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An Investigation on the Phytoplankton Dynamics from the Coastal Waters of New Mangalore Port, Southwest Coast of India

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ABSTRACT

Phytoplankton species composition and distribution in relation to environmental parameters was investigated from the inshore and coastal waters of New Mangalore Port. A total of 16 stations were selected in such a way that 3 were inside the port and 13 in near shore coastal waters. Water quality parameters such as temperature, salinity, pH, dissolved oxygen along with nutrients such as nitrate, phosphate and silicate were monitored; along with phytoplankton biomass (chlorophyll *a*) and species composition. Chlorophyll *a* ranged between 0.01 and 4.95 mg m^{-3} among the stations. Cumulative abundance of phytoplankton was mainly dominated by diatoms (63 %), followed by dinoflagellates (24 %) whereas average number of phytoplankton are more observed in station 4 followed by station 6 and station 1. The present study infers that the phytoplankton diversity and distribution are subject to changes in physico-chemical conditions of the ecosystem. Therefore, a frequent monitoring of these ecosystems with its physico-chemical conditions and biological diversity provides knowledge of the health of ecosystem.

Key Words: Chlorophyll *a*; Diatoms; Dinoflagellates; Nutrients; Diversity

INTRODUCTION

Coastal waters are highly dynamic and productive ecosystems includes estuaries, sea grass beds, coral reefs and continental shelves that cover only 6 % of the world's surface but are providing around 22 to 43 % of the estimated value of the world's ecosystem services (Huertas et al. 2011). Phytoplankton communities forms the basis of marine and freshwater food webs, their composition fluctuates depending on hydrological conditions, such as light, temperature, salinity, pH, nutrients, turbulence etc. (Huertas et al. 2011, Supate and Bhosale 1989). The assessment of primary productivity of aquatic ecosystem is prerequisite for the forecast of fishery potential of an area (Rajkumar et al. 2009). Phytoplankton composition is dominated by diatoms or dinoflagellates, depending on the combination of hydrological conditions and climate variability (Leterme et al. 2006). They act as bio indicators with reference to water quality and thus serve as a tool for assessing the health of the aquatic ecosystems. The port is one of such important habitats, which are highly prone to bio invasion, eutrophication or pollution due to increased anthropogenic activities such as shipping, dry docking and exchange of ballast waters (Anil et al. 2002, Bax et al. 2004, Bulleri and Chapman 2010, Sin et al. 2013). The port waters are exposed to different anthropogenic activities with an increase in the establishment of different industries in the last two decades (Verlecar et al. 2006, Shirodkar et al. 2009). The spatio temporal distribution of these aquatic organisms can be used as indicators of the environmental health or biological integrity of an aquatic system.

Due to increased anthropogenic activities, many manmade structures include ports are established along the coastal region. Information on various environmental parameters, phytoplankton composition and density of these artificial structures is a prerequisite. In this prelude, the coastal and inshore waters of New Mangalore Port were selected in the present study, in which the phytoplankton composition and distribution in relation to water quality parameters are assessed.

STUDY AREA

New Mangalore port a major sea port, is an artificial lagoon type harbor located in Karnataka state on the west coast of India (latitude 12°55'N, longitude 74°48'E). MRPL – Mangalore Refineries and Petro-Chemicals Limited (for crude import and their product load out) is the major users of this port. The traffic through this Port has been increased manifold over the years. This lagoon type harbor is entered through a dredged channel, about 705 m long. The entrance is protected by two break waters extending to a length of 770 m on either side of the channel. The dredged channel has a bottom width of 245 m and with a dredged depth of 15.40 m. The present work on phytoplankton dynamics in the inshore and coastal waters of New Mangalore Port were carried out during pre-monsoon in the month of March, 2016. A total of 16 stations, in which 3 were inside the port and 13 in near coastal waters were selected (Figure 1).

METHODS

The surface water samples were collected using Niskin water sampler with the help of a motorized boat. The temperature and salinity were measured *in situ* using CTD (Sea bird electronics), pH using an ELICO LI 610 pH meter (accuracy ± 0.01). Dissolved oxygen was estimated according to Winkler's method (Grasshoff et al. 1983). Nutrient concentrations were analyzed following standard methodologies (Zhong and Charles 2006, UNESCO 1994). For chlorophyll *a* estimation, 250 ml of water sample was filtered through GF/F filters (nominal pore size, 0.7 µm), then extracted with 90 % acetone for 24 h, and kept in freezer. Chlorophyll *a* concentration was determined fluorometrically (Turner Designs, Model 7200) after acidification following standard protocol (UNESCO 1994). For quantitative and qualitative studies of phytoplankton, 1 L of water samples was taken and fixed with few drops of Lugol's iodine solution. After the settling and siphoning procedure, 1 ml of the aliquot of the sample were taken in a Sedgwick- Rafter counting cell, observed under the inverted microscope (Leica DFC- 450) for qualitative and quantitative estimation (Tomas 1997).

The graphical representation of data is portrayed using Ocean Data View (ODV) software developed by Alfred-Wegener-Institute for Polar and Marine Research (AWI). Univariate and multivariate community analysis were carried out using PRIMER

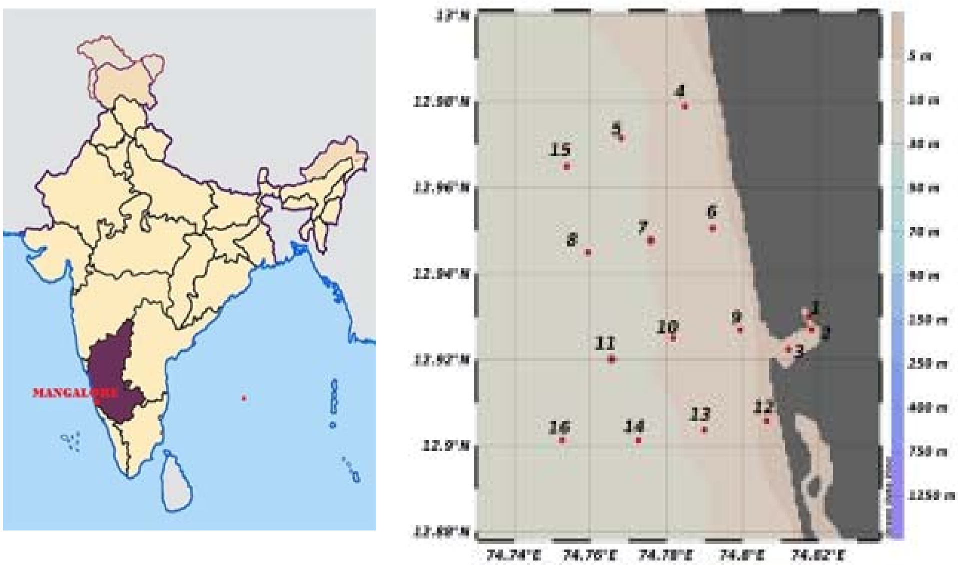
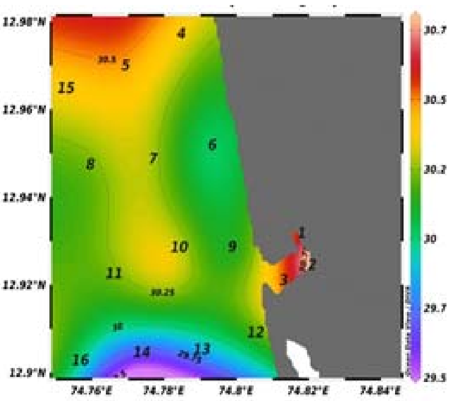


Figure 1. Study area in the Coastal waters of New Mangalore Port

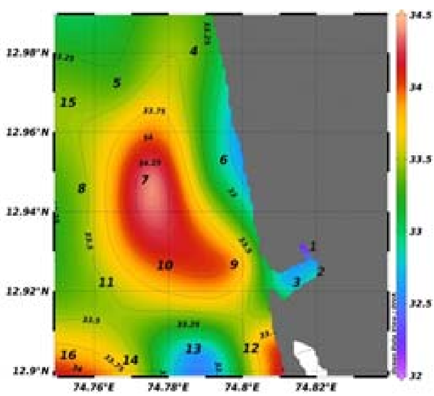
version 6.1.5 (Plymouth and Routines in Multivariate Ecological Research). Univariate measures such as Shannon – Wiener index (H') for species diversity and Marglef's index for species richness and multivariate method. Bray- Curtis similarity index (dendrogram) was portrayed for the plankton assemblage between stations.

RESULTS

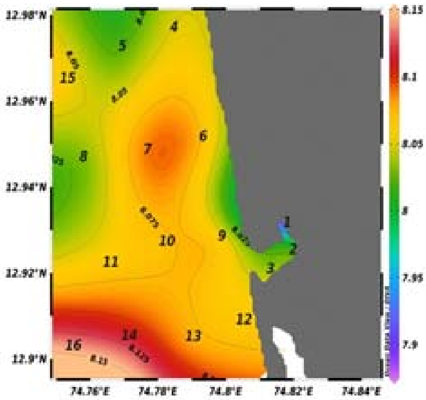
The surface water temperature ranged between 29.5 and 30.8 C among the stations (Figure 2a). The salinity was in the range of 31.5-34.5 ppm (Figure 2b), whereas pH ranged from 7.89 to 8.15 (Figure 2c). Dissolved Oxygen varied from 5.04 to 6.62 µM between the stations (Figure 2d). Concentration of nitrate ranged from 0.30 to 2.36 µM with a mean value of 1.05±0.66 µM (Figure 2e). Phosphate level did not show any marked spatial variations and it ranged between 0.09 and 0.35 µM (Figure 2f). Concentration of silicate also did not show prominent spatial variations ranged between 1.59 and 5.16 µM (Figure 2g). However, Analysis of variance (ANOVA – one way) did not exhibit any pronounced variation in the values of various parameters between stations.



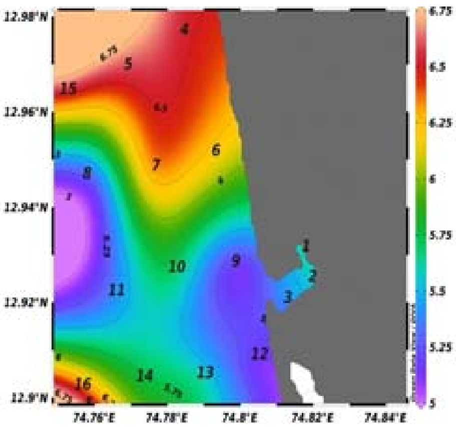
a. Temperature (°C)



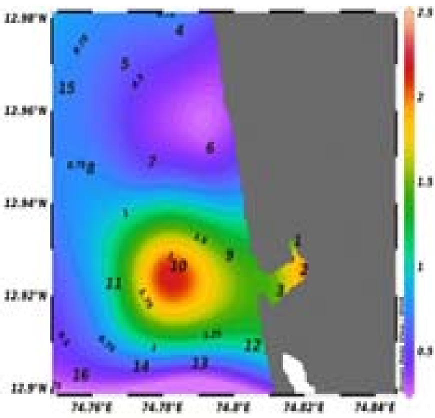
b. Salinity (psu)



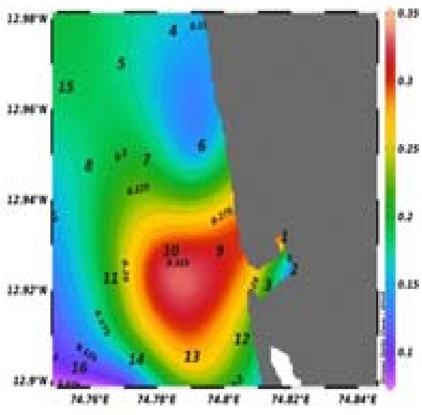
c. pH



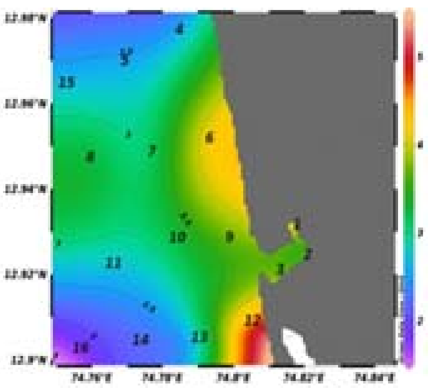
d. Dissolved oxygen (Mg/L)



e. Nitrate (µM)



f. Phosphate (µM)



g. Silicate (µM)

Figure 2. Water quality parameters

Analysis of biological parameters and phytoplankton diversity

Diatoms are the most dominant group in almost all the stations, except in station 9, where dinoflagellates were dominated, whereas silicoflagellates were least dominant (Figure 3). Total phytoplankton abundance varied between 1800 and 2704 cells LÉ[1] (Figure 4) between the stations in such a way that station 6 recorded maximum density, followed by stations 4, 1, 3,5, 9 and others stations respectively in its descending order. The genus wise abundance of phytoplankton revealed that *Rhizosolenia* spp., *Dactyliosolen* spp., *Skeletonema costatum, Ceratulina* spp and *Nitzchia* spp, were generally found abundant among the stations**.** Distribution of Chlorophyll *a* showed a conspicuous spatial variation and it varied between 0.01 and 4.95 mg m^{-3} (Figure 5), station 9 exhibited higher values followed by stations 4, 6, 1, 3 and 12 in their order of descend and others respectively.

The diversity indices showed that species richness (D) ranged between 0.75 and 4.63 with the higher value at station 6; the species diversity (H') ranged between 1.44 and 3.11 with minimum at station 15 and maximum at station 6 respectively (Table 1) and does not exhibits any pronounced coherence between the stations.

The dendrogram derived from cluster analysis (Bray-Curtis similarity index) is depicted (Figure 6) in such a way that stations 3 and 6 were found to be linked at highest similarity level; whereas station 3 is linked to this group at the next similarly level; followed by stations 1and 5 linked together at successive stages than others. Cumulative abundance of phytoplankton was mainly dominated by diatoms (63 %), followed by dinoflagellates (24 %) whereas average number of phytoplankton are more observed in station 4 followed by station 6 and station 1 are shown in the Figure 7.

DISCUSSION

The purpose of this study was exploring the taxonomic composition of coastal phytoplankton assemblages and how hydrographic factors influences. Few studies of this kind have been carried out in the area, and gaining more insight into the influence of different environmental factors on phytoplankton community development is of great

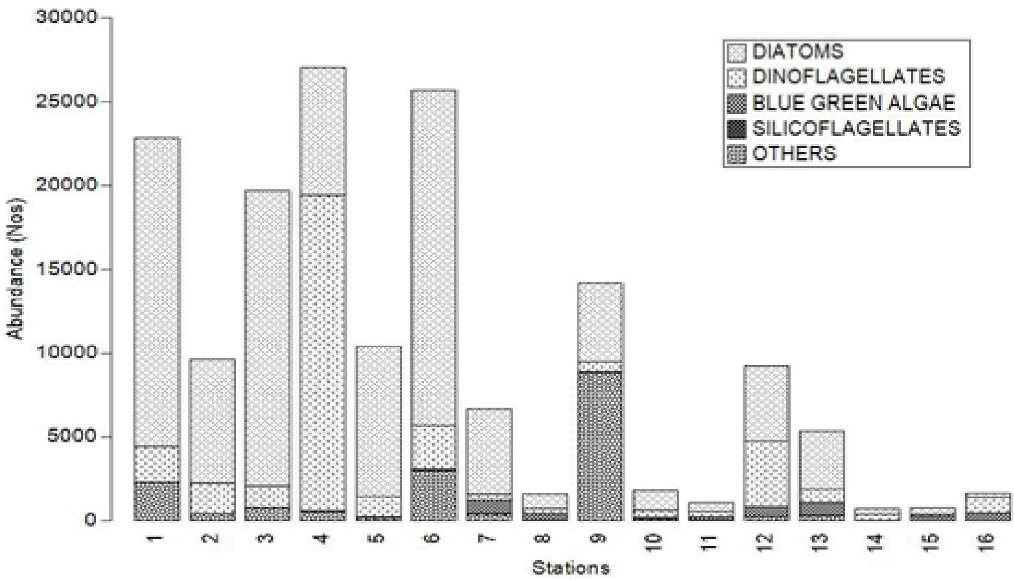


Figure 3. Phytoplankton abundance

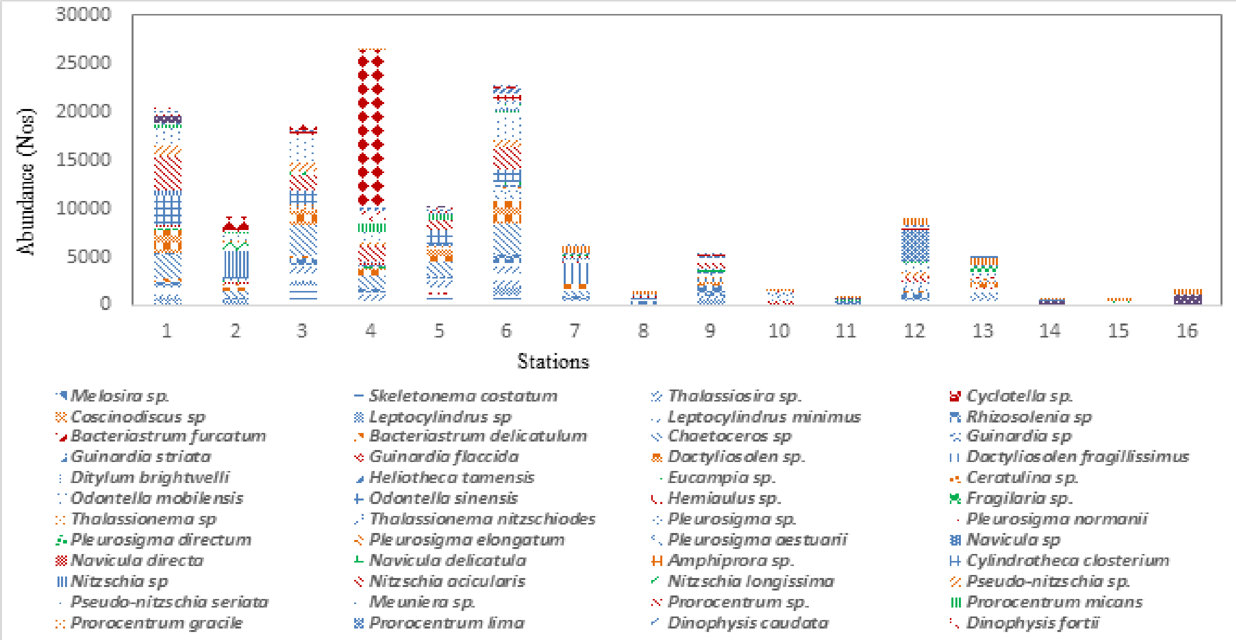


Figure 4. Phytoplankton species abundance in different sampling sites

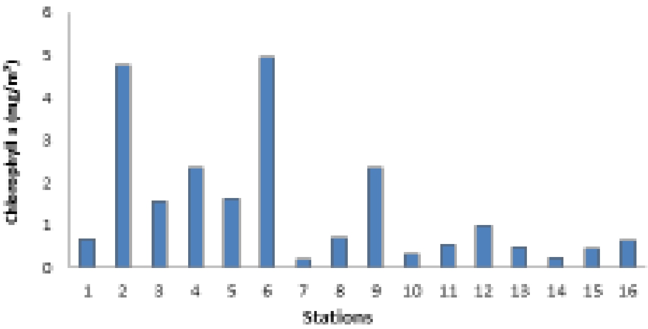


Figure 5. Chlorophyll a (mg m^{-3}) concentration at different sampling sites

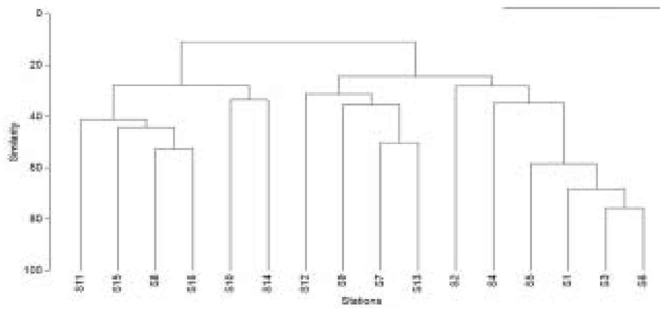


Figure 6. Dendrogram showing clustering of group average

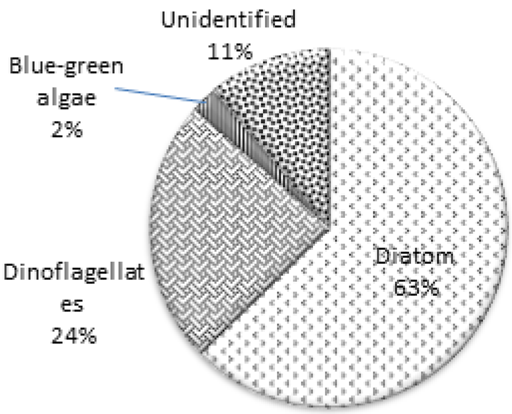


Figure 7. Abundance (%) of phytoplankton

interest. In the present study the phytoplankton communities have been characterized by quantifying and identifying microalgal taxa and also several environmental variables have been monitored during the observational period. An investigation on the qualitative and quantitative assessment of phytoplankton has been carried out in the present study from the inshore waters of artificial lagoon of the harbor and also from the adjacent coastal waters of Mangalore port, southwest India. Fluctuations in physico-chemical parameters of coastal waters influence the phytoplankton community structure, density and diversity. The water quality parameters such as temperature, salinity, pH, dissolved oxygen

Table 1. Phytoplankton species diversity and richness

Station	Total species S	Total individual N	Species richness D	Shannon H'(log e)
S1	43	22840	4.18	2.84
S2	35	9640	3.70	2.73
S3	36	19680	3.53	2.70
S4	30	27040	2.84	1.72
S5	32	10400	3.35	2.57
S6	48	25680	4.62	3.10
S7	34	6680	3.74	2.67
S8	18	1600	2.30	2.44
S9	37	14200	3.76	1.80
S10	23	1800	2.93	2.91
S11	14	1080	1.86	2.40
S12	27	9240	2.84	2.46
S13	35	5280	3.96	3.10
S14	11	720	1.51	2.29
S15	6	760	0.75	1.43
S16	10	1640	1.21	1.58

and nutrients such as nitrate, phosphate and silicate were well within the optimum levels and do not exhibit any significant difference between the stations. Nutrient's concentrations play a very significant role in structuring the phytoplankton community. Nitrogen or phosphorus is considered to represent the limiting nutrients for phytoplankton growth (Sakka et al. 1999) and is present in their optimum ranges in the present study. The port waters are affected by different activities such as loading or unloading of petroleum products, wood lodges, liquid ammonia and different types of furnished fertilizers (Naik and Kunte 2016), the average TRIX suggest that the New Mangalore port water quality is in a good state (Aseem et al. 2018). If waste flows into the stagnant port water, it can decline through an increase of phytoplankton resulting from eutrophication of water caused by nutrients in the waste water (Champ 2003). Poor water quality due to high anthropogenic activities and weak flushing has been reported at major ports (Mumbai, Jawaharlal Nehru, Cochin) along the west coast of India (Swant et al. 2007, Rajaneesh et al. 2015).

The phytoplankton community structure was ruled by seasonal hydrography and environmental variables. The well mixed turbulent water column of the port could be responsible for the lower abundance of dinoflagellates and silicoflagellates as compared to diatoms (Romero et al. 2012). The dominance of the diatom community by the pelagic species such as *N. sigma, P. sulcata, M. nummuloides,* and *Cylindrotheca closterium* during the non-monsoon seasons implies that the degree of turbulence rather than nutrient availability is the fundamental factor controlling the predominance of diatoms in the surface waters (McQuoid and Nordberg 2003a, Patil and Anil 2005, Kingston 2009, Guilloux et al. 2013, Pan et al. 2016). This diatom has a wide distribution and is often found in temperate brackish to marine planktonic and benthic waters, in both littoral and sublittoral zones (McQuoid and Nordberg 2003b). Increase in phytoplankton standing crops was found in harbor area compared to other coastal waters could be due to the discharge of domestic and industrial effluents (Braaud 1945, Braaud 1969, Goodbody 1970, Turner and Hopkins 1974). Apart from species composition, earlier studies have used species diversity as a proxy for water quality (Ismail and Dorgham 2003, Shekhar et al. 2008) wherein species diversity increases in clean waters and decreases in polluted waters.

The consideration of cell density and biomass gives a more accurate picture of variation in water quality. At present study, the species diversity with

3.11 maximum does not exhibits any pronounced coherence between the stations. Several earlier workers used species diversity as an indicator for water quality (Ismail and Dorgham 2003, Shekhar et al. 2008) where in species diversity increases in pristine water and decreased in polluted waters. The phytoplankton community structure was governed by seasonal hydrography and environmental variables. In this study reveals that nutrients such as nitrate, phosphate and silicate were well within the optimum levels and do not exhibit any significant difference. Total phytoplankton abundance varied between 1800 and 2704 cells LÉ[1]. Phytoplankton community was mainly dominated by diatoms (63 %), followed by dinoflagellates (24 %), blue green algae (2 %), and silicoflagellates (2 %) in their order of descend. The well-mixed nutrient rich turbulent water column of the port and adjacent coastal waters could be the reason for the lower abundance of dinoflagellates and silicoflagellates as compared to diatoms (Romero et al. 2012) The dominance of the diatom community during the premonsoon seasons implies that the level of turbulence rather than nutrient availability is the fundamental factors controlling the pre-dominance of diatoms in the surface water (Patil and Anil 2005, Kingston 2009, McQuoid and Nordberg 2003, Guilloux et al. 2013, Karolina et al. 2009). The higher relative abundance of diatoms throughout the sampling period could be a consequence of the relatively high silicate concentrations and generally faster growth rate in diatoms (Egge and Aksnes 1992, Karolina et al. 2009). Environmental condition during the pre-monsoon season along this coast is very conducive for the proliferation of both diatoms and dinoflagellates. This could be attributed to the local upwelling phenomenon which is infact been reported as a common event in the Arabian Sea of Mangalore (Suresh et al. 1978, Kumar 1984, Ramesh et al. 1992).

CONCLUSIONS

In this study revealed that the species composition of the phytoplankton community and that the relative abundance of each species might be dependent on particular environmental variables. Group wise percentage contribution of phytoplankton was generally in the decreasing order as follows, Diatom> Dinoflagellates > Cyanobacteria > Silicoflagellates. The coastal waters of Mangalore with moderate amounts of inorganic nutrients during premonsoon and this might have triggered the moderate levels of phytoplankton growth and abundance. The present study stands as a baseline reference for a more comprehensive work of this kind in future. The inference of the present study is based on one-time collection and a more in-depth studies covering different season and inter-annual variations are warranted that will give a more clear and precise results of phytoplankton abundance and distribution.

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Author(s) contribution: GM; Designed and performed sampling for research, analyzed data and corresponding author of the paper. PA; Performed statistical analysis, software to express data in figures (ODV). RA; Analysis using PRIMER software, review and editing. SMR; Experimental design, supervised the research, review and editing.

Conflict of Interest: The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

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