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Diel vertical migration of zooplankton in Andaman Sea

Sameer Terdalkar and I. K. Pai

Department of Zoology,
Goa University,
Goa - 403 206

Abstract

Zooplankton exhibit diel vertical migration (DVM) in which, the hours of darkness are spent near the surface and the day light hours at deeper depths. DVM, though studied by many workers, is poorly understood. Hence an attempt has been made to study and understand DVM pattern in Andaman Sea, known not only for its oligotrophic nature, but also for low primary and secondary productivity. The zooplankton samples were collected from the upper most euphotic zone for 24 hrs at an interval of two hours by using a Bongo net. The biomass and wet weight varied from 0.01 - 0.05 ml m^{-3} m and 0.4-2.2 mg m^{-3} respectively. Copepods dominated the samples, followed by chaetognaths, amphipods, siphonophores, crustaceans and pelagic tunicates. The present studies reveal that, not only the light intensity, but also the feeding habits, reproductive stage and age of organism alters DVM in zooplankton.

Vertical migration in zooplankton is well documented but rather poorly understood (Boaden and Seed, 1985). Members of zooplankton undertake DVM through the water column of somewhat less than 400m on average by smaller and over 600m by larger species. These vertical movements, which may involve sustained upward swimming speeds of 12-200 mh^{-1} dependent on the size and downward speeds, some three time faster, may be undertaken twice a day. During the day time, the zooplankton are relatively deep in the water column, but by dusk, they ascend to the surface (Herring and Campbell, 1990). They then dispense somewhat through the water column in the middle of night, the phenomenon termed as "midnight sinking" as explained by Raymont (1983), which is due to random wanderings of the animals in absence of any light stimulus. The zooplankton again rise towards the surface just before dawn and this phenomenon is termed as "dawn rise". Further, some species display (in some areas/at some times) reversed migrations, being near the surface during the day and move to deeper areas at night (Parsons and Takahashi, 1979).

DVM of zooplankton with greater nocturnal feeding rates has been scrutinised with respect to grazing impact on phytoplankton and bacteria. With increased densities of zooplankton in surface waters at night, a decline in the concentration of food particles occurs, which is inversely proportional to the length of time the zooplankton remaining in the upper layers. Conclusions from other investigators suggest that DVM behaviour and feeding activity may not be strongly linked (Kennish, 1989).

There are several studies on DVM from various parts of the world (Por, 1989, Checkley, 1992 and Chae and Nishida, 1995). However, such studies in the Andaman Sea are limited to the work of Goswami and Rao (1981) and Madhupratap *et al.* (1981). The present study was conducted to understand more about the DVM of zooplankton in Andaman Sea.

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Material and methods

The data for the present study was collected on board ORV *Sagarkanya* during the multidisciplinary cruise organised by National Institute of Oceanography from 15th Oct. to 15th November 1996 in the Andaman Sea (Lat 10°30.23'N and Long 93°15.25'E). The depth of the station was 2300 m.

The zooplankton biomass was determined by displacement volume method and the collected samples were preserved in 4% formaldehyde. The wet weight was determined by following the method given by Omori and Ikeda (1984). Later, the samples were brought to the laboratory and analysed for abundance of major zooplanktonic groups and identified upto species level by using available literature (Daniel 1985, Zheng Zhong *et. al.*, 1989, Santhanam and Srinivasan., 1994). The diversity was calculated by using the indices given by Margalef (1968) for species of zooplankton encountered in the sample.

The 12 samples were subjected to Linkage clustering within a similarity matrix, which is considered as 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. showed that the biomass fluctuating from 0.01-0.05 ml m^{-3}, while the wet weight varied from 0.04-2.2mg m^{-3} (Figure 1). Further, major zooplanktonic groups encountered were copepods, chaetognaths, amphipods, crustaceans, siphonophores and pelagic tunicates.

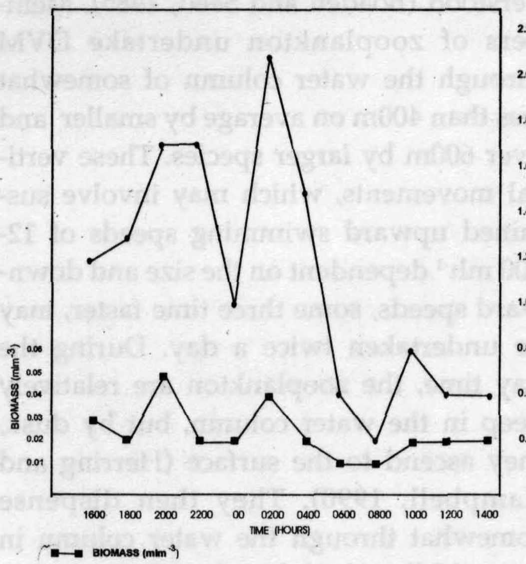

Fig. 1. *Diel fluctuation of biomass and wet weights of zooplankton in Andaman Sea*

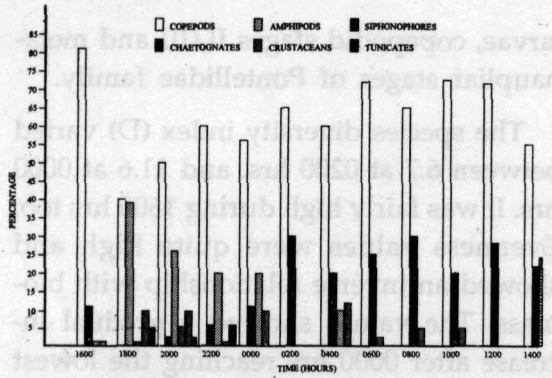

Fig. 2. *Major zooplankton groups exhibiting diel vertical migration in Andaman Sea*

Copepods formed the dominant group representing as many as 35 species. They showed their maximum presence (82%) during 1600 hrs., representing 16 species. After 1600 hrs., the percentage of copepods dropped down to 40-50% showing an abrupt fall after 1800 hrs. (Figure 2).

Copepods like *Candacia pachydactyla, Corycaeus affinis, Euchaeta concinna, Oncaea venusta, O. media, Rhinocalanus nasutus* and *Sapphirina nigromaculata* showed their presence continously between 2000 hrs to 1200 hrs. But the members of the family Pontellidae such as *Pontellopsis tenuicauda,* and *P. securifer* appeared at 1600 hrs and again from 1000 hrs to 1200 hrs The maximum abundance of various copepods during a particular time of diel cycle, was 24% at 000 hrs for *C. pachydactyla,* 12% at 2000 hrs for *Copilia mirabilis,* 24% at 2200 hrs for *E. concinna,* 22% at 1400 hrs for *R. nasutus* and 12% at 2000 hrs for *S. nigromaculata* (Figure 3).

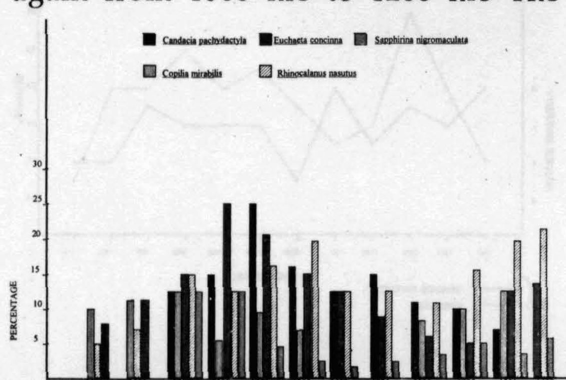

Fig. 3. *Species composition of copepods, exhibiting diel vertical migration in Andaman Sea*

Chaetognaths were represented by ten species. They showed their maximum (30% amongst all major groups) presence at 0200 hrs (Figure 2). Among the group, *Pterosagitta draco,* was dominant species; followed by *Sagitta robusta* and *S. bipunctata.* The maximum abundance of chaetognath species during particular time of the diel cycle was, 42% at 1200 - 1400 hrs for *P. draco* and 44% at 0400 hrs. for *S. robusta* (Figure 5).

Amphipods represented by ten species showed their maximum (40% amongst all major groups) (Figure 2) presence during 1800 hrs. Among the group, *Lestrigonus schizogeneios* was dominant species fol-

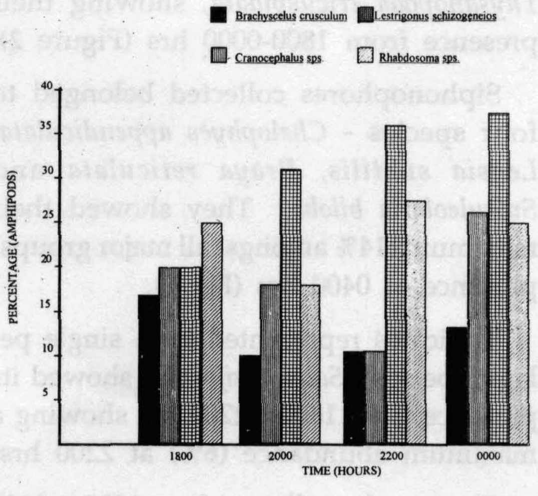

Fig. 4. *Species composition of amphipods, exhibiting diel vertical migration in Andaman Sea*

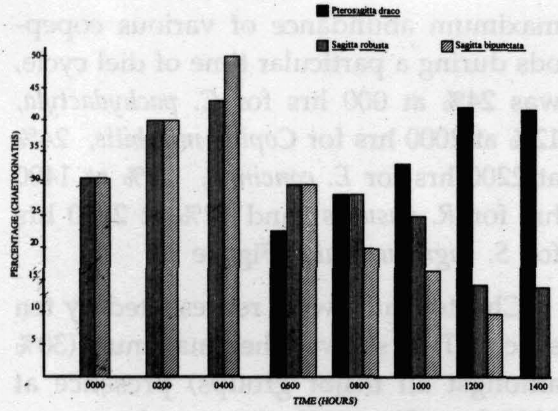

Fig. 5. *Species composition of cheatognaths, exhibiting diel vertical migration in Andaman Sea*

lowed by *Brachyscelus crusculum, Cranocephalus sp* and *Rhabdosoma sp* . The maximum abundance of amphipod species during a particular time of diel cycle was, 37% at 00 hrs for *L. schizogeneios,* 16% at 1800 hrs for *B. crusculum,* 26% at 00 hrs for *Cronocephalus* species and 27% for *Rhabdosoma* species (Figure 4).

Crustaceans consisted of three species, a sergestidae member - *Lucifer typus* and euphausids like *Stylocherion carinatum* and *Thysanopoda tricuspidata,* showing their presence from 1800-0000 hrs (Figure 2)

Siphonophores collected belonged to four species - *Chelophyes appendiculata, Lensia subtilis, Praya reticulata* and *Sulculeolaria biloba.* They showed their maximum (14% amongst all major groups) presence at 0400 hrs (Fig 2).

Tunicates represented by a single pelagic species - *Salpa fusiformis,* showed its presence from 1600 - 2200 hrs showing a maximum abundance (6%) at 2200 hrs.

The samples collected from 1600 to 0000 hrs also showed presence of echinoderm larvae, copepodid stages II/III and metanaupliar stages of Pontellidae family.

The species diversity index (D) varied between 6.7 at 0200 hrs. and 11.6 at 0000 hrs. It was fairly high during 1600 hrs too. Evenness values were quite high and showed an inverse relationship with biomass. The values showed a gradual increase after 0000 hrs reaching the lowest at 1400 hrs and highest by 2000 hrs (Figure 6)

The similarity matrix resulted into a dendrogram (simple linkage method) (Figure 7) showing the highest value of 0.91 for the samples collected at 1200 hrs and 1000 hrs, and hence these two samples are linked together at 0.91 level. The second highest similarity is 0.81 between the samples collected at 0600 hrs and 0800 hrs, hence linked together. The third highest link at 0.78 is between the samples collected at 0800 hrs and 1000 hrs thus forming a group. The next new group is formed at 0.66 level by the samples collected at 2000 hrs and 2200 hrs. Finally the least similarity value of 0.25 was re-

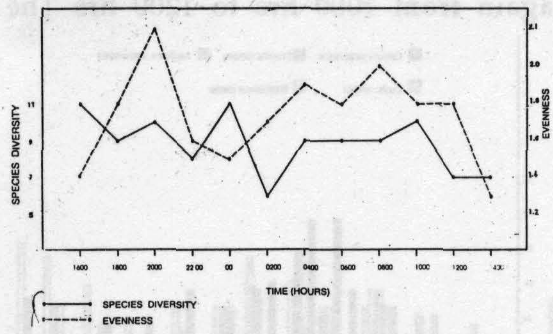

Fig. 6. *Diel fluctutation of species diversity and evenness of zooplankton in Andaman Sea*

TIME (HOURS)											
1800	0.31										
2000	0.34	0.56									
2200	0.28	0.54	0.66								
0000	0.25	0.42	0.53	0.62							
0200	0.30	0.38	0.41	0.42	0.42						
0400	0.25	0.26	0.40	0.45	0.55	0.54					
0600	0.26	0.22	0.35	0.30	0.42	0.51	0.73				
0800	0.22	0.16	0.35	0.41	0.46	0.43	0.50	0.81			
1000	0.35	0.27	0.40	0.41	0.51	0.50	0.61	0.70	0.78		
1200	0.33	0.17	0.32	0.38	0.55	0.48	0.66	0.64	0.74	0.91	
1400	0.25	0.33	0.36	0.37	0.43	0.32	0.71	0.53	0.51	0.51	0.57
TIME (HOURS)	1600	1800	2000	2200	0000	0200	0400	0600	0800	1000	1200

CLUSTER ANALYSIS FOR 12 SAMPLES (SIMILARITY MATRIX METHOD)

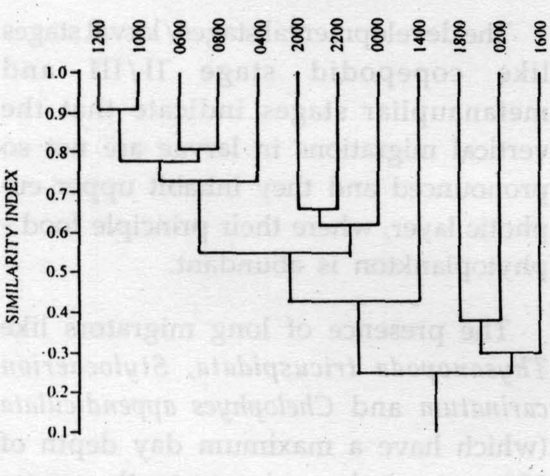

Fig. 7. *Dendrogram comparing similarity index with the time of sampling (clustering with simple linkage method of Omori and Ikeda, 1984)*

corded for samples collected at 1600 hrs and 1400 hrs.

Discussion

These observations suggest that, while changing light intensities are of significance in migration, an "optimum zone" of light intensities is not the only factor determining the vertical movement of deep water animals of the scattering layer. Either, the animals must adapt during the day to a considerable different light intensity or the rate of change of light intensity may trigger- off other behavioural patterns, which cause the animals to move into higher light intensities during the latter part of the day, as seen in case of amphipods like *Anchylomera blossevillei, B. crusculum, Vibilia gibbosa, L. scizogeneios* in contrast to *Hyperia bengalensis* and *Phronima sedentaria,* which show their presence only during 0400 hrs.

The observations also indicate that the copepods like *C. pachydactyla, E. concinna, O. venusta, C. mirabilis* and *S. nigromaculata* have the capability to adapt to changing light intensities during the day time unlike *Schmackeria poplesia, Subeucalanus longiceps* and *Undinula vulgaris* which were present in the samples collected only between 2200 and 0600 hrs. It can be said that the day time distributions of Sapphirinids are determined by underwater light conditions as proximate cue. It is also hypothesised that the well developed eyes, the irridescence of the male and day time shoaling in the Sapphirinids are closely related and constitute presumed mate finding mechanism which may be unique in oceanic plankton (Chae and Nishida, 1995)

Raymont (1983) showed that marked pigmentation reduced photodamage to the copepod and made it easily visible to the carnivores. Hence to survive, the copepods like *Subeucalanus longiceps* and *Undinula vulgaris* must remain at a depth where the light is too low for them to be seen during the day time. This is also seen in siphonophores like *Praya reticulata, Sulculeolaria biloba* and tunicates like *Salpa fusiformis* which lack photo protection and hence descend to depth during the day light hours. This has been observed by earlier workers like Vinogradov (1970), who has pointed out that, by feeding actively on rich phytoplankton of epiplanktonic layer during darkness, herbivores may avoid their visual predators.

Observations indicate that the copepods like *Acartia* species, *Clausocalanus brevipes, Sinocalanus* species appear during sun set which proves that, diffused light triggers their movements towards the surface, probably as a result of geotactic response. Raymont, (1983) has shown that *Acartia tonsa,* exhibited movement towards the surface at sun set or in darkness.

One more phenomenon observed, which is parallel to the suggestion given by Raymont, (1983), is that copepods like *Corycaeus speciosus, Cosmocalanus darwinii* and *Eucalanus subcrassus* appear just before sun set which may be a strategy to avoid visible interactions with luminous dinoflagellates and reduce nocturnal predation.

The members of Centropagidae appearing only during 0800 hrs in negligible percentage show that, though under experimental conditions they do not show any migration away from light (Raymont, 1983) require a relatively low light intensity to exhibit migration.

Further, appearance of Pontellidae members, during 1000 hrs, 1200 hrs and again at 1600 hrs shows that these members with large dorsal and rostral eye lenses will be able to locate the predators and hence afford to be in the uppermost euphotic zone during day time. Hence, it can be said that, the reaction of zooplankton to environmental factor like light will be strongly conditioned by the amount and perhaps even by the type of food which they consume.

The developmental stages/larval stages like copepodid stage II/III and metanaupliar stages indicate that the vertical migrations in larvae are not so pronounced and they inhabit upper euphotic layer, where their principle food - phytoplankton is abundant.

The presence of long migrators like *Thysanopoda tricuspidata, Stylocherion carinatum* and *Chelophyes appendiculata* (which have a maximum day depth of 250 meters) that migrate to the upper euphotic zone suggests that their migration is not affected by the discontinuity layer (Madhupratap *et. al.,* 1981). Also copepods like *Candacia pachydactyla, Copilia mirabilis, Rhinocalanus nasutus* are able to migrate to optimum light intensities above the thermocline layer during the day time.

Further, the copepod *Oncaea venusta* appeared abundantly all through the 30 meter water column, however its percentage relatively decreased during the day time and females are seen dominating their population during night. Raymont (1983) also has shown that ripeness of the gonads is certainly a factor of migration, hence, DVM is more pronounced in adult female as compared to their juveniles, which is in concurrence with the observations in the present studies.

Taking into consideration all these observations, it can be said that, apart from light and availability of food the organism's age, physiological condition, reproductive stage, chemical stimulus like that of fish exuded kairomones as suggested by Lampert (1991), alters the DVM, there by adding more complexity to this area of study.

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