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Phytoplankton Abundance and Variability in the Inshore Waters of Mangaluru, South-West Coast of India

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Abstract The present study was carried out over a period of 8 months from Oct 2012 to May 2013. Three stations were selected along Chitrapur, Mangaluru at 3 different depth contours viz., 4m (St 1), 8m (St 2) and 12m (St 3) where 2 industries, Boulique Aniline Soda Factory (BASF) and Mangalore Refineries and Petro Chemical Limited (MRPL) discharge their effluents. The plankton flora comprised of 18 genera of which 14 were diatoms, 3 dinoflagellates and 1 species of Blue Green Algae at Station 1. In Station 2 and 3, a total of 19 genera of phytoplankton was recorded of which 14 were diatoms, 4 dinoflagellates and 1 blue green algae. Diatoms formed the most dominant group (97.22%, 95.07% and 81.64% at St 1, 2 and 3 respectively) followed by dinoflagellates (2%, 3.59% and 15.08% at St 1, 2 and 3 respectively) and blue green algae (0.78%, 1.35% and 3.28% at St 1, 2 and 3 respectively). The total phytoplankton density varied between 42,500 (Dec) to 24,94,500 (Jan), 12,692 (May) to 1,03,435 (Oct) and 14,700 (May) to 1,23,500 cells/m^3 (Oct) at St 1, 2 and 3 respectively. Relatively high population density was observed during postmonsoon months as compared to premonsoon season. Species diversity (H^I) values ranged between 0.56 (Dec) to 1.98 (Mar), 0.3 (Nov) to 1.82 (Mar) and 0.025 (Nov) to 1.81 (Mar) in St 1, 2 and 3 respectively. Species evenness (J^I) values ranged between 0.05 (Jan) to 0.82 (Oct), 0.16 (Dec) to 0.79 (April) and 0.13 (Nov) to 0.77 (Apr) in St 1, 2 and 3 respectively. Species richness (D^I) values ranged from 0.85 (Dec) and 0.99 (Mar), 0.82 (Nov) and 0.98 (Mar) at St 1 and 2 respectively while in St 3 it varied between 0.87 (Nov) to 0.98 (Apr). The correlation matrices indicated that the phytoplankton counts was positively correlated with chlorophyll a (r = 0.86), ammonia (r = 0.65) and pH (r = 0.63) while it was inversely correlated with salinity (r=0.51) and reactive silicate (r = 0.71).

Keywords Phytoplankton, Diversity, Abundance, Mangaluru, South-West coast.

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Introduction

Phytoplankton is one of the initial biological components from which the energy is transferred to higher organisms through food chain (Kumar and Perumal 2012). Phytoplankton are the microscopic single celled aquatic plants forming the prime component in the food chain of aquatic ecosystems. Phytoplankton production contributes about 95% of total production in the marine environment. The rate of gross primary productivity is important for assessing the fisheries yield, i.e., how much can be harvested on a sustainable basis. Hence the abundance of phytoplankton can be taken as the best means for quantitative assessment of potential fisheries of an area. Phytoplankton abundance and composition of an aquatic ecosystem are governed by various physico-chemical factors (Sin et al. 1999). Data on environmental parameters are a pre-requisite to understand the ecological changes in relation to the biotic parameters. There is good information available on phytoplankton distribution in the coastal waters along East and

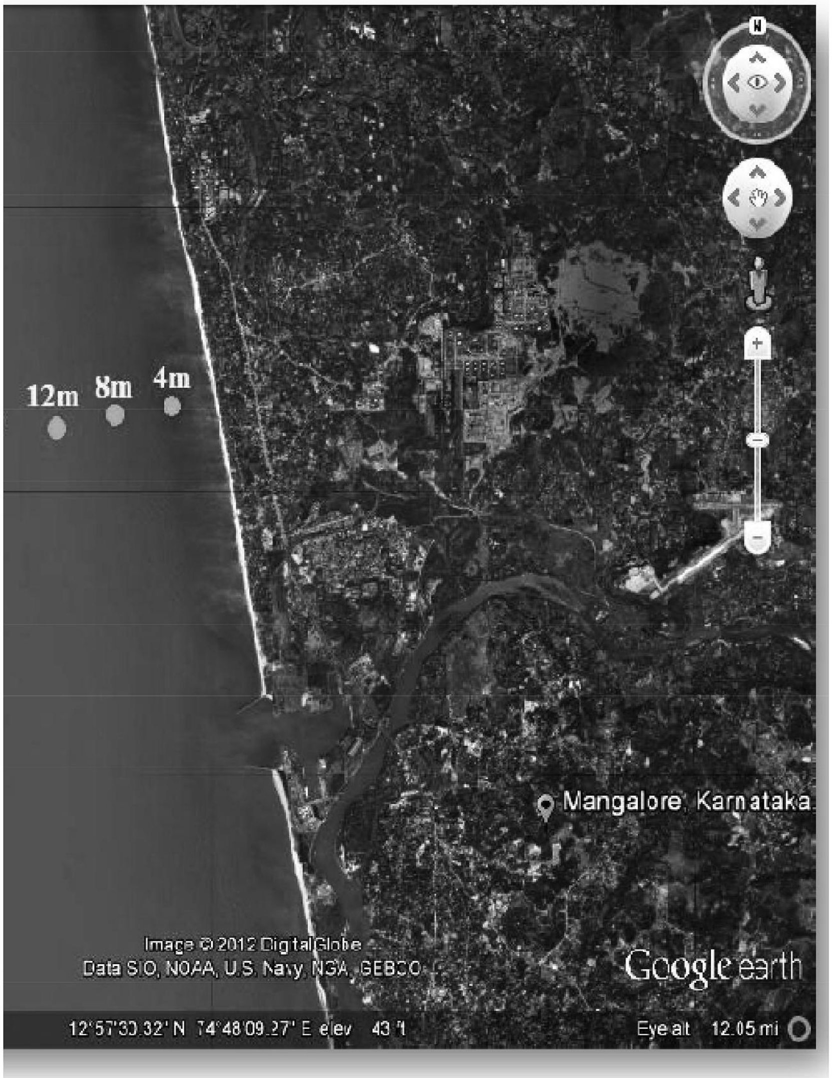

Fig. 1. Map showing the location of sampling station.

West coasts of India (Prabhahar et al. 2011, Pandiyarajan et al. 2014, Tiwari and Nair 1998 and Mridula and Rajesh 2002). However, such studies in the South-West coast of India are meager except for the studies of Ramesha et al. (1992), Lingadhal (1998) and Mridula et al. (2009). Hence, the study envisioned to assess the composition and species diversity in relation to hydrographical parameters from the inshore waters of Mangaluru, S-W coast of India. The study also throws light on the impact of effluents discharged from the nearby industries on phytoplankton abundance and variability.

Materials and Methods

In the present investigation, 3 stations were selected along Chitrapur, Mangaluru at 3 different depth contours viz., 4m, 8m and 12m (Fig. 1) and were designated as St 1, 2 and 3 respectively. In this area 2 industries, Boulique Aniline Soda Factory (BASF) and Mangalore Refineries and Petro Chemical Limited (MRPL) discharge the effluents. The present study

Table 1. Physico-chemical characteristics of waters of Mangaluru (values are pooled ranges for the period Oct, 2012 to May 2013, values in parentheses are mean values ± SE).

Parameters	Stations 1	2	3
Water temperature (°C)	29.5–32.37 (32.37 ± 0.37)	29.43–32.20 (30.70 ± 0.35)	29.5–32.33 (30.68 ± 0.32)
pH	7.77 to 8.1 (7.94 ± 0.04)	7.9 to 8.1 (7.99 ± 0.02)	7.87 to 8.17 (8.02 ± 0.04)
Transparency (m)	0.77–4.13 (2.37 ± 0.36)	0.6 – 2.75 (1.48 ± 0.24)	0.33 – 1.12 (0.72 ± 0.09)
Salinity (ppt)	29.27 to 32.92 (30.86 ± 0.5)	29.69 to 33.13 (31.25 ± 0.47)	30.1 to 33.13 (31.56 ± 0.41)
Dissolved oxygen (mg/l)	3.19–7.47 (5.8 ± 0.49)	3.74–7.34 (6.14 ± 0.47)	4.75–7.61 (6.4 ± 0.33)
Ammonia-nitrogen (µg-at/l)	2.16–12.36 (5.8 ± 1.44)	2.02–12.65 (5.42 ± 1.50)	1.7–12.91 (5.19 ± 1.66)
Nitrate-nitrogen (µg-at/l)	1.11–12.93 (8.62 ± 1.52)	1.22–15.02 (7.27 ± 1.57)	1.24–14.47 (5.89 ± 1.52)
Nitrite-nitrogen (µg-at/l)	0.37–4.07 (1.73 ± 0.44)	0.32–2.26 (1.25 ± 0.25)	0.27–2.03 (1.17 ± 0.21)
Phosphate-phosphorus (µg-at/l)	0.3–1.03 (0.78 ± 0.10)	0.6–1.33 (0.92 ± 0.09)	0.33–0.95 (0.68 ± 0.08)
Silicate-silicon (µg-at/l)	13.07–72.04 (32.49 ± 6.65)	15.65–45.41 (29.34± 3.98)	12.46–39.93 (24.72 ± 3.78)
Chlorophyll-a (mg/m^3)	2.12–4.26 (2.99 ± 0.25)	1.26–3.82 (2.15 ± 0.28)	1.12–2.16 (1.55 ± 0.13)

was carried out over a period of 8 months from Oct 2012 to May 2013 at monthly intervals during the cruises of the fishing vessel M.F.V. Dolphin of the College of Fisheries, Mangaluru. It was possible to conduct the study only for 8 months because the other 4 months of the year (Jun-Sep) experienced heavy rainfall due to South-West monsoon and during this period fishing and other activities in the sea are banned.

Temperature, pH and transparency were measured by using standard thermometer, Systronics 323-pH meter and secchi disc, respectively. Salinity, dissolved oxygen, BOD, ammonia, nitrite, nitrate, phosphate, silicate and chlorophyll content of the water samples were estimated following standard methods (APHA 1995).

Phytoplankton from the columnar waters were collected at each station using a Heron-Tranter net which is a square net of 0.25 m^2 mouth area and having a filtering cone of 1.2 m length with 60 µ pore size. The hauls were taken given 2m safe depth from the bottom. Plankton samples were preserved in 2% formalin. The phytoplankton samples were filtered through a 200 µ mesh size nylon netting to separate the zooplankton. Following this, the samples were divided into two equal parts using a Folsom Plankton Splitter. One half of the phytoplankton sample was poured into centrifuge tubes, which were then centrifuged and the settling volume was recorded after 12 h and the values are expressed in ml/m^3. The wet weight and dry weight of the plankton was determined using a monopan electrical balance and expressed as mg/m^3. The second half of phytoplankton sample was used for qualitative analysis. The phytoplankton sample was made upto a known volume and from which 1 ml was taken for estimating the numerical abundance of different genera using a Sedgwick-Rafter type of cell and the values are expressed in number / m^3.

Diversity indices such as species richness (D), diversity (H´) and evenness (J´)were calculated

(Margalef 1967, Shannon and Weiner 1949 and Pielou 1966).

Results and Discussion

Hydrography

The coastal waters of Mangaluru is influenced by seasons namely monsoon (Jun-Sep), postmonsoon (Oct-Jan) and premonsoon (Feb-May) season. Monthly variation of physico-chemical parameters is given in Table 1. The surface water temperature at St 1, 2 and 3 ranged from 29.5–32.37, 29.43–32.20 and 29.5–32.33 °C. From the data, it is evident that the surface water temperature at all the stations decreased from October and subsequently it reached a maximum in the month of March.

pH values at different stations (St 1, 2 and 3) varied from 7.77 to 8.1, 7.9 to 8.1 and 7.87 to 8.17 respectively. Higher values of pH for all the stations were recorded in the month of October while lower values were recorded in the month of March. There was no much difference in the pH values between the stations and seasons.

Transparency of water is a function of sun's position in the sky, degree of cloudiness and its variability. Further, this parameter gives an idea about the quantity of suspended matter in the environment. The extinction co-efficient values at St 1, 2 and 3 were in the range of 0.77–4.13, 0.6–2.75 and 0.33–1.12 m respectively. High turbidity conditions during postmonsoon season could be attributed to the greater quality of suspended matter carried away by freshwater inflow into the sea.

The salinity is the main physical parameters that can be attributed to the plankton diversity and act as a limiting factor which influences the distribution of plankton community (Sridhar et al. 2006). The salinity values ranged from 29.27 to 32.92, 29.69 to 33.13 and 30.1 to 33.13 ppt at St 1, 2 and 3 respectively. The lower salinity recorded during October could be due to the influence of South-West monsoon while higher values recorded in the month of April and May could be due to the greater evaporation during the peak summer season (Rajasegar 2003).

The dissolved oxygen content at St 1, 2 and 3 fluctuated from 3.19–7.47, 3.74–7.34 and 4.75–7.61 mg/l respectively. The dissolved oxygen content during the present study is much higher than that of the values recorded in this region. It is known that the dissolved oxygen content in the South-West coast mainly depends on circulations, water movement and wind action. Besides the biological conditions like photosynthesis and respiratory activities of organisms are also important particularly in case of coastal waters (Mridula et al. 2009).

The ammonia values fluctuated from 2.16–12.36, 2.02–12.65 and 1.7–12.91 µg-at/l. Generally ammonia value were found to decrease with increasing depth and the seasonal variation is more pronounced than that of the spatial variation. The higher values of ammonia coincided with the greater abundance of phytoplankton. This relationship could be attributed to the biological activity of phytoplankton (Nassar et al. 2014).

Nitrate-nitrogen is the most stable form of inorganic nitrogen in the oxygenated waters. In the present study, nitrate was found to range from 1.11–12.93, 1.22–15.02, 1.24–14.47 µg-at/l in St 1, 2 and 3 respectively. The recorded low values of nitrate may be due to the utilization by phytoplankton (Kumar and Perumal 2012).

Nitrite-nitrogen is one of the dissolved inorganic nitrogen form present in water bodies and could be used as pollution indicator. It is not a stable end product and could be obtained from the transformation of either nitrate or to ammonia. The values ranged from 0.37–4.07, 0.32–2.26 and 0.27–2.03 µg-at/l in St 1, 2 and 3 respectively. The recorded high nitrite values could be due to the increased phytoplankton excretion, oxidation of ammonia, reduction of nitrate, recycling of nitrogen and also due to bacterial decomposition of planktonic detritus present in the environment (Govindasamy et al. 2000).

The role of dissolved inorganic phosphorus could be considered as an important nutrient for marine phytoplankton in the oligotrophic settings (Macky et al. 2007). Phosphate - phosphorus values at different stations (St 1, 2 and 3) varied from 0.3–

1.03, 0.6–1.33 and 0.33–0.95 µg-at/l respectively. In this study, there was no much difference in the values between different stations. The variation of phosphate content depends upon its concentration in the freshwater that mixes with the seawater, phytoplankton uptake, addition through localized upwelling, adsorption and desorption of phosphate, buffering action of sediment under varying environmental conditions and replenishment as a result of microbial decomposition of organic matter (Satpathy et al. 2010).

The variation of silicate in coastal water is influenced by several factors, most importantly the proportional mixing of seawater with freshwater, adsorption of reactive silicate into suspended sedimentary particles and biological removal by phytoplankton, especially by diatoms and silicoflagellates (Aston 1980). The values of silicate was found to range between 13.07–72.04, 15.65–45.41 and 12.46–39.93 µg-at/l at St 1, 2 and 3 respectively. The recorded high concentration of silicate was high during the premonsoon season and minimum concentration was found during the postmonsoon season. The low value of silicate recorded during the postmonsoon season could be attributed to uptake of silicates by phytoplankton for their biological activity (Mishra et al. 1993).

Chlorophyll-a constitutes the chief photosynthetic pigment of phytoplankton and is an index that would provide the primary production potential upon which the biodiversity, biomass and carrying capacity of the system depends (Satpathy et al. 2010). The chlorophyll-a values ranged between 2.12–4.26, 1.26–3.82 and 1.12–2.16 mg/m^3 respectively. The observed high chlorophyll-a content during postmonsoon months could be attributed to high nutrient laden monsoon associated land and river run-off.

Phytoplankton

Species composition

The plankton flora comprised of 18 genera of which 14 were diatoms, 3 dinoflagellates and 1 species of blue green algae at Station 1. In Station 2 and 3, a total of 19 genera of phytoplankton was recorded of which 14 were diatoms, 4 dinoflagellates and 1 blue green algae. Diatoms formed the most dominant group (97.22%, 95.07% and 81.64% at St 1, 2 and 3 respectively) followed by dinoflagellates (2%, 3.59% and 15.08% at St 1, 2 and 3 respectively) and blue green algae (0.78%, 1.35% and 3.28% at St 1, 2 and 3 respectively).

Among the phytoplankton, the contribution of diatoms was found to be high throughout the season when compared to dinoflagellates and blue green algae in all the stations. Diatoms always prefer to inhabit and dominates the phytoplankton community in shallow, turbulent and upwelling region, i.e., coastal region. Moreover adequate amount of nutrients and sunlight in this turbulent and shallow zone facilitate these microscopic autotrophs to photosynthesize and reproduce vigorously. Furthermore, dominance of diatoms reflects the physical instability of shallow coastal environments (Fernandez and Brandini 2004). Thus dominance of diatoms as observed during the present study in the coastal waters is very common. Similar observations have also been reported from different parts of Indian coasts (Sahu et al. 2012 ; Babu et al. 2013 ; Velmurugan et al. 2014). Among the phytoplankton, *Chaetoceros* was found to be dominant in all the 3 stations followed by *Coscinodiscus*. Higher number of taxa was observed during postmonsoon season followed by premonsoon months in all the stations, coinciding with the optimum salinity and nutrient conditions which had possibly facilitated the proliferation of phytoplankton. Similar observation has been made by Gouda and Panigrahy (1996) and Sahu et al. (2012).

Population density

Pronounced fluctuation in the phytoplankton density was observed during the course of investigation. The total phytoplankton density varied between 42,500 (Dec) to 24,94,500 (Jan), 12,692 (May) to 1,03,435 (Oct) and 14,700 (May) to 1,23,500 cells/m^3 (Oct) at St 1, 2 and 3 respectively. Relatively high population density was observed during postmonsoon months as compared to premonsoon season. Similar wide fluctuations in phytoplankton density have also been reported in the coastal waters of Gopalpur (Gouda

Table 2. Diversity indices of phytoplankton during the study period.

Months	Station 1 Species diversity (H^I)	Station 1 Species Evenness (J^I)	Station 1 Species Richness (D^I)	Station 2 Species diversity (H^I)	Station 2 Species Evenness (J^I)	Station 2 Species Richness (D^I)	Station 3 Species diversity (H^I)	Station 3 Species Evenness (J^I)	Station 3 Species Richness (D^I)
Oct	1.95	0.82	0.98	1.09	0.47	0.95	1.26	0.49	0.97
Nov	0.68	0.42	0.86	0.3	0.19	0.82	0.25	0.13	0.87
Dec	0.56	0.35	0.85	0.32	0.16	0.87	0.52	0.27	0.89
Jan	0.13	0.05	0.92	0.55	0.28	0.89	0.51	0.26	0.88
Feb	1.17	0.46	0.96	0.5	0.23	0.91	0.89	0.46	0.92
Mar	1.98	0.77	0.99	1.82	0.69	0.98	1.81	0.75	0.98
Apr	1.36	0.59	0.96	1.64	0.79	0.97	1.84	0.77	0.98
May	1.42	0.65	0.97	1.27	0.58	0.96	1.58	0.66	0.97

and Panigrahy 1996), coastal waters of Mangalore (Mridula and Rajesh 2002) and along Kalpakkam coast (Poornima et al. 2005). However, the density in the present study could be attributed to the intense blooming of diatoms like *Chaetoceros*, *Cosinodiscus* and dinoflagellates like *Ceratium* along this coast. Higher values were encountered throughout the postmonsoon season which shows that the environmental condition during the premonsoon 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 has been reported as a common event in the Arabian Sea of Mangalore (Kumar 1984 and Ramesha et al. 1992).

Diversity indices

The diversity of phytoplankton organisms is important for the ecology and biogeochemistry of the ocean and almost certainly leads to stability to the system (Ptacnik et al. 2008). The monthly variations in diversity indices are shown in Table 2. Species diversity (H^I) values ranged between 0.56 (Dec) to 1.98 (Mar), 0.3 (Nov) to 1.82 (Mar) and 0.025 (Nov) to 1.81 (Mar) in St 1, 2 and 3 respectively. Species evenness (J^I) values ranged between 0.05 (Jan) to 0.82 (Oct), 0.16 (Dec) to 0.79 (Apr) and 0.13 (Nov) to 0.77 (Apr) in St 1, 2 and 3 respectively. Species richness (D^I) values ranged from 0.85 (Dec) and 0.99 (Mar), 0.82 (Nov) and 0.98 (Mar) at St 1 and 2 respectively while in St 3 it varied between 0.87 (Nov) to 0.98 (Apr).

The least values of biodiversity indices were recorded during postmonsoon season but more higher during premonsoon season at all the stations which could be attributed to the higher salinity values as reported by Ramakrishnan et al. (1999).

Statistical analysis

The correlation matrices indicated that the phytoplankton counts was positively correlated with chlorophyll a (r=0.86), ammonia (r=0.65) and pH (r=0.63) while it was inversely correlated with salinity (r=0.51) and reactive silicate (r=0.71).

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