*Indian J. Fish., 44(2) : 141-154, Apr.-Jun., 1997*

# Zooplankton abundance and secondary production in the seas around Andaman-Nicobar Islands

GEETHA ANTONY, K. N. KURUP, T. S. NAOMI, K. SOLOMAN AND K. J. MATHEW

*Central Marine Fisheries Research Institute, Cochin - 682 014, India*

ABSTRACT

Areas of remarkably higher concentrations of zooplankton standing stock were encountered in the northeastern (12°46'-13° 30 N and 93°03'-93°35' E) and southern (08°30'-09°30'N and 92°00'-92°41'E) regions the Andaman and Nicobar seas. The NE monsoon (October-January) was the most productive season followed by the premonsoon (February-May). The zooplankton population occurred in high abundance when the surface waters were characterised by low temperature and salinity. Occurrence of eggs and larvae of finfishes, pelagic tunicates, euphausiids, copepods, amphipods, foraminifers and lucifers in profusion accounted for the NE monsoon maximum. SW monsoon (June-September) was the least productive season. Monthly variations displayed high standing stock during November-February period and low during April-October with slight improvements in May-June and August-September. A comparison made on the standing stock of the southern and northern regions with respect to 10°N revelaed a rich population in the less saline waters north of 10°N to the west and east of islands contributing to the overall abundance of almost all the groups especially of the fish eggs and larvae, larval decapods, larvae of molluscs and mysids. The difference in biomass observed with reference to 93°E to the east and west was conspicuous such that the lowest 45.97 ml occurred in the eastern Bay of Bengal and the highest 54.44 ml in the western Andaman sea. Greater proliferation of zooplankton fauna encountered in the southwest, southeast and northwest regions of the island system during the NE monsoon was followed by the premonsoon maximum in the northeastern region. The neretic areas upto 50 m depth showed poor abundance, however, the 50-100 m depth zone was singularly rich recording further steady decline with increasing depth.

The average values of secondary production estimated for the entire area of investigation was 4.8 gC/m$^2$/yr. The peak period of the zooplankton population in the northern and southern sectors coincided with the maximum landings of the pelagic fishery resources of the Andaman-Nicobar Islands.

## Introduction

Out of the two million sq.km of the EEZ of India, about 0.6 million (30 %) lies around Andaman and Nicobar Islands (CMFRI, 1987X The exploitable fishery resources of the EEZ surround ing these islands estimated from the exploratory surveys show an average potential production between 50,000 and 1,60,000 per annum of which the tunas account for 1,00,000 t (James, 1989). However, the present rate of exploitation shows an annual production of only 26,1201 in 1995 (NMLRDC-CMFRI). The major contributors to the fishery are the planktivorous sardines, *Stolephorus* spp., mackerels, silverbellies, carangids and the young perches. The forage fish, *Spratelloides delicatulus* have their spawning and feeding grounds in these waters (Gopakumar *et al.,* 1990).

It may be seen that despite the economic importance of the Andaman and Nicobar waters detailed investigations on the secondary producers covering the different seasons are far from complete. Rangarajan and Marichamy (1972) highlighted the seasonal changes occurring in the zooplankton standing stock off Port Blair during 1964-70 and Marichamy (1983) on the zooplankton of the nearshore waters of the Andaman sea during February-April. Recently Mathew *et al.* (1990 a) estimated the zooplankton abundance and secondary production of the seas around Andaman and Nicobar Islands based on a random collection from 83 stations. The present paper incorporates the investigations conducted on the zooplankton population of the seas around the Andaman-Nicobar Islands from April 1988 to May 1990 covering a total of 249 stations during the 12 cruises ofFORV *Sagar Sampada.* Special emphasis has been laid on the seasonality in relation to hydrographical parameters and the fishery resources of the Andaman and Nicobar Islands.

## Material and methods

Zooplankton samples were collected by oblique hauls using Bongo 60 (mesh aperture 0.505 urn) fitted with a calibrated flowmeter. Aliquots were analysed whenever the biomass determined by displacement volume exceeded 5 ml. The average volume and the number of specimens present in 1000 $m^3$ of water were estimated per half a degree square area.

The abundance of the biomass and the faunal content of the northern waters around the Andaman group of islands (10°00' - 14°30'N) are compared with that of the southern waters around the Nicobar group of islands (06°00'-10°00'N). The variations observed in the western side (90°30'-93°00' E) of the islands are compared with those of the eastern side (93°01' - 95°00' E). The three seasons namely, premonsoon (February-May), southwest monsoon (June-September) and northeast monsoon (October-January) are identified for the purpose of comparison bet-ween the seasons. Fig. 1 shows the sa-mpling frequency of zooplankton in each half degree square area. Contour map of the biomass was produced by kriging (SURFER Version 4.14) and is shown in Fig. 2. Two-way ANOVA was attempted to ascertain the variations of the mean values of biomass over areas, seasons and different depth zones and are given in Table 1. The four depth zones identified were 50 m (Depth 1), 50-100 m (Depth 2), 100-200 m (Depth 3) and more than 200 m (Depth 4). Mean values of temperature, salinity and dissolved oxygen of the water column upto 50 m depth zone of the stations sampled are compared with the changes observed in the zooplankton population and discussed.

## Results and discussion

### *Biomass*

The average zooplankton biomass

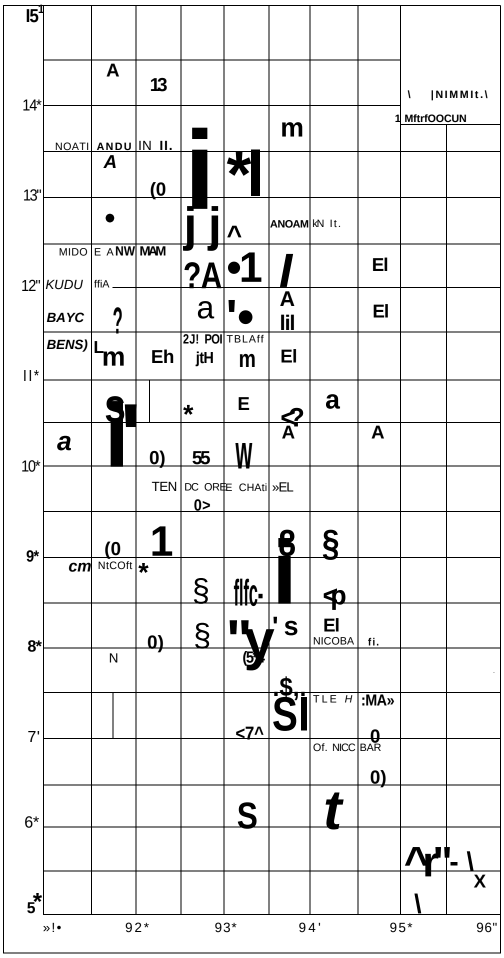

Fig. 1. Map showing the location of stations. A - Premonsoon; • - Southwest monsoon andO- Northeast monsoon. The number inside symbols indicates the season wise frequency of sampling per half a degree square area.

estimated in the seas around Andaman and Nicobar islands during the present study was low (49.7 ml) when compared to that observed for the shelf waters of the northeast (105.5 ml) Mathew *et al.* (1996 a) and the southeast (87.3 ml) coasts of India (Mathew *et al.*, MS.). The narrow continental shelf with limited mixing characterised by the prevalence of stable stratification (Mathew and Pillai, 1990) and the low primary production (Nair and Pillai, 1972) encountered in the ambient waters of the island region might have caused the less abundance of zooplankton as found in the earlier reports (Mathew *et al.,* 1990 a) and in the present study. Nevertheless, patches of high standing crop were recorded identical to those delineated from the east coast of Andamans (IOBC, 1968, Marichamy, 1983) and the west of Nicobar Island (Tsuruta, 1963).

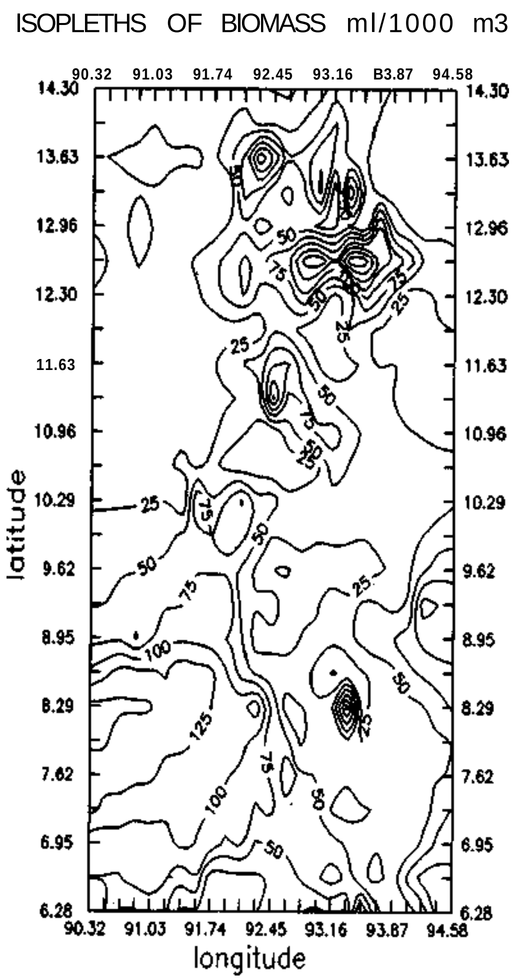


**Fig. 2. Isopleths of biomass: m]/1000m$^3$.**

TABLE 1. *Analysis of variance : Biomass by latitude and depth*

| Sources of variation | Sum of squares | DF | Mean square | F | Significance of F |
|---|---|---|---|---|---|
| Main effects | 51350.395 | 4 | 12837.599 | 4.834 | 0.001 |
| Latitude | 1389.479 | 1 | 1389.479 | 0.523 | 0.470 |
| Depth | 51340.486 | 3 | 17113.495 | 6.445 | 0.000 |
| 2-way interactions | 9323.341 | 3 | 3107.780 | 1.170 | 0.322 |
| Latitude and Depth | 9323.341 | 3 | 3107.780 | 1.170 | 0.322 |
| Explained | 60673.736 | 7 | 8667.677 | 3.264 | 0.002 |
| Residual | 639975.937 | 241 | 2655.502 | | |
| Total | 700649.673 | 248 | 2825.200 | | |

Isopleths of biomass (Fig. 2) show that areas remarkable for higher concentrations were confined to the northeastern (12°46'-13° 30'N and 93°03' - 93°35' E) and southern (8°30'-09°30' N and 92°00-92° 41'E) regions of the island ecosystem. The primary productivity studies conducted by Nair and Pillai (1972) and Nair and Gopinathan (1983) in different coastal stations corroborate the above mentioned areas as highly productive. The mangrove swamps of several places situated to the east of Andamans exhibit high rates of primary production which in turn support a host of detritus feeding zooplankters (Gopinathan and Rajagopalan, 1983). Particulate carbon, coral mucus and zooxanthellae occurring in the northeast coast of Andamans contribute significantly to the reef productivity in these waters and aid as a source of food to zooplankton (Pillai, 1983). Besides, Andaman sea is known to sustain a rich population of dinoflagellates and many of them are capable of utilising remarkably low inorganic nutrient levels (Taylor, 1973). Their importance as primary producers has long been recognised off little Andamans (Devassy and Bhattathiri, 1981) and near Nicobar Island (Zernova, 1962). All these factors may have a major role in favouring the growth of a rich population of secondary producers in the northeastern region.

### *Monthly variations*

Monthly variations as depicted in Fig. 3 revealed a high standing stock of zooplankton in the Andaman-Nicobar waters during the November-February period but it was considerably low during April-October with slight variations in May-June and August-September. The values fluctuated from 70-79 ml in December to 100.72 ml, the highest observed in February. The

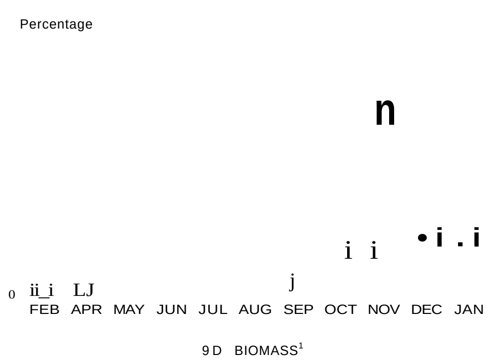


Fig. 3. Monthly variations of biomass.

zooplankters occurred in abundance when the surface waters were characterised by low temperature and salinity as observed during November-February period. The temperature varied from 28.09° C in November to 26.87°C in February and the salinity from 32.81 to 32.36 ppt. during the same period. During April-October the corresponding values fluctuated between 28.38°C in April and 27.80°C in July, and 34.04 ppt. in April and 33.07 ppt. in October. It is likely that the stratification and limited mixing in the water column as reported by earlier workers would have contributed to the narrow changes in the hydrographical parameters. Marichamy (1983) also indicated low abundance of zooplankton in places where the temperature and salinity were relatively high.

***Seasonal variations***

The southwest monsoon was observed to be the least productive season when the estimated average biomass denoted only 39.92 ml (Fig. 4). It was 56.51 ml in the northeast monsoon and 58.27 ml in the premonsoon season. It is highly significant to note that the reports on the seasonal changes of the productivity and other trophic components of the island system in general showed enrichment of coastal zone with high chlorophyll values (Krey and Babenard, 1976), proliferation of the dinoflagellate flora (Taylor 1973) and an increasing trend of the secondary producers (Rangarajan and Marichamy, 1972) during or immediately after the onset of the northeast monsoon.

PM SW NE WEST EAST DEP-1 DEP-2 DEP-3 DEP-4

LD BIOMASS

Fig. 4. Distribution of biomass in different seasons, areas and depth zones.

***Depth-wise distribution***

It was evident that the 50-100 m depth zone was the most populated in these waters with 43.5 % of total zooplankton (Fig. 4). The zooplankton biomass was poor in the shallow neritic areas upto 50 m where silting and turbidity were reported (Pillai, 1983) to be the major limiting factors to a variety of fauna. In the area beyond 100 m depth zone also low standing stock was observed where oceanic conditions prevail due to the narrow continental shelf around the islands. The statistical analyses (Tables 1 & 2) show that there is significant interaction between the mean values of biomass and depth zones (p=0.002). Evidence of significant difference in the mean values over seasons and different zones are indicated by the results in Table 2 (p=0.000).

***Latitudinal abundance***

A comparison was made on the standing stock of the southern and northern regions with respect to 10°N and to the west and east of 93°E in the eastern Bay of Bengal and the western Andaman sea (Figs. 5 & 6). It was found that practically there was not much variation in abundance south of 10°N (06°-10°N) between the west or east of 93°E where the biomass fluctuated between 49.34 and 49.81 ml respectively. On the contrary, the difference

TABLE 2. *Biomass by season and depth*

| Sources of variation | Sum of squares | DF | Mean square | | Significance of F |
|---|---|---|---|---|---|
| Main effects | 65175.626 | 5 | 13035.125 | 5.097 | 0.000 |
| Season | 15214.710 | 2 | 7607.355 | 2.974 | 0.053 |
| Depth | 46766.727 | 3 | 15588.909 | 6.095 | 0.001 |
| 2-way interactions | 26762.800 | 5 | 5352.560 | 2.093 | 0.067 |
| Season and Depth | 26762.800 | 5 | 5352.560 | 2.093 | 0.067 |
| Explained | 91938.426 | 10 | 9193.843 | 3.595 | 0.000 |
| Residual | 608711.247 | 238 | 2557.610 | | |
| Total | 700549.673 | 238 | 2825.200 | | |

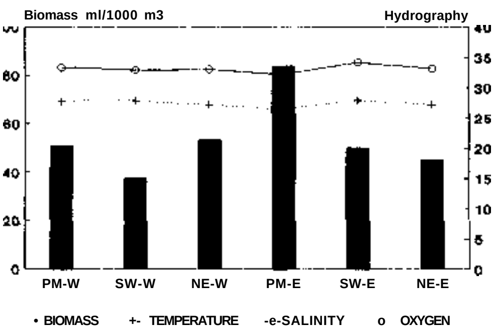


Fig. 5. Area-wise seasonal distribution of biomass in the north in relation to hydrography. (Biomass: ml/1000 $m^3$; Temperature : °C; Salinity : ppt; Oxygen : ml/1).

observed in the standing stock was highly conspicuous north of 10°N (10°-14°30'N) such that the lowest 45.97 ml occurred in the eastern Bay of Bengal while the highest 54.44 ml in the western Andaman sea. The overall abundance was 0.64 % less in the southern region south of 10°N where the mean surface temperature (28.40°C), salinity (33.55 ppt) and dissolved oxygen (4.03 ml/1) registered comparatively higher values when compared to those of the waters north of 10°N (27.58°C, 33.01 ppt, 4.19 ml/1). The faunal content of the western Andaman's Sea on the east was 5.58 % higher than that of the waters of the eastern Bay of Bengal on the west coast of the Island (Fig. 4). These observations confirm the earlier findings of Mathew *et al.* (1990 a). They reported equal values of secondary production to the east and west of 93°E. in the south of 10°N. and the highest values in the eastern side and the lowest on the western side of the Andaman-Nicobar Islands. It may be noted that Murty *et al.* (1981) have concluded that the waters of the eastern Andaman Island especially on the northern side were different from those of the western side due to the prevaleance of

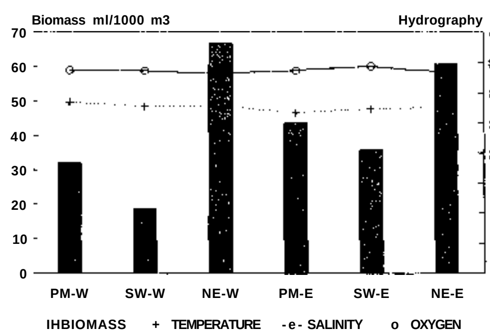


Fig. 6. Area-wise seasonal distribution of biomass in the south in relation to hydrography. (Biomass: ml/1000 $m^3$; Temperature : °C; Salinity : ppt; Oxygen : ml/1).

a mixed water column and deeper thermocline.

Regionwise seasonal distribution as depicted in Figs. 5 & 6 towards the north and south of 10°N clearly demonstrated the northeast monsoon maximum in the northwestern (53.25 ml) and southern areas of the Islands but far more intense in the southwest (66.60 ml) and southeast (66.86 ml) of 93°E. As the southern parts of the Andaman Sea areas are of intense air-sea interactions (Ramaraju *et al.,* 1981) the higher values of zooplankton encountered during the northeast monsoon may be due to the wind generated, upwelling as a result of storm surge activities (Pant, 1992) and the subsequent biological interactions. Furthermore, it is interesting to note that the increasing trend coincided with values of moderate salinity 33.12-33.31 ppt and the mean temperature 27.66-27.75°C with less fluctuations in the respective areas.

In the eastern part of the Andaman Islands the biomass was the lowest (45.18 ml) during the northeast monsoon. This area is well known for freshwater influx from the rivers of India and Myanmar. The peak abundance was in the premonsoon(83.62 ml) (Figs. 5 & 6) months of January-February when decreased rainfall, stable environment, low salinity (32.14 ppt) and temperature (26.44°C) favoured the growth and proliferation of the zooplankters. It may be noted that the only area where upwelling, though weak, reported is on the northeastern region of the Andaman ea (Wyrtki, 1973). In general, it may be stated that the higher concentration of zooplankton encountered in the southwest, southeast and northwest regions of the islands during the northeast monsoon was followed by the premonsoon maximum in the northeast region. But the standing stock was considerably reduced during the southwest monsoon throughout the area of investigation (Figs. 5 & 6). The southern areas are characterised by warmer and more saline waters all through the year except during the southwest monsoon. According to Ganapathy (1973) nutrient enhancement of the offshore waters of the Bay of Bengal occurs during January-February when the prevailing current is northerly bringing in the nutrient rich Indian equatorial waters enriched by the Antarctic bottom waters.

***Faunal composition***

The variations in the numerical abundance of the zooplankton populations of the island ecosystem observed during the different months, seasons, latitudes and depths are depicted in Figs. 7 to 15. Copepods formed the most dominant group contributing to 68.72 % of the total. The percentage compositions of the rest of the groups are as follows: chaetognaths 7.8, pelagic tunicates 3.9, siphonophores and euphausiids 3.7 each, larval decapods and planktonic molluscs 2.8 and 2.4 respectively, foraminifers 1.7, ostracods

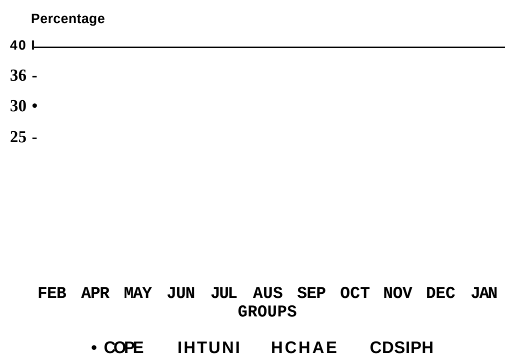


**Fig. 7. Monthly variations of different groups.**

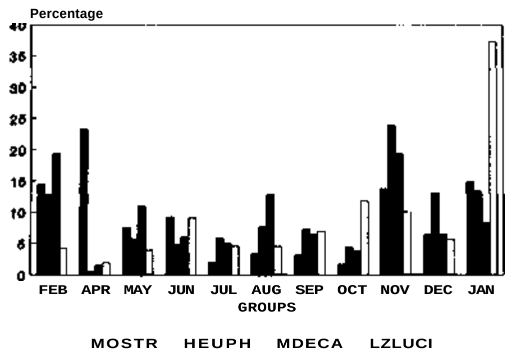


Fig. 8. Monthly variations of different groups.

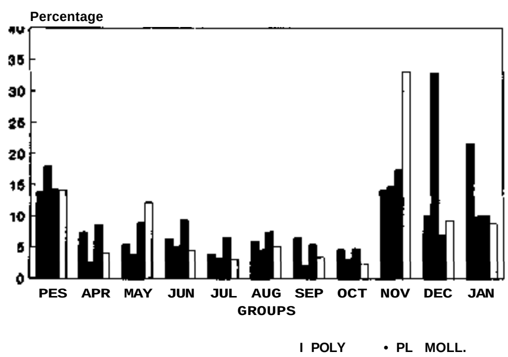


Fig. 9. Monthly variations of different groups.

1.5, lucifers 1.1, amphipods, fish eggs and larvae of finfishes and mysids 0.7 each respectively, larval polychaetes 0.5, medusae 0.3, phyllosoma, ctenophores, cephalopods, stomatopods and cladocerans together 0.2 of the total plankters.

The general pattern of occurrence showed that almost all the major groups and larval forms exhibited peak abundance during November-February (Figs. 7-10). The numerical abundance of pelagic tunicates, euphausiids, siphonophores, mysids, planktonic molluscs, larval polychaetes and the eggs and larvae of finfishes was the highest in November, while that of foraminifers in December, copepods, chaetognaths, lucifers and amphipods in January and the larval decapods and the miscellaneous groups in February. Ostracods displayed maximum proliferation in April and the medusae in June.

Seasonal distribution of the zooplankton groups for the entire area of investigation as depicted in Fig. 11 revealed a northeast monsoon (October-

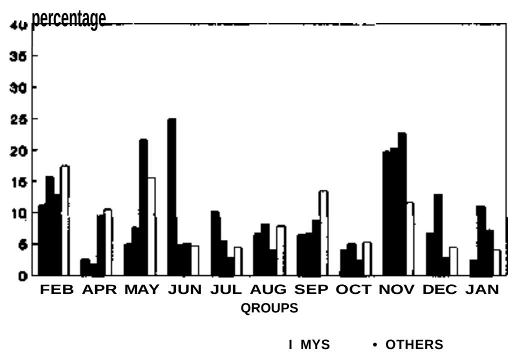


Fig. 10. Monthly variations of different groups,

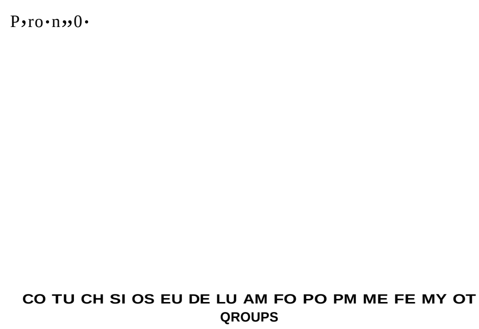


Fig. 11. Seasonal variations of different groups.

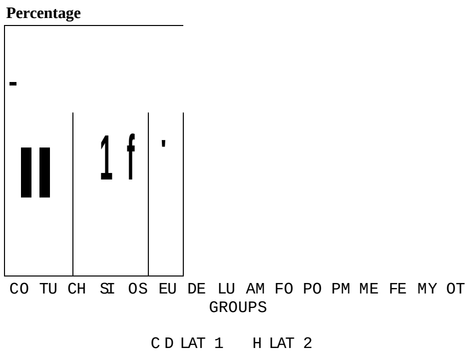


**Fig. 12. Latitudinal distribution of zooplankton.**

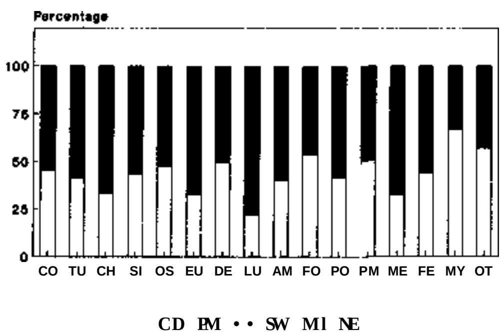


Fig. 13. Seasonal variations in the north (Lat. 1).

January) maximum attained by lucifers, foraminifers, amphipods, pelagic tunicates, euphausiids fish eggs and fish larvae while the rest of the population composed of copepods, mysids, ostracods, planktonic molluscs, larval decapods, chaetognaths, siphonophores and larval polychaetes in the premonsoon (February-May). Cladocerans, cephalopods, phyllosoma and stomatopod larvae were also in considerable numbers during this season. The southwest monsoon (June-September) maximum was shown by the single component medusae. It is significant to note that the northeast monsoon maximum exhibited by the different groups and larval forms of the zooplankton community bears close resemblance to that reported for the northwestern part of the Bay of Bengal (Mathew *et al*, 1996).

Majority of the groups resided in the comparatively cooler, less saline waters (26.4-27.8°C, 32.14-34.14 ppt) north of 10°N on the west and east of the islands (Fig. 12). The mean number of larval decapods, planktonic molluscs and mysids was remarkably high in the northern waters apart from the other common constituents. Similar observations of high concentrations of mysids (Mathew *et al.,* 1990 b), euphausiids (Mathew *et al.,* 1990 c) and larval molluscs (Antony *et al.,* 1990) are reported by earlier workers for the northern part of the islands. Lucifers, chaeto-gnaths and foraminiferans were highly conspicuous in the warmer more saline (26.7-28.4°C, 33.12-34.32 ppt) southern waters south of 10°N.

All those constituents of the zooplankton community which showed an affinity for the northern waters (Fig. 12) occurred in maximum in the premonsoon season (Figs. 13 & 14) when the environmental conditions became more stable. High concentration of copepods in the island waters was observed in the premonsoon by Pillai (1990). Cladocera appeared in appreciable numbers though the group was reported to be of poor abundance in the area by Naomi *et al.* (1990). The other plankters namely chaetognaths, euphausiids and lucifers proliferated in the northern waters during the northeast monsoon. According to Srinivasan (1990) the high population density of chaetognaths encountered in the north-

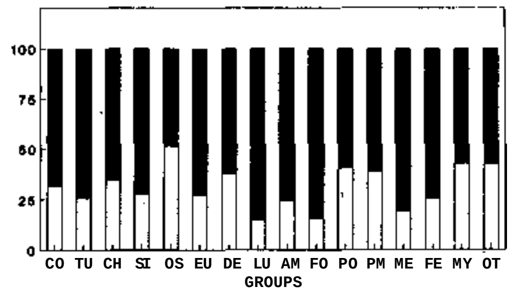


Fig. 14. Seasonal variations in the south (Lat. 2).

east monsoon might be the result of the free mixing of the waters between Indian Ocean and the Pacific Ocean.

In the southern waters predominance ofa few groups in the premonsoon was caused by chaeto-gnaths, ostracods, polychaetes and mysids (Fig. 14) while the major constituents appeared in large numbers during the northeast monsoon. Whether it is in the north or in the south, the abundance of zooplankton observed was low in the southwest monsoon except medusae. In the north the peak encountered in the Bay of Bengal was in the northeast monsoon and in the western Andaman sea it was in the premonsoon. Moreover, the Andaman-Nicobar Islands receive rainfall for a period of nine months and the yearly cycle of northeast and southwest monsoonal wind systems reversing the surface currents of the Bay of Bengal and the Andaman sea along with the intervening transitional period have a profound bearing over the zooplankton abundance in different regions around the island system. Besides, the northeast Andaman receives heavy freshwater influx from the rivers of India and Myanmar. All these and the strong convergence noticed in the Andaman Sea during northeast monsoon (Prasad, 1969), the high chlorophyll content and productivity values observed in the eastern Andamans (Nair and Gopinathan, 1983), and near Nicobar Islands during November-April (Krey and Barnard, 1976) in association with the presence of a rich dinoflagellate population during and immediately after the northeast monsoon (Movachan, 1973) are presumed to be the causative factors for the large concentrations of zooplankton in the respective seasons.

The variations of the zooplankton in the different depth zones (Fig. 15) revealed that the pelagic tunicates, especially appendicularians, siphonophores, molluscan larvae, pteropods, heteropods, fish eggs, cladocerans and young cephalopods displayed a higher percentage in the shallow depth zone upto 50 m. The remaining groups including decapod larvae, euphausiids, chaetognaths, copepods, amphipods, mysids, medusae, salps, doliolids, fish larvae, polychaetes, stomatopod and phyllosoma larvae appeared in greater numbers in the intervening zone of 50-100 m. Around 44 % of the luficers occurred in the deeper areas between

Percentage

CO TU CH SI OS EU DE LU AM FO PO PM ME FE MY OT
3HOUP8

I I I Depth 1 • Depth 2 H Depth 3 *C3* Depth 4

Fig. 15. Distribution of zooplankton in different depth zones.

100-200 m in the northeast monsoon and assemblages of ostracods, foraminifers and pyrosomae in the region beyond 200 m. Cladocerans, phyllosoma, stomatopods and cephalopods were present in the different depth zones investigated. A discernible change observed was the presence of maximum number of fish larvae (706) in the 51-100 m depth zone while the eggs (926) in the shallow area.

***Secondary production***

The secondary production was estimated following the method suggested by Dalai and Parulekar (1986). The average production computed for the entire area of investigation was 4.8 gC/$m^2$/yr almost equivalent to that of the north western Bay of Bengal (Mathew *et al.,* 1996). The estimated annual values fluctuated between 0.09 and 24.89 gC/$m^2$/yr at different times of the year. The northernmost region (12°31' - 14°30' N) was found to be more productive (5.62 gC/$m^2$/yr) than the southernmost region (06°30'-08°30'N) (3.64 gC/$m^2$/yr).

Andaman Sea is the most productive area for tuna and tuna like fisheries (FSI, 1993, 1995) and there are extensive trawling grounds on the eastern side. Trends in the exploratory and commercial fishing activities signify that the regions demarcated for high plankton production as observed in the present study are also areas known for their rich fishing grounds. The pelagic fishes such as sardines, anchovies, carangids, ribbon fishes and mackerels constitute a significant percentage of the catches. Shoals of mackerels migrating to the west from the east at the onset of northeast monsoon were reported earlier by Kumaran (1973). Sivakami (1990) and Nair and Reghu (1990) highlighted that the highest catch rate of demersal resources such as silverbellies, nemipterids, and perches was from the 51-100 m depth zone, the most populated water column of zooplankton abundance. Higher catches are reported in the northern sector during the 4th quarter of the year followed by 1st and 2nd quarters, whereas in the southern sector the 1st quarter delineates a highly significant level of exploitation (John, 1993). It is interesting to note that the major ecosystems of the tropical waters like estuaries, mangroves, fringing coral reefs, minor upwelling zones and coastal and oceanic areas are represented here making it a unique ecosystem and further investigations are of prime importance to assess and understand the potential production of the ambient waters around the Andaman-Nicobar Islands.

## Acknowledgements

The authors wish to express their sincere thanks to Dr. P.S.B.R. James, former Director, CMFRI, for his keen interest and constant encouragements. Thanks are also due to Shri T. V. Satyanandan and Shri M. B. Seynudheen of the Institute for the help rendered in the computer analysis of the data.

## References

Antony, G., T. S. Naomi and K. J. Mathew 1990. Studies on the occurrence and abundance of planktonic gastropods other than pteropods and heteropods from the EEZ of India and adjoining seas. In : *Proc. First Workshop Scient. Resul. FORV* Sagar Sampada, (Ed. K. J. Mathew, CMFRI, Cochin): 165-177.

CMFRI, 1987. An appraisal of the marine fisheries of Lakshadweep and Andaman and Nicobar Islands. *Spl. Publ.* No. 39, 18 pp.

Dalai, S. G. and A. H. Parulekar 1986. Validity of zooplankton biomass and energy equivalent in the Indian Ocean. *Indian J. Mar. Sci.,* 15 : 264-266.

Devassy, V. P. and P. M. Bhattathiri 1981. Distribution of phytoplankton and chlorophyll - a around Little Andaman Island. *Indian J. Mar. Sci.,* 10 : 248-252.

FSI 1993. Resource information series. *Resour. Infor. Ser.,* 3 (4 ) (Jan.-Mar. 1992).

FSI 1995. Chartered fishing vessels operations in the Indian EEZ as reported during the year 1993. No. 5, March.

Ganapati, P. N. 1973. Biological Oceanography of the Bay of Bengal. *Mahasagar, Bull. natl. Inst. Oceanogr.,* 6 (2) 84-94.

Gopakumar, G., C. S. Gopinadha Pillai and D. B. James 1990. The occurrence of live bait fish in south Andaman waters and its significance. *Mar. Fish. Infor. Serv., T&ESer.,* No. 105: July-Sept. 1990, 5-7.

Gopinathan C. P. and M. S. Rajagopalan 1983. Mangrove resources. In: *Mariculture Potential of Andaman and Nicobar Islands - an Indicative Survey. Bull. Cent. Mar. Fish. Res. Inst.* No. 34, KAlgarswami (Ed.), p. 44-46.

IOBC, 1968. Maps on total zooplankton biomass in the Arabian Sea and the Bay of Bengal. *International Indian Ocean Expedition Atlas,* l(i), N. K. Panikkar (Ed.). NIO/CSIR, New Delhi.

James, P.S.B.R. 1989. On the scope for marine fisheries research and development in the Andaman and Nicobar Islands. *Mar. Fish. Infor. Serv., T & E Ser.,* No. 102 : 1-4.

John, M. E. 1993. Density indices of yellowfin tuna in Indian seas as observed in long line surveys. In : *Tuna Research in India,* FSI, 1993, p. 63-75.

Krey, J and B. Babenard 1976. Phytoplankton production. Atlas of the International Indian Ocean Expedition. *Inst. Meer. Kiel. Univ.,* 1-70.

Kumaran, M. 1973. The fishery potential of Andaman and Nicobar Islands. *Proc. Symp. Living Res. Seas India., Spl. Publ.,* C.M.F.R.I., Cochin, p. 387-389.

Marichamy, R. 1983. Zooplankton production in coastal waters. In : *Mariculture Potential of Andaman and Nicobar Islands - an indicative Survey. Bull. Cent. Mar. Fish. Res. Inst.,* KAlgarswami, (Ed.), No. 34, p. 33-35.

Mathew, K. J., T. S. Naomi, Geetha Antony, D. Vincent, R. Anilkumar and K. Soloman 1990a. Studies on zooplankton biomass and secondary and tertiary production of the EEZ of India. In : *Proc. First Workshop Scient. Resul. FORV* Sagar Sampada, K. J. Mathew (Ed.) CMFRI, Cochin, p. 59-69.

Mathew K. J., Geetha Antony, T. S. Naomi and K. Soloman 1990 b. On the quantitative abundance of mysidacea collected from the eastern Arabian Sea and Bay of Bengal. In : *Proc. First Workshop Scient. Result. FORV* Sagar Sampada, K. J. Mathew (Ed.), CMFRI, Cochin, p. 109-114.

Mathew, K. J., T. S. Naomi, Geetha Antony and K. S. Scariah 1990 c. Distribution of euphausiacea in space and time in the Indian EEZ and contiguous seas. In : *Proc. First Workshop Scient. Resul. FORV* Sagar Sampada, K. J. Mathew (Ed.), CMFRI, Cochin, p. 121-127.

Mathew, K. J., K. N. Kurup, T. S. Naomi, Geetha Antony and K. Soloman 1996. Zooplankton abundance in the continental shelf waters of the northeast coast of India. In: *Proc. Second Workshop Scient. Resul. FORV* Sagar

Sampada, V. K. Pillai, S- A. H.Abidi, J. Ravindranathan, K. K. Balachandran and V. Agadi (Eds.), p. 257-269.

Mathew Laly and V. Narayana Pillai 1990. Chemical characteristics of the waters around Andamans during late winter. In : *Proc. First Workshop Scient. Resul. FORV* Sagar Sampada, K. J. Mathew (Ed.), CMFRI, Cochin, p. 15-18.

Movachan, O. A. 1973. Soviet fisheries investigations in the Indian Ocean. A. S. Bogdanov (Ed.) (translated from Russian) : *Israel Program for Scientific Translation, Jerusalem* 1973, 62 pp.

Murty, C. S, P. K. Das and A. D. Gouveia 1981 Some physical aspects of the surface waters around the Little Andaman Islands. *Indian J. Mar. ScL,* 10 : 221-227.

Nair, P. V. R. and C. S. G. Pillai 1972. Primary production of some coral reefs in the Indian seas. *Proc. Symp. Coral Reefs,* Mar. Biol. Ass. India, p. 33-42.

Nair, P. V. R. and C. P. Gopinathan 1983. Primary production in coastal waters. In : *Mariculture Potential of Andaman and Nicobar Islands - an Indicative Survey. Bull. Cent. Mar. Fish. Res. Inst,* No. 34, Algarswami, K (Ed.), p. 29-32.

Nair, Somasekharan, K. V. and R. Reghu 1990. Studies on the threadfin bream and the lizard fish resources in the exclusive economic zone of India based on the demersal trawling operations of FORV *Sagar Sampada.* In: *Proc. First Workshop Scient. Resul. FORV* Sagar Sampada, K. J. Mathew (Ed.), CMFRI, Cochin, p. 239-255.

Naomi, T. S., Geetha Antony and K. J. Mathew 1990. Studies on the distribution of cladocera in the eastern Arabian Sea and the Bay of Bengal, In : *Proc. First Workshop Scient. Resul. FORV* Sagar Sampada, K. J. Mathew (Ed.), CMFRI, Cochin, p. 85-93.

NMLRDC-CMFRI. 1995. *National Marine Living Resources Data Centre of CMFRI,* Cochin - 14.

Pant Aditi 1992. Primary productivity in coastal and offshore waters of India during two southwest monsoon, 1987 and 1989. In: *Oceanography of the Indian Ocean,* B. N. Desai (Ed.), Oxford and IBH Publ. Co.

Pillai, C. S. G. 1983. Coral reefs and their environs. In : *Mariculture Potential of Andaman and Nicobar Islands.* - an Indicative Survey. *Bull Cent. Mar. Fish. Res. Inst.,* K. Algarswami (Ed.), p. 36-43.

Pillai, P. P. 1990. Heterogeneity in the distribution pattern of pelagic copepods collected on board *FORV Sagar Sampada,* in the Indian EEZ In : *Proc. First Workshop Scient. Resul. FORV* Sagar Sampada, K. J. Mathew (Ed.), CMFRI, Cochin, p. 95-108.

Prasad, R. R. 1969. Zooplankton biomass in the Arabian Sea and Bay of Bengal with a discussion on the fisheries of the region. *Proc. Natl. Inst. Sci. India,* No. 35 : 389-437.

Rama Raju, D. V., A. D. Gouveia and C. S. Murty 1981. Some physical characteristics of Andaman Sea waters during winter. *Indian J. Mar. Sci.,* 10 : 211-218.

Rangarajan, K and R. Marichamy 1972. Seasonal changes in the temperature, salinity and plankton volume at Port Blair, Andamans. *Indian. J. Fish.,* 19 : 60-69.

Sen Gupta, R., Caroline Moraes, M. D. George, T.W. Kureishy, R. J. Noronha and S. P. Fondekar 1981. Chemistry and hydrography of the Andaman Sea. *Indian J. Mar. Sci.,* 10 : 228-233.

Sivakami, S. 1990. Observations on the

demersal fishery resources of the coastal and deep sea area of the EEZ of India. In: *Proc. First Workshop Scient. Resul. FORV* Sagar Sampada K. J. Mathew (Ed.), CMFRI, Cochin, p. 215-235.

Sreenivasan, M. 1990. Studies on the quantitative distribution of chaetognatha from the Indian seas collected during the cruises 1-44 of FORV *Sagar Sampada.* In : *Proc. First Workshop Scient. Resul. FORV* Sagar Sampada, K. J. Mathew (Ed.), CMFRI, Cochin, p. 81-84.

Taylor, F. J. R. 1973. General features of dinoflagellate material collected by the "Anton Bruun" during the International Indian Ocean Expedition. In: *Ecological Studies* 3. *The Biology of the Indian Ocean,* Bernt Zetzschel (Ed.), p. 155-169.

Tsuruta, Arao 1963. Distribution of plankton and the characteristics in the oceanic fishing grounds with special reference to their relation to fishery. *J. Shimonoseki, Univ. Fish.,* 12 (1) : 13-214.

Wyrtki, K. 1973. Physical oceanography of the Indian Ocean. In: *Ecological Studies 3. The biology of the Indian Ocean,* Bernt Zeitzschel (Ed.), p. 18-36.

Zernova, V. U. 1962. Quantitative distribution of the phytoplankton in the northern Indian Ocean. *Trud. Inst. Okeanol,* 48 : 45-53.