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Zooplankton abundance in the continental shelf waters of the northeast coast of India

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ABSTRACT

Higher concentrations of zooplankton standing stock and population occurred in the region off Chilka lake and Paradip (19° 10'N-19° 55'N and 85°09'E-86° 50'E) during January and off Visakhapatnam (17°30'N- 18°28'N and 83°14'E- 84°29'E) during November and April. The most productive period along the northwestern part of the Bay of Bengal was the northeast monsoon season (October-January) followed by the premonsoon season (February-May). High abundance of copepods, chaetognaths, siphonophores, cladocerans, fish larvae, planktonic molluscs, amphipods, foraminifers and larval polychaetes constituted the northeast monsoon maximum. Very low biomass values were recorded during the southwest monsoon season (June-September). The neretic zone up to 50 m depth was rich in zooplankton population during northeast monsoon and further to a lesser extent up to 100 m during the premonsoon season. However, a steady decline was evident with increasing depth zones. The less saline northern part exhibited remarkable differences in the abundance of the population and standing stock in such a way that 63% of the total was confined to the northern region. Fish eggs were predominant during February-May and larvae in July and January-February. The peak period of the zooplankton population coincided with the maximum landings of the pelagic and demersal fishery resources of the northwestern coast of the Bay of Bengal.

INTRODUCTION

After the IIOE, investigations on the coastal zooplankton standing stock and population in relation to hydrographical parameters of the northwestern part of the Bay of Bengal were a few and far between. Nair *et al.* (1977,1981) and Achuthankutty *et al.* (1980) studied the zooplankton of the area during the southwest monsoon. Further, Pati (1980) and Vijayakumar & Sarma (1988) made observations for a period of one year. Recently the wealth of data collected by *FORV Sagar Sampada* during her random surveys in the EEZ and the contiguous seas of India from 1985 to 1988 yielded valuable information on plankton abundance, production and the potentials of different fishery resources (CMFRI, 1990). However, in subsequent years special emphasis was laid to study the importance of specific regions in the Bay of Bengal based on their overall productivity and estimates of fish catch. The northwestern shelf region of the Bay of Bengal (16°-20° N) is well-known for the rich harvest of demersal fishery resources like croakers, perches, catfish, elasmobranchs, prawns, etc. (Krishnamurthy, 1976) and recently of the pelagic resources like mackerels and sardines (CMFRI, 1995). Therefore, exclusive surveys were undertaken along the continental shelf of the northeast coast of India between April 1988 and February 1989 and the present paper incorporates the observations made on the pattern of abundance and seasonal fluctuations of zooplankton at different depth zones together with hydrography and appraises the abundance of the fishery of the region during the peak period of the secondary producers.

MATERIALS AND METHODS

Monthly samples of zooplankton were taken from a total of 99 stations covering an area of about 65000 km^2 along the northeast coast of India (Fig. 1). Zooplankton samples by oblique hauls were collected from an average depth of 200 m to the surface using Bongo 60 net (mesh aperture 0.33 mm) fitted with a calibrated flowmeter "Hydrobios". The biomass values by displacement volume and the numerical abundance of constituent groups and larval forms were estimated per 1000 m^3 of water filtered. The more saline southern part (16°- 18°N) of the study area is differentiated from the less saline northern part (18°- 20°N) as lat.1 and lat.2 respectively. The entire area from which the collections taken was divided into four depth zones (stations with less than 50 m as 1, 50 to 100 m as 2, 100 to 200 m as 3 and more than 200 as 4) for the purpose of comparison of the neretic from the deeper areas. 'Two-way ANOVA' was attempted to ascertain the significance of the difference of mean values of standing stock over seasons, latitudes and different depth zones. Contour map of biomass was produced by kriging (SURFER version 4.14, Golden Software Inc.).

RESULTS AND DISCUSSION

Biomass

Isopleths of biomass (Fig.2) show that there were regions of higher concentration in the northwestern part of the Bay of Bengal in the area off Chilka lake and Paradip (19°10'N-19°55'N and 85°09'E-86°50'E) and off Visakhapatnam (17°30'N-18°28'N and 83°14'E-84°29'E). The biomass value registered off Paradip in January was the highest (757.0 ml) while that occurred off Visakhapatnam during November and April was moderate (316-352 ml). In general, the observed mean value (105.5 ml) for the whole study area was higher than that of the earlier observation (Mathew *et al.* 1990a) for the same region.

The variations of mean biomass shown against season, latitude and depth zones (Fig.3) reveal that the most productive period is the northeast monsoon season

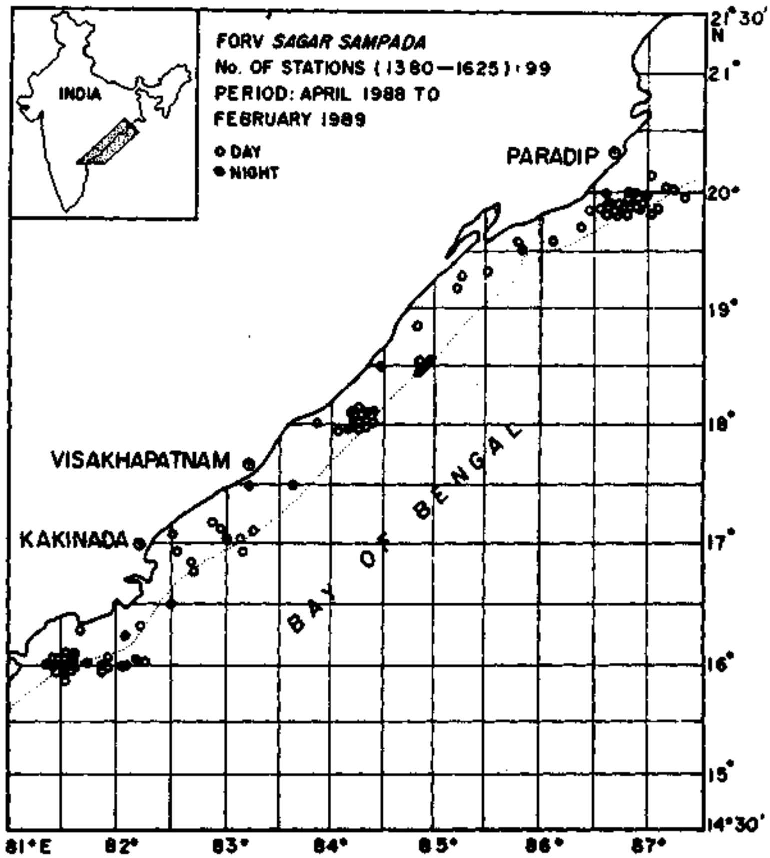

Fig. 1 — Map showing the location of sampling stations

followed by the premonsoon. The neretic zone up to 50 m depth was rich in zooplankton population and thereafter a steady decline was observed with the increasing depth. The more saline southern part (lat.1) and the less saline northern part (lat.2) exhibited remarkable differences in abundance of the population and standing stock in such a way that 63% of the total was confined to the northernmost region. The statistical analyses (Table 1) show that there is significant interaction between the season and depth (F=0.001) and that the mean values differ significantly in different depth zones over seasons (F=0.000). Similarly there is indication that significant variation of biomass occur in latitudes over the seasons (F=0.001).

It is generally acknowledged that high abundance of zooplankton population occur in the northwest coastal belt of the Bay of Bengal during the southwest monsoon and that there is comparatively low production in the following northeast monsoon. There are reports of coastal upwelling in the region off Waltair (Murty & Varadachari, 1968) and off Visakhapatnam (Rao, *et al.* 1986) during premonsoon and southwest monsoon, and a 40 km wide band of upwelling driven by local wind along the western

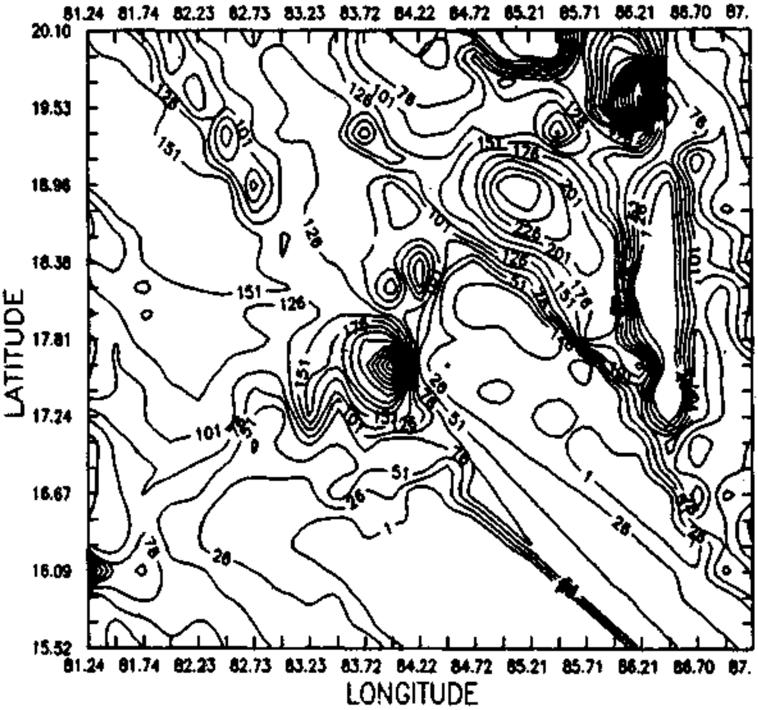

Fig. 2— Isopleths of biomass (ml/1000 m^3)

boundary of Bay of Bengal during July-August (Shetye *et al.* 1991).According to Sankaranarayanan & Reddy (1968) there is evidence of coastal upwelling in the northwestern Bay in January and all these point towards nutrient enrichment of the surface layers and the subsequent enhancement of phytoplankton production followed by zooplankton abundance. The average temperature and salinity of the water column recorded for the season were the lowest (27.20°C and 29.09$\times$ 10^{-3}) during the northeast monsoon when the highest mean (144.39 ml) biomass was observed. The freshwater influx and the high nutrient load towards the head of the Bay (Qasim, 1977) coupled with the southwesterly current and the prevailing wind pattern along with the effect of upwelling would have caused the gradual piling up of the standing crop in the coastal waters especially between the regions 18°N and 20°N. It may be noted that the biomass registered higher values towards the end of November and throughout January and the nutritional status of the predominant zooplankters encountered were either herbivores or filter feeders, though there were other carnivores and omnivores. The percentage contribution of the biomass during the premonsoon was 37.86 and that of the southwest monsoon 13.67. Vijayakumar & Sarma (1988) observed the peak in zooplankton biomass along the northwest coast during the northeast monsoon and low values in the southwest monsoon and attributed it to the

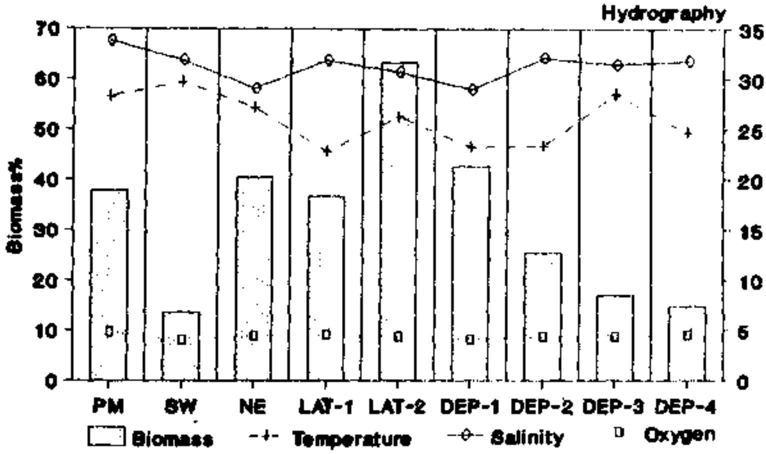

Fig. 3— Variations in biomass against season, latitude and depth

Table I— Analysis of variance

Source of variation	Sum of squares	DF	Mean square	F	Significance of F
			Biomass of season and depth		
Main effects	344375.223	5	68875.045	5.330	0.000
Season	179361.503	2	89680.751	6.941	0.002
Depth	163037.001	3	54345.667	4.206	0.008
2-way interactions	334568.649	6	55761.442	4.316	0.001
Season depth	334568.649	6	55761.442	4.316	0.001
Explained	678943.872	11	61722.170	4.777	0.000
Residual	1124134.298	87	12921.084		
Total	1803078.170	98	18398.757		
			Biomass by latitude and season		
Main effects	279770.624	3	93256.875	5.883	0.001
Latitude	98432.402	1	98432.402	6.210	0.014
Season	200414.747	2	100207.373	6.322	0.003
2-way interactions	49197.414	2	24598.707	1.552	0.217
Lat. season	49197.414	2	24598.707	1.552	0.217
Explained	328968.038	5	65793.608	4.151	0.002
Residual	1474110.132	93	15850.647		
Total	1803078.170	98	18398.757		

mixing of low saline surface waters with that of the high saline nutrient rich bottom water during upwelling or turbulence caused by other factors leading to proliferation of zooplankters as suggested by Ganapati (1973).

It deserves special mention here that along with the peak in abundance of the secondary producers the commercially important fishes caught from the northwestern region during this particular season also showed maximum. Scariah *et al.*(1987) while giving the average annual catch for the ten year period, up to 1984, records the highest landings in the last quarter followed by the first quarter for the Orissa coast where the planktivorous fishes such as sardines, pomfrets etc. constituted more than 33%. But in later years the percentage contribution of the pelagic fishes in terms of mackerels, carangids, ribbon fishes and pomfrets varied from 31% in 1988 to 45% in 1989 (CMFRI, 1995). Along the Andhra coast landings of the pelagic fishes which were more than 53% up to 1984 (Alagaraja *et al.* 1987) further increased to 62% in 1988 and 63% in 1989 (CMFRI,1995) and the estimated catch was the highest during the first or last quarter of the year. The abundance observed in oil sardine, pomfrets, tuna and tuna like fishes was conspicuously more during 1988 and 1989 (CMFRI,1995) along the northwestern coast. Therefore, it is logical to conclude that the spurt observed in the proliferation of the zooplankton population in the northeast monsoon might bear a close trophic link to that of the fishery resources harvested from the northwestern part of the Bay of Bengal. It may be that the plankton production funnelled either by pelagic or demersal route into the fish production (Sheldon *et al.* 1975).

Monthly variations

The monthly mean biomass value of 285.42 ml was the maximum in January and the hydrographic parameters registered were 23.98°C, 29.85×10^{-3} and 4.34 ml. Almost all the major groups and larval forms exhibited increased abundance during January. There was sizable reduction in the constituent groups in February (Fig.4). Many groups dwindled except euphausiids, fish eggs and larvae and their combined association was very prominent in February. Euphausiids were poorly represented during May-June and their relative abundance was never more than 5% at any time. Fish eggs were predominant during February-May and larvae in July and January-February. Pelagic fish in spent or partially spent condition were commonly found in the area off Visakhapatnam during January-May (Luther, 1995).

Copepods formed the most abundant group constituting more than 54% of the total population except in July. Though the percentage contribution was as high as 76% in June it came down to 48%, the lowest, encountered in July when siphonophores, chaetognaths, pelagic tunicates especially the appendicularians and salps, lucifers, planktonic molluscs, euphausiids, larval decapods and fish larvae occurred in appreciable numbers. The density of copepods was the highest in January.

Greater concentration of pelagic tunicates was found in January when aggregates of thaliaceans and appendicularians appeared in the collections. The salps were

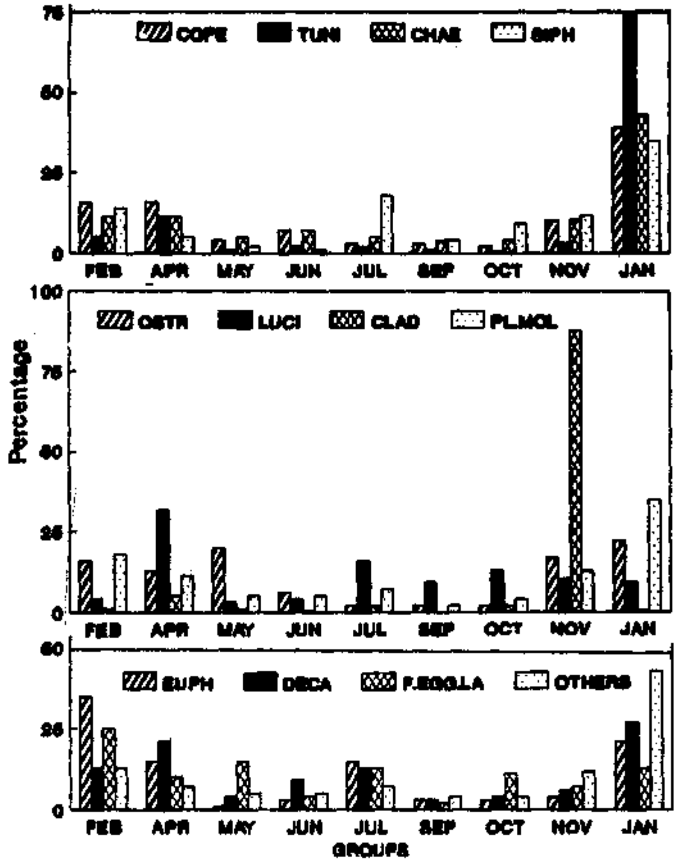

Fig. 4— Monthly variations of different groups

always more in number than the doliolids except in April. Appendicularians were also present in large numbers during April. The zooids of *Pyrosoma* were very common in February.

Chaetognaths were most abundant in January and to a lesser extent in February and July though they were present throughout the period of observation and contributed 5 to 9% of the total population. The highest density of siphonophores was observed in January, and their relative abundance was 15 and 12% respectively during July and October.

Ostracods were moderately abundant throughout but the peak was noticed in January. After reaching the maximum in April, lucifers recorded the lowest number in May but formed 7% of the total in October. The population of the cladocerans exhibited wide fluctuations in their abundance throughout the period of study but appeared in swarms during November. The density of larval decapods was the highest in January. They were well represented in the coastal waters during February and April.

The planktonic molluscs included larval lamellibranchs, gastropods, heteropods and pteropods and occurred in considerable numbers during January. A few phyllosoma appeared in the samples taken from the second and fourth depth zones during January and April respectively. Planktonic foraminifers were present throughout the period of observation and were remarkably high in January. Amphipods as a group was quite significant among the planktonic crustaceans and were found to form an important component of the population during January-February. Larval polychaetes were present in large numbers during January and April. Stomatopod larvae in January and mysids in February appeared in appreciable numbers. Hydromedusae were abundant in the neretic waters during January-February. Juveniles of cephalopods and *Amphioxus* occurred occasionally in significant numbers, the former in June and the latter in November and January. A few isopods were also encountered in the collections.

Seasonal abundance

The zooplankton standing stock and the many groups like copepods, chaetognaths, siphonophores, fish larvae, planktonic molluscs, cladocerans, amphipods, larval stomatopods, polychaetes, hydromedusae, ctenophores and foraminifers were at the peak of their abundance during the northeast monsoon season (Fig.5) when the mean temperature and salinity observed were low. On the other hand, pelagic tunicates, ostracods, lucifers, euphausiids, larval decapods and fish eggs showed greater affinity to high temperature (28.32°C), salinity (33.82×10^{-3}) and dissolved oxygen (4.85 ml/l) and their maximum abundance was observed in the premonsoon. The distribution pattern exhibited by copepods, cladocerans and euphausiids agree with the findings of earlier workers (Pillai 1990; Naomi *et al.* 1990; Mathew *et al.* 1990b). The abundance of zooplankton was very low during the southwest monsoon when the average temperature (29.70°C), salinity (31.89×10^{-3}) and oxygen (3.98 ml/l) recorded were moderate. It may be noted that the earlier works on the northwestern coast

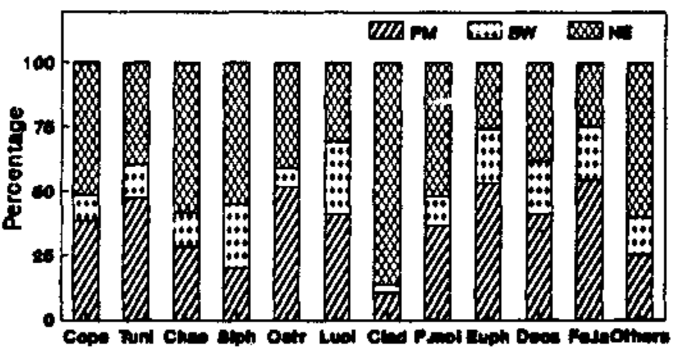

Fig. 5— Seasonal variations of different groups

(Nair *et al.* 1977; Achuthankuty *et al.* 1980; Nair *et al.* 1981) were confined to either 1 or 2 months during the southwest monsoon period. It is probable that the large inflow of fresh water entering the marine environment at several points might have helped in strengthening the stratification particularly in the northern part due to incomplete mixing and reduced wind forcing at times (Suryanarayana *et al.* 1992). The prevailing characteristics of the Bay waters at the time of sampling would not have been favourable for the continued development and proliferation of zooplankters. The number of stations covered in the present study during the premonsoon, southwest monsoon and northeast monsoon were 30, 28 and 41 respectively. Continuous observations of longer duration would throw more light on the pattern of zooplankton abundance and distribution along the northwestern region of the Bay of Bengal.

Latitudinal abundance

There were wide variations in the biomass and numerical abundance of the groups collected from the southern (lat.1) and northern (lat.2) sectors. Out of the 99 stations sampled, 52 were from lat.1 and the rest from lat.2. An increasing trend in abundance towards north was evident in the majority of the groups. When the mean biomass recorded from north was 135.36 ml it was only 78.51 ml from the south. Almost all the groups except euphausiids showed a northward shift in numerical abundance (Fig.6). The prime components among them were cladocerans followed by pelagic tunicates. The average temperature and salinity observed for the northern and southern latitudes were 26.30°C and 30.69×10^{-3} and 22.83°C and 31.88×10^{-3} respectively. The pattern of distribution over seasons in both the sectors (Fig.7) reveal that more than 50% of copepods, pelagic tunicates, ostracods, euphausiids, fish eggs and larvae occurred in the premonsoon and the rest in the northeast monsoon in the southern latitude. In the northern latitude the trend was completely different in that all the major groups except lucifers, larval decapods,and fish eggs displayed maximum abundance in the northeast monsoon season. No groups attained peak in the southwest monsoon season in both the sectors.

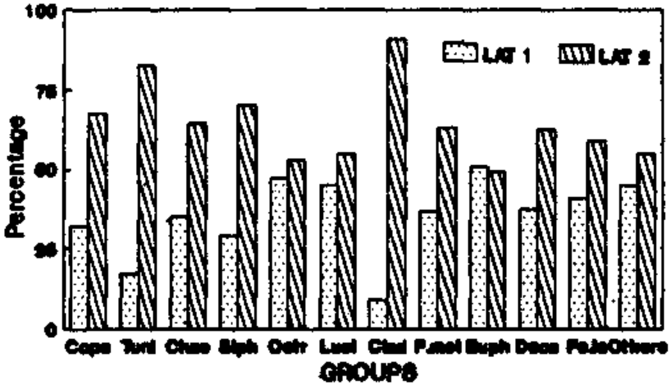

Fig. 6— Latitudinal variations of different groups

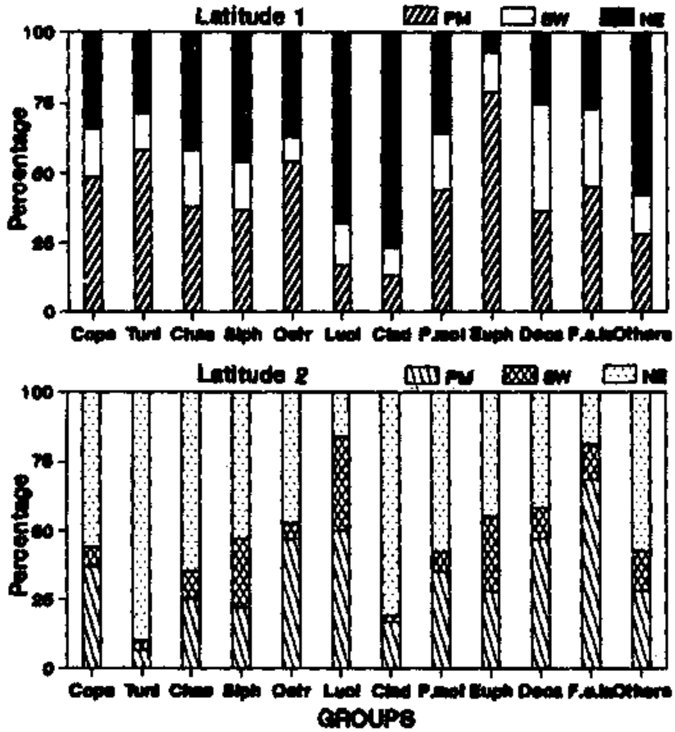

Fig. 7— Seasonal variations in lat.1 and lat.2

Depthwise distribution

Though the fish larvae (3999) were present in large numbers in the first depth zone, the highest number of fish eggs (7322) were collected from the third depth zone, euphausiids from the second zone and ostracods from the fourth zone respectively (Fig.8). The rest of the zooplankton population resided mainly in the neretic region up to 50 m depth zone of the northwestern Bay. The average salinity of the different depth zones fluctuated from 28.99 to 32.14×10^{-3}. During the northeast monsoon the salinity registered 22.43×10^{-3} and oxygen 2.89 ml/l in the first depth zone when it supported more than 58% of the total population.

The day-night variations (Fig.9) show that the ostracods, lucifers and planktonic molluscs occurred more in the nighttime collections and that there was no difference in the distribution of larval decapods during day or night.

Secondary production

The secondary production was estimated following the method suggested by Dalal & Parulekar (1986). The average production of the area, 4.91 $gC/m^2/y$ was relatively higher than that of an earlier observation which was less than 3 $gC/m^2/y$(Mathew *et*

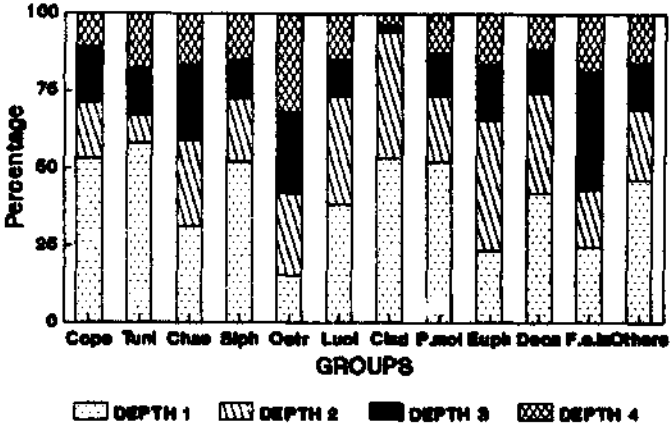

Fig. 8— Variations in different depths

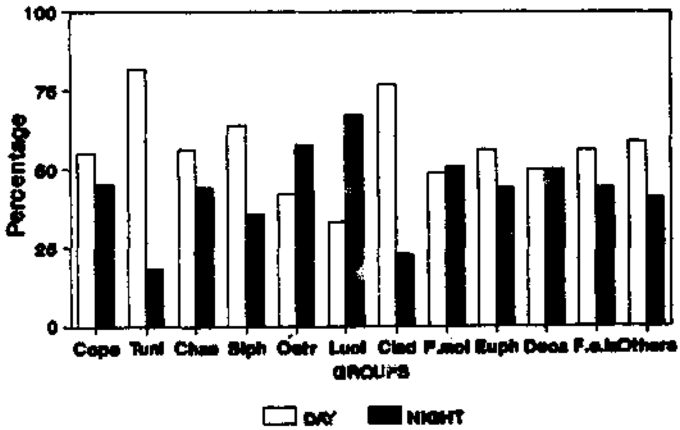

Fig. 9— Day-night variations of different groups

al. 1990a). The production estimated per degree square area showed the highest value off Chilka lake (9.07 gC/m^2/y) followed by that off Paradip (7.47 gC/m^2/y) and Visakhapatnam (7.9g C/m^2/y).

Fluctuations in the community structure and zooplankton standing stock have frequently been referred to biological interactions including selective predation. Further investigations of longer duration covering the three seasons of the area are necessary to understand and assess the trophodynamics of the coastal waters of the northwestern Bay of Bengal.

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REFERENCES

Achuthankutty, C.T., Madhupratap, M., Nair, V.R., Nair, S.R.S. & Rao, T.S.S. 1980. Zooplankton biomass and composition in the western Bay of Bengal during late southwest monsoon. *Indian J. Mar. Sci.* 9: 201-206.

Alagaraja, K., Yohannan, K.C., Ammini, P.L. & Pavithran, P.P 1987. An appraisal of the marine fisheries of Andhra Pradesh, *Spl. Publn. CMFRI*, 33: 1-53.

CMFRI. 1990. *Proceedings of the first workshop on scientific results of FORV Sagar Sampada*, 5-7 June, Cochin. (Ed.) K.J.Mathew, (CMFRI,Cochin-14), 1-465.

CMFRI, 1995. Marine fish landings in India during 1985-1993 *Mar. Fish. Infor. Serv. T & E Ser.* 136: 1-30.

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

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

Krishnamurthy, B. 1976. An assessment of the demersal fishery resources off the Andhra-Orissa coast based on exploratory trawling. *Indian J. Fish.* 21 (2): 557-565.

Luther, G. 1995. Fishery and resource characteristics of mackerel of Visakhapatnam coast, *Mar. Fish. Infor. Serv. T &. E Ser.* 138: 1-5.

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

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

Murty, C.S. & Varadachari, V. V. R. 1968. Upwelling along the east coast of India. *Proc. Symp. Indian Ocean, Bull Natn Inst. Sci. India*, 38: 80-86.

Nair, V. R., Peter, G. & Paulinose, V. T. 1977. Zooplankton studies in the Indian Ocean. I. From Bay of Bengal during southwest monsoon period, *Mahasagar—Bull. Natn. Inst. Oceanogr* 10 (1&2): 45-54.

Nair, S.R. S., Nair, V. R., Achuthankutty, C. T. & Madhupratap, M. 1981. Zooplankton composition and diversity in the western Bay of Bengal, *J. Plankton Res.* 3(4): 493-508.

Naomi, T. S., Antony, G. & Mathew, K. J. 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*. edited by K. J. Mathew, (CMFRI, Cochin) pp. 85-93.

Pati, S. 1980. Observations on the hydrography and inshore plankton of the Bay of Bengal off Balasore, *Hydrobiologia*, 70: 123-132.

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

Qasim, S. Z. 1977. Biological productivity of the Indian Ocean, *Indian J. Mar. Sci.* 6(2): 122-137.

Rao, T. V. N., Rao, D. P., Rao, B. P. & Ramaraju, V. S. 1986. Upwelling and sinking along Visakhapatnam coast, *Indian J. Mar. Sci.* 15 (2): 84-90.

Sankaranarayanan, V. N. & Reddy, C. V. G. 1968. Nutrients of the northwestern Bay of Bengal, *Proc.Symp. Indian Ocean., Bull. Natn. Inst. Sci. India.* 38: 148-163.

Scariah, K. S., Philipose, V., Dan, S. S., Nair, P. K. & Subbaraman, G. 1987. An appraisal of the marine fisheries in Orissa, *Spl. Publn. CMFRI,* 32: 1-37.

Sheldon, R. W., Sutcliffe Jr. W. H. & Paranjape, M. A. 1975. Structure of pelagic food chain and relationship between plankton and fish production, *J. Fish. Res. Board Can.* 34: 2344-2353.

Shetye, S. R., Shenoi, S. S. C., Gouveia, A. D., Michael, G. S., Sundar, D & Nampoothiri, G. 1991. Wind driven coastal upwelling along the western boundary of the Bay of Bengal during southwest monsoon, *Continental Shelf Research.* 11 (11): 1397-1408.

Suryanarayana, A., Murty, C. S. & Rao, D. P. 1992. Characteristics of coastal waters of the western Bay of Bengal during different monsoon seasons, *Aust. J. Mar. Freshwater Res.* 43: 1517-1533.

Vijayakumar, R. & Sarma, V. V. 1988. Zooplankton studies in Visakhapatnam harbour and nearshore waters of east coast of India, *Indian J. Mar. Sci.* 17: 75-77.

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