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Distribution of Hydro-biological Parameters in Coastal Waters off Rushikulya Estuary, East Coast of India: A Premonsoon Case Study

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Abstract: The hydro-biological parameters of coastal waters off Rushikulya estuary was investigated during premonsoon 2011. Important hydro-biological parameters such as water temperature, salinity, pH, DO, NO_2, NO_3, NH_4, PO_4, SiO_4, TSM, Chl-*a*, phytoplankton and zooplankton were measured during the present study. Temperature established a strong positive correlation with salinity and pH during the present study. Chl-*a* found in positive relation with NO_3, SiO_4 and TSM. Analysis of variance revealed significant monthly variation in pH, salinity and TSM. Significant station wise variation was observed in DO and most of the nutrients i.e., NO_3, NH_4, PO_4, SiO_4. A total of 119 species of phytoplankton were identified of which 84 species are of diatoms, 22 species of dinoflagellates, 7 species of green algae, 5 species of cyanobacteria (blue green algae) and 1 species of cocolithophore. Phytoplankton abundance varied between 25543 (Nos. L^{-1}) and 36309 (Nos. L^{-1}). Diatoms dominated the phytoplankton community followed by dinoflagellates in all the months. Diatoms contributed to 82-89% of the total phytoplankton population density whereas dinoflagellates contributed to 6-12%. The regression between Chl-*a* and phytoplankton abundance resulted with weak relation (R^2 = 0.042). Zooplankton fauna composed of 134 species of holoplankton and 20 types of meroplankton were encountered during the study period. Zooplankton population dominated by copepod during all months and accounted for 74 to 85% to the total zooplankton. The population density ranged from 6959 to 35869 Nos./10 m^3. Analysis of variance explained no significant variation in total zooplankton abundance and also for different groups of zooplankton.

Key words: Nutrients, phytoplankton, zooplankton, coastal water, premonsoon

INTRODUCTION

Hydro-biological study is an important requisite in coastal waters as it is very susceptible to natural and manmade influence. The measurement of physico-chemical parameters in the marine environment helps to understand the aquatic ecosystem. In coastal as well as in offshore waters phytoplankton plays an important character in regulating marine food chain. More than 90% of total marine primary production is supplied by the phytoplankton. They initiate the food chain by the process of photosynthesis and lead the food chain up to higher tropic level (Saravanakumar *et al*., 2008; Mathivanan *et al*., 2007). Nutrient enters into coastal seas through various modes viz., terrestrial runoff, estuary, effluent discharge etc. The quick alteration in nutrient structure effects the phytoplankton taxonomic composition and in order leads to the eutrophication and algal blooms (Bethoux *et al*., 2002; Piehler *et al*., 2004). Phytoplankton community structure changes spatio-temporally in response to alterations in the physical and hydro-biological variables and in order that can give an idea about the water quality (Achary *et al*., 2010). Composition and distribution of phytoplankton and its index biomass i.e., Chlorophyll-*a* (Chl-*a*) vary from coast to coast according to respective hydro-biological environments. Zooplankton, the heterotrophic animals that inhabit the oceans at all depths and occupy almost every type of ecological niche, are considered as the chief index of utilization of aquatic biotope at the secondary trophic level (Goswami and Padmavati, 1996). Zooplankton is the secondary producers in the aquatic systems which act as important link between the primary producers phytoplankton. In many corners of the globe zooplankton is considered to be as source of bioactive substances (Mitra *et al*., 2004). Few zooplankton species can be used as potential indicators of water pollution. Regional fisheries can be predicted by studying zooplankton of an area (Russell, 1939). Against this backdrop the present study was made in coastal waters off Rushikulya Estuary, east coast of India to decipher the status and distribution of hydro-biological parameters.

MATERIALS AND METHODS

Study area: The current study was conducted off Rushikulya estuary, southern coast of Odisha at five selected stations (19°10'0"N to 19°30'0"N and

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85°00' 0"E to 85°10'0" E) as shown in Fig. 1. Monthly field surveys were carried out during all the premonsoon months (March-June) using a fishing trawler as sampling platform. The study area receives international attention due to its mass nesting beaches of Olive Ridley Sea Turtles. The study region is under threat due to overfishing, activities of Gopalpur Port and effluent discharge by nearby industries.

Methodology: Water and plankton samples were collected from five selected stations (Fig. 1) of the study area. Four sampling surveys were carried out during PRM. Water Temperature (WT) were measured using a mercury filled centigrade thermometer of 0.1°C accuracy. The pH of the water sample was recorded by a digital field pH meter (Model Eutech pH scan 2) with 0.1 accuracy. Phytoplankton samples (1 L) were collected from surface

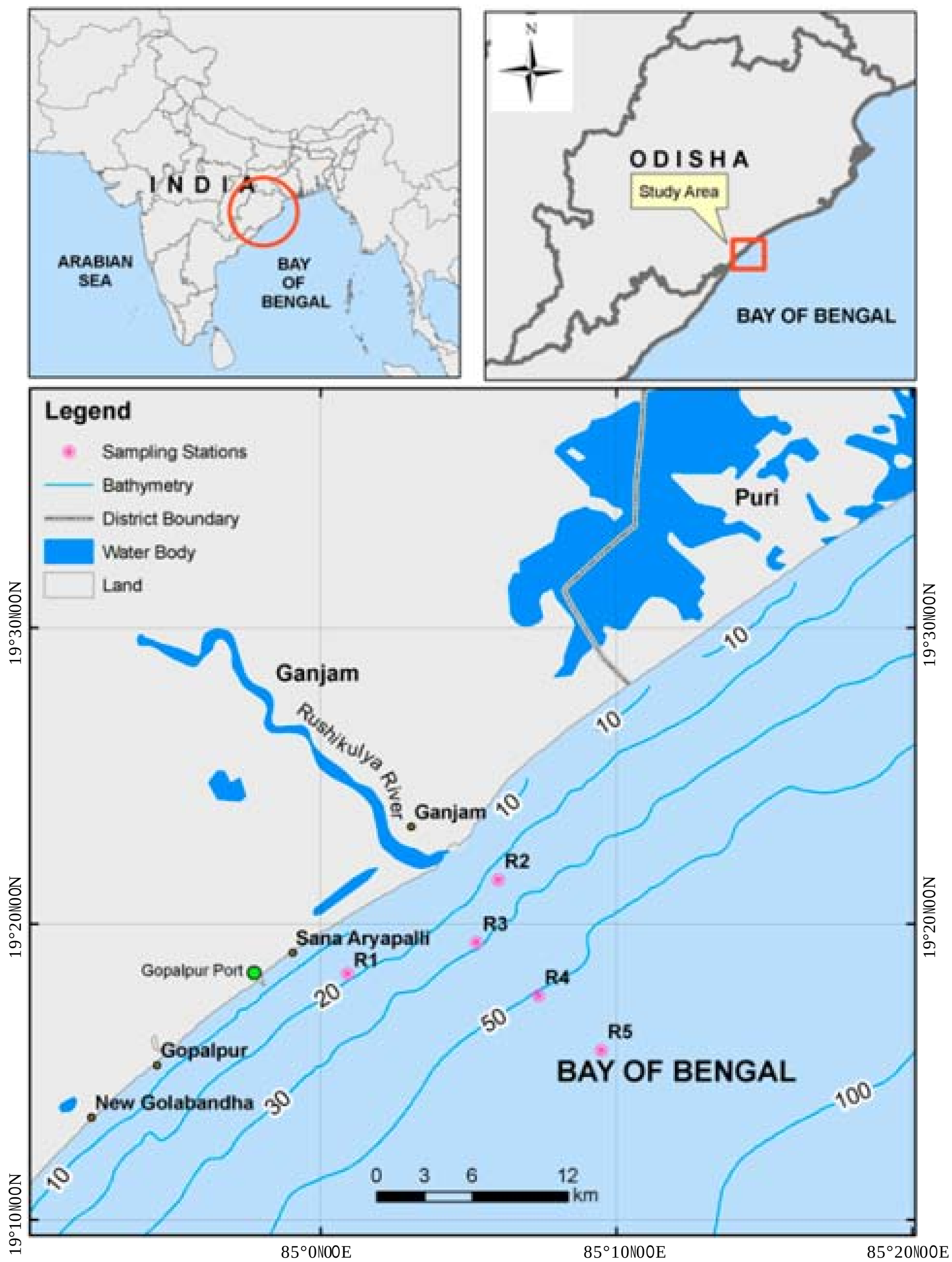

Fig. 1: Sampling locations in the study area (R1-R5) with depth contours in meters

in clean plastic bottles. After collection, the samples were immediately preserved with Lugol's iodine and 3% neutralized formaldehyde. Zooplankton samples were collected at each station by horizontal haul using a conical plankton net (mesh size of 120 mm) and were preserved with 5% neutralized formaldehyde after their collection.

Laboratory analysis: Salinity was estimated following the Knudsen's titrimetric method (Grasshoff *et al*., 1983). DO (Dissolved Oxygen) was determined following Winkler's method. Chl-*a* was estimated by adopting spectrophotometric method (Strickland and Parsons, 1984). For the analysis of salinity and nutrients, water samples were collected in clean polyethylene bottles and were transported to the laboratory in an ice box. The collected water samples were filtered and analyzed for nutrients such as nitrite (NO_2), nitrate (NO_3), ammonia (NH_4), inorganic phosphate (PO_4) and silicate (SiO_4). Nutrients were analyzed following standard procedures (Grasshoff *et al*., 1983). Total Suspended Matter (TSM) was measured by gravimetric techniques (Strickland and Parsons, 1984).

Investigation on phytoplankton involved determining species composition, contribution to biomass and numbers. The fixed water samples were finally concentrated to 80 ml by sedimentation. In the laboratory, phytoplankton identification was made with the aid of an inverted fluorescence microscope (Make: Cippon; Model No. 21033). A Sedgwick Rafter counting chamber was used as a platform for qualitative and quantitative estimation of phytoplankton. The phytoplankton abundance was represented as cell numbers per liter (Nos. L^{-1}). Standard taxonomic identification keys were used for the identification of phytoplankton species.

Zooplankton samples were collected at each station by horizontal haul of a zooplankton net (mesh size of 120 μm) for 5 min. Samples from the receiver were transferred to precleaned polythene bottles and preserved in 5% formaldehyde. A digital flow meter (HydroBios) was used to determine the volume of water filtered. In the laboratory, the zooplankton samples were sub-sampled with the help of a Folsom plankton splitter for quantitative and qualitative analysis. An aliquot of the sample was taken from the sub-sample and observed under an inverted microscope (Cippon; Model No. 21033) for identification and counting. The numerical abundance values were represented in Nos. 10 m^{-3}. The relative abundance was computed from total density and the density of each group. Different groups of zooplankton were identified following standard literature.

Statistical analyses: Hydrographic and biological parameters were subjected to analysis of variance (ANOVA) to see any significant variation among seasons and stations and correlation matrix was evaluated to know the parameters that co vary. Microsoft Excel programme 2007 was used to compute the above statistical analyses.

RESULTS AND DISCUSSION

The mean and standard deviation values of the hydrographical parameters and nutrient of different months of premonsoon are given in Table 1. WT, salinity, pH and DO showed spatial and monthly variation. Monthly analysis showed that average water temperature varied from 27.98°C (May)-29.60°C (June). Temperature established a strong positive correlation ($p \leq 0.01$) with salinity during the present study. Which might be attributed to the low amount of rainfall, higher rate of evaporation and also due to neritic water dominance (Sampathkumar and Kannan, 1998). Monthly salinity values ranged from 32.04 PSU (June)-35.59 PSU (March and April). Statistical analysis (Table 2) showed

Table 1: Monthly variation of hydro-biological parameters during premonsoon 2011

	March		April		May		June	
	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD
WT(C°)	28.28	0.81	28.82	0.81	27.98	1.86	29.60	0.98
pH	7.94	0.20	7.94	0.20	8.11	0.16	7.90	0.43
DO (mg L^{-1})	8.07	0.39	8.07	0.39	7.19	0.40	7.99	0.23
Salinity (PSU)	32.59	1.00	32.59	1.00	32.16	2.59	32.04	2.37
NO_2 (μmol L^{-1})	0.58	0.15	0.58	0.15	0.39	0.13	0.48	0.11
NO_3 (μmol L^{-1})	1.69	0.22	1.69	0.22	1.39	0.22	1.13	0.36
NH_4 (μmol L^{-1})	1.57	0.40	1.57	0.40	1.87	0.38	9.06	4.62
PO_4 (μmol L^{-1})	0.62	0.21	0.62	0.21	0.31	0.10	0.68	0.10
SiO_4 (μmol L^{-1})	12.81	5.75	12.81	5.75	2.12	0.61	3.32	0.89
TSM (mg L^{-1})	9.04	2.11	8.92	2.75	8.08	3.01	6.18	1.43
Chl-*a* (mg m^{-3})	1.83	0.53	1.83	0.52	1.36	0.28	1.13	0.43
Phytoplankton (Nos. L^{-1})	36309	20518	34639	12096	30441	10262	25543	5414
Zooplankton (Nos. 10 m^{-3})	9615	8174	6959	2123	11384	4505	35869	43060

Table 2: Correlation matrix among different hydro-biological parameters

Variables	WT	pH	DO	Salinity	NO_2	NO_3	NH_4	PO_4	SiO_4	Chl-*a*	TSM	Tot. phyto	Diatom	Dinoflagellate	Green algae	Tot. Zoo	Copepoda	OC	NC	Meroplankton
WT	1																			
pH	0.315	1																		
DO	-0.095	-0.500*	1																	
Salinity	0.715**	0.753**	-0.308	1																
NO_2	-0.090	-0.265	0.234	-0.132	1															
NO_3	-0.329	-0.026	0.006	-0.069	0.642**	1														
NH_4	0.175	-0.367	0.196	-0.332	0.115	-0.441	1													
PO_4	0.207	-0.425	0.379	-0.116	0.482*	0.188	0.303	1												
SiO_4	-0.183	-0.201	0.640**	-0.030	0.355	0.445*	-0.323	-0.070	1											
Chl-*a*	-0.446*	-0.080	0.261	-0.216	0.074	0.515*	-0.376	0.082	0.502*	1										
TSM	-0.670**	-0.453*	0.340	-0.615**	0.079	0.336	-0.323	-0.044	0.374	0.455*	1									
Tot. Phyto	-0.594**	-0.516*	0.419	-0.501*	-0.028	0.106	-0.219	0.011	0.321	0.205	0.827**	1								
Diatom	-0.598**	-0.478*	0.416	-0.472*	0.052	0.165	-0.213	0.046	0.327	0.179	0.797**	0.980**	1							
Dinoflagellate	0.138	-0.240	-0.201	-0.110	-0.357	-0.314	0.140	-0.193	-0.184	0.015	-0.089	-0.165	-0.320	1						
Green algae	0.119	0.102	-0.197	0.015	-0.271	-0.131	-0.001	0.052	-0.363	-0.118	-0.075	0.004	-0.116	0.305	1					
Tot.zoo	0.065	-0.127	0.131	-0.228	0.088	-0.108	0.759**	0.143	-0.227	-0.249	-0.181	-0.197	-0.182	0.096	0.060	1				
Copepoda	0.062	-0.131	0.179	-0.233	0.140	-0.069	0.757**	0.194	-0.180	-0.224	-0.160	-0.164	-0.141	0.037	0.061	0.987**	1			
OC	0.154	-0.129	0.064	-0.200	0.011	-0.223	0.633**	0.054	-0.171	-0.354	-0.130	-0.168	-0.182	0.180	0.160	0.745**	0.762**	1		
NC	-0.468*	-0.372	0.075	-0.655**	0.186	-0.067	0.610**	0.086	-0.240	-0.017	0.159	0.057	0.074	0.066	-0.173	0.626**	0.608**	0.283	1	
Meroplankton	-0.049	-0.264	0.188	-0.349	0.154	-0.112	0.802**	0.226	-0.176	-0.158	-0.153	-0.160	-0.153	0.162	0.003	0.955**	0.958**	0.728**	0.716**	1

*Significance level at 0.05, **Significance level at 0.01, OC: Other crustacean, NC: Non cmstacean, Tot. Phyto: Total phytoplankton, Tot. Zoo: Total zooplankton a significant positive correlation with water temperature and pH ($p \leq 0.01$) which might be attributed to the high biological activity during premonsoon and also freshwater influx (Das *et al*., 1997). pH in the coastal waters off Rushikulya estuary varied between 7.90 (June)-8.11 (May). pH found in positive relation with salinity ($p \leq 0.01$). DO values ranged from 7.19 mg L^{-1} (May)-8.07 mg L^{-1} (March and April). More fluctuation in dissolved oxygen concentration was observed in May (SD: 0.40 mg L^{-1}). DO showed a negative correlation with salinity which was manifested by the fact that minimum DO coincided with salinity maximum (Sahu *et al*., 2012). TSM values ranged from 6.18 (mg L^{-1}) 9.04 (mg L^{-1}). TSM showed strong negative correlation with WT ($p \leq 0.01$), pH ($p \leq 0.05$) and salinity ($p \leq 0.01$). This type of negative relation might have been resulted due to low fresh water influx and complete dominance of marine water in the coastal waters during premonsoon.

Month wise data of NO_2 showed that it varied from 0.39 (May)-0.58 μmol L^{-1} (March, April). Monthly Avg. NO_3 ranged from 1.13 (June)-1.69 μmol L^{-1} (March and April) during premonsoon. NO_3 found in a strong positive relation with NO_2 ($p \leq 0.01$). Average NH_4 concentration was found maximum in June (9.06 μmol L^{-1}) and minimum in two months i.e., March and April (1.57 μmol L^{-1}). Monthly, PO_4 and SiO_4 varied from 0.31-0.68, 2.12-12.81 μmol L^{-1}, respectively. PO_4 and SiO_4 content was maximum in May. TSM concentration was found to be minimum during June (6.18 μmol L^{-1}) and maximum in March (9.04 μmol L^{-1}). Though there is low river influx during premonsoon but wind induced turbulent condition in the Indian coastal waters favoring the resuspension of the bottom sediment due to stirring action to increase the TSM concentration (Qasim *et al*., 1968; Nixon, 1988). Mean Chl-*a* showed its maximum in June (1.13 mg m^{-3}) and minimum in March and April (1.83 mg m^{-3}) with maximum deviation in March (SD-0.53 mg m^{-3}). Chl-*a* found in positive relation with NO_3 ($p \leq 0.05$), SiO_4 ($p \leq 0.05$) and TSM ($p \leq 0.05$). Positive correlation of TSM with Chl-*a* might be due to increased phytoplankton biomass during this period which could have contributed to the TSM content considerably (Satpathy *et al*., 2011). Chl-*a* performed negative correlation with WT ($p \leq 0.05$). Analysis of variance revealed significant monthly variation in pH ($p<0.01$), salinity ($p<0.01$) and TSM ($p<0.01$). Significant station wise variation was observed in DO ($p<0.01$) and most of the nutrients i.e., NO_3 ($p<0.05$), NH_4 ($p<0.01$), PO_4 ($p<0.05$), SiO_4 ($p<0.01$) (Table 3).

Phytoplankton community: Taxonomic identification revealed a total 119 species of phytoplankton, of which 84 species are of diatoms, 22 species of dinoflagellates, 7 species of green algae, 5 species of cyanobacteria (blue green algae), 1 species of cocolithophore in the shallow coastal water off Rushikulya estuary during the observation period (Table 4). According to the number of species under different groups a pattern of Diatom>Dinoflagellate>Green algae>Cyanobacteria> Cocolithophore was noticed during premonsoon. This type of pattern in all the seasons is a little deviation against reported sequence i.e., Diatoms>Dinoflagellates> Cyanobacteria>Green algae>others in Indian coast (Prabhahar *et al*., 2011; Achary *et al*., 2010). Further the monthly variability of phytoplankton community is described as below. Station-wise total phytoplankton population density was higher in R-1 in comparison to other stations. This might be attributed to the riverine influence and terrestrial runoff as this station is close to both estuary and coast (Fig. 1). So the nutrient rich resultant environment stimulates phytoplankton growth and as a consequence nutrients reduction in the ambient medium occurs. In our case during this season with low amount of nutrients we recorded highest abundance which can be justified by the above reason.

Monthly analysis showed that the phytoplankton population varied from 25543 to 36309 Cells L^{-1} (Table 1). Among all the groups, Diatoms dominated the phytoplankton community followed by dinoflagellates in all the months (Fig. 2). Diatom dominance in Indian

Table 3: Analysis of variance of different hydro-biological parameters

Variables	Between months	Between stations
WT	0.060	0.196
pH	**0.000**	0.643
DO	0.391	**0.003**
Salinity	**0.000**	0.950
NO_2	0.665	0.122
NO_3	0.973	**0.010**
NH_4	0.851	**0.000**
PO_4	0.394	**0.011**
SiO_4	0.520	**0.001**
Chl-*a*	0.093	0.059
TSM	**0.002**	0.249
Tot. Phyto	**0.007**	0.589
Diatom	**0.030**	0.578
Dinoflagellate	0.927	0.596
Green algae	0.774	0.773
Zooplankton	0.376	0.180
Copepoda	0.366	0.155
Other crustaceans	0.182	0.166
Non crustaceans	0.215	0.465
Meroplankton	0.201	0.177

Significant values at $p<0.05$ are given in bold

Table 4: Phytoplankton number in different months during premonsoon 2011

Groups	Mar	Apr	May	June	PRM
Diatom	44	41	39	39	84
Dinoflagellates	8	10	10	8	22
Green algae	4	4	4	3	7
Cyanobacteria	1	3	3	3	5
Cocolithophores	0	1	0	0	1
Total	57	59	56	53	119

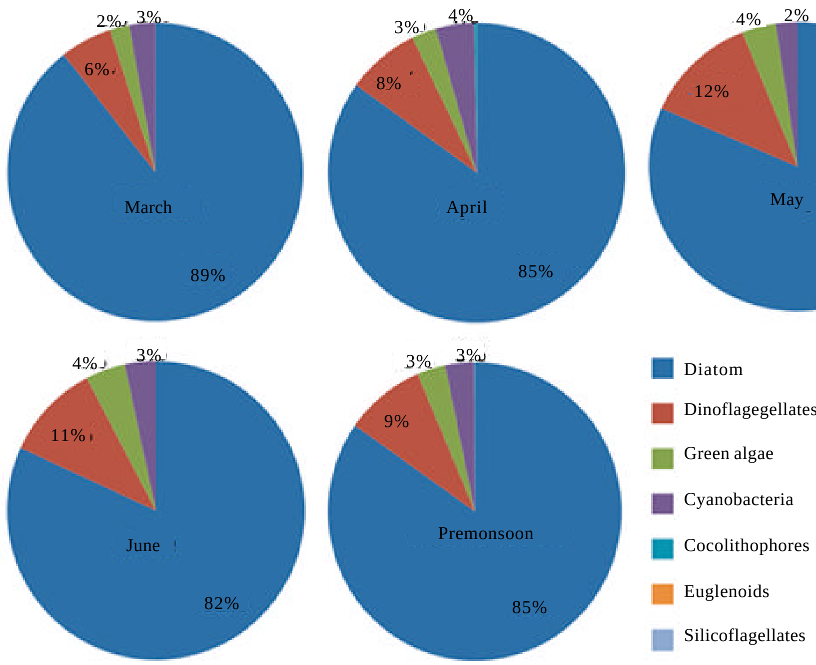

Fig. 2: Phytoplankton composition during premonsoon 2011

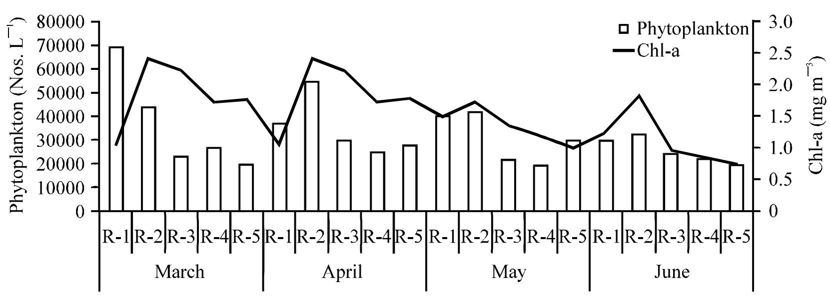

Fig. 3: Monthly variation of phytoplankton and Chl-*a* during premonsoon 2011

coastal water was previously reported by Choudhury and Pal (2010). This type of dominance of diatoms over dinoflagellates coincides to a lot of reports in world oceans (Chisholm, 2000;Palleyi *et al*., 2008). This might be due to the eurythermal and euryhaline nature of diatom (Naik *et al*., 2009) which favors diatom dominance. The other groups found during the study period were green algae, cyanobacteria and cocolithophore. From the different diversified distribution and composition of phytoplankton obtained from present study it can be assumed that phytoplankton population and their growth depend on several environmental factors which are variable in spatio-temporal scale (Ei-Gindy and Dorghan, 1992).

Among all the stations, R-2 showed higher density of phytoplankton during all the months except in March where R-1(69028 Cells L^{-1}) showed higher population density (Fig. 3). Monthly total phytoplankton diversity in terms of number of species during premonsoon varied from 53 (June) to 59 (April). Comparatively higher species diversity of diatoms was recorded in March than other months. The Dinoflagellates diversity ranged from 8 to 10. The species diversity under green algae varied form 3-4. Cyanobacteria diversity varied form 1-3. Coccolithophores encountered only with a single species during April and totally absent in other months (Table 4).

Phytoplankton and other hydro-biological variables: Phytoplankton abundance varied between 25543 and 36309 Nos. L^{-1}. Maximum standard deviation (±20518) was observed during March. Chl-*a* is regarded as an index of phytoplankton biomass. The regression between Chl-*a* and phytoplankton abundance resulted with weak relation (R^2 = 0.042) (Fig. 4). To explain better, Chl-*a* values were superimposed on spatio-temporal phytoplankton abundance values (Fig. 3) and it was observed that Chl-*a* found in positive relation with phytoplankton abundance except deviation at station R-1 during initial premonsoon months (March and April). This type of linear relation was also reported by many investigators (Kalchev *et al*., 1996; Sridhar *et al*., 2010). Deviation in this trend observed at R-1 might be attributed due to low contribution rate of quantified phytoplankton fraction to total Chl-*a* at particular station of particular season (Polat and Piner, 2002).

An irregular relationship was observed between phytoplankton abundance and zooplankton abundance i.e., sometimes they were positively related and sometimes negative (Fig. 5). Among various investigators, Prasad (1956) found inverse relationship between phytoplankton and zooplankton in Gulf of Mannar. However, Prasad (1956) has also recorded direct relationship in Palk Bay which also corroborated in the present study.

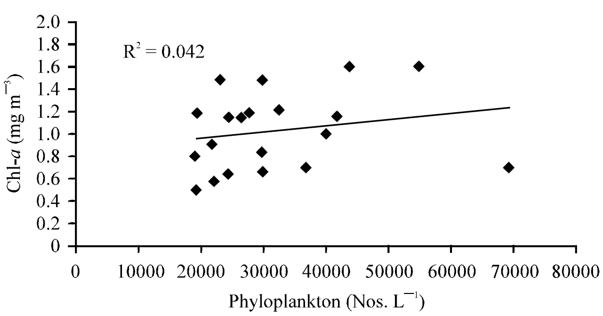

Fig. 4: Regression between Chl-*a* and phytoplankton

Correlation matrix explained that phytoplankton abundance was positively correlated with TSM (p≤0.01) and negatively with WT (p≤0.01), pH (p≤0.05) and salinity (p≤0.05) (Table 2). Diatom which was the most dominant group of phytoplankton exhibited strict similar relationship with above parameters as phytoplankton. The dominancy of diatom can also be proved from the strong positive relation between total phytoplankton abundance and diatom abundance (p≤0.01) (Table 2). Analysis of variance explained significant monthly variation in total phytoplankton abundance (p≤0.01) and diatom abundance (p≤0.05) (Table 3).

Zooplankton community: A total of 134 species of holoplankton and 20 types of larvae were encounterd during the present study (Table 5). According to the number of species under different groups a pattern of copepoda>other crustaceans>larvae>non crustaceans was noticed during premonsoon (Table 5). Further the monthly variability of Zooplankton community is described as below.

Monthly analysis showed that the zooplankton population varied from 6959 to 35869 Nos./10m^3 (Table 1). Among all the groups, Copepoda dominated the zooplankton community with 74 to 85% (Fig. 6). Fernandes and Ramaiah (2009) have reported the contribution of copepod up to 76-89% in the Central Bay and 80-99% in the Western Bay. So the observed relative abundance of copepod in the present study can be comparable with the study of Fernandes and Ramaiah (2009). Copepoda dominated the zooplankton community followed by the meroplankton during March and June. This type of pattern of copepoda>larvae was also reported by Perumal *et al*. (2009). During April and May Copepoda remained as the 1st order of dominancy where as other crustaceans and non crustaceans were 2nd order of dominancy, respectively.

Among the five stations, R-3 showed higher density of zooplankton during all the months except in May where R-4 showed higher population density (Fig. 5).

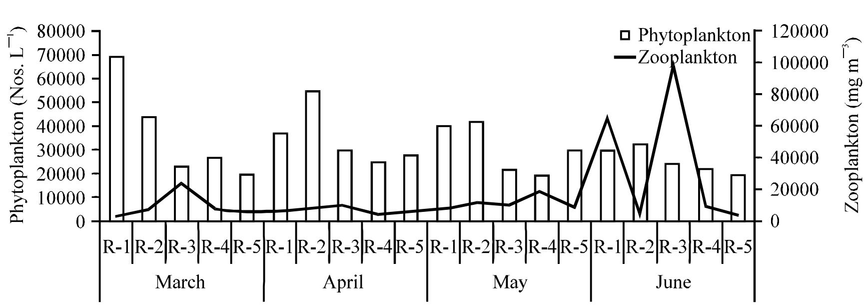

Fig. 5: Monthly variations of phytoplankton and zooplankton during premonsoon 2011

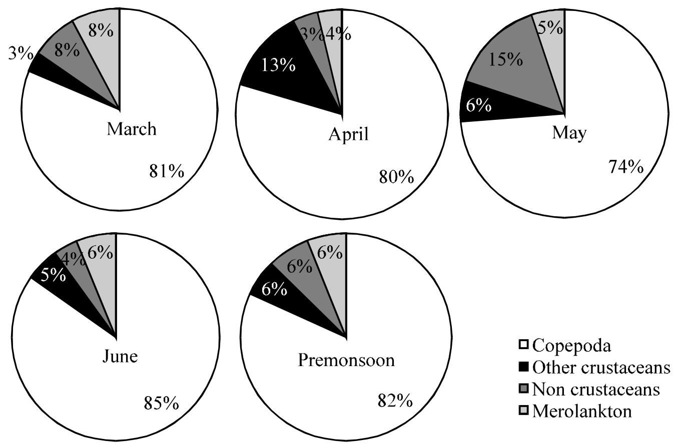

Fig. 6: Zooplankton composition during premonsoon 2011

Table 5: Zooplankton number in different months during premonsoon 2011

Groups	Mar.	Apr.	May	June	PRM
Copepoda	47	38	39	23	85
Other crustaceans	16	14	16	11	36
Non crustaceans	5	8	5	6	13
Meroplankton	16	14	12	11	20
Total	84	74	72	51	154

Monthly total zooplankton diversity in terms of number of species during premonsoon varied from 51 (June) to 84 (March) (Table 5). Comparatively higher species diversity of copepoda was recorded in March than other months. Other crustaceans diversity ranged from 11 to 16. The species diversity under non crustaceans varied form 5-8. Meroplankton diversity varied form 11-16 (Table 5).

Zooplankton and other hydro-biological variables: In oceanic ecosystem phytoplankton are the primary producers and zooplankton are the primary consumers which feed upon the phytoplankton. The relation between these two important variables are discussed in above paragraph. In regards of statistical analyses, zooplankton abundance exhibited strong positive relation with NH_4 ($p\leq 0.01$) (Table 2). Copepoda the most dominant group of zooplankton performed similar relations like total zoopankton abundance. The dominancy of copepoda can also be proved from the strong positive relation between total zooplankton abundance and copepoda abundance ($p\leq 0.01$) (Table 2). Analysis of variance explained no significant variation in total zooplankton abundance and also for different groups of zooplankton (Table 3).

CONCLUSION

Monthly hydro-biological parameters of coastal waters off Rushikulya estuary was investigated during premonsoon, 2011. Significant variation was observed in nutrient distribution during the study period. Correlation analysis revealed nitrate and silicate as the influencing nutrient components for Chl-*a* distribution. Dominancy of diatom in phytoplankton floral composition was observed during the study period. But the controlling factors of season-wise and station-wise fluctuation in phytoplankton population as well as species composition shall be further studied. Presence of 20 different meroplankton indicated that coastal waters off Rushikulya estuary acts as a biological breeding ground. During the present study, zooplankton population density was positively related with zooplankton biomass which denotes equal size distribution of species. From the present study it can be assumed that coastal waters off Rushikulya estuary play an important character in coastal food chain in terms of regulating the phytoplankton and zooplankton. Further floral and faunal composition of phytoplankton and zooplankton respectively signified a healthy environment in this coastal area. The present study will serve as baseline information for future research in this region.

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