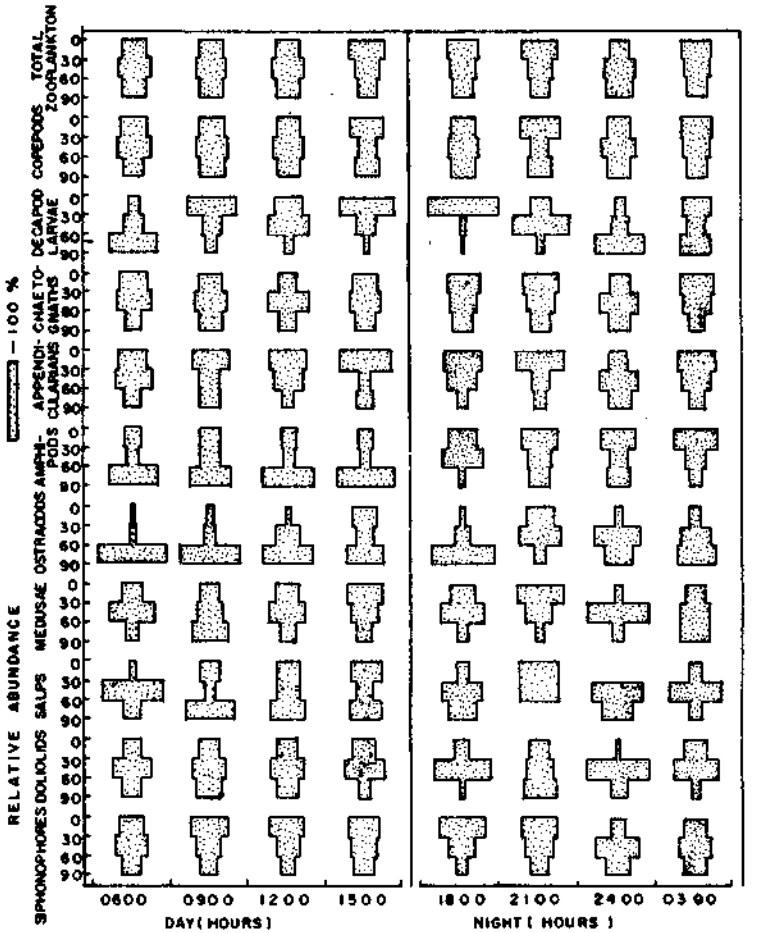


Fig.3 - Relative abundance of zooplankton groups during day and night hours showing diurnal vertical migration and mid-night sinking

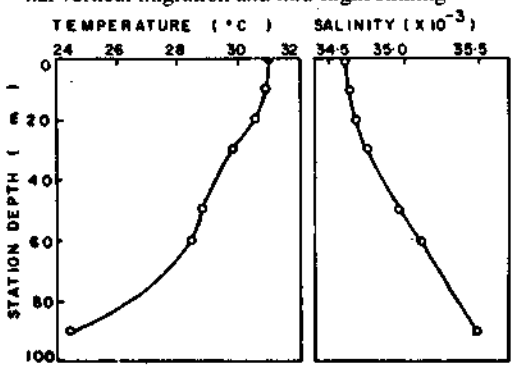


Fig.4 - Vertical profiles of temperature and salinity in the shelf waters off Cochin during April

ence between minimum and maximum values) in temperature above and below thermocline was 3.1° and 6.1°C respectively while that of salinity was 0.7 and 0.65 x $10^{-3}$ respectively. Hence, salinity does not seem to be a limiting factor for the distribution, abundance and vertical migration of zooplankton groups in April. The relatively low density of zooplankton recorded below 60 m depth (thermocline) might be attributed to the wide (diurnal) variation in temperature (6.1°C) observed between 60 and 90 m water column (Fig.1). Compared to this variation, the variation of 3.1°C observed in the 0-60 m water column is less which seems to favour the distribution and abundance of zooplankton groups in the water column above the thermocline as evidenced from the results of the present study (Tables 2, 3). Peter & Nair (1978) reported higher concentration of zooplankton biomass in the water column above thermocline dominated by copepods, chaetognaths and decapod larvae along the southwest coast of India during December 1976. Madhupratap *et al.* (1981) also recorded highest zooplankton biomass value for the water column above thermocline in the Andaman Sea during February 1979, and according to them, chaetognaths, appendicularians, decapods and euphausiids were dominant above the thermocline. However, in the present investigation, euphausiids were numerically less, in general, and were relatively more in the middle zone (Table 2).

As observed in the present study, Madhupratap *et al.* (1981) also reported the abundance of ostracods below the thermocline. However, in the present investigation, the amphipods and ostracods distributed more below thermocline (60-90 m) in daytime (Fig.3) showed their remarkable abundance in the surface layer (0-30 m) and middle layer (30-60 m) respectively during night hours indicating their upward migration above thermocline. To those planktonic groups showing diurnal vertical migration from the bottom zone (60-90 m) such as ostracods, amphipods and planktonic molluscs (other than pteropods and heteropods) and to those groups evenly distributed above and below 60 m depth such as salps and fish larvae, thermocline does not appear to be a limiting factor. However, the numerical counts of these groups are insufficient to draw at any definite conclusion. George *et al.* (1975) stated that thermocline seems to act as a barrier in the vertical movement of some species of ostracods; Nair (1977) on some species of chaetognaths; Daniel (1977) on some species of siphonophores; and Peter & Nair (1978) concluded that thermocline influences the distribution of zooplankton significantly. However, the results in the present investigation indicated that some of the species of these zooplankton groups are not influenced by the thermocline in the shelf waters.

The zooplankton abundance in relation to high tide and low tide phases revealed that majority of the zooplankton groups were abundant at this station during low tide period only (Table 5). The abundance of copepods, chaetognaths, decapod larvae, appendicularians, medusae, siphonophores, amphipods, planktonic molluscs, salps, lucifers, euphausiids and fish larvae during the low tide phase than at high tide phase indicated that these zooplankton groups were abundant in the inshore shelf waters than in the offshore oceanic realm at the respective depths. Those groups which were more

Table 5 - Zooplankton abundance (no/100 $m^3$) at 0-90 m in relation to tides

| Zooplankton groups | High tide influence | | | Low tide influence | | |
|---|---|---|---|---|---|---|
| | 0900 hrs | 1200 hrs | Average | 1500 hrs | 1800 hrs | Average |
| Copepods | 8197 | 9622 | 8909 | 9856 | 13089 | 11472 |
| Chaetognaths | 669 | 852 | 760 | 968 | 1009 | 988 |
| Decapod larvae | 568 | 1737 | 1152 | 1815 | 1510 | 1662 |
| Appendicularians | 305 | 332 | 318 | 363 | 333 | 348 |
| Madusae | 42 | 51 | 46 | 72 | 81 | 76 |
| Siphonophores | 27 | 35 | 31 | 48 | 32 | 40 |
| Amphipods | 15 | 23 | 19 | 29 | 19 | 24 |
| Pl. polychaetes | 23 | 29 | 26 | 32 | 26 | 29 |
| Ostracods | 43 | 36 | 39 | 29 | 41 | 35 |
| Pl. molluscs | 60 | 77 | 68 | 98 | 134 | 116 |
| Salps | 9 | 8 | 8.5 | 6 | 19 | 12.5 |
| Doliolids | 33 | 28 | 30.5 | 37 | 19 | 28 |
| Fish larvae | 9 | 8 | 8.5 | 17 | 14 | 15.5 |
| Lucifers | 3 | 3 | 3 | 5 | 6 | 5.5 |

during high tide phase than at low tide phase such as ostracods and doliolids indicated their relative abundance in the offshore oceanic waters at the respective depths (Table 5).

The results revealed that most of the zooplankton groups exhibited the phenomenon of mid-night sinking by their reduction in number in the surface layer at 2400 hrs and their retrieval back to surface water column within the next two or three hours. This phenomenon might be related to the influence of light (Sverdrup *et al.* 1942). It is presumed that the exclusive disappearance of the light in the mid-night hour might cause confusion in their movement and lead to their dispersion downward for a while till the desired intensity of light penetrates the surface of the sea; and then they might move upward according to the desired light as preferred by the different groups of zooplankton in the species level.

In general, the mean zooplankton number indicated an increasing trend during the day as well as night and the number in the night collections were more as compared to that of day hours at the three depth zones. Gajbhiye *et al.* (1984) also reported higher zooplankton population during night than day collection in the inshore waters off Versova (Bombay). Such increase in the zooplankton number might be attributed to the spawning activities of the respective dominant groups with intensive spawning at night; and their considerable reduction in number noticed in the early morning hours

might be due to subsequent grazing by the higher organisms of the sea. The results indicated that the proportionate increase noticed at three hourly interval was, in general, more in the upper euphotic water column (0-30m) during the day hours whereas the relative increase observed at the bottom zone (60-90m) below the thermocline was more in the night hours. The increase in the upper euphotic layer might be attributed to the congenial environment present there with less variability in water quality influencing rapid productivity of copepods and other dominant groups. The increase observed at the bottom zone might be attributed to the reproductive cycle of demersal species of zooplankton groups and the influence of tidal flow in the bottom layer (below thermocline) providing more plankton from the neighbouring inshore/offshore waters. The increasing trend in zooplankton number observed, in general, at the three depth zones and the average zooplankton density of 6.34 ml/100 $m^3$ recorded in the 0-90 m water column in April, as compared to the average zooplankton volume (4.71 ml/100$m^3$) recorded in the inshore waters off Versova (Bombay) during a diurnal study in February (Gajbhiye *et al.* 1984), proves that the environment prevailing along the continental shelf off Cochin during April is very favourable for zooplankton production.

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