

Myctophid and pelagic shrimp assemblages in the oxygen minimum zone of the Andaman Sea during the winter monsoon

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Stratified samples were collected with a Multiple Plankton Net for assessing the myctophid and pelagic shrimps composition from the Andaman Sea during the winter monsoon. Andaman Sea has a fair representation of mesopelagic micronektonic fauna such as the myctophids and pelagic shrimps in the upper 1000 m depth. Among the myctophids, *Benthosema fibulatum* had the maximum biomass followed by *Diaphus lucidus* and *Benthosema pterotum*. Among the pelagic shrimps *Sergestes seminudus* and *Oplophorus types* were the dominant species. *Sergestes seminudus* was present at all depths [up to 1000 m] and its distribution pattern suggested the cocurrence of a strong diurnal vertical migration. Temperature decreased from the mixed layer depth downwards. Salinity did not show any significant variation. Dissolved oxygen ranged between 2.8 and 4.8 mL.L⁻¹ in the upper 75 m and from 0.05 to 0.2 mL.L⁻¹ in the 150-650 m column, with a gradual increase in the bottom layers [>0.8 mL.L⁻¹]. Majority of myctophids and shrimps occurred in abundance in the oxygen minimum zone [150-650 m].

[**Keywords:** Micronekton, vertical migration, oxygen minimum zone, winter monsoon, Andaman Sea]

Introduction

The Andaman Sea is a region where the complex air-sea interaction releases enormous energy for the genesis of the tropical cyclones almost every year¹. A peculiar composition of myctophid and pelagic shrimps are observed in this region. These micronektonic animals show strong vertical and horizontal migrations and play a significant role in the transport and redistribution of organic matter from epipelagic to mesopelagic zones². During the daytime they migrate to deeper suboxic waters where the oxygen is less than 1 mL.L⁻¹. These midwater/mesopelagic organisms (200 to 1000 m depth) are important components of the pelagic food webs in the world open oceans. In the tropics, many groups of micronekton are prey organisms of bunching predators like tuna, sharks, and barracudas. The abundance and distribution of the barracudas in the oceanic waters provide clues to the quantitative and qualitative nature of micronekton⁴. Larger animals migrate to deeper waters (300-400 m) than the smaller zooplankton (100-200 m), as indicated by

the high day/night biomass ratios at these depths. The prominent diel vertical migrators are the krill *Euphausia diomedaea* and several species of myctophid fishes⁵.

Myctophid play an important trophic role in the open ocean; display a high diversity that can be used as an indicator of biogeographic distinctness of a specific area. Many micronekton species demonstrate ontogenetic migrations as well, living in epipelagic layers (0-200 m) as larvae or early juveniles and moving to deeper layers as they grow². In the water column, the oceanic currents supply enough O₂ and the development of anoxia in most oceanic areas is rare. However, there are three regions where some unusual oceanographic processes cause the oxygen demand to exceed its supply, resulting in complete oxygen depletion at the intermediate depths⁶. Two of these sites are located in the eastern tropical north and south Pacific, while the third site is in the northern Arabian Sea⁷, where the oxygen depletion is more pronounced during the winter monsoon^{8&9}. Kamykowski and Zentara¹⁰ opined that the midwater oxygen minimum zones (OMZ) exist in all the world oceans, but are more prominent in the Arabian Sea.

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OMZ chiefly occur for the interplay of the degradation of phytoplankton, and high oxygen consumption by the zooplankton and bacterial fauna besides the sluggish horizontal mixing below the thermocline¹¹.

The present study is part of the Marine Research-Living Resources Assessment Programme (FORV *Sagar Sampada* Cruise # 220), the myctophids and pelagic shrimps of the Andaman Sea (Lat.08°00 to 14°00'N, Long. 90°00 to 95°00'E) were studied. The aim of the study was to assess the influence of OMZ on their vertical distribution.

Materials and Methods

Fourteen stations in the Andaman Sea were sampled for this study (Fig. 1). Stratified samples were collected with a Multiple Plankton Net (MPN – HYDROBIOS - 200 µm mesh width and 0.25 m² mouth area/opening and closing mechanisms attached) from five standard depths, viz., 1000-500 m, 500-300 m, 300 m-BT (bottom of thermocline), BT-TT (bottom to top of thermocline), and TT- surface (mixed layer). The hauling speed was restricted to one meter per second. Samples collected were preserved in 4% formalin-seawater. Myctophid and pelagic shrimps were sorted. The numerical abundances (no./100 m³) of each species were calculated by

$$\frac{\text{Number of organisms (no.)}}{\text{Volume of filtered water (m}^3\text{)}} \times 100$$

where the Volume of water filtered = 0.25 (m²) multiplied by the depth difference in hauls (m)

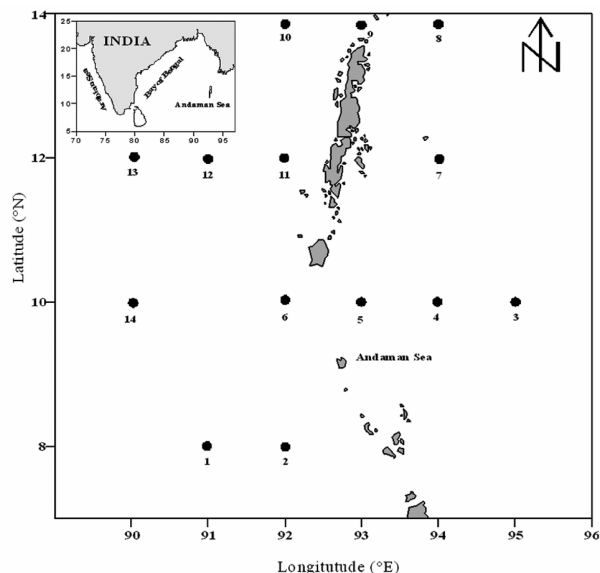


Fig. 1—Station locations in the Andaman Sea.

Since the sample size was limited for a realistic estimation of abundance, the data could be considered as an indication of the distribution pattern with depth of the myctophid and pelagic shrimps in the surveyed area. A Sea-Bird CTD (Conductivity, Temperature and Depth) was used for collecting temperature-salinity profiles. CTD salinities were calibrated, with respect to the salinity of sample collected from standard depths, following the Guideline 8400 Autosal onboard. The sea surface temperature (SST) was measured using a bucket thermometer. In this study, a mixed layer is defined as the depth at which the surface temperature dropped by 1°C and the bottom of thermocline was taken as the depth of 15°C isotherm. Dissolved oxygen (DO) was measured onboard using Winkler method¹².

Diversity is a concise expression of how individuals of a community are distributed in subsets of groups. Diversity decreases when one or a few groups dominate in a community, when individuals of a more common group replace individuals of a rare group or when one or a few groups rapidly reproduce. To mathematically analyze and compare changes in aquatic communities due to environmental influence, diversity indices can be used as one of the tools.

Shannon and Weaver diversity index¹³

$$H(S) = -\sum [p_i (\log_2 p_i)]$$

$P_i = n_i/n$ (proportion of the sample belonging to the i^{th} species).

Margalef's richness index¹⁴

$$D = (S-1)/\log_e N$$

S = number of species

N = total number of individuals of all the species in the sample.

Results and Discussion

Environment characteristics

Temperature decreased sharply up to the thermocline and gradually thereafter. Salinity values were almost similar between stations. Mixed Layer Depth (MLD) was maximum (96 m) at Stn. 5 and minimum (71 m) at Stn. 9. Average vertical distribution of temperature and dissolved oxygen along transects located at 8°, 10°, and 12° N are shown in Fig. 2. Similarly, temperature and DO profiles at Stns. 8, 9 and 10 located at 13.5°N transect are shown in Fig. 3. The maximum depth of the base of the thermocline was at 190-200 m at Stn. 3 and minimum was at 170-180 m at Stn. 2. Generally, DO was high at the surface (4.5-4.8 mL.L⁻¹); suddenly dropping at

the sub-surface layers (0.2-0.05 mL.L⁻¹). At deeper depths (>750 m), the DO level slightly increased (0.8-1.2 mL.L⁻¹). The oxygen minimum zone (150-650 m) varied along transects. The values gradually decreased from 8°N (Av. 0.40 mL.L⁻¹) to 13.5°N (0.08 mL.L⁻¹) transect (Figs. 2 & 3). In the surface waters majority

of stations along 13.5°N transect, the DO varied from 4.5 to 4.8 mL.L⁻¹, being invariantly above 4 mL.L⁻¹ in the upper 75 m water column. But, it sharply decreased to 0.2 and 0.05 mL.L⁻¹ in the 150-650 m layer at the northernmost transect (Stns. 8, 9 & 10) causing an intense oxygen depletion (Fig. 3).

Species composition

The samples comprised 9 species of myctophids and 8 of pelagic shrimps representing 7 genera of

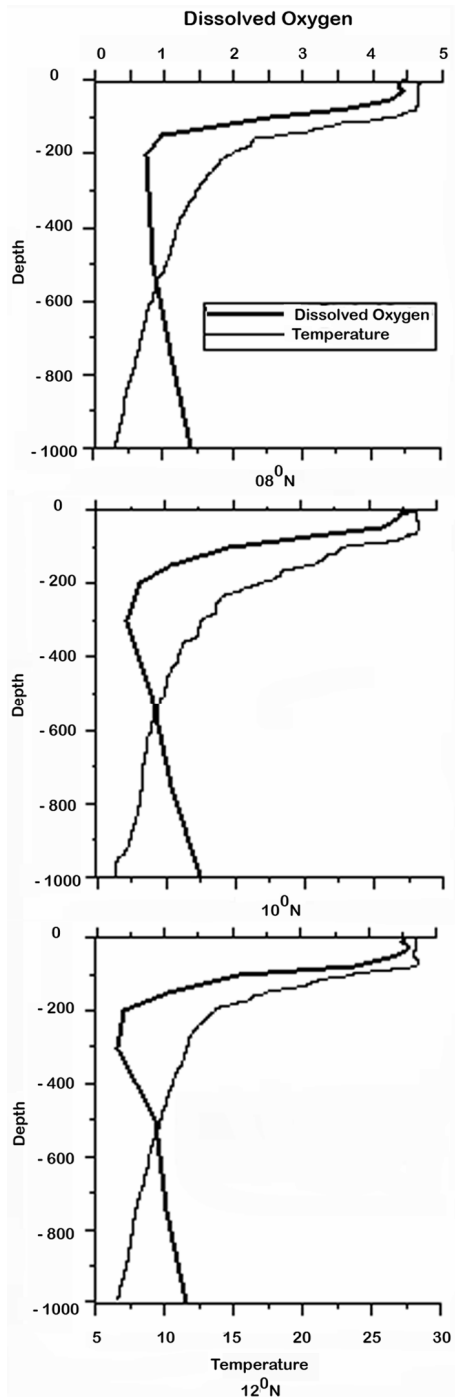


Fig. 2—Vertical profile of average dissolved oxygen (mL. L⁻¹) and Temperature (°C) along 08, 10 and 12°N Transects.

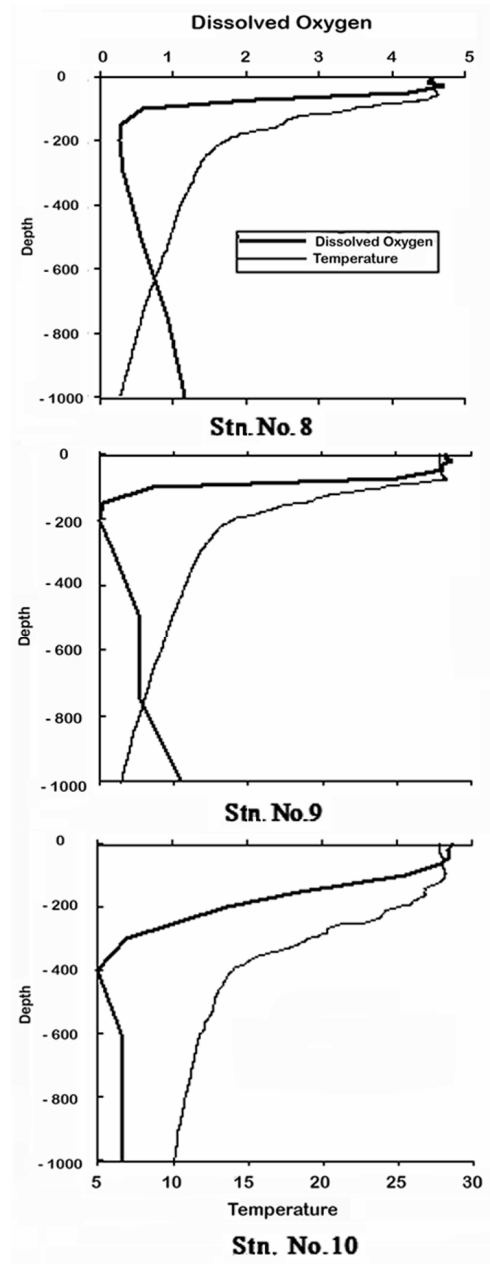


Fig. 3—Vertical profile of dissolved oxygen (mL. L⁻¹) and Temperature (°C) along 13.5°N Transects.

4 families. Out of the 17 species, 7 occurred both in day and night samples, 7 only in daytime and 3 at the night. The dominant species exhibited clear depth zonation. The distribution of each species during day

and night is given in Fig. 4. Vertical distribution of myctophid and pelagic shrimps showed maximum concentration during day in the 150-650 m layers, which included the lower interface of the OMZ.

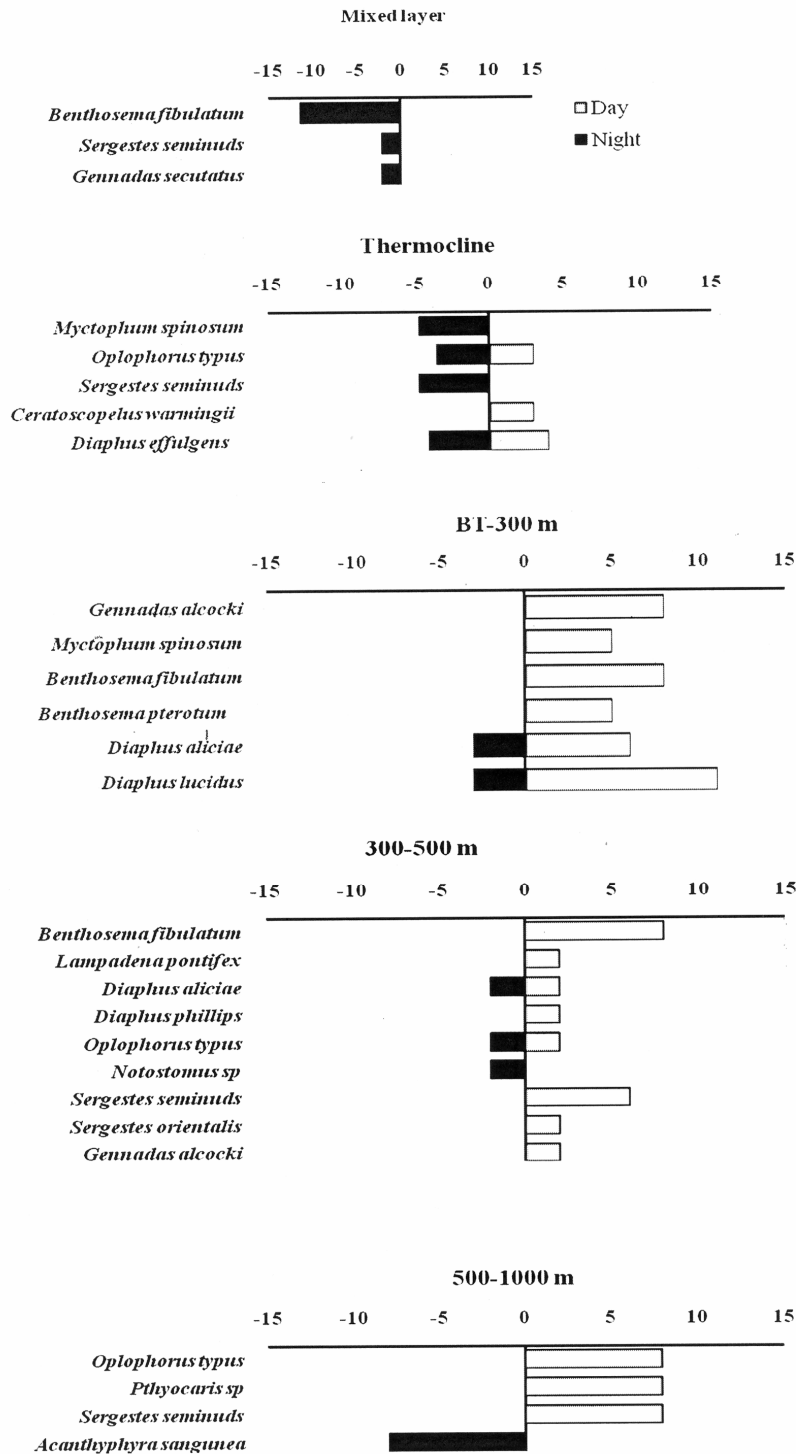


Fig. 4—Depthwise distribution of myctophid and shrimp species (No/100 m³) during day and night.

According to the day and night difference, the total myctophid population was recorded more at day depths [$56/100\text{m}^3$] than the night depths [$28/100\text{m}^3$]. *Benthoosema pterotum* [$13/100\text{m}^3$] showed maximum at day and *Benthoosema fibulatum* was at night [$11/100\text{m}^3$]. The total shrimps showed the maximum population at daytime [$28/100\text{m}^3$] while compared to night [$21.7/100\text{m}^3$]. *Gennadas alcocki* [$10/100\text{m}^3$] displayed more biomass at daytime and *Sergestes seminudus* that showed high biomass at night [$6.7/100\text{m}^3$]. During nighttime the species diversity ($H'=1.379$) was higher in the depth range of MLD-BT and richness ($d=0.697$) was higher in the depth of 0-MLD. Whereas the species diversity ($H'=2.041$) and richness ($d=1.334$) were higher in the deeper waters of 300-500 m during daytime (Table 1).

Myctophids

The family Myctophidae was represented by nine species. *Benthoosema fibulatum* [$11.3/100\text{m}^3$] was present in the mixed layer and *Myctophum spinosum* [$4.7/100\text{m}^3$] in the thermocline layer only in nocturnal samplings. *Ceratoscopelus warmingii* [$3/100\text{m}^3$] was present only at daytime and *Diaphus effulgens* [each $4/100\text{m}^3$] was present both during the day and the night in the thermocline layer. *B. fibulatum* [$8/100\text{m}^3$], *B. pterotum* [$5/100\text{m}^3$] and *M. spinosum* [$5/100\text{m}^3$] were found during day at BT-300 m depth. *D. aliciae* and *D. lucidus* were caught during both the day and the night at BT-300m. *Lampadena pontifex* [$4/100\text{m}^3$], and *D. phillipsi* [$2/100\text{m}^3$] on the other hand, were caught only during day at 300-500 m. *D. aliciae* [$4/100\text{m}^3$] occurred at 300-500 m in both day and night samples. *D. aliciae*, *D. lucidus*, *D. phillipsi* were present only at low oxygen mid-depths (150-650 m). Below 500 m depths, they were not present in both day and night samples.

Table 1—The species diversity and richness of during the winter monsoon seasons.

Depth range (m)	Night		Day	
	Diversity index (H')	Richness index (d)	Diversity (H')	Richness index (d)
0-MLD	0.9864	0.697	—	—
MLD-BT	1.379	0.5835	—	—
BT-300	—	—	—	—
300-500	1.04	0.4564	2.041	1.334
500-1000	—	—	1.099	0.6293

— The sample has not taken

Pelagic shrimps

A total of 8 species of pelagic shrimps were reported in samples. Their distribution and diel vertical migration were reported over a great extent, limited to a relatively narrow depth strata. Among these, only the sergestoid shrimp, *Sergestes seminudus* can be considered as a strong vertical migrator because it was collected from all depths (0-1000 m) except BT-300m. *Gennadas scutatus* was found only in the upper mixed layer at night [$2/100\text{m}^3$] as well as *G. alcocki* and *S. orientalis* at 300-500 m [$2/100\text{m}^3$]. The caridean species were found to segregate at different depths in the water column. At TT-BT depth range, only *Oplophorus typus* occurred in modest numbers at night [$3.5/100\text{m}^3$]. *Acanthyphra sangunea* was recorded in low numbers below 500 m depth at night [$3.5/100\text{m}^3$]. The other species encountered were *Notostomus* sp, *Pthyocaris* sp and *Sergestes orientalis*.

Myctophid and pelagic shrimps are one of the major components in pelagic community and form an important link between zooplankton and higher trophic level. Seventeen species were recognized in the upper 1000 m water column of the Andaman Sea during the winter monsoon season: nine species of myctophids and eight species of shrimps. The assemblages of these species plays a major role in the diet of oceanic tunas¹⁵. One behavioral characteristic of the majority of mesopelagic fish species is their nocturnal vertical migration, from daytime depths below 500 m into the more productive surface layers at night^{16,17}.

The DO concentration in the Andaman Sea during the winter monsoon decreased sharply to the suboxic level at 300-650 m depth range. Since long, it has been known that oxygen is not distributed uniformly in the oceans¹⁸. The Arabian Sea has been recognized as a region of intense O₂ deficient zone. The mid depth O₂ deficiency in the Arabian Sea is perhaps the most significant in the world oceans, as the concentration within 150-1000 m is less than 0.2 mL.L⁻¹ in a vast central and northeastern area¹⁹. Significantly, the Arabian Sea contains huge stocks of (~100 million tons) of myctophids²⁰, which are specially adapted to low (<0.1 mL.L⁻¹) ambient O₂ levels²¹.

The OMZ appears to be an important factor influencing the vertical distribution of myctophids and pelagic shrimps in the Andaman Sea. Most of the species showed a primary maximum within the OMZ (150-650 m). Some species like *Benthoosema*

pterotum, *Diaphus aliciae*, *D.lucidus*, *D.phillipsi*, *Lampadena pontifex*, *Gennadas alcocki*, *Notostomus* sp, *Sergestes orientalis* occurred mostly within the OMZ. In the entire region studied, myctophids and pelagic shrimps were most abundant in the mesopelagic oxygen minimum zone. Tsarin²² and Boltacher (2006) recently recorded 16 species of myctophid in the oxygen minimum zone of Northern Arabian Sea.

The Joint Global Ocean Flux²³ study showed a strong relationship between the distribution of organisms and the oxygen profiles in the Arabian Sea, especially in locations where the OMZ was pronounced. Anyway, the biological response to the OMZ varied with the type of organisms^{3&23}. Morrison *et al*³. also observed high biomasses of diel vertical migrators moving upwards to the surface waters at night and downwards to the suboxic waters during daytime.

The OMZ occupied a larger geographical extent in the Indian EEZ during winter, indicating the maximum horizontal shift²⁴. The "suboxic" layer is an important biological boundary where the oxygen apparently becomes physiologically limiting for several bacterial species, causing a shift from oxygen respiration to nitrate reduction and denitrification²⁵. Micronekton is constituted by a group of species of well known nocturnal vertical migratory habit. Besides light intensity, these vertical migrations may be closely related to the food habits and trophic relationship in these species. As a consequence, migration may occur in order to maintain the populations in areas of maximum prey availability²⁶. Myctophids are capable of crossing density gradients such as thermocline and halocline and both of which normally shows a mixing for different physical processes. By migrating vertically to the surface waters, they often represent an important source of forage for commercial fishes²⁷.

In the present study it was observed that only shrimps occurred at the depth range of 500-1000 m. The rates of oxygen consumption decline rapidly with depth in deeper living pelagic crustaceans, but the composition of these organisms varies as a function of depth^{28&29}. Omori³⁰ stated that the distribution of many pelagic shrimps are uneven and patchy and probably shoaling might occur as a result of intraspecific interaction in these shrimps, through its mechanisms and functions are not well understood. Although the present study has highlighted the major

micronektonic groups such as myctophid and pelagic shrimps within the OMZ in the Andaman Sea during the winter monsoon season, the mechanism involved and the physiological adaptation have not been studied. This would require detailed *in-situ* and *in-vitro* investigations so that the importance of the OMZ and its potential productivity in the mesopelagic depth zones in the Andaman Sea can be well understood.

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