Available online at: www.mbai.org.in doi: 10.6024/jmbai.2016.58.1.1877-09

Influence of lunar cycle and hydrological parameters on the depth-wise distribution of zooplankton in the inshore waters off Tuticorin, Gulf of Mannar

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Received: 8 Dec 2015, Accepted: 25 Jun 2016, Published: 30 Jun 2016

Original Article

Abstract

A study was conduced to assess the depth wise variation and influence of lunar cycle and hydrological parameters on the distribution of zooplankton constituents in Tuticorin inshore waters between April 2011 and March 2012. Fortnightly sampling of zooplankton and hydrological parameters at four different depths like 5 m, 10 m, 15 m and 20 m was carried out on every full moon and new moon day to assess the variation. The zooplankton constituents were found in dominance in the order of copepod> decapod>*Lucifer*>fish eggs>cladocerans> Alima larvae>chaetognatha at all the depths. The swarming of zooplankton constituents were noticed more towards 15 m depth especially during new moon period. The full moon and new moon variation in the density was statistically significant for bivalve larvae and *Lucifer* ($p<0.05$) and the depth wise variation was significant only for decapods ($p<0.05$). The studies indicated that northeast monsoon which starts during late September in Tuticorin influences the environmental conditions as well as the distribution patterns of the zooplankton constituents in the Tuticorin inshore waters.

Keywords: *Lunar cycle, distribution, zooplankton constituents, Tuticorin*

Introduction

Zooplankton plays a key role in oceanic food web as consumers, producers, and prey. They are the major contributors of elemental cycling and vertical flexes. The zooplankton species composition, densities and seasonal fluctuations in relation to environmental parameters are important in determining the trophic level. Zooplankton responds quickly to aquatic environmental changes and is therefore used as indicators of the overall health of the ecosystem (Carriack and Schelskek, 1977). They are highly influenced by spatio temporal variations in hydrochemical parameters and physical forces (Bianchi *et al*., 2003). It is reported that the vertical movements of marine organisms may be a direct response to the change in light intensity in terms of phototaxis (Richardson, 1952; Enright and Hamner, 1967).

Considerable information is available about the plankton of the inshore area off Tuticorin (Sambandamurty, 1962; Marichamy and Pon Siraimeetan, 1979; Marichamy *et al*., 1985). Asha and Diwakar (2007) summarise the hydrology and zooplankton constituents of the inshore waters off Tuticorin. Apart from this no recent detailed study has been conducted on plankton population from this region. The present study was conduced to assess the depth wise variation in the zooplankton composition and the influence of lunar cycle and hydrological parameters on their distribution.

Material and methods

The present study was conducted from April 2011 to March 2012. Fortnightly sampling of zooplankton on every full moon and new moon day was done from four stations between 06.00 and 08.30 hrs at different depths; 5 m (Station 1- 08047.478′ N lat; 078013.078′E long.) 10 m (Station 2- 08047.286′ N lat; 078014.257E long.) 15 m (Station 3-08046.975′ N lat; 078013.078′E long.) and 20 m (Station 4- 08047.478′ N lat 078013.078′E long.). Zooplankton samples were collected from the sub-surface water by towing a plankton net of 50 cm diameter made of bolting net of mesh size 0.33 mm for 10 minutes at a uniform speed. A flowmeter (make-Hydro-Bios) was mounted at the centre of the net opening to measure the volume of water filtered by the net. The water volume passed through the zooplankton net was calculated by the method suggested by the manufacturer (Hydro-Bios, Germany). The volume of water filtered by the net = number of revolution of the flowmeter x 0.3 x net opening area (m^2) x 1000. The plankton samples were preserved in 4% buffered formaldehyde solution in sea water for sorting work. The volume of plankton was measured by displacement method. The abundance and diversity of zooplankton were estimated by fractioning the sample by means of a sub sampler (make- Krishna plastic, Kochi, Kerala) and the total number of organisms in one such sample was counted and identified from an aliquot of 5 ml sample. The population density was expressed in nos. l^{-1}. The relative abundance in percentage was computed from total density and the density of each group/taxa. The zooplankton was identified based on standard literatures (Newell and Newell, 1977; Santhanam *et al.*, 1987).

Hydrographic data were recorded by analysis of surface seawater samples following the standard methods. *In situ* measurement of air and water temperatures was made using a high precision thermometer. The water quality parameters namely pH, productivity, and chlorophyll were determined following the standard procedures (Strickland and Parson, 1968). The salinity was determined by Mohr's titration method and dissolved oxygen by Winkler method (Winkler, 1888). Nutrients were estimated by using Spectrophotometer (Genesis 5 model) as per the procedure of Grsshoff *et al.* (1999). Transparency was measured during water sampling using a secchi disc and expressed in meters. The mean values of all the parameters were used for statistical analysis to test the correlation and one way analysis of variance (ANOVA) by using SPSS 16 statistical package. The conventional diversity indices like H' (log 2)-Shannon diversity index (Shannon and Wiener, 1963) and d-Margalef's richness index (Margalef, 1958) was applied to compare the results.

Results and discussion

The relative abundance of major zooplankton constituents observed is given in Fig.1. Copepod was the most dominant group which constituted 12.2 to 88.8% of the total population followed by decapods with 1.32 to 53.8% of the total population. *Lucifer* was the third dominant group with the highest of 58% of the total population during the new moon period. The displacement volume of zooplankton varied between 1-49.2 ml. Comparatively a higher settlement volume was observed at 15 m depth and lower at 5 m depth (Fig. 2). The displacement volume increases with increasing numbers of zooplankton constituents. High positive correlation was noticed between settlement volume and the zooplankton densities ($p<0.01$). The settlement volume was lower during monsoon season (7.4±0.9 ml) and higher during pre-monsoon period (19.64±2.9 ml). The biomass of zooplankton was higher towards the new moon period especially in the shallowest 5 m depth and varied between the lowest of 0.07 ml m^{-3} during the full moon period at 15 m depth to the highest of 38.5 ml m^{-3} during the new moon period at 5 m depth (Fig. 2). Higher biomass of zooplankton was noticed during summer season (2.3±1.5 ml m^{-3}) and lower during monsoon season (0.26±0.03 ml m^{-3}). The lower biomass of zooplankton observed during the monsoon period in the present study is in accordance with the findings of Sahu *et al.* (2013) which might be due to the freshwater influx and associated variation of hydrological parameters as reported by Damotharan *et al.* (2010).

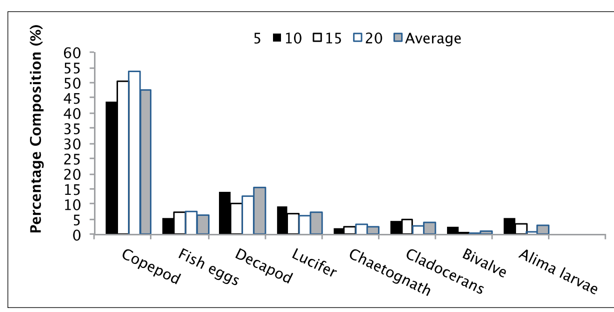

Fig. 1.Relative abundance of major zooplankton constituents at different depth.

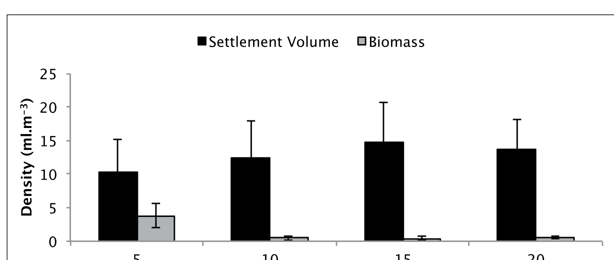

Fig. 2.Variation in the settlement volume and biomass (mean ±SE) values of zooplankton at different depth

The density of the copepod varied from a minimum of 6500 nos l^{-1} at 5 m depth and to the maximum of 609000 nos l^{-1} at 15 m depth. The mean value was minimum of 10305.8 ±1710.1 nos l^{-1} at 5 m depth during the full moon to the maximum of 19230.4±6043.4 nos l^{-1} at 15 m depth during the new moon period (Fig 3a). Flourishing of copepods was noticed during the post monsoon season (January-March) where as lower density was noticed during the pre-monsoon period (July to September). High significant difference was noticed in the seasonal variation of copepods ($p<0.01$). Copepod as the dominant zooplankton constituents among different groups have been reported by several workers from both west (Rani *et al.*, 1981; Padmavati and Goswami, 1996) and east coasts of India (Marichamy *et al.*, 1985; Mishra and Panigrahy, 1999; Sahu *et al.*, 2010).

The density of decapod varied between 4000 to 238500 nos l^{-1}. The mean value was minimum of 2212.1 ±468.6 nos l^{-1} at 15 m depth during new moon and maximum of 6395.8 ±1485.8 nos l^{-1} at 5 m depth during full moon period (Fig. 3b). The density of *Lucifer* ranged between 0 to 108000 nos l^{-1} and the mean value was the lowest of 414.9 ±160.2 nos l^{-1} at 20 m depth to the highest of 3543.08±1137.2 nos l^{-1} at 10 meter depth (Fig. 3c). Comparatively higher density of decapod and *Lucifer* was noticed during summer months and lower during monsoon period. The seasonal variation of both the groups was significantly different ($p<0.01$).

Fish eggs, the fourth dominant group constituted a maximum of 44.92% of the total population and the density was the highest of 109330 nos l^{-1}. The mean value varied between a minimum of 585.2±209.3 nos 1-1 at 20 m depth during full moon period to a maximum of 2733.4±993.9 nos l^{-1} at 15 m depth during the new moon period (Fig. 3d). Swarming of fish eggs was noticed during the pre-monsoon period and comparatively lower density was noticed during summer months. The seasonal variation was statistically significant ($p<0.01$). The period of higher dominance of fish eggs in the present study coincides with the spawning period of

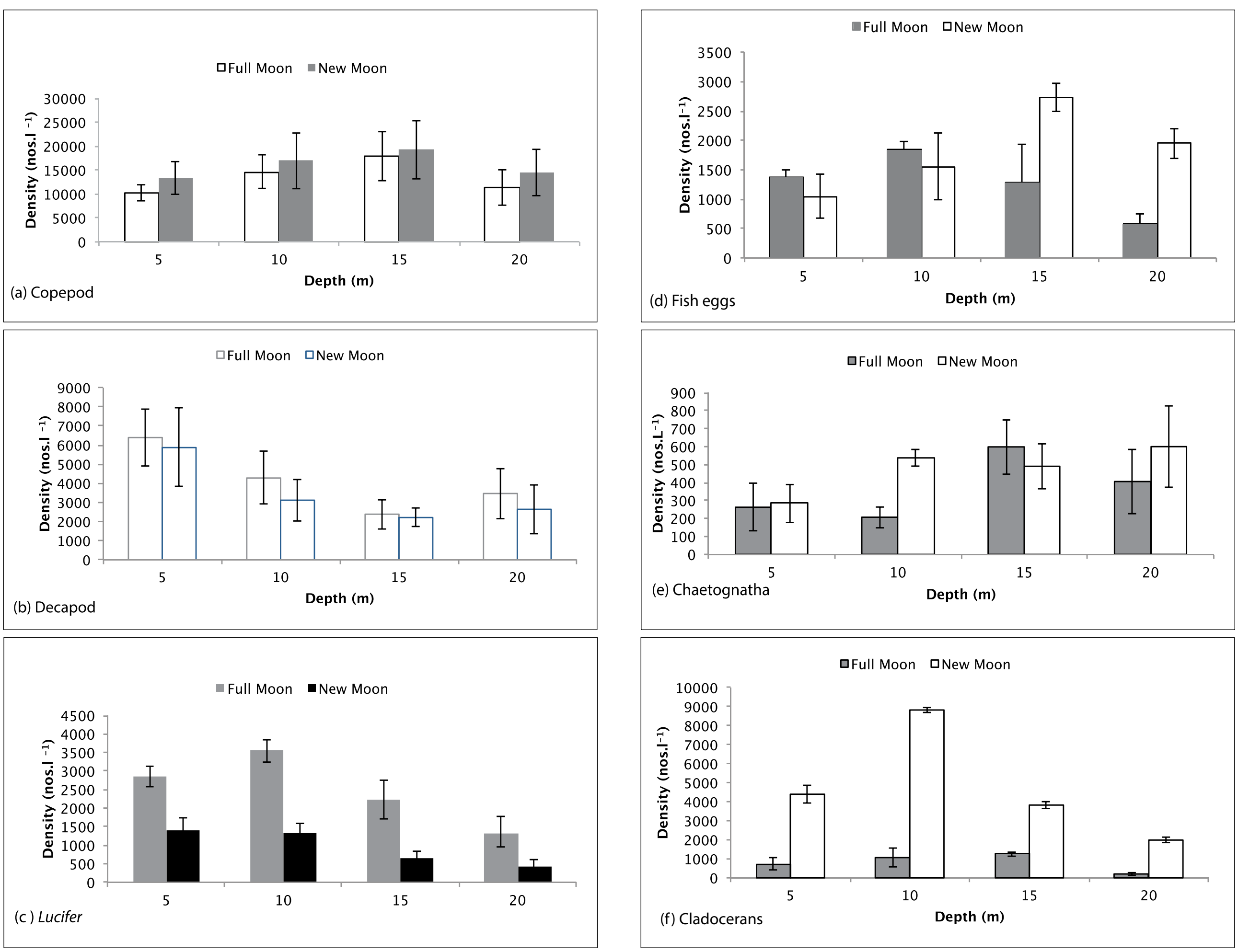

Fig. 3.Full moon and new moon variation in the density of major zooplnakton constituents (a) copepod; (b) decapod; (c) Lucifer; (d) fish eggs ; (e) chaetognatha ; (f) cladocerans

various fishes in Tuticorin as reported by Marichamy and Pon Siraimeetan (1979) in their findings, which might be attributed to the variation in surface temperature and salinity.

Cladocerans, the fifth dominant group comprised the maximum of 56.02% of the total population with the highest density of 900500 nos l^{-1}. The mean value varied between the lowest of 200 $\pm$78.17 nos l^{-1} at 20m depth to the highest of 8825.8$\pm$812.8 nos l^{-1} at 10 meter depth (Fig.3f). Comparatively higher density was noticed during the post monsoon season. Alima larva and chaetognatha represented the sixth and the seventh major groups with the highest density of 98500 nos l^{-1} and 28670 nos l^{-1} for Alima and chaetognatha respectively (Fig. 3e). Alima was predominant during pre-monsoon season and chaetognatha during summer months.

The number of zooplankton groups or taxa observed was generally lower during December–January months and higher during September-October months and varied between 8-21 numbers. The species richness index "d" was comparatively higher during the new moon period and varied between the lowest of 0.56 during April 2012 at 5 meter depth to the highest of 1.47 during September 2011 at 20 meter depth (Fig. 4b). The diversity index "H" varied between a minimum of 0.60 bits individual during December 2011 at 15 m depth to a maximum of 2.04 bits individual during April 2014 at 15 meter depth (Fig. 4a). In the present study higher density of zooplankton during August to September (pre monsoon) indicated the favourable condition for the growth of zooplankton population, which is similar to the findings of Abdus and Altaff (1995); Kumar (2001) and Pramod *et al.*, 2011.

The studies indicated the congregation of *Lucifer* and cladocerans towards 10 m depth and copepod, decapods and fish eggs towards 15 m depth, but the depth wise variation was significant only for decapods ($p<0.05$). Such variation might be due to the close relationship of zooplankton with environmental variables like salinity,

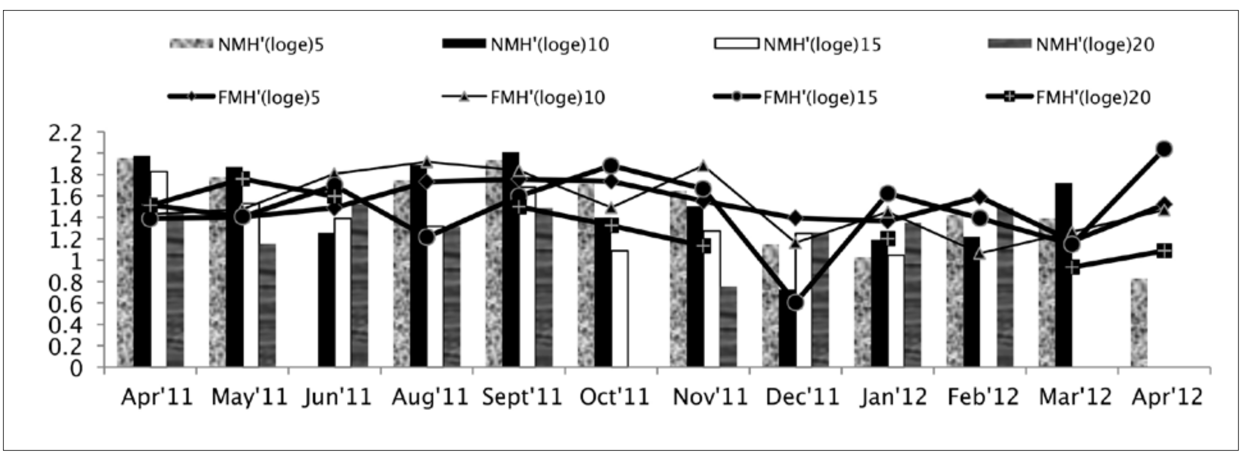

Fig. 4a. Variation in diversity index of zooplankton constituents at different depth during full moon and new moon

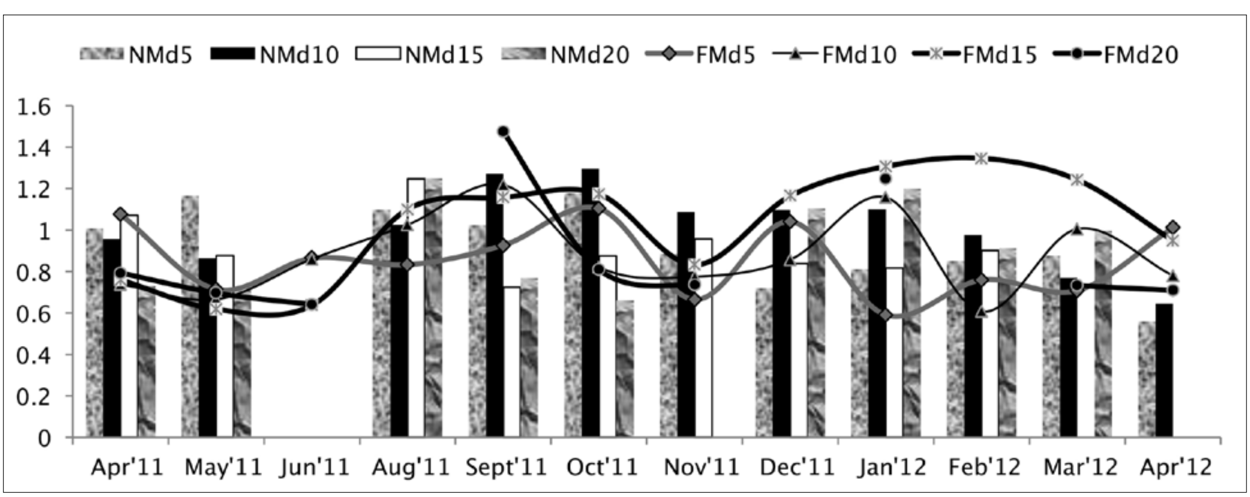

Fig. 4b Variation in species richness of zooplankton constituents at different depth during full moon and new moon

temperature, and dissolved oxygen concentration as indicated by Terazaki *et al.* (1986).

Swarming of constituents like decapods, *Lucifer*, fish eggs, Alima and bivalve larvae were more towards the full moon period. This indicated that these groups are positive to phototaxis showing their maximum rhythmic activities during day light, whereas groups like copepod, cladocerans and chaetognatha were more towards the new moon period, which indicated that these are negative in phototaxis and are more active in dark (Parker, 1902; Tanusree and Patra, 2006). The full moon and new moon variation in the density was statistically significant only for bivalve larvae and *Lucifer* ($p<0.05$). It is likely that the zooplankton activity is oriented to a band of optimum moon light intensity and they adjust their upward and downward movement accordingly (Cushing, 1951; Hardy and Bainbridge, 1954).

In the present study an inverse relationship was exhibited between the occurrence of larval forms and other major zooplanktonic organisms like copepod and decapods and such inter-relationship of common zooplankter has already been reported by Marichamy and Pon Siraimeetan (1979) in their studies.

Temperature and oxygen concentration are the key factors restricting the zooplankton occurrence and it is known that copepod is more sensitive to alterations in the quality of water (Gannon and Stremberger, 1978), they respond to environmental changes faster than other groups. Not much variation was observed in the sea surface temperature, salinity and pH between stations. The SST ranged between 25 to 32.2°C with the highest mean value of 29.5±0.5°C in the shallowest 5 meter depth. The SST was less in monsoon season due to fresh water influx and higher in summer season (Table1). Very high significant difference was observed in the seasonal variation of SST ($P>0.001$).

Chlorophyll varied between 0-3.4 mg m^{-3} and the mean value was more or less same at 5, 10 and 15 m depths during full moon periods. Chlorophyll was higher during summer months and lower during monsoon months. Similar trend in both SST and Chlorophyll was also reported by several authors (Reddi

Table 1. Seasonal variation in the mean values (±SE,) of density (nos l-1) of major zooplankton constituents and hydrological parameters at collection sites during the study period

Summer	Pre monsoon	Monsoon	Post monsoon	
Settlement Volume	14.15±2.5	19.64±2.9	7.4±0.94	15.07±23
Boimass	2.3±1.5	0.48±0.063	0.26±0.03	0.55±0.11
Copepods	54981.5±9793.9	31440.7±50.95	141740.9±27524.4	169826.7±22531.9
Fish eggs	4814.4±1031.1	51237.8±9232.6	17068.2±4045.2	5130.4±1770.3
Decapods	245122±5475.6	87928.6±19928.7	27795.5±5998	36673.9±5397.9
Lucifer	53704±1401.1	30226.4±6198.2	9204.5±2743.1	6847.8±1921.8
Cheatognatha	53704±1401.1	6571.4±1634.7	2250±566.8	3304.3±830.2
Mysis	3154.1±759.3	3797.6±1734.9	613.6±2732	608.7±275.5
Cladocerans	1672.6±313.8	24202.1±4476.8	7159.1±2184.7	82521.7±43432.9
Bivalve larvae	3074.0±1364.1	6059.3±2079.7	727.3±232	1089.1±708.2
Alima larvae	8462.6±3668.3	23535.7±5238.1	5000±1843.9	7130.4±2843.4
Fish larve	1395.2±933.01	821.4±280.5	4.9.1±149.5	217.4±136.3
SST (°C)	31.3±0.14	29.0±0.18	28.3±0.4	28.2±0.33
Salinity (ppt)	34.4±0.4	35.6±0.25	34.03±0.27	32.63±0.32
pH	7.9±0.06	8.26±0.05	8.5±0.04	8.32±0.028
Chlorophyll (μg. l^{-1})	0.893±0.195	0.59±0.3	0.54±0.12	0.441±0.09
GPP (mg C l^{-1}day^{-1})	1.24±0.33	1.7±0.7	0.82±0.28	1.4±0.44
NPP (mg C l^{-1}day^{-1})	1.32±0.4	1.7±0.9	3.1±0.93	1.94±0.7
DO (ml l^{-1})	3.58±0.185	3.856±0.185	3.863±0.24	3.858±0.162
NO2 (μg l^{-1})	0.27±0.04	0.33±0.07	0.205±0.1	0.84±0.32
NO3 (μg l^{-1})	0.244±0.18	0.14±0.06	0.044±0.03	0.26±0.11
PO4 (μg l^{-1})	1.04±0.15	0.580.09	0.57±0.05	1.00±0.3
SiO2 (μg l^{-1})	11.92±1.7	26.4±5.5	19.3±4.00	3.61±0.38
Transparency (m)	3.9±0.65	2.8±0.37	3.7±0.36	5.8±0.64

et al., 1993 Sarupria *et al.*, 1998; Sridhar *et al.*, 2010; Sahu *et al.*, 2010). The salinity was more or less same at all the stations and varied between 30.5 to 37.7 ppt. Salinity was higher during pre-monsoon season and lower during post monsoon season (Table1). Achary *et al.* (2010) and Mitra *et al.* (1990) also observed similar trend in their studies. pH varied between 7.3 to 8.7 and it was higher during monsoon season and lower during summer season, which might be due to the influx of land run off associated with monsoon season. High significant difference was also noticed in the seasonal variation of pH ($p<0.001$). Not much variation was noticed in the GPP between stations. The mean value was the lowest of 0.5 ± 0.2 mg C l^{-1}.day-1 at 15 meter depth and the highest of 2.2 ± 0.8 mg C l^{-1} day-1 at 10 meter station. Higher values of GPP were noticed during the pre-monsoon season and lower during monsoon season. NPP was comparatively higher at 5 m depth at St.1 with the highest mean of 4 ± 1.5 mg C l^{-1} day^{-1}

Dissolved oxygen varied between 1.4 to 4.6 ml l^{-1} at 5 m depth, 2.8 to 7.8 ml l^{-1} at 10 m depth, 2.1 to 5.7 ml l^{-1} at 15 m depth and 3.3 to 4.9 ml l^{-1} at 20 m depth. The mean value was the lowest of 3.2 ± 0.2 ml l^{-1} at 5 m and the highest of $4.4\pm$ 0.36 ml l^{-1} at 10 m depth. High significant difference was noticed in the variation between stations ($p<0.01$). Nitrite and phosphate concentrations were comparatively higher in the new moon period samples at all the stations. The mean value was the highest of 0.8 ± 1.6 μg l^{-1} for nitrite at 20 m depth, $1\pm$ 0.3 μg l^{-1} for phosphate at 10 m depth and 17.1 ± 6.9 μg l^{-1} for silicate at 15 m depth. The nutrients were lower during monsoon season and were higher during post-monsoon season (Table 1). Significant difference was also noticed in the seasonal variation of nitrite and silicate ($P<0.001$). Similar observation of higher nutrients concentration during post monsoon season has already been indicated in the studies of Subrahmanyan (1959), Qasim *et al.* (1972) and Gopinathan *et al.* (1974).

There was a gradation noticed in the transparency with respect to the depth of stations. The transparency was the lowest of 0.5 meter at 5 meter depth to the highest of 12 m at 20 meter depth. The transparency was higher during post monsoon season and lower during pre-monsoon season and similar trend was reported by Sahu *et al.* (2010) in their studies. Very high significant difference was also noticed in the seasonal variation ($p<0.001$).

The northeast monsoon which starts during late September in Tuticorin water was observed to exert greater influence on the environmental conditions as well as in the distribution pattern of zooplankton constituents in the Tuticorin coastal waters. Similarly the swarming of zooplankton groups was more during the new moon period at 15 m depth observed in the present study emphasises the importance of zooplankton groups in the pelagic ecosystem studies.

Acknowledgements

The authors gratefully acknowledge the support and the facilities provided by the Director, CMFRI, Kochi and the Scientist–in-Charge, Tuticorin for carrying out this study.

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