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Proliferation of dinoflagellates in Kochi estuary, Kerala

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Abstract

Phytoplankton community structure and dynamics of Kochi estuary (bar mouth) have been studied seasonally. Three seasonal samplings namely pre-monsoon, monsoon and post-monsoon were made , and a wide variation was observed in phytoplankton community with respect to nutrients and other physico-chemical parameters. Contrary to other seasons, dinoflagellate cell density increased during pre-monsoon season though species diversity was less pronounced (D > 0.15). *Peridinium oceanicum* was the dominant dinoflagellate during pre-monsoon season. Significant fluctuation in three principal nutrients namely total nitrogen, total phosphorous and silicate were observed during pre-monsoon (TP < 1.8 µmol l^{-1}, TN > 40 µmol l^{-1} and SiO_4< 20 µmol l^{-1}) season as compared to monsoon season (TP > 3.20 µmol l^{-1}, TN<20 µmol l^{-1} and SiO_4> 27 µmol l^{-1}). Salinity values were also found to be high during pre-monsoon (> 25 psu). Study suggests that variation in salinity and nutrient concentration during transition of seasons could result in succession of species, thereby causing change in phytoplankton community structure. High salinity and nitrogen values along with low values of silicate and phosphorous resulted in proliferation of dinoflagellates during pre-monsoon season.

Key words

Dinoflagellates, Monsoon, Nutrients, Phytoplankton

Introduction

In addition to its vital role in food web mechanics, phytoplankton contributes largely to the functioning of marine ecosystems. Each phytoplankton species have a different set of favorable conditions that promotes its growth and reproduction. Seasonal fluctuation affects physico-chemical parameters thus resulting variation in abundance and diversity of plankton (Davies *et al*., 2009). Dinoflagellates occupy second position after diatoms as primary producers (Hoppenrath and Leander, 2008). These organisms exhibit high versatility in habitat adaptation (Gomez, 2012). One of the most prominent factors resulting in the proliferation of dinoflagellates is attributed to the eutrophication resulting from over-fertilization of the sea and the nutrient input from agricultural, domestic and industrial wastes (Baytut *et al*., 2010).

Kochi estuary is more or less being affected by anthropogenic activities. Seasonal variation accounts for the changes in hydro-chemical, marine biological and microbiological parameters of the estuary. The monsoon season exhibits peculiarity of governing the plankton community structure, as more than 70 % of the annual rainfall is associated with monsoon from June to September (Quasim, 2003). Transportation of industrial effluents into the estuary during monsoon season by rivers results in nutrient enrichment. Monsoon rainfall brings about fundamental changes in the functioning of food web of the estuary (Madhu *et al*., 2007), where the change in plankton community is a matter of interest. This study intends to describe the proliferation of dinoflagellates in Kochi estuary in relation to physico-chemical parameters and nutrients.

Materials and Methods

Three seasonal samplings (pre-monsoon, monsoon and post-monsoon of 2012) were performed in the Kochi bar mouth region (09º58'16"N; 76º14'43"E) at an interval of 3 hrs viz., 6:00 hrs, 9:00 hrs, 12:00 hrs, 15:00 hrs and 18:00 hrs (Fig.1). Surface water samples were collected for nutrient analysis, chlorophyll quantification and phytoplankton enumeration. Water

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temperature was measured using standard mercuric calibrated thermometer. Salinity, pH and conductivity values were measured using Thermo Scientific Eutech Probe (Water proof Cyber scans PCD 650). Winkler's method was applied for estimating DO values. Nutrient values (Nitrogen, Phosphorous and Silicate) were estimated by using spectrophotometric method (APHA, 2005). Phytoplankton samples were preserved using Lugol's solution (Parsons *et al*., 1984). The phytoplankton samples were enumerated up to the lowest taxonomic rank with the aid of a binocular phase contrast microscope (Tomas, 1997). Chlorophyll *a* content in water samples were estimated by filtering one liter of water through GF/C glass filter paper and the extraction of pigments were done with 90% acetone (Santhanam *et al*., 1987). SPSS (version 16) software packages were used for statistical correlations of phytoplankton species with physico-chemical parameters.

Results and Discussion

Seasonality does not have much impact on temperature range as the mean temperature obtained during pre-monsoon, monsoon and post-monsoon are 30.1º, 26.7º and 28.6 ºC, respectively. pH values during the pre-monsoon season ranged from 7.38 to 7.92. Monsoon season exhibited more or less similar pH range (7.15 to 7.64) and post-monsoon season showed a wider range of 7.86 to 8.07. Low salinity values were reported during the monsoon season (mean value: 19.26 psu) as compared to the pre-monsoon (mean value: 27.82 psu) and post-monsoon seasons (mean value: 27.14 psu). DO level in Kochi near shore water showed relatively low values during the post-monsoon as compared to pre-monsoon and monsoon season. Mean DO values observed during the pre-monsoon, monsoon and post-monsoon were 5.44 mg m^{-3}, 5.33 mg m^{-3} and 4.84 mg m^{-3}, respectively. Nutrient data depicted an obvious picture of varying trend from pre-monsoon to post-monsoon. Total nitrogen values were higher during pre-monsoon season (Fig 2). Total nitrogen values during pre-monsoon season ranged from 28.42 µmol l^{-1} (6:00 hrs) to 42.2 µmol l^{-1} (18:00 hrs). On the other hand, mean values of total nitrogen during monsoon was 17.8 µmol l^{-1} and that of post-monsoon was 15.25 µmol l^{-1}. As far as silicate values are concerned, the trend increased from pre-monsoon season (mean value: 19.78 µmol l^{-1}) to monsoon season (mean value: 27.93 µmol l^{-1}) and again a noted decrease was observed during post-monsoon season (mean value: 21.35 93 µmol l^{-1}). A reverse trend of increase in the value of total phosphorus could be observed from pre-monsoon season to post-monsoon with respect to total nitrogen. Mean values recorded were 1.74 µmol l^{-1} (pre-monsoon), 3.22 µmol l^{-1} (monsoon) and 4.34 µmol l^{-1} (post-monsoon) respectively for total phosphorus (Table 1).

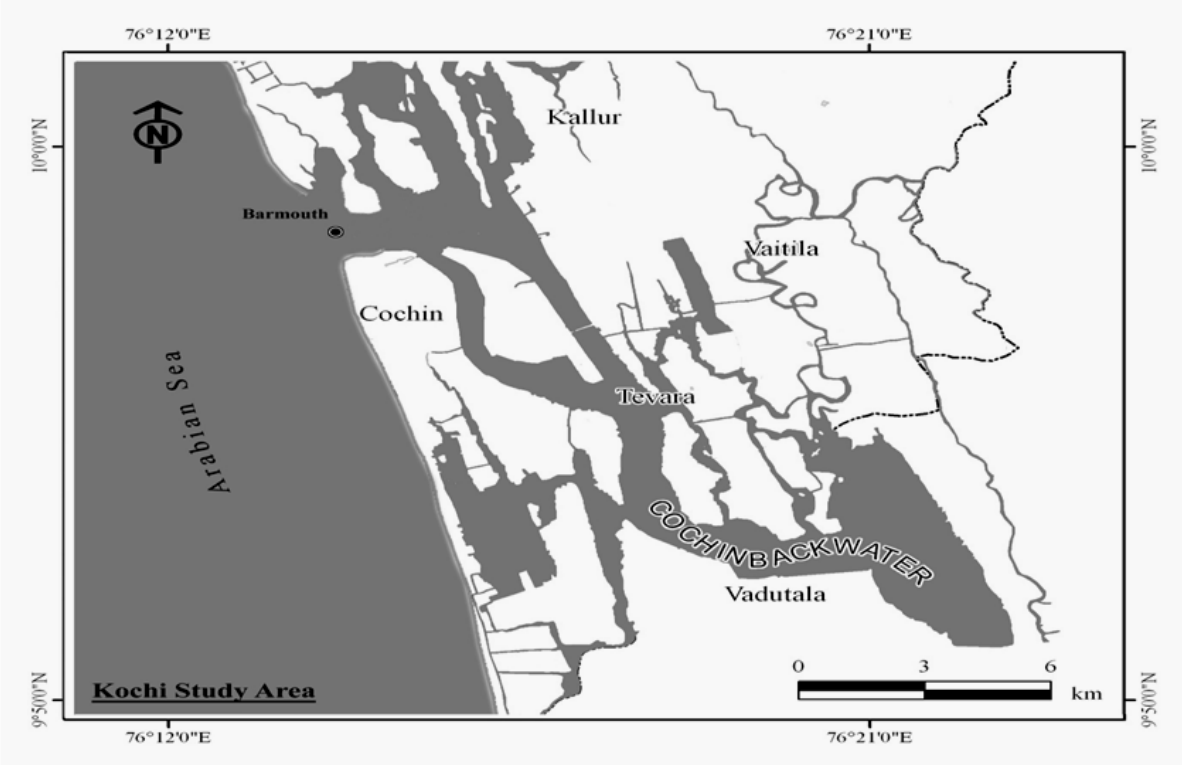

Fig.1 : Study area : The Kochi bar mouth, Kerala

Table 1: Physico-chemical parameters of pre-monsoon, monsoon and post-monsoon seasons at Kochi bar mouth

Season	Pre monsoon					Monsoon					Post monsoon				
Time (hr)	6:00	9:00	12:00	15:00	18:00	6:00	9:00	12:00	15:00	18:00	6:00	9:00	12:00	15:00	18:00
Water temperature (ºC)	29.10	30.50	31.10	31.00	30.80	25.80	27.10	26.50	26.90	27.20	27.70	27.90	28.90	28.80	29.80
Suspended solids (mg l^{-1})	21.31	22.26	20.14	22.54	31.00	11.00	9.70	11.80	12.80	18.45	11.92	6.80	7.12	7.12	11.68
pH	7.49	7.38	7.53	7.81	7.92	7.23	7.15	7.29	7.64	7.30	7.86	7.87	8.05	8.01	8.07
Salinity (psu)	23.40	29.60	29.50	28.90	27.70	19.60	20.20	16.30	18.70	21.50	27.30	30.50	24.20	28.10	25.60
DO (mg l^{-1})	5.20	5.14	5.32	5.39	5.62	5.28	5.53	5.18	5.60	5.14	4.63	4.96	5.02	4.75	4.85
BOD (mg l^{-1})	1.65	1.83	1.76	1.61	1.77	1.77	1.83	1.46	1.49	1.70	1.87	1.82	1.94	1.24	1.16
Nitrite nitrogen (µmol l^{-1})	4.23	2.26	3.40	2.92	1.85	0.10	0.01	0.16	0.01	0.15	0.07	0.35	0.28	0.33	0.69
Nitrate nitrogen (µmol l^{-1})	8.86	6.03	6.10	5.40	5.62	1.81	0.93	6.53	0.64	1.69	1.22	0.83	0.56	2.70	1.06
Ammonia nitrogen (µmol l^{-1})	0.18	0.15	0.16	0.10	0.08	0.34	1.20	0.75	1.09	1.24	0.65	0.66	0.87	0.98	1.82
Total nitrogen (µmol l^{-1})	28.49	28.98	38.01	36.07	42.20	21.31	19.70	18.71	13.19	16.15	14.74	17.71	14.41	19.03	10.34
Inorganic phosphate (µmol l^{-1})	1.26	1.10	1.73	0.81	0.67	2.20	2.00	2.04	1.77	1.38	0.83	1.39	2.09	2.43	1.57
Total phosphorous (µmol l^{-1})	2.20	1.82	2.02	1.48	1.18	3.74	3.17	3.20	3.65	2.36	3.58	4.13	4.11	5.57	4.31
Silicate (µmol l^{-1})	21.05	22.05	35.43	9.07	11.28	30.53	40.64	37.09	21.13	10.25	7.13	22.88	31.63	28.88	16.25

Table 2 : Simpson's Indices of phytoplankton in bar mouth region of Kochi estuary

Seasons		6:00 hr	9:00 hr	12:00 hr	15:00 hr	18:00 hr
Pre-monsoon	Simpson's Index (D)	0.19	0.23	0.17	0.18	0.18
	Simpson's Reciprocal Index (1/D)	5.14	4.42	5.96	5.56	5.45
Monsoon	Simpson's Index (D)	0.09	0.08	0.09	0.09	0.08
	Simpson's Reciprocal Index (1/D)	11.5	12	11.7	10.3	12
Post-monsoon	Simpson's Index (D)	0.15	0.23	0.13	0.19	0.11
	Simpson's Reciprocal Index (1/D)	6.72	4.19	7.7	5.16	8.98

Table 3 : Pearson correlation values of phytoplankton species with physico-chemical parameters (pre-monsoon season)

	Correlations											
Species	Water Temp.	pH	Salinity	DO	BOD	Nitrite nitrogen	Nitrate nitrogen	Ammonia	Total nitrogen	Inorganic phosphate	Total phosphorus	Silicate
Ceratium furca	-0.626	-0.472	-0.38	-0.395	0.493	-0.134	0.459	0.32	-0.573	-0.129	0.203	-0.001
Ceratium fusus	0.353	0.347	0.316	0.06	-0.595	-0.085	-0.44	-0.423	0.023	-0.425	-0.343	-0.565
Ceratium macroceros	-.975**	-0.318	-.967**	-0.373	-0.402	0.713	.974**	0.578	-0.584	0.145	0.583	0.035
Ceratium pentagonium	0.343	0.451	0.234	0.167	-0.7	-0.007	-0.399	-0.45	0.125	-0.409	-0.353	-0.572
Dinophysis caudata	0.571	0.228	0.464	0.071	-0.517	0.175	-0.447	-0.178	0.253	0.144	-0.066	-0.007
Peridinium oceanicum	-0.472	-0.162	-0.26	-0.343	-0.048	-0.194	0.945**	-0.04	0.919**	-0.867	-0.097	-0.579
Peridinium steinii	-0.569	-0.78	-0.195	-0.796	0.36	0.071	0.437	0.566	-0.877	0.098	0.476	0.158
Prorocentrum sp.	0.875	0.327	0.718	0.389	0.017	-0.168	-0.694	-0.32	0.68	0.264	-0.253	0.257
Pyrophacus steinii	0.533	-0.236	0.53	-0.002	0.455	0.039	-0.281	0.244	0.359	0.747	0.25	0.818
Rhabdospheara sp.	0.411	-0.235	0.363	-0.042	0.221	0.279	-0.12	0.344	0.308	0.829	0.38	0.836
Asterionella japonica	-0.57	0.292	-0.664	0.025	-0.765	0.277	0.41	-0.146	-0.304	-0.573	-0.1	-0.731
Biddulphia reticulata	-0.548	-0.792	-0.387	-0.804	-0.218	.890*	0.724	.957*	-0.688	0.812	.987**	0.685
Chaetoceros indicus	-0.772	0.123	-0.918	0.161	-0.228	0.34	0.738	0.15	-0.099	-0.145	0.136	-0.172
Cosinodiscus gigas	0.418	-0.408	0.471	-0.207	0.385	0.198	-0.154	0.422	0.163	0.858	0.433	.897*
Cosinodiscus radiatus	-0.863	-0.729	-0.877	-0.715	0.17	0.376	0.79	0.71	-0.851	0.209	0.638	0.224
Skeletonema costatum	0.126	-0.138	0.064	0.186	0.596	-0.011	0.06	0.228	0.377	0.555	0.185	0.692

*. Correlation is significant at the 0.05 level (2-tailed);**. Correlation is significant at the 0.01 level (2-tailed)

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Chlorophyll *a* values are the measurements of phytoplankton density in general as well as the extent of eutrophication. Maximum range of chlorophyll was recorded during pre-monsoon season with an average value of 5.91 mg m^{-3}.

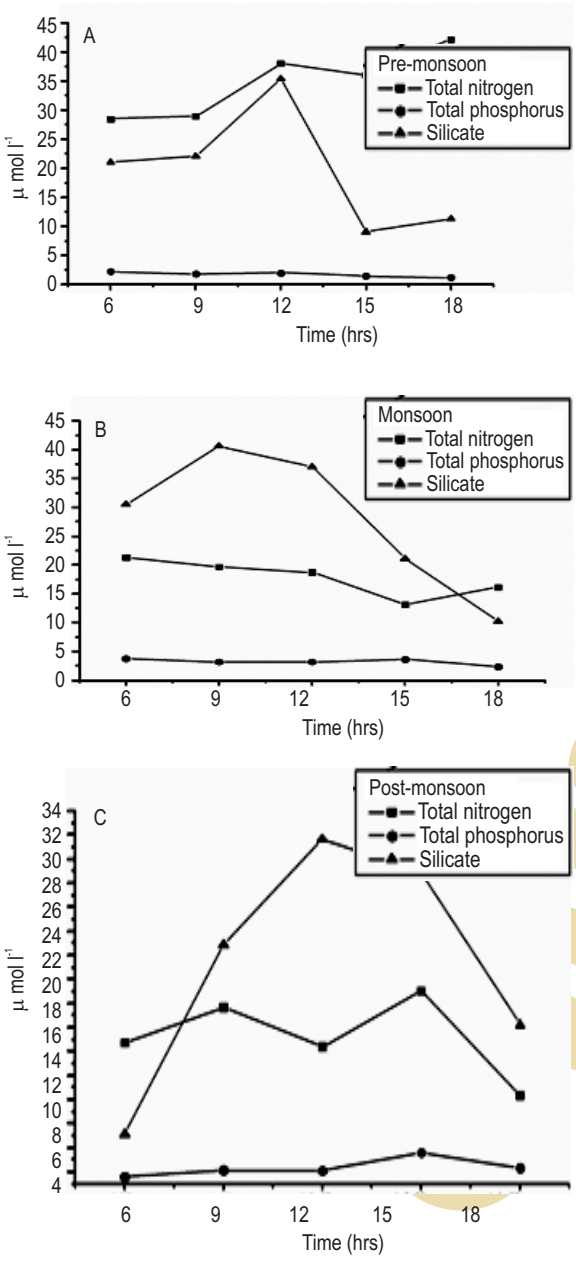

Fig. 2 : Hourly variation of nutrient parameters during (A) pre monsoon, (B) monsoon and (C) post monsoon seasons in Kochi bar mouth, Kerala (total nitrogen, total phosphorous and silicate)

While in monsoon and post-monsoon seasons, chlorophyll *a* concentration values were relatively low ranging from 3.18 mg m^{-3} to 5.64 mg m^{-3} (monsoon) and 3.32 mg m^{-3} to 4.76 mg m^{-3}(post-monsoon). Timely variation in chlorophyll values in each season was not negligible suggesting, the dynamic nature of the hydrographic system. Hourly sampling results showed that there was a considerable range of variation in chlorophyll a concentration from 0.6 mg m^{-3} to 2.98 mg m^{-3} between two consecutive sampling hours (Fig. 3).

Our study recorded 57 species of phytoplankton comprising diatoms, dinoflagellates and cyanophytes. The total diatoms encountered throughout the study were *Amphora lineolata, Asterionella japonica, Aulacodiscus sp., Bacillaria paradoxa*, *Bacteriastrum comosum*, *Biddulphia haeteroceros*, *B. mobiliensis*, *B. reticulata*, *B. sinensis*, *Chaetoceros curvicetus*, *C. decipiens*, *C. indicus*, *Corethron hystrix*, *Cosinodiscus eccentricus*, *C. gigas*, *C. radiatus*, *Cyclotella sp.*, *Diploneis sp.*, *Ditylum brightwelli*, *Eucampia zoodiacus*, *Fragilleria oceanica*, *Gyrosigma balticum*, *Hyalodiscus sp.*, *Lithodesmium undulatum*, *Melosira sulcata*, *Navicula sp.*, *Nitzchia longissima*, *N. sigma*, *Phaeocystis sp.*, *Pinnularia alpina*, *Planktonella sol*, *Pleurosigma elongatum*, *P. directum*, *Rhizosolenia crassispina*, *R. curvata*, *R. setigera*, *R. stolterfothii*, *Skeletonema costatum*, *Thalassionema nitzchioides*, *Thalassiothrix fraunfeldii* and *Triceratium favus*. Dinoflagellates composed of *Ceratium extensum*, *C. furca*, *C. fusus*, *C. macroceros*, *C. pentagonium*, *C. tripos*, *Dinophysis caudata*, *Noctiluca scintillans*, *Peridinium oceanicum*, *P. steinii*, *Prorocentrum sp.*, *Pyrocystis lunula*, *P. steinii* and *Rhabdosphera sp*. Cyanophytes were low in number *viz. Oscillatoria cutissima*, *Trichodesmium erythraeum* and *T. thiebautii*.

It was observed that diatoms dominated during the three seasons (40 to 50 No's), followed by dinoflagellates (12 to 15 No's) and cyanophytes (3 to 5 No's). As far as the number of species is concerned, they ranged from 69.04 to 73.33%. Dinoflagellates constitute 20.00 to 27.77% followed by cyanophytes with low range of 2.77 to 7.14% in terms of number of species. Quantitative analysis of the phytoplankton showed a different picture with respect to cell density, where the diatoms dominated in monsoon season (95.08%) and post-monsoon season (77.58%), while in pre-monsoon, dinoflagellates contributed much of the net phytoplankton cell density. Dinoflagellates comprised 66.10 to 75.49% of the total cell density (Fig 4). Among them, *Peridinium oceanicum* was the dominant species (38.14 to 41.02%). On the other hand, the pennate diatom, *Asterionella japonica* dominated both during monsoon season (37.07%) and post-monsoon season (16.65%). Simpson's Index showed a relatively low diversity of species during the pre-monsoon season having high values of Simpson's Index (D0 and low values of 1/D (Simpson's Reciprocal Index). The mean value of D was 0.19 and 1/D was 5.3 during the pre-monsoon season. Mean values of Diversity Index showed a wide variation during monsoon season (D = 0.08, 1/D = 11.5). Further,

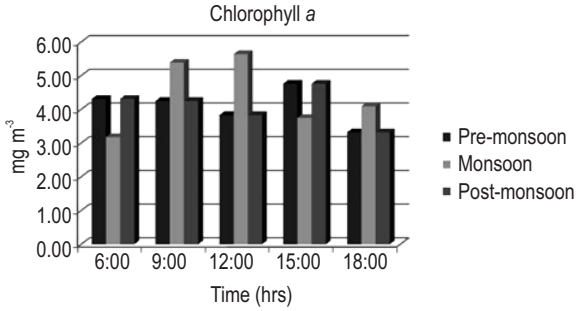

Fig. 3 : Hourly variation of chlorophyll ain pre monsoon, monsoon and post monsoon season at Kochi bar mouth, Kerala

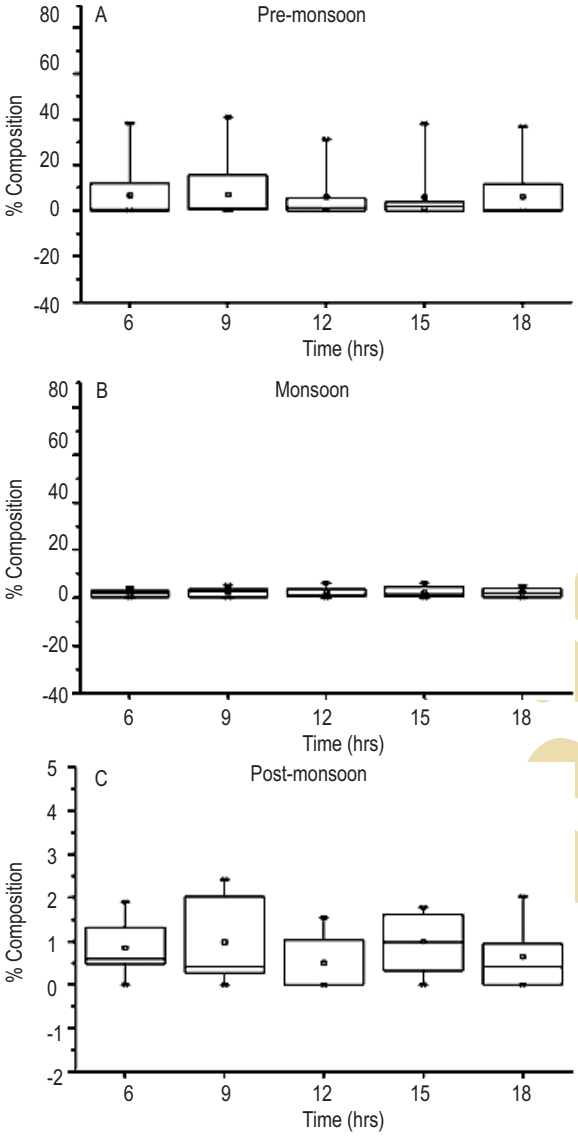

Fig. 4 : Box plot showing percentage composition of dinoflagellates in pre-monsoon, monsoon and post-monsoon seasons

the species diversity decreased during the post-monsoon season (D = 0.16, 1/D = 6.55) as compared to monsoon (Table 2). Pearson correlation results describe major relationship between physico-chemical parameters and phytoplankton species of pre-monsoon season. Salinity and temperature were negatively correlated with phytoplankton in general and dinoflagellates in particular. Dissolved oxygen levels were more or less negatively correlated with dinoflagellates and diatoms density. Species density of *Peridinium oceanicum* and *Ceratium macroceros* showed positive correlation with NO_3 and total nitrogen concentration. While in case of inorganic phosphate concentration, majority of the dinoflagellates species showed positive correlation. Conversely, diatoms exhibited positive relationship with phosphate content though the correlation values were less significant (Table 3).

Sampling was conducted at certain intervals of time to study the nature and temporal fluctuation of phytoplankton density. Relatively high salinity and high temperature conditions are favorable for dinoflagellates proliferation (Mendon *et al*., 2002). The present study corroborated with the general observation that salinity and temperature were high during pre-monsoon season compared to monsoon season. Temperature is an important factor regarding the succession of phytoplankton community (Richardson *et al*., 2000). Kochi coastal waters are predominantly subjected to anthropogenic activities including dredging process that is taking place continuously as a part of channel widening process. Kochi is one of the productive areas on the south west coast of India (Balachandran *et al*., 2003). Kochi estuary is continuously receiving annual dredge spoil and organic wastes from the harbor area (Balachandran *et al*., 2003). Chlorophyll content of Kochi bar mouth was relatively high during pre-monsoon season that could be attributed to phytoplankton community composition, position in water column and seasonal variations (De stasio *et al*., 2008). Proliferation of dinoflagellates is a result of seasonal variation that provides favorable environmental conditions including optimum nutrient concentration. The study describes the proliferation of dinoflagellates during pre-monsoon season was primarily due to the enhanced supply of nitrogenous nutrients along with high temperature and salinity. Unlike other groups of phytoplankton, dinoflagellates can take full advantage of nutrients and light by positioning themselves in the water column owing to its mobility (Hackett *et al*., 2004). Phytoplankton community structure may be exceedingly affected by small scale hydrographic changes (Harnstrom *et al*., 2009). Total phosphorous content was found to be very low during the pre-monsoon season, which may be regarded as limiting nutrient for the dinoflagellates growth, provided an enhanced supply of nitrite and nitrate. Total nitrogen values of pre-monsoon season support this fact, as the nitrogen values were remarkably high. Entrainment of significant nutrients such as nitrite, nitrate, silicate and phosphate (limiting nutrient) during the monsoon season from river discharges and anthropogenic activities are being saturated with the advent of

pre-monsoon season where high temperature and relatively high salinity prevails. Major nutrients like NO_3, $NO_2$and PO_4 vary seasonally in the euphotic zone, where they influence succession patterns of resident phytoplankton communities (Monier *et al*., 2012). Thus the physico-chemical factors and nutrient concentrations became favorable for excess growth of dinoflagellates. Phytoplankton succession occurs, when there is a considerable change in environment like seasonal variation.

Variation in phytoplankton community structure corresponding to seasonal transition could be observed during all the three seasons. Dominance of diatoms during monsoon and post-monsoon seasons along with decrease in salinity and temperature supports the results observed in the present study. Spatial distribution of dinoflagellates got disturbed during monsoon season when the ecological equilibrium which provided a suitable environment for dinoflagellates growth, declined. Species diversity was found to be more pronounced during monsoon and post-monsoon seasons, where the numerical density of phytoplankton was obviously high. Moreover, Simpson's index values were low during monsoon and post-monsoon, which could be regarded as an indication of high species diversity during both the seasons. Low salinity and changes in nutrient concentration induced the growth of diatoms of euphotic layers of Kochi waters. Studies conducted by Sahu *et al*. (2012) suggests, that species like *Skeletonema costatum*, *Rhizosolenia sp*. were found to be adapted to low saline water conditions. Study coincides with this observation as the salinity and nutrient concentration varied considerably during monsoon and post-monsoon season, when the dominance of dinoflagellates was replaced by diatoms. Phytoplankton succession induced by seasonal variation would result in alteration of species, and thereby causing changes in community structure of primary producers.

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