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Chapter 3

Diel Vertical Migration of Zooplankton in Andaman Sea

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ABSTRACT

Several groups of zooplankton exhibit Diel Vertical Migration (DVM), during which, hours of darkness are spent near the surface of the water and the day light hours at deeper depths. Though many earlier workers (Gunther, 1953; Ussings, 1938; Raymond, 1939; Marshell, 1960; Koslow, 1979 (cf. Raymont, 1983); Castel and Courties, 1982; Paffenhoper, 1983; Piatskowski, 1985; Mackas and Anderson, 1986; Ryan *et al.*, 1986; Kimmerer and McKinnen, 1987; Okemwa, 1989; Valdes *et al.*, 1990; Chakley, 1992; Meckas, 1992; Lafontaine, 1994; Haywood, 1996) have worked on the DVM all several regions of the world, the phenomenon is said to poorly understood (Raymont, 1983).

Andaman Sea is partially isolated part of north eastern Indian Ocean, which lies enclosed between the coasts of Myanmar. Thailand and Malaysia on east and chain of Andaman and Nicobar islands in Sumatra in the west, occupies 6.6×10^3 km^3 with an average depth of 1096M, is connected to Bay of Bengal by numerous channels. It is oligotrophic in nature with

low primary and secondary productivity. It is also known to be rich in marine wealth and hence, attracted many researchers and several cruises in this area, dating back from 1869 lead by Francis Day. Inspite of this, due to poor sampling, as rightly pointed out by McAllister *et al.* (1994), not much is known either about the diversity or DVM of zooplankton in this area.

Hence, to fill this lacunae of information, an attempt has been made to study the DVM at Andaman Sea. ORV Sagar Kenya was made to station at a particular place and 12 samplings of 3 replicates each at an interval of two hours for entire diel cycle was conducted, by using Bongo net. The samples were collected from 30–OM depth. They were subjected for analysis for biomass, wet weight, species composition, species diversity, patchiness, evenness fluctuation and later the data obtained thus was subjected for cluster analysis (Similarity matrix method) and dendrograms were prepared to compare the similarity index with the time of sampling. The results obtained are discussed in the light of available literature.

Keywords: *Andaman sea, Zooplankton,-Species diversity, Diel vertical migration (DVM), Biomass, Wet weight, Patchiness, Evenness.*

Introduction

Migration in zooplankton may be studied under two broad headings, on time scale-seasonal/annual migration, as studied by Turner (1982), Villatte (1991) related to life history patterns and diurnal pattern in which hours of darkness are spent near to the surface and day light hours at deeper depths as studied by Castel and Courties, 1982; Paffenhoper, 1983; Pialskowski, 1985; Mackas and Anderson, 1986; Ryan *et al.*, 1986; Kimmerer and MoKinnen, 1987; Okemwa, 1992; Valdes *et al.*, 1990; Checkley, 1992; Mackas, 1992; Lafontaine, 1994; Heywood, 1996), which is said to be beneficial for the organism (Ohman, 1990) and helps in their population budget and diurnal deficiency (Desstasio, 1993).

During DVM, members of zooplankton move as much as 400M an average small body sized species and over 600M in larger ones. They move rapidly at a speed of 12–200M per hour, which is about 45,000 times of body length per hour which would equal to a speed of 81 Km/h for a human of 1.8M height (Durbaum and Kunnemenn, 1999). The DVM may some times be undertaken twice a day in a diel cycle. During day time, they live in deeper depths of water, but during dark they ascend to surface. They then disperse through the water column in the middle of the night, phenomenon termed as 'midnight sinking' as explained by Russel, 1937 (cf; Raymont, 1983). They rise towards the surface again just before dawn, which is termed as 'dawn rise'. Some species may also exhibit reverse migration as reported by Parsons and Takahashi (1979). Further, the plankton can also be classified as drifting and residual one based on their behaviour (Kaartvedt, 1993).

Several workers, working in different parts of the world, have assigned various reasons for phenomenon of DVM in zooplankton (Zaret and Suffern, 1976; Enright, 1977; Stich and Lampret, 1981; Hauris, 1988; Bollens and Frost, 1989a,b,c; Magnesen, 1989; Neuman, 1989; Hansson *et al.*, 1990; Ohman, 1990; Jerling and Wooldridge, 1992; De Stasio, 1993).

The Andaman Sea, which is located south eastern side of Bay of Bengal, which is partially isolated portion of south eastern Indian Ocean, lying enclosed between the coasts of Myanmar, Thailand, Malaysia on the east and chain of Andaman and Nicobar Islands and Sumatra in the west, and occupies 6.02×10^3 km^2 with a volume of $6.6. \times 10^5$ km^3 with an average depth of 1096M. Unlike temperate seas, where spring bloom with regards to biomass is recorded (Lignell *et al.*, 1993), Andaman sea shows some what constant biomass all through the year. Further, due to its oligotrophic nature, it has low primary and secondary productivity (Anonymous, 1981) and hence high diversity of life. In this region, apart from a few stray works (Bhattathiri and Devassi, 1981; Goswami, 1981; Madhupratap, 1981; Vijayalaxmi, 1981) not much work has been carried out on zooplanktology in general and DVM in particular. Hence, an attempt has been made to study DVM of zooplankton in Andaman Sea.

Materials and Methods

During the Department of Ocean Development (Government of India) and National Institute of Oceanography, Goa organised multidisciplinary cruise SK-118 on ORV Sagar Kanya, which had predetermined area of operation as Andaman sea, the ship was stationed at 10°30'237"N latitude and 93°15'257"E longitude, where the depth was about 2300M, and the experiments were conducted.

The zooplankton samples required for the present studies were collected for a period of 24 hrs at an interval of 2 hrs, from the upper most euphotic zone, *i.e.*, from 30M to surface by Bongo net (Dia 0.6M, length 2.5M and mesh width 300 μm). A pre-calibrated flow meter (T.S. flow meter model no. 4512) was attached to calculate the amount of water filtered through the mouth of the net.

The zooplankton biomass was determined by displacement volume method and collected samples were preserved in 4 per cent formaldehyde. The wet weight was determined by following the method mentioned by Omori and Ikeda (1984). Later the samples were brought to the laboratory and analysed for abundance of major zooplanktonic groups and identified up to species level by using available literature (Kasturirangan, 1963; Mori, 1964; Daniel, 1985; Zheng Zhong, 1989 and Santhanam and Srinivasan, 1994). The diversity was calculated by using the indices given by Margalef (1968) for species of zooplankton encountered in the samples. All the zooplankton groups as well as species under study were analysed for their presence/absence in every sample of day/night individually and separately.

The 12 sample sets with three replicates were subjected for linkage clustering within the similarity matrix, which is considered as a convenient method for illustrating relationships. The method used was simple linkage method as described by Omori and Ikeda (1984).

Results

The samples collected during the entire diel cycle of 24 hrs with an interval of 2 hrs showed the biomass fluctuating from 0.01 m/m^{-1} to 0.05 m/m^{-1}, with an average of 0.018 m/m^{-1}. The night samples exhibited higher biomass ranging from 0.02 to 0.05 m/m^{-1} with an average of 0.028 m/m^{-1}. Thus showing higher quantity and concentration of zooplankton at 0–30 M depth at night (Figure 3.1).

Similarly wet weight varied from 0.4 to 2.2 mgm^{-3} (Figure 3.2), with an average of 0.65 mgm^{-3} for day samples and from 1.0 to 2.2 mgm^{-3} (average 1.55 mgm^{-3}) for night samples (Figure 3.2), thus recording considerably higher wet weight for night samples.

The zooplankton groups encountered in the samples were copepods, chaetognaths, emphipods, crustaceans, siphonophores, pelagic tunicates, fish eggs/larvae etc.

at 0600 hrs and other at 0000 hrs), exhibiting its diel vertical migration pattern. Their existence, in the catches ranged from 0 per cent (at 1400 hrs and 1600 hrs) to 24 per cent at 0000 hrs. Further, at an average, they were found in relatively abundant in night collection than daytime collection.

Eucheata concinna, though exhibits its presence in upper water column (0-30M) an through the diel cycle, it ranges at an average of 9.33 per cent at day to 13.33 per cent at night, with their day peak at 1400 hrs and night peak of their existence at 2200 hrs, thus exhibiting DVM (Figure 3.5).

Figure 3.6 shows the existence of *Sapphirina negromacculata* in 0-30M water column. During the day it ranges from 0 per cent (at 1600 hrs) to 6.0 per cent (at 1400 hrs) with an average of 3.66 per cent. While at night it ranges from 0 per cent (at 1800 hrs) to 12.0 per cent (at 0000 hrs and 0200 hrs) with an average of 6.0 per cent, clearly indicating peaks at corpuscular period of the diel cycle. The figure also demonstrates the DVM in *S. negromacculata*.

Diel vertical migration of copepod *Copilia mirabilis* has been explained in Figure 3.7. It can be seen that at 1400 hrs and between 0400 hrs and 0600 hrs they are not found in the surface waters. While, between 0800 hrs and 1200 hrs as well between 1600 hrs and 2000 hrs they are found at a percentage ranging from 9.0 per cent to 12.0 per cent. Further it can also be seen that whenever they are there, their existence is almost similar.

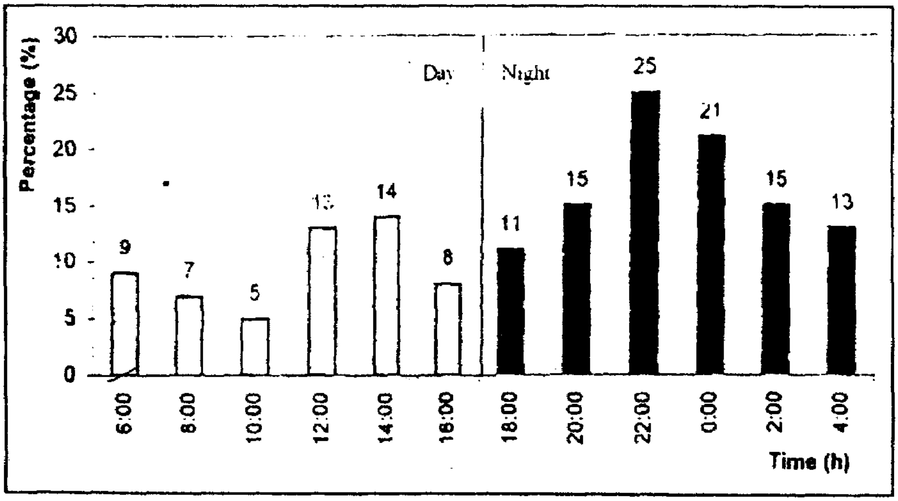

Figure 3.5: Percentage of *Eucheata concinna* among Copepods

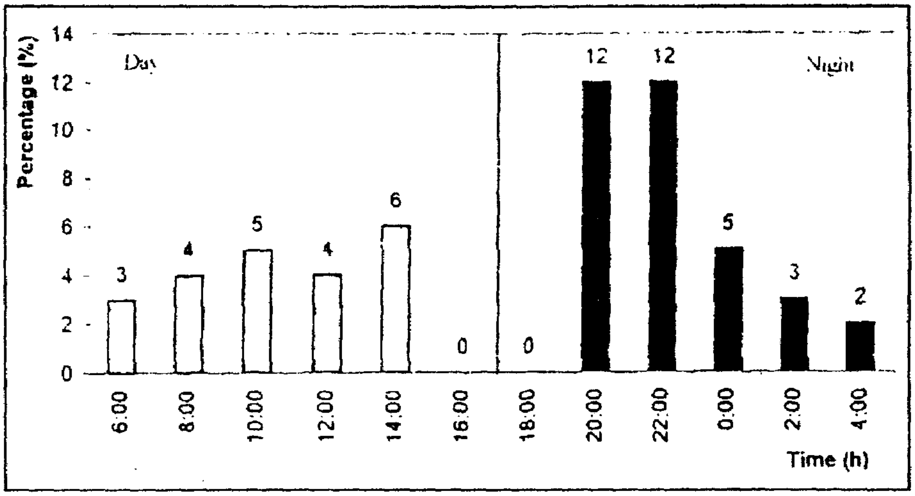

Figure 3.6: Percentage of *Sapphirina negromcullata* among Copepods

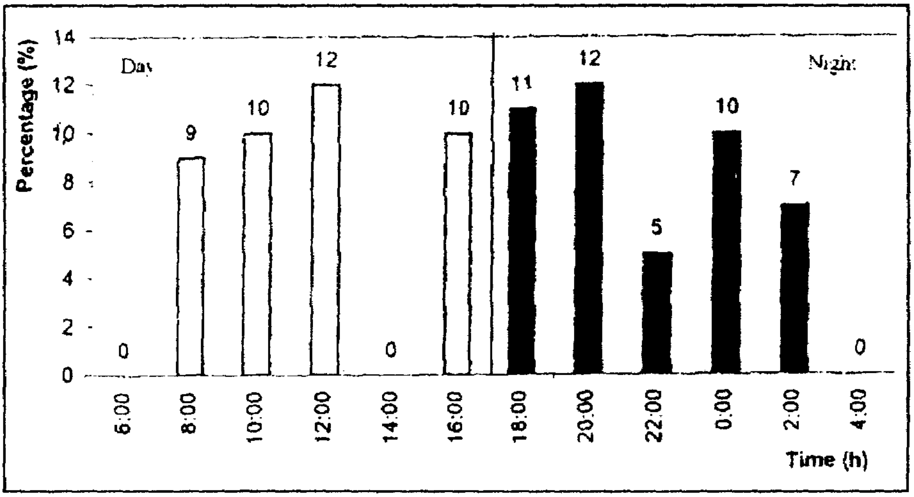

Figure 3.7: Percentage of *Copilia mirabilis* among Copepods

Rhinocalanus nasutus, though exhibits its presence in surface waters at all the time, higher percentage of 22.0 per cent and 20.0 per cent was seen at 1400 hrs and 0200 hrs respectively, while the minimum of 5.0 per cent and 7.0 per cent between 1600 hrs and 1800 hrs and 11.0 per cent and 12.0 per cent between 0400 hrs and 0800 hrs, clearly exhibiting two diel cycles (Figure 3.8).

Though individuals belonging to 10 species of amphipods were collected during the studies, *Brachyscelus crusculum, Lestrigonus*

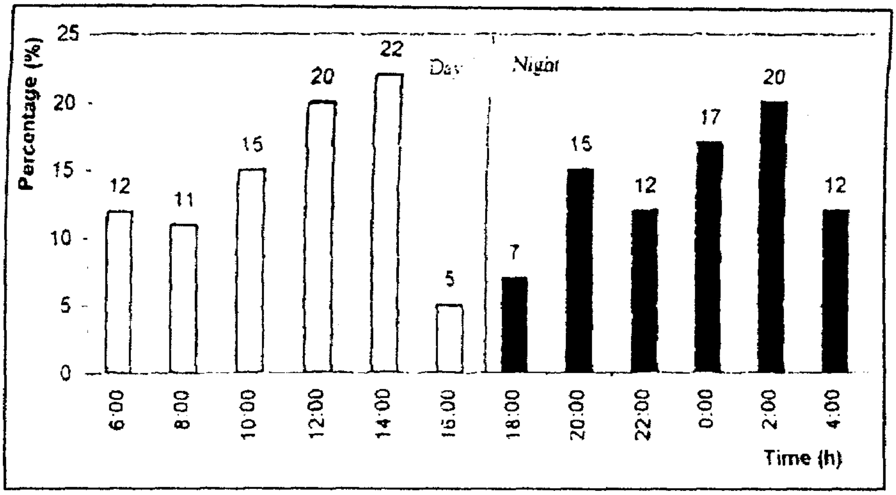

Figure 3.8: Percentage of *Rhinocalanus nasutus* among Copepods

schizogeneios, *Cranocephalus* spp. and *Rhabdosome* spp. were prominent ones.

Amphipods seem to come to the surface waters only at night. They also show a clear "mid-night sinking". It can be seen from Figure 3.9, amphipods start showing their presence in 0-30M water column at around 1600 hrs with peak immediately after sun set, *i.e.*, at 1800 hrs and later show reduction in their population and by 0200 hrs show a "mid-night sinking" to re-appear at 0400 hrs.

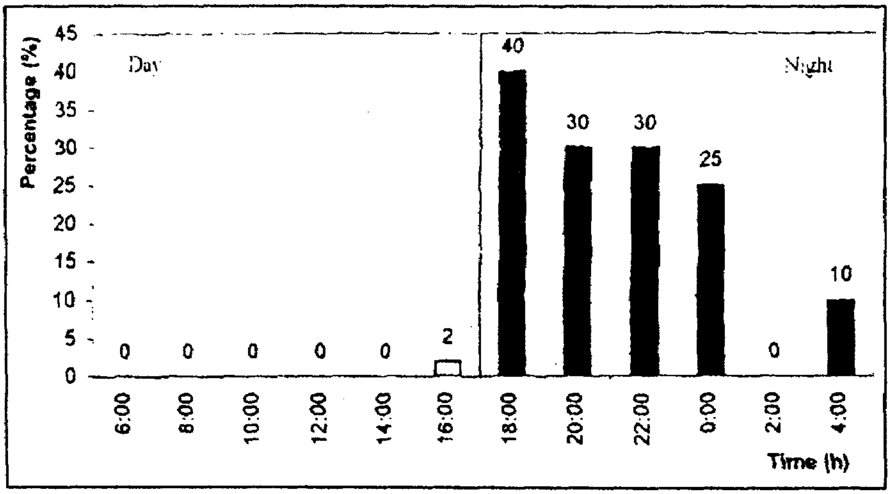

Figure 3.9: Percentage of Amphipods in Collection

Figure 3.10 indicates the pattern of DVM of amphipod *Brachyscelus crusculum*, which shows that the organism comes to the surface water only between 1800 hrs and 0000 hrs and they complete their feeding and other activities in about 6 hrs and they move down 10 spend rest of the part of their diel cycle.

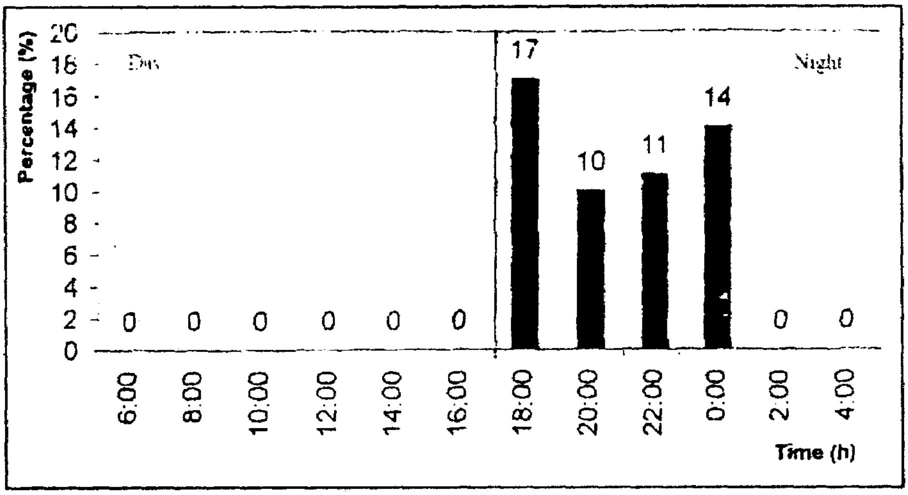

Figure 3.10: Percentage of *Brachyscelus crusculum* among Amphipods

Similarly, *Lestrigonus schizogeneios* shows its presence in 0-30M water column from 1800 hrs to 0000 hrs and after completing their feeding of phytoplankton they sink down to spend other part of their diel cycle (Figure 3.11), like other amphipod *Brachyscelus crusculum*.

Amphipod *Cranocephalus* spp. also exhibits its presence in 0-30M water column between 1800 hrs to 0000 hrs. After peak existence (26.0 per cent among amphipods) they sink down to spend other time of their diel cycle (Figure 3.12).

Rhabdosoma spp. also exhibit similar pattern of diel cycle as that of *Cranocephalus* spp., *Lestrigonus schizogeneios* and *Brachysceles crusculum* by spending 1800 hrs to 0000 hrs at surface waters with maximum density of 27 per cent among amphipods at 2200 hrs and spend rest of the time of their diel cycle at deeper water column (Figure 3.13), thus indicating that all four species under study under take a single DVM cycle a day.

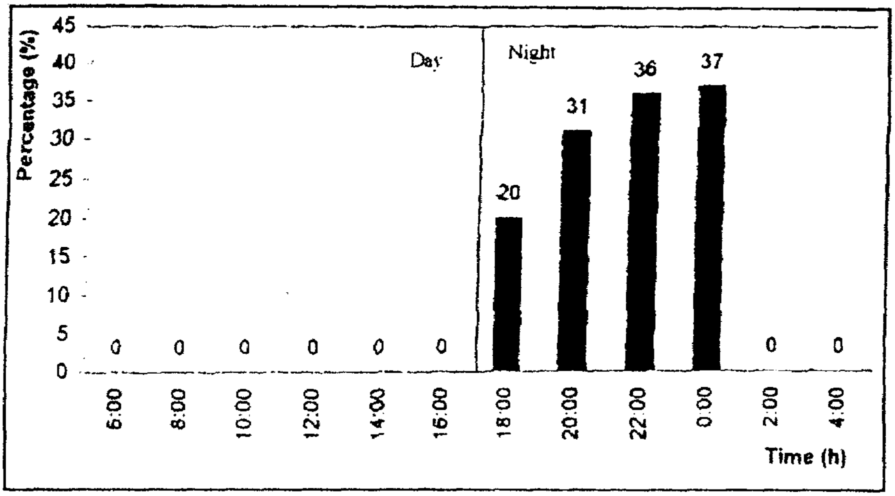

Figure 3.11: Percentage of *Lestrigonus schizogeneios* among Amphipods

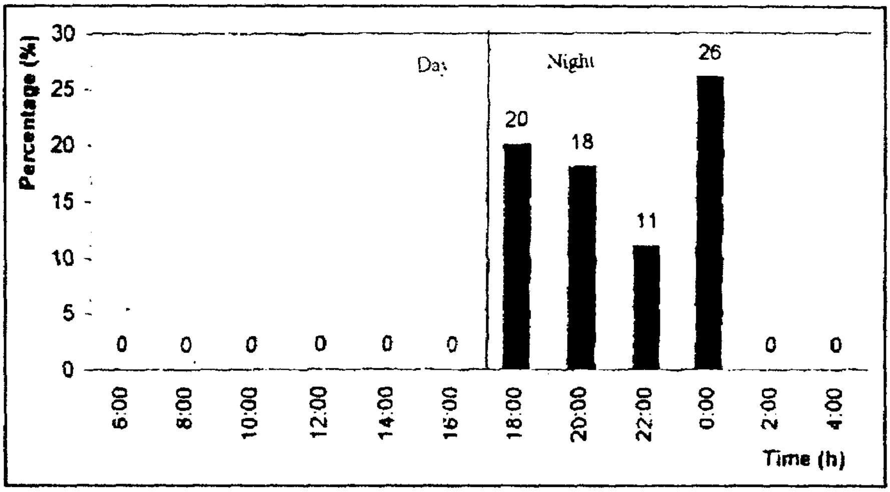

Figure 3.12: Percentage of *Cranocephalus* spp. among Amphipods

Cheatognaths in general, as they have larger body size and prominent eye, seems from Figure 3.14, that they spend more day time at surface waters. But they too show a peak existence of 30 per cent at 0800 hrs and 0200 hrs, white a minimum of 0 per cent was seen at 1800 hrs indicating their cyclic movements.

Pterosagitta draco, a chaetognath with larger body size and large eyes seems to prefer grazing at upper layers during 0600 hrs to 1400 hrs, when there are less plankton grazers at that time. Figure 3.15

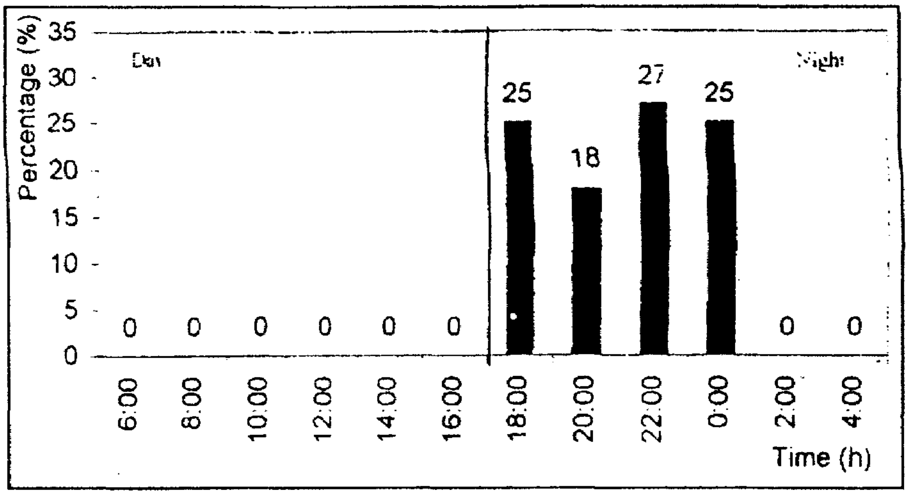

Figure 3.13: Percentage of *Rhabdosoma* spp. among Amphipods

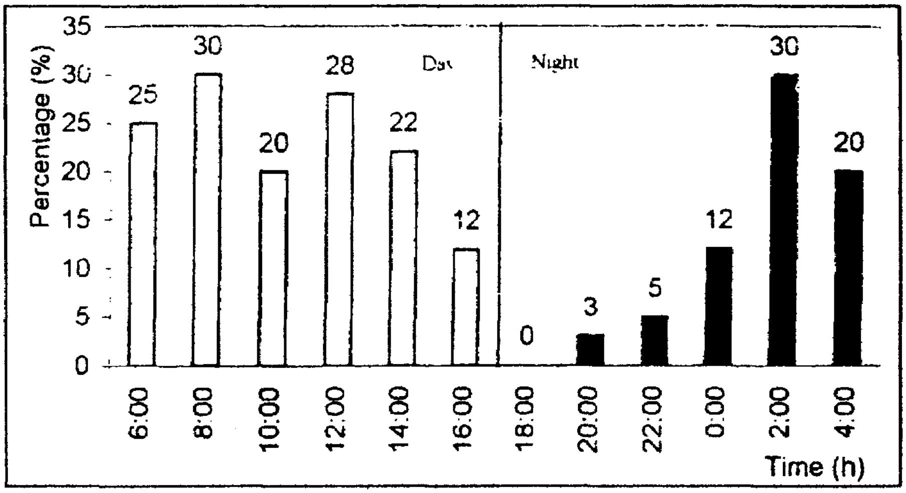

Figure 3.14: Percentage of Chaetognaths in Collection

demonstrates *P. draco*'s presence at 23.0 per cent to 43.0 per cent from 0600 hrs to 1400 hrs and later they move down to lower water column to spend rest of the time of their diel cycle. It looks as if they follow one DVM cycle a day.

Sagitta robusta, one more example for chaetognath, shows its presence during day time as well at night time (Figure 3.16), but at relatively a lower percentage (15.0 per cent to 30 per cent) among chaetognaths at day compared to 31.0 to 44.0 per cent at night

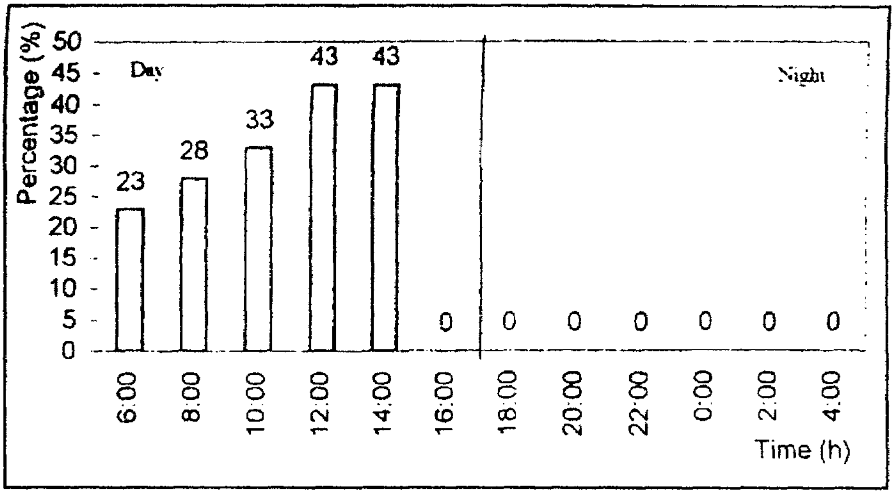

Figure 3.15: Percentage of *Pterosagitta draco* among Chaetognaths

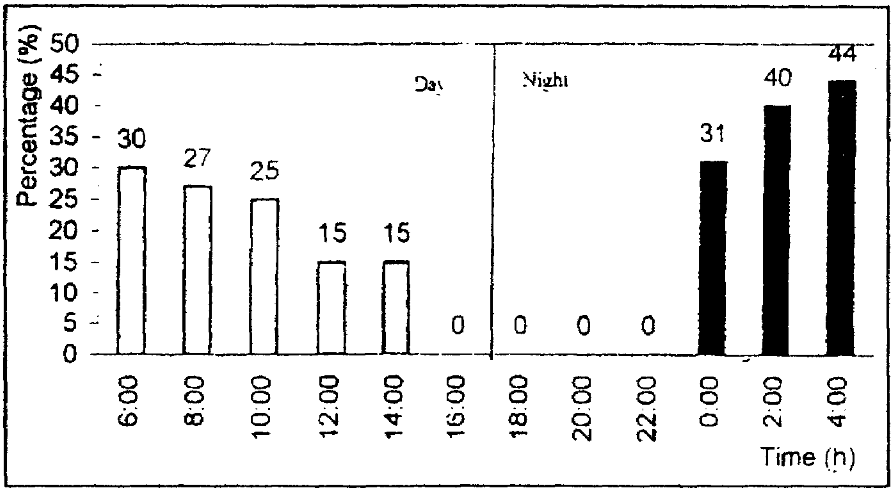

Figure 3.16: Percentage of *Sagitta robusta* among Chaetognaths

whenever they are present. Apart from the above, it can also be seen from Figure 3.16, that they move to lower waters from 1600 hrs to 2200 hrs, to demonstrate that they too undertake diel vertical migration, though once a day. Further, it seems, both *P. draco* and *Sagitta* spp, to avoid competition among themselves, size of the populations present during daytime is inversely proportional to each other.

Sagitta bipuncta, also falls in line with *S. robusta* with regard to its diel vertical movements. It can be seen from Figure 3.17, the peak existence of this organism among chaetognaths is 50.0 per cent at 0400 hrs while from 1400–2200 hrs, they do not show their existence in 0-30M water column, indicating that they too have one DVM cycle per day. As there is no existence of *P. draco* at night, probably there is sufficient food for both *S. robusta* and *S. bipunctata,* if they are feeding on same kind of food, or else, they must be having different feeding habits, to avoid competition for same source.

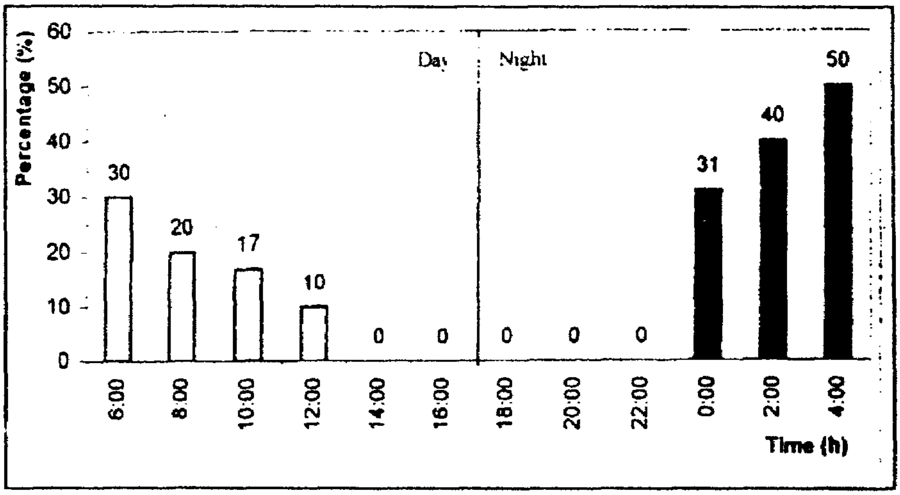

Figure 3.17: Percentage of *Sagitta bipunctata* among Chaetognaths

Figure 3.18 exhibits the percentage of adult crustaceans among the total collection. It ranged from 1.0 per cent to 10.0 per cent between 1600 hrs and 0000 hrs and later they sink down. Thus exhibiting a diel migratory cycle.

Siphonophores, clearly show two cycles of their vertical migration in a day with zero presence between 1200 hrs and 1600 hrs and between 2200 and 0200 hrs, with peak presence of 10 per cent at 1800 hrs and 2000 hrs and 14.0 per cent at 0400 hrs (Figure 3.19). It can also be seen that they prefer night (presence 10.0 per cent to 14.0 per cent) than day (presence 3.0 per cent to 5.0 per cent) time to come to surface of the water. Further, by going through Figure 3.19, one can see that they appear at corpuscular period of the day, when most of the other predator species like amphipods and chaetognaths

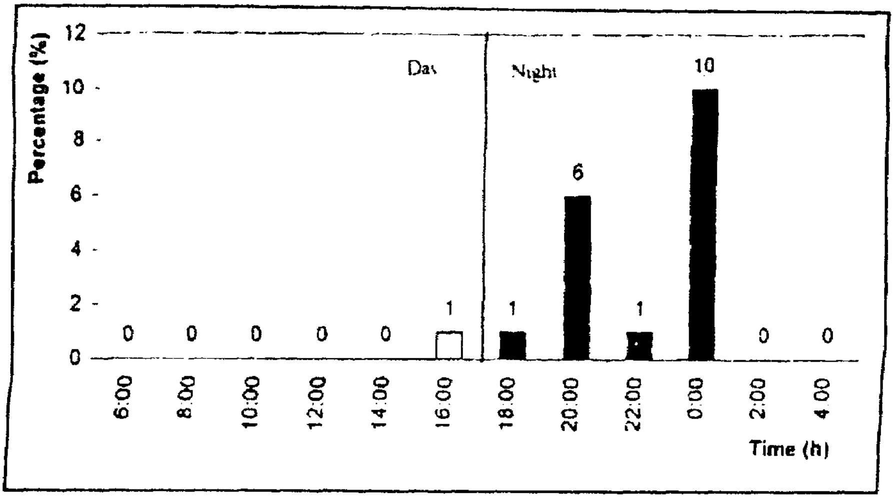

Figure 3.18: Percentage of Crustaceans in the Collection

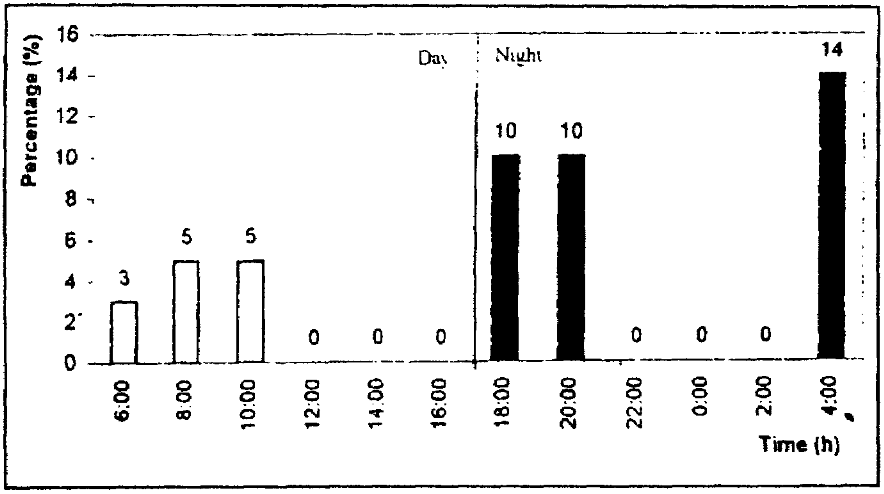

Figure 3.19: Percentage of Siphonophores in the Collection

are absent or at a low density, though the siphonophores are also predators in general, but with smaller body size.

Tunicates spend less time of about 6 hrs in 0.30M water column that too after sunset and finish their activity quickly and sink down (Figure 3.20).

Figure 3.21, explains the diel fluctuations of species diversity index for zooplankton in Andaman Sea. It is interesting to see that, though the zooplankton exhibit vertical migration, and the range of species diversity varies from 6.7 at 0200 hrs to 11.3 at 1600 hrs, with

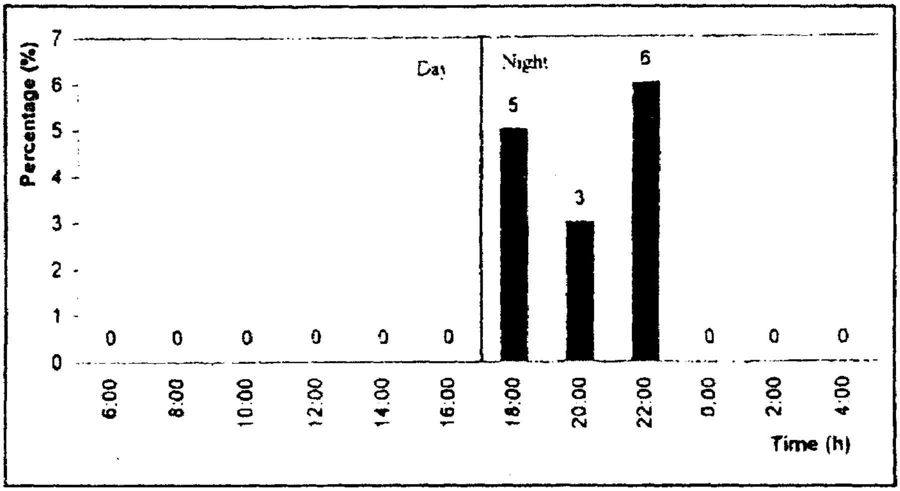

Figure 3.20: Percentage of Tunicates in the Collection

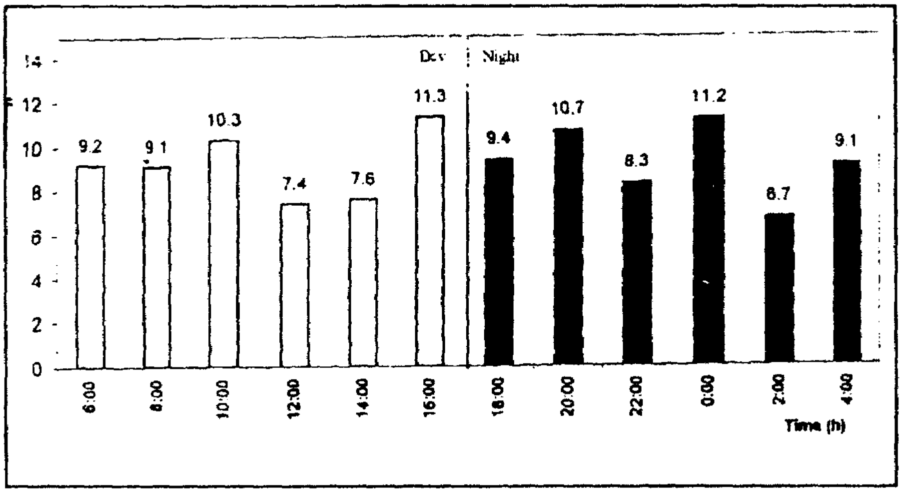

Figure 3.21: Diel Fluctuation of Species Diversity Index of Zooplankton in Andaman Sea

an average of 9.15 and 9.23 diversity index for day and night respectively, which is all most similar.

Diel fluctuations with regard 10 evenness of zooplankton at Andaman Sea is represented in Figure 3.22. It can be seen that evenness varies during day as well at night. The maximum evenness was 2.0 at 0800 hrs for day and 2.2 at 2000 hrs for night and the least evenness for day time was 1.3 at 1400 hrs, white for night jt was 1.5 at 0000 hrs, indicating the fluctuation of populations, thus providing support for vertical migration.

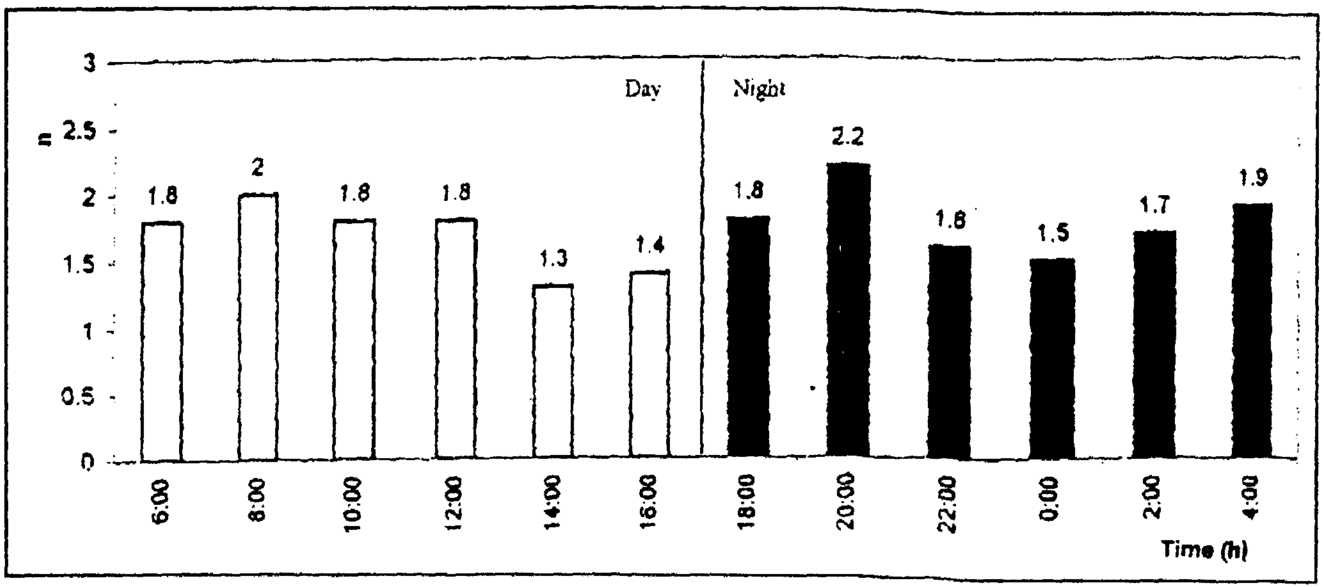

Figure 3.22: Diel Fluctuation of Evenness of Zooplankton in Andaman Sea

The result of cluster analyses and dendrogram comparing similarity matrix with time of sampling. It can be seen that the highest value of 0.91 for sample collected at 1200 hrs and 1000 hrs thus linking them together at 0.91 level. Second highest similarity was at 0.81 between samples collected at 0600 hrs and 0800 hrs thus linking them together. Third highest link was at 0.78 between the sample collected at 0800 hrs and 1000 hrs, thus forming a group. The next groups was at 0.66 level by the samples collected at 2000 hrs and 2200 hrs and finally the least similarity value was 0.25 recorded for the samples collected at 1600 hrs and 1400 hrs.

Discussion

Biomass and wet weight analyses are two well known yard sticks to analyse the density of living organisms, generally in marine environment. Figures 3.1 and 3.2 clearly shows that both biomass and wet weight is higher for samples collected during night time, than the day samples, indicating higher density of organisms at night. Lesser biomass and wet weight of the samples during the day time indicates that the organisms descend down to lower depths for several reasons as mentioned by earlier workers (Zaret and Suffern, 1976; Enright, 1977; Stich and Lampret, 1981; Hauris, 1983; Bollens and Frost, 1989a,b,c; Magnesen, 1989; Neuman, 1989; Hansson *et al.*, 1990; Ohman, 1990; Jerling and Wooldridge, 1992; De Stasio, 1993), one of the major reason is said to be avoidance of predators. The second is said to be passively to facilitate the phytoplankton to grow during day time thus to ensure continuous food for zooplankton.

In animal kingdom, members of different groups exhibit distinct behaviours, which are specific to a particular group, though among the members of the slame group one can find variation with regard to that behaviour. Diel Vertical Migration (DVM) though known to be prominent and well studied in zooplankton by earlier workers like Gunther, 1935; Ussings, 1938; Raymond, 1939; Marshall, 1960; Koslow, 1979 (Cf: Raymont, 1983) is poorly understood. Several workers have assigned various reasons for migratory and non-migratory behaviour of zooplankton (Vinogradov, 1970; Raymont, 1983; Chae, 1995). One of the major cues for migration has been assigned to light intensity (Neuman, 1989; Jerling and Wooldridge, 1992), and have suggested while changing light intensity is significant for migration as "optimum zone" of light intensities is *not only the determining factor.* Animal has to either adapt to changing light intensity during the day, which will trigger off other behavioural patterns, like copepod in general and *Euchaeta concinna* and *Rinocalanus nasuta* in particular which show their presence throughout the diel cycle, though in varied degree. But among copepods, one can also see the species like *Candacia polydactyla, Sapphirina negromaculata, Copilia mirabilis*, which can not adopt to surface waters all the time. Hence, they sink to lower depths between 1400 hrs and 1800 hrs, 1600 hrs–1800 hrs and around 1400 hrs respectively, indicating variation in adaptability among the species of same group. While some other species like *Schmackeria poplosia, Subeucalanus longiceps, Unadula vulgaris* etc., appeared at the surface waters only for a short period, that too during 2200 hrs to 0600 hrs. The reason for this may be that, the daytime distribution of sapphirinids are determined under water light conditions as proximal cue as hypothesised by Chae (1995), that the well developed eyes, the irridescence of the males and day time shoaling in sapphirinids are closely related and constitute presumed mate finding mechanisms, which may be unique in oceanic planktons. Further, as explained by Reymont (1983) marked pigmentation reduces the photodamage to copepods and make it easily visible to predators. This seems to be the case with copepods like *Subeucalanus longiceps, Unadula vulgaris*, which remain in lower depths, where the light intensity if low during day time and surface at night.

Regarding amphipods, from the present experiments, it is seen that they come to the surface water twice a day, once for long duration from around 1600 hrs to 0000 hrs and after a short "midnight sinking" reappear for a short period at around 0400 hrs and then they will have a long sinking from 0600 hrs to 1600 hrs may be to avoid predators at day time, or this may also be a natural phenomenon, where nature allows the phytoplankton to grow during the day time when sunlight is available, to ensure continuous food supply as suggested by Hauris (1988).

About Amphipods, all the species under study (Figures 3.10–3.13) showed their existence in 0.30M water column from 1800 hrs to 0000 hrs indicating their group behaviour. All the species under study showed simultaneous appearance for about 6 hrs and after completing their feeding and other activities at upper layer seems to descend to lower levels together, to re-appear in next cycle. As the size of the organism is relatively small, it seems to avoid the predators at day time, they do not come to surface layers. Further, as they show a short period of grazing, due to less consumption, to save energy, they may be sinking down to lower water column, where metabolic rate is low due to low temperature thus needing less energy requirements as suggested by De Stasio (1993). Further, appearance and disappearance of amphipoda as a group may be a strategy to make way to other groups to come to surface layers for feeding. It seems like a natural adjustment and adaptability phenomenon to reduce competition for same resource as suggested by Rothaupt (1990).

It is interesting to see from Figure 3.14, that though chaetognaths, a relatively larger animals with prominent eyes can afford to stay at upper layer of waters during day as well at night time, but indicates that they too undertake DVM, which is evident from total absence of chaetognaths at 1800 hrs and re-appear at a later stage to show their maximum percentage (30 per cent) at 0200 hrs. They also show the fluctuation with regards to their percentage of existence, though they exhibit their existence all through the daytime.

It can be seen from Figures 3.9 and 3.14 that, when amphipod population decreases from 40.0 per cent to 0 per cent from 1800 hrs to 0200 hrs, the chaetognath population increases from 0 per cent to 30 per cent, indicating that they avoid competition in grazing the same ground at the same time.

However, it can also be seen that among chaetognaths too seemingly to avoid inter and intra-specific competition, they distribute themselves during day and night. For *e.g. Pterosagitta draco* surfaces for grazing at day time and do not show its existence at night (Figure 3.15), while *Sagitta robusta* shows its presence day as well at night. With a zero presence from 1600 hrs to 2200 hrs (Figures 3.16) the *Sagitta bipunctata*, shows its presence from 0000 hrs (31.0 per cent) and peaks to 50.0 per cent at 0400 hrs and then reduces its presence steadily from 0600 hrs to reach 0 per cent at 1400 hrs. Thus not only reducing the competition among the members of the same groups but also giving enough time for phytoplankton to grow during the day time.

When copepods, amphipods, chaetognaths, tunicates, siphonophores are not present at their maximum concentration (Figures 3.3, 3.9, 3.14, 3.19, 3.20) adult crustaceans are found to be present at their maximum at the surface layer (at around 0000 hrs). Again supporting the evidence for avoidance of competition for same source of food as reported by Rothaupt (1990). *As the crustaceans are generally smaller in size* and exhibit a prolonged larval stages, it seems to avoid of being predated, they start surfacing from 1600 hrs, when the light intensity reduces and spends time upto 0000 hrs and then sink to lower layers of water.

While the siphonophores, by showing their presence at 0-30M water column at 1800 to 2000 hrs and 0400 to 1000 hrs clearly exhibit two diel cycles of their vertical migration (Figure 3.19). They exhibit midnight sinking too (Figure 3.19), it can also seen from the above, that they show their existence at day and night, their density demonstrates that they prefer night time than day. From the collections it was also observed that day time surfacers have relatively larger body size and large eyes, indicating that the body size has a bearing on day/night migration as reported by Mackas (1992). Further, siphonophores appear when competition pressure from other fellow predators is less, which is evident from Figure 3.19. Apart from that, they appear strictly during corpuscular hours of the diel cycle, when most of the other larger predator species such as amphipods, chaetognaths are either absent of in their low population. This may he a natural phenomenon of avoiding competition among various groups of organism for same source of food.

From Figure 3.20, it can be concluded that tunicates have relatively small range of timing for feeding and other activities at surface waters. As they are not known as long migrants, show a quick appearance at 1800 hrs and sink down to certain level at 2000 hrs to aappear at 2200 hrs and sink down to re-appear at next cycle. The short period of spending time at surface layer seems to either they are quick feeders or feed on surface phytoplankton to a less extent and prefer to stay at lower water columns may be safety or for their probable capacity to feed at that level too.

It is Pielou (1966) explained the importance of study of species diversity and its patter while studying ecological succession and later Peel (1914) in his review, described role and method of measuring species diversity. Hence, based on the importance, when an attempt was made to analyse the zooplankton diversity in the study area, the results obtained has been represented in Figure 3.21.

It can be seen from the figure, though there is a species diversity fluctuation during day or night time, a some what constant number of species (9.15 during day and 9.23 during night) was recorded, there is a record of higher species diversity during corpuscular period. Similarly patchiness also shows, its higher value at corpuscular period. Though the biomass of zooplankton at night was comparatively higher (2.83 m/m^{-3}) than the day time (1.83 m/m^{-3}), which may be a strategy of nature to see that all planktonic groups get an opportunity to graze, through at different times of the diel cycle. At the same time, by keeping low grazing pressure at day time, provides sufficient time for phytoplankton to grow in order to provide a continuous food supply for these zooplankton, thus maintaining the food chain in an efficiently operating manner. Thus indicating that Andaman sea ecosystem sustains a large, mature community with stability, where in a number of organisms live in absolute harmony for the their as well as community success.

Similarity index, patchiness and evenness are important criteria to determine the pattern of distribution of any organism (Omori and Hamner, 1982; Washington, 1989; Davies *et al.*, 1991). Hence, the results obtained in the present experiments were subjected for cluster analyses and dendrogram were prepared from comparing similarity index. The results obtained are represented, which clearly demonstrates, that there is a distinct grouping with regard to cluster formation in terms of similarity matrix. For example sampling at 1200 hrs and 1000 hrs belong to same cluster, with similarity matrix around 0.91, between 0600 hrs and 0800 hrs (0.81).

From the present studies, it becomes clear that the biomass in Andaman Sea remains some what similar during entire diel cycle, though whose higher peak at 2000 hrs and 0200 hrs, mainly due to the presence of maximum number of zooplankton. While the wet weight of the collected sample is significantly high at night than the day.

Regarding zooplankton, copepod groups seems to occupy the surface waters at all the times with some what equal distribution, though certain species like *Candacia pachydactyla, Sapphirina negromacculata, Copilia mirabilis* exhibit a complete (2 cycles per day) diel vertical migration, *Rhinocalanus nasutus, Euchaeta concinna* show their cyclic migration once a day, thus leading to the fluctuation of population size at the surface layers.

Amphipods show a general tendency as a groups to be at the surface waters at 1800 hrs to 0000 hrs, as exemplified by *Brachyscelus crusculum*, *Lestrigonus schizogeneios*, *Cranocephalus* spp., *Rhabdosoma* spp. etc. There are other amphipod species which may surface slightly early (1600 hrs) or at a slightly later stage (at around 0400 hrs), but they do not surface between 0600 hrs to 1400 hrs.

Similarly chaetognaths show fluctuation with regard to their existence, they do surface at all the times of the diel cycle except at around 1800 hrs *i.e.*, immediately after sunset. There are chaetognaths which surface during day time (*e.g.*, *Pterosagitta draco*) or at day and night (*e.g. Sagitta robusta* and *S. bipunctata*), with distinct sinking between 1600 hrs and 2200 hrs.

The Crustaceans have a short span of surfacing from 1600 hrs to 0000 hrs with peak at 0000 hrs, before sinking to re-appear at next cycle. While the siphonophores show clearly two cycles in a day by appearing between 0400 hrs and 1000 hrs and later between 1800 hrs and 2000 hrs. While the tunicates appear to surface waters only once a diel cycle from 1800 hrs to 2200 hrs.

The present studies indicate that at all given times, of a diel cycle an average of 9.16 species of zooplankton will be at surface compared to 9.23 species at night indicating no significant variation with regard to species diversity. While the density of zooplankton varies from 1.3 to 2.0 at day (Average 1.68) and between 1.5 to 2.2 at night (Average 1.78) indicating higher evenness of grazers at night.

The studies also leads one to conclude that at Andaman sea, the biotic community supports some what same number of species during day as well at night, though the biomass varies, indicating ecological and trophic maturity of the community, thus exhibiting equilibrium. One can also see the equilibrium between day and night time production. There also exists equilibrium for competition for same resource between and among the members of different groups of organism.

Another aspect revealed by the present studies is the formation of distinct clusters of similarity with the time of sampling of zooplankton. For example there is a day group (0400, 0600, 0800, 1000 and 1200 hrs) and an evening group (1600 and 1800 hrs), while the catches at 1400 hrs do not show clustering with any group. While the catches at 0200 hrs, based on their numerical biomass and wet weight, seems to be near to evening group.

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