Proceedings of the Second Workshop on Scientific Results of *FORV Sagar Sampada*

Editors

V.K. Pillai
S.A.H. Abidi
V. Ravindran
K.K. Balachandran
Vikram V. Agadi

सत्यमेव जयते

Department of Ocean Development
Government of India
New Delhi
1996

Department of Ocean Development (DOD)
Government of India
Mahasagar Bhavan, Block No-12
C.G.O. Complex, Lodi Road
New Delhi-110 003
India

ISBN : 81-900656-0-2

Citation Styles

For entire volume

Pillai, V.K. Abidi, S.A.H., Ravindran, V., Balachandran, K.K. & Agadi, V.V. (Eds.) 1996. *Proceedings of the Second Workshop on Scientific Results of FORV Sagar Sampada*, (Department of Ocean Development, New Delhi), pp. 564.

For individual article

Goswamy, S.C. & Shrivastava, Y. 1996. Zooplankton standing stock, community structure and diversity in the northern Arabian Sea, In: *Proceedings of the Second Workshop on Scientific Results of FORV Sagar Sampada*, edited by V.K. Pillai, S.A.H. Abidi, V. Ravindran, K. K. Balachandran & V.V. Agadi, (Department of Ocean Development, New Delhi), pp. 127-137.

Designed and Printed by:

Publications & Information Directorate
Council of Scientific & Industrial Research
Pusa Campus, New Delhi-110 012
India

Proc. Second Workshop Scient. Resul. FORV Sagar Sampada, 1996, pp. 103–113

Some observations on primary production and plankton biomass along the continental shelf and slope off the northeast coast of India during January 1989

G.S.D. Selvaraj

Central Marine Fisheries Research Institute, P.B.No-1603, Cochin - 682 014

and

V. Srinivasan

Botany Department, University of Madras, Madras - 600 005

ABSTRACT

The present study deals with the quantitative aspects of chlorophyll pigments, primary productivity and plankton biomass from the continental shelf and slope off the northeast coast of India between 16° and 20°N latitudes towards the end of northeast monsoon season. In surface waters, the mean values of chl-*a*, -*b*, and -*c* were 0.249, 0.275 and 0.837 mg/m^3 along the shelf and 0.246, 0.260 and 0.805 mg/m^3 in the slope respectively while the net primary productivity values were 0.074 and 0.081 g C/m^3/d for the shelf and slope waters respectively. Column productivity in the upper 0-50 m water in the shelf and slope regions were 2.9 and 3.25 g C/m^2/d with an average production of 3.08 g C/m^2/d. Higher rate of production was observed around 18° and 20°N latitudes. Zooplankton biomass exhibited progressive increase in volume from 16° to 20°N. The estimated mean zooplankton biomass volume of the study area was 28.83 ml/m^2. The mean transfer coefficient from primary to secondary production was found to be 14% when 50% of the zooplankton biomass was considered as the daily rate of production. From the mean primary and secondary productivity values, potential tertiary production of pelagic fishery resources in the upper 0-50 m water column of the study area for the month was assessed. The factors that are likely to cause error in the estimation of secondary production are discussed.

INTRODUCTION

It is well-known that plankton plays a vital role in the distribution and abundance of marine living resources. A perusal of literature reveals that studies on the hydrological features and plankton productivity from the offshore waters of the east coast of India are limited since 1975 (Radhakrishna, 1978; Radhakrishna *et al.* 1978; Achuthankutty *et al.* 1980; Sreekumaran Nair *et al.* 1981; Kaladharan *et al.* 1989; Mathew *et al.* 1989; Prakash & Raman, 1989; Selvaraj *et al.* 1989; Krishnakumari & Goswami, 1993) as compared to the studies from offshore waters of the west coast of India. The present study provides some information on the hydrological features and primary and secondary productivity of the continental shelf and adjacent slope waters off the northeast coast of India between lat. 16°N and 20°N towards the end of the northeast monsoon (January) season.

MATERIALS AND METHODS

The study is based on the hydrographic and plankton data collected on board *FORV Sagar Sampada* (cruise No. 57) from 14 stations along the continental shelf and the adjacent slope off the northeast coast of India (Fig.1) during January 1989. Water samples were collected at the stations onboard using Rossette water sampler from 1, 25, 50, 100 and 200 m depths. Water temperature, salinity, dissolved oxygen and chlorophyll pigments (chl-*a*, -*b*, -*c*) were determined adopting standard methods (Strickland & Parsons, 1968). Phytoplankton pigments were measured for the surface samples only using Perkin-Elmer UV/VIS spectrophotometer onboard. Primary productivity experiments were conducted for the water samples collected from 1, 25, 50

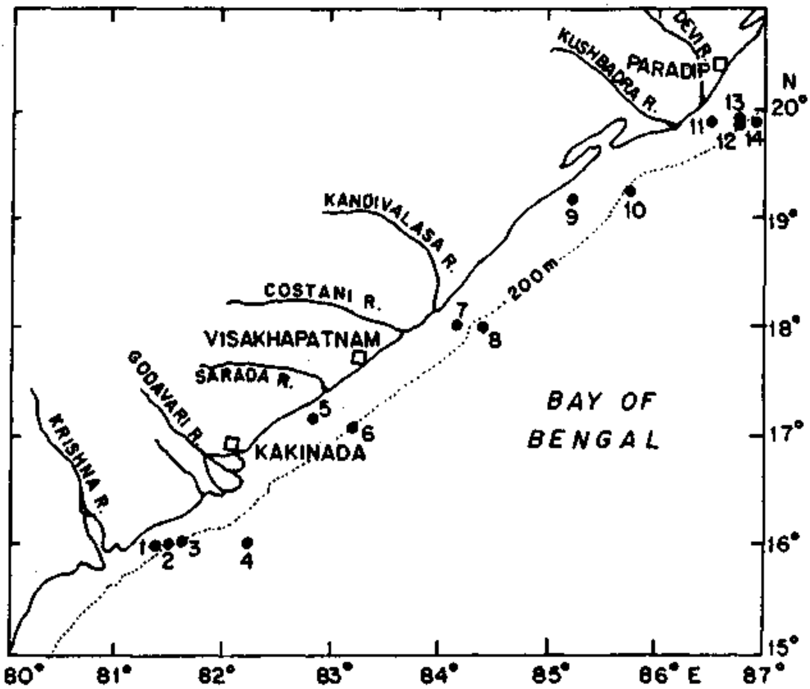

Fig. 1 - Map of northeast coast of India showing stations

and 100 m column depths adopting L and D bottle oxygen technique under simulated light incubation for 3 hours. The productivity values thus derived were extrapolated for 12 hours of the day.

Oblique sampling of zooplankton was made by Bongo-60 net at desired warp length, by releasing the warp to a maximum of 200 m in the oceanic stations and withdrawing the net immediately at the vessel speed of one nautical mile per hour. Wet displacement volume of the zooplankton was determined onboard for each sample within 12-24 hours of preservation in 5% formalin and then after a month of preservation to determine the percentage of shrinkage due to preservation. The wet volume of each sample was quantified in ml per 100 m^3 water. To convert the zooplankton biomass volume into organic carbon, the ratio (1 ml wet volume = 78.5 mg dry weight; 38% of dry weight = mg organic carbon) standardised by Dalal & Parulekar (1986) for the Indian Seas was adopted; and to convert the biomass volume into daily rate of secondary production, 50% of the biomass (used by Qasim & Ansari, 1981) was tested.

RESULTS

Water temperature — The daily average sea surface temperature in different latitudes ranged from 24.1°C at 20°N to 26.4°C at 16°N showing a decreasing trend towards north in January. The column average values in the upper 0-50 m also indicated almost the same trend (Fig.2). At 50 m depth zone, it was higher (26.9°C) around 17°N and low (24.8°C) around 20°N. At 100 m and 200 m depths, higher values of 25.5°C and 26.3°C respectively were observed at 18°N while low values of 19.8° and 19.9°C were recorded at 100 m around 20° and 16°N and 12.6° and 12.8°C at 200 m around 19° and 20°N respectively. In general, low temperature was recorded around 20°N at surface and deeper waters during January.

Salinity — The daily average salinity values at different latitudes between 16°-20°N varied from 29.3 to 33.7x10^{-3} at surface, 33.7-35.7x10^{-3} at 50 m, 34.9-36.9x10^{-3} at 100 m and 34.3-36.9x10^{-3} at 200 m depth zones. In general, the salinity values were less in the upper 0-50 m around 16°N and 20°N in the shelf and slope waters (Fig.2). Below 50 m, the daily average varied between 34.3 and 36.9x10^{-3} among the different latitudes. Relatively low salinity was recorded at surface around 20°N and in the deeper waters (50-200 m) around 16°N.

Dissolved oxygen — The daily average dissolved oxygen values at surface varied from 3.75 ml/1 at 16°N to 5.59 ml/1 at 20°N showing an increasing trend towards north (Fig.2) while this trend was not clear in the column waters. Below 50 m, the values were 2.5 ml/l (except at 18°N). At 100 m, the mean dissolved oxygen values at each latitude (16°-20°N) were 0.64, 1.20, 3.46, 1.92 and 1.82 ml/1 , while the values at 200 m depth were 0.61, 0.66, 2.01, 1.47 and 1.12 ml/1 respectively. The ranges and mean for the surface and the upper 0-50 column waters of the shelf and slope are given in Table 1.

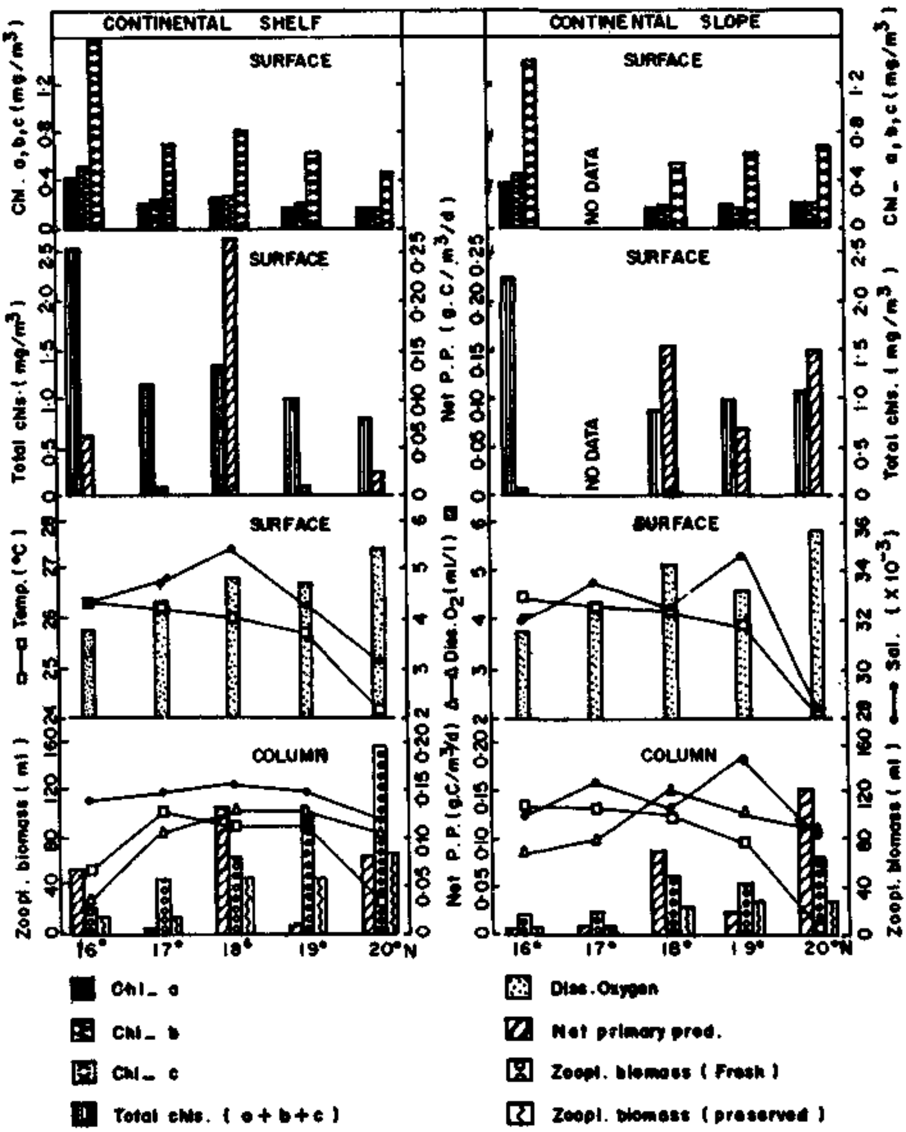

Fig. 2 - Hydrography, phytoplankton pigments, primary production and zooplankton biomass of the shelf and slope waters during January 1989

Phytoplankton — Phytoplankton was constituted by multispecies population, dominated by species of *Rhizosolenia, Ceratium, Chaetoceros* and *Amphisolenia* in the order of abundance. Other groups encountered were *Biddulphia, Coscinodiscus, Thalassiothrix, Peridinium, Hemidiscus, Skeletonema* and *Planktoniella*. Among them, *Rhizosolenia* and *Biddulphia* were more along the shelf edge and adjacent slope region.

Chlorophyll concentration — In the shelf region, the concentration of chl-*a* in the surface water ranged from 0.169 to 0.424 mg/m^3, chl-*b* 0.164-0.514 mg/m^3, and chl-*c* 0.461-1.592 mg/m^3 with their mean values recorded as 0.249, 0.275 and 0.837 mg/m^3 respectively (Table 2). In the slope waters, the concentration of chl-*a* at surface ranged from 0.178 to 0.390 mg/m^3, chl-*b* 0.181-0.456 mg/m^3 and chl- *c* 0.539-1.391 mg/m^3 with their mean values recorded as 0.246, 0.260 and 0.805 mg/m^3 respectively. In general, the chl- *c* concentration was more at all the latitudes in the shelf and slope region during January (Fig.2). The mean total chlorphyll concentration (chl-*a* + *b* + *c*) for the shelf and slope waters were 1.361 and 1.311 mg/m^3 respectively.

Primary production — The average net productivity values along the shelf and slope were 0.074 and 0.081 g C/m^3/d at surface, 0.042 and 0.048 g C/m^3/d at 50 m and 0.026 and 0.040 g C/m^3/d at 100 m depth. Out of the 10 stations where experiments were conducted at 100 m depth, 8 stations showed no values, while at 50 m depth, 8 out of the 14 stations showed productivity values. Hence, the production values in the upper 0-50 m water column alone were considered in the present study. The net

Table 1 - Distribution of temperature, salinity and dissolved oxygen in the continental shelf and slope waters

Parameters	Shelf		Slope	
	Range	Mean	Range	Mean
		Surface		
Temp. (°C)	24.10-26.30	25.70	24.10-26.45	25.80
Sal. ($\times 10^{-3}$)	30.30-34.80	32.70	28.35-34.75	32.20
Diss. O_2(ml/l)	3.75-5.35	4.59	3.74-5.83	4.71
		Column (upper 0-50 m)		
Temp. (°C)	24.65-26.50	25.80	24.20-26.70	26.00
Sal. ($\times 10^{-3}$)	32.80-34.20	33.65	32.15-35.45	33.70
Diss.O_2(ml/l)	2.67-4.56	4.00	3.70-5.03	4.30

production values of the shelf and slope in the surface and upper 0-50 m water column are depicted in Fig.2. In general, the productivity values were higher around 18° and 20°N and the values in the slope waters were higher than in the shelf region with the productivity values recorded up to 100 m depth (2 stations) at 19° and 20°N. The mean net primary productivity values in the upper 0-50 m water column of the shelf and slope were 2.90 and 3.25 g C/m^2 /d respectively and the overall average for the shelf and slope together was 3.08 g C/m^2/d (Table 3).

Zooplankton — Biomass was constituted by copepods, chaetognaths, siphonophores, appendicularians, ostracods, mysids, lucifers, salps, doliolids, medusae,

Table 2 - Phytoplankton pigments and primary productivity in the surface waters of continental shelf and slope

Parameters	Shelf		Slope	
	Range	Mean	Range	Mean
Chl-*a* (mg/m^3)	0.169-0.424	0.249	0.178-0.390	0.246
Chl-*b* (mg/m^3)	0.164-0.514	0.275	0.181-0.456	0.260
Chl-*c* (mg/m^3)	0.461-1.592	0.837	0.539-1.391	0.805
Total chlorophyll ($a + b + c$) (mg/m^3)	0.794-2.530	1.361	0.902-2.237	1.311
Net prod. (mg. C/m^3/d)	0.007-0.264	0.074	0.007-0.154	0.081

Table 3 - Estimated mean primary and secondary production in the upper 0-50 m water column (shelf and slope station values are pooled together to get the mean)

Lat. (°N)	N.P.P. (g C/m^2/d) (T C/km^2/d)	Zoopl. biomass fresh volume (ml/m^2)	Rate of zoopl. prod. (50% of biomass)		Transfer coefficient (P.P. to sec. prod.) (%)
			(ml/m^2/d)	(g C/m^2/d) (T C/km^2/d)	
16	1.800	09.15	4.575	0.136	7.58
17	0.550	15.97	7.985	0.238	43.31
18	5.350	28.42	14.210	0.424	7.92
19	0.950	35.50	17.750	0.529	55.73
20	6.750	55.13	27.565	0.822	12.18
Average	3.080	28.83	14.415	0.430	13.96

pteropods, heteropods, other gastropods, decapod larvae, euphausiids, polychaetes, fish eggs and larvae. Gelatinous planktonic groups such as salps, doliolids, medusae and siphonophores contributed more by volume around 20°N sector in the continental shelf.

Secondary production — Displacement volumes (soon after preservation) of the biomass showed the lowest value of 20.66 ml/100 m^3 water at 16°N and the highest of 157.8 ml/100 m^3 at 20°N along the shelf indicating a progressive increasing trend towards north while the respective values in the slope were 15.95 and 62.73 ml/100 m^3 (Fig.2). The averages for the shelf and slope were 76.7 and 38.64 ml/100 m^3 water respectively. The overall mean biomass volume between 16° and 20°N along the shelf and adjacent slope waters was 28.83 ml/m^2 (Table 3). When 50% of the zooplankton biomass was considered as the daily rate of production (Qasim & Ansari, 1981), the overall average value of the secondary production was 0.430 g C/m^2/d (Table 3).

DISCUSSION

The hydrographic features at surface indicated that the ranges in temperature, salinity and dissolved oxygen were higher in the slope than in the shelf region while in the column waters, the dissolved oxygen values showed wide fluctuation in the shelf region (Table 1). Wide fluctuation in dissolved oxygen is due to the low value (1.59 ml/l) recorded at 50 m around 16°N, which indicates low biological productivity in this region. The fall in salinity noticed especially around 16° and 20°N (Fig.2) might be attributed to the influence of the northeast monsoon and the subsequent fresh water discharge through large rivers.

The chlorophyll concentration and primary productivity values recorded in January during the present survey are higher than those values recorded by Kaladharan *et al.* (1989) in the shelf and slope waters of this region in October 1988 and by Prakash & Raman (1989) in December 1986. Qasim (1977) has stated that the surface primary production per unit area in the Bay of Bengal is higher than that of the Arabian Sea while the column production is much higher in the Arabian Sea. While the earlier studies have recorded primary productivity range of 0.1-0.5 g C/m^2/d in the northern Bay of Bengal, the average value of 3.08 g C/m^2/d recorded during January 1989 between 16°N and 20°N along the shelf and slope suggests that this area, in general, is fertile towards the end of the northeast monsoon season.

The mean displacement volume of the zooplankton biomass (soon after preservation) showed high values of 76.7 and 38.64 ml/ 100 m^3 water in the shelf and slope respectively indicating that the shelf region had a double fold of production as compared to the slope waters. Highest volume of 157.8 ml/100 m^3 recorded in the shelf region at 20°N was chiefly contributed by the gelatinous groups like salps, doliolids and medusae. Higher concentrations to the extent of 90 ml/100 m^3 and a mean volume of 33.2 ml/100 m^3 water have been recorded earlier from the shelf region between Madras and Visakhapatnam during June 1978 (Sreekumaran Nair *et al.*

1981). The overall average production rate of zooplankton in the study area estimated is 0.430 g C/m^2/d, while Qasim & Ansari (1981) have estimated the production rate for Andaman Sea as 0.144 g C/m^2/d in the 0-200 m water column. This also indicates that the study area is relatively fertile during January.

The data also indicated a progressive increasing trend in dissolved oxygen content and zooplankton abundance towards northern latitudes along the shelf and slope (Fig.2). The availability of higher level of dissolved oxygen (above 4 ml/l) in the upper 0-50 m water column with plankton biomass abundance towards north reveals that the shelf and the adjacent slope waters between 18° and 20°N latitudes are highly productive zones especially towards the end of the northeast monsoon season. The very low dissolved oxygen level (<2 ml/l) recorded at 100 m and 200 m between 16° and 20°N (except around 18°N) indicates that the deeper waters are neither productive nor suitable for fishery resources during this period. The variation observed in plankton abundance among the different latitudes and between the shelf and slope might be due to the changes in water quality as evidenced from place to place.

In the present study, the chlorophyll concentrations do not indicate any direct relationship with primary productivity values. However, while the concentration of chlorophyll pigments helps as an index to indicate the abundance of phytoplankton in water, it is clear that the primary productivity values, in relation to chlorophyll concentration, determine the nature and physiological state of the phytoplankton cells.

In the present survey, the phytoplankton production and zooplankton biomass volume indicated, in general, an inverse relationship especially towards north in the shelf region (Fig.2). This inverse relationship indicates that the turnover from primary to secondary production level is very high. The transfer coefficient from primary production to secondary production ranged from 7.58% to 55.73% (Table 3) showing an average of 14% when 50% of the zooplankton biomass (Qasim & Ansari, 1981) was considered as the daily rate of secondary production. The range in the transfer coefficient observed in the present study falls within the range (0.3-56.2%) recorded by Cushing (1973) for the day and night samples collected from 0-200 m depth with the mean turnover of 3.3%. According to Qasim & Ansari (1981), the mean turnover from primary to secondary production is 10%. As compared to these mean values, the transfer coefficient value of 14% obtained in the present investigation indicates that the turnover from primary to secondary level of production is high in the upper 0-50 m water column towards the end of the northeast monsoon season. If the transfer coefficient value in the present study is considered as 10%, the daily rate of secondary production would come to about 35% of the zooplankton biomass (mean 0.301 g C/m^2/d) which would appear to be a more realistic figure since the zooplankton biomass volume was significantly contributed by the gelatinous groups like salps and doliolids in January.

According to Qasim & Ansari (1981), the potential tertiary production is 0.1% of primary production and 1% of secondary production in terms of organic carbon which, when multiplied by the factor 10, gives the live weight of tertiary production.

Accordingly, the mean primary productivity of 3.08 g.C/m^2/d (3.08 tonnes C/km^2/d) amounts to 95.48 tonnes C/km^2/month along the shelf and slope between 16° and 20°N which would be 0.955 tonne live weight of tertiary production of pelagic resources per km^2 for January. When 50% of the zooplankton biomass is considered as the daily rate of production, the mean secondary production of 0.430 g C/m^2/d (0.430 tonne C/km^2/d) would be 13.33 tonnes C/km^2/month leading to 1.333 tonnes live weight of tertiary production/km^2/month; and if 35% of the zooplankton biomass is considered as the daily rate of production, then the mean secondary production of 0.301 g C/m^2/d (0.301 tonne C/km^2/d) would give rise to 0.933 tonne live weight of tertiary production of fishery resources/km^2/month during January.

In the case of zooplankton sampling for quantitative assessment of the biomass, when the flow meter is not available onboard or if it goes out of order during the cruise, the biomass displacement volumes obtained from the shallow and deeper stations at varying warp length do not, as such, give the correct picture of their relative abundance; and this may at times mislead to wrong conclusions. The error that is likely to occur in the case of the actual biomass volume and relative abundance of the samples is indicated in Table 4. In such cases, when the warp length (WL) varies from sample to sample, the biomass volumes obtained could be converted into volume per 100 m WL as a standard to compare the data within the cruise (Table 4). However, this data cannot be compared with the other published data. Instead, the biomass displacement volume (ml) may be converted into volume per 100 m^3 of water filtered adopting the formula at 1 m WL =1.26 m^3 water filtered when the twin Bongo-60 net is used at the vessel speed of 1 nautical mile per hour while withdrawing the net. (The mean value of 200 m WL = 252 m^3 water filtered was derived from several such sampling using the flow meter onboard *FORV Sagar Sampada* cruises).

Another serious error normally occurring in the volumetric estimation of the plankton biomass is due to the shrinkage of plankton in preservation, especially when the duration of cruise is one month or more, or when the unloading of plankton

Table 4 - Quantitative estimation of plankton biomass

Lat. (°N)	Warp length (m)	Actual volume obtained (ml)	Estimated volume (ml/100m WL)	Estimated volume (ml/100m^3)
16	70	19.6	28.00	22.27
16	100	24.0	24.00	19.05
16	200	50.4	25.20	20.00
16	200	30.0	15.00	11.90
17	30	16.8	56.00	44.21
17	100	24.8	24.80	19.68

Table 5 - Shrinkage of plankton biomass due to preservation

Lat.(°N)	Shelf Fresh ($ml/100m^3$)	Shelf Preserved ($ml/100m^3$)	Shelf Shrinkage (%)	Slope Fresh ($ml/100m^3$)	Slope Preserved ($ml/100m^3$)	Slope Shrinkage (%)
16	20.66	13.85	32.96	15.95	8.29	48.02
17	44.21	14.21	67.86	19.68	8.57	56.45
18	63.05	45.03	28.58	50.63	25.08	50.46
19	97.78	46.35	52.60	44.23	28.99	34.46
20	157.80	67.11	57.47	62.73	27.10	56.80
Average	76.70	37.31	51.36	38.64	19.61	49.25

samples from the ship is delayed. This may cause error in the quantitative assessment, especially in the computation of plankton biomass data to assess the potential fishery resources. Keeping this in view, the percentage of shrinkage of zooplankton volume after one month was determined in the present study (Table 5). The mean displacement volume of zooplankton biomass (soon after preservation) indicated high values of 76.7 and 38.64 ml/100 m^3 in the shelf and slope waters respectively while their volumes reduced to 37.31 and 19.61 ml/100 m^3 respectively due to shrinkage after a month of preservation in 5% formalin. This shrinkage varied from sample to sample. The fluctuation in the shrinkage is due to the changes in the percentage composition of zooplankton groups which varied from about 30% to 70%. The percentage increased where the gelatinous groups of plankton were more in the samples. On average, the shrinkage of 50% in one month could be considered to get a more realistic picture. However, more work on these aspects would be desirable.

ACKNOWLEDGEMENT

Authors are grateful to Dr. P.S.B.R. James, former Director, CMFRI, Cochin for the facilities provided to carry out this work. Thanks are also due to (late) Mr. I. David Raj of CMFRI, and Mr Supriya Pal, Research Scholar, Berhampur University for rendering their co-operation onboard in the collection of zooplankton samples.

REFERENCES

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

Cushing, D.H. 1973. Production in the Indian Ocean and the transfer from primary to the secondary level, In: *The biology of the Indian Ocean*, edited by B. Zeitzschel (Springer Verlag, Berlin) 475-486.

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

Kaladharan, P., Alavandi, S.V. & Pillai, V.K. 1989. Dissolved Mercury levels and chlorophyll concentrations in the offshore waters of the northeast coast of India, In: *Proc. First Workshop Scient. Resul. FORV Sagar Sampada*, edited by K.J. Mathew, (CMFRI, Cochin) 25-27.

Krishna Kumari, L. & Goswami, S.C. 1993. Biomass and biochemical composition of zooplankton from northwest Bay of Bengal during January 1990. *Indian J. Mar. Sci.* 22: 143-145.

Mathew, K.J., Naomi, T.S., Geetha A. Vincent, D., Anilkumar, R. & Solomon, K. 1989. 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) 59-69.

Prakash, K.P. & Raman, A.V. 1989. Primary productivity and phytoplankton pigments in the southwest Bay of Bengal during December, 1986. In: *Proc. First Workshop Scient. Resul. FORV Sagar Sampada*, edited by K.J. Mathew, (CMFRI, Cochin) 55-58.

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

Qasim, S.Z. & Ansari, Z.A. 1981. Food components of the Andaman Sea, *Indian J. Mar. Sci.* 10: 276-279.

Radhakrishna, K. 1978. Primary productivity of the Bay of Bengal during March-April 1975, *Indian J. Mar. Sci.* 7: 58-60.

Radhakrishna, K., Bhattathiri, P.M.A. & Devassy, V.P. 1978. Primary productivity of the Bay of Bengal during August-September 1976, *Indian J. Mar. Sci.* 7: 94-98.

Selvaraj, G.S.D, Paulpandian, A L. & Purushothaman, A. 1989. Primary productivity and plankton abundance along the shelf and oceanic waters off southeast coast of India during August. 1987, In: *Proc. First Workshop Scient. Resul. FORV Sagar Sampada*, edited by K.J. Mathew., (CMFRI, Cochin) 47-53.

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

Strickland, J.D.H. & Parsons, T.R. 1968. *A practical handbook of seawater.analysis*, Bull. No. 167. (Fish. Res. Bd. Canada, Ottawa) pp. 311.

* * *