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SEASONAL ABUNDANCE OF DIATOMS IN CORRELATION WITH THE PHYSICO-CHEMICAL PARAMETERS FROM COASTAL WATERS OF PAKISTAN

TAHIRA NAZ*, ZAIB-UN-NISA BURHAN, SONIA MUNIR AND PIRZADA JAMAL AHMED SIDDIQUI

Centre of Excellence in Marine Biology, University of Karachi, Karachi, Pakistan.
**Corresponding author, e-mail: tahira.saeed@yahoo.com*

Abstract

The seasonal abundance of diatom (20-200µm) and variations in physicochemical properties were studied using bimonthly collected samples at Manora Channel coastal waters of Karachi, north Arabian Sea bordering Pakistan through the period of May 2002 to July 2003 for two stations. Triplicate samples were settled for 24 hours in a settling chamber and were observed using inverted microscope and number of diatoms counted. Seasonal abundance was clearly evident throughout the study period. This variation was due to the influence of monsoon system existing in the region. Primary productivity and hydrographical parameters in the northern Arabian Sea are greatly affected by the monsoon system that prevails from May to October for southwest monsoon and between November and March for northeast monsoon. The total phytoplankton community was dominated by diatoms and the mean proportion was 69% at station A and 56% at station B. Diatom abundance showed a peak in September, 2002 at station B and in February, 2003 at station A. There were about $0.847\text{-}13.093\times10^3$ average cells l^{-1} in station A and $0.667\text{-}30.067\times10^3$ cells l^{-1} in station B waters showing polluted station **A** had low abundance compared to non-polluted station **B**. Seasonal change in chlorophyll a has shown a strong negative correlation with diatom abundance. Highest total average abundance of pennate diatoms was observed at both stations as compared to centric diatoms. Statistical analysis shows overall lower species diversity from 0.1 to 3.6 at both stations. It suggests that organic loads decreased the abundance and diversity of diatom communities in the region.

Introduction

Diatoms constitute the dominant phytoplankton group in tropical coastal waters of the Arabian Sea (Schiebel *et al*., 2001, 2004). These planktonic algae are the main producer at the primary stages of the food chain (Qasim, 1977; Taylor, 2005; Verlecar, 2006). Their abundance is closely related with the availability of specific environmental variables because different diatom taxa exist according to ecological demand for nutrients, food and physical parameters like light, vertical mixing, temperature, salinity, competition within the species, and grazing pressure (Smayda, 1980; Marshall *et al*., 2005; Ara *et al*., 2011). Marine diatoms are also considered as the important contributors to global carbon flux. Following the phytoplankton blooms they export great amount of primary production to the ocean floor because of vertical flux and settled in the form of sediments (Rixen *et al*., 2000, 2005). The abundance and distribution of diatoms are very important in the food chain of marine ecosystem because they are the food source of organisms related with higher trophic levels like shell fish and larger mammals. The population growth and reproductive cycle of many marine organisms are related with the abundance of diatoms because their larvae feed on them (Yentsch, 1957). Their various taxa and families play major part in the primary production of the oceans and at different levels of food chain, so community structure and analysis of changes in their total seasonal abundance is very important in the dynamics of marine ecosystem (Cloern, 1992; Naz *et al*., 2012; Naz *et al*., 2013).

Abundance and distribution of diatoms are also known to determine the water quality as indicators of nutrient rich environment. The knowledge about the seasonal variations and species occurrence with related climatic conditions are very useful for the assessment of water quality and eutrophication in the related area (Gasiunaite *et al*., 2005; Wang, 2006).

The monsoonal system of the Arabian Sea with strong wind force causes coastal upwelling throughout the region. The northern part of the Arabian Sea is evident for the higher rates of summer productivity (Barlow *et al*., 1999; Schiebel *et al*., 2004). Abundance and seasonality of diatoms population is an obvious response to the reversal of inter-annual monsoonal system of the Arabian Sea. In the present studies for the investigation of seasonal changes during a year the bimonthly samples were collected to get ensured the seasonal developments in the area.

This research work on the seasonal abundance of diatom community with reference to polluted and non-polluted sites of Manora Channel from northern portion of Arabian Sea is the first attempt that will provide information on seasonal change in abundance of diatom community under different climatic conditions and give an understanding about the survival of different taxonomic groups in the region (Indian Ocean).

Materials and Methods

Sampling was done bimonthly from May 2002 to July 2003 at the Manora Channel located on the estuary of Layari River. The study area represents the coastal waters of Karachi from where industrial effluents enter the Channel and cause the coastal pollution (Fig. 1). Samples were taken at two stations established for regular sampling, Station A (24˚49.77'N 66˚57.85'E) inside the channel, a polluted area with impact from Layari River and station B (24˚47.93'N 66˚58.87'E) outside the Channel (open waters) a non-polluted station with more oceanic influence. Seasonal abundance of diatom population was studied according to the procedure described earlier by Utermohl (1958). Triplicate samples were settled for 24 hours in a settling chamber (50 mL; Hydro-Bios, Germany). The settled samples were observed using inverted microscope (Olympus, BX-51, Japan) and number of diatoms counted. Qualitative study involves the assessment of diatom community using available identification keys (Thomas, 1993).

Physicochemical parameter assessment: Water parameters like temperature (thermometer), salinity (refrectometer), dissolved oxygen (DO; Wrinkler's method: Hanna C100), pH (Hanna HI9023, Italy) and chlorophyll a were also measured and correlated with total abundance of diatoms at both stations A and B. For the analysis of chlorophyll a 250mL of sample were passed through GF/F filter papers and extracted with 90% acetone solution, then analyzed spectrophotometrically (Strickland & Parsons, 1972).

Results

Seasonal distribution and abundance: Seasonal variation in total abundance of diatoms assemblage was examined at two stations of Manora Channel. Total phytoplankton abundance was high with peak of cell abundance in the month of October, 2002 and a clear seasonality was observed at both stations. The total average abundance ranged from 2.41-16.82 $\times 10^3$ cells l^{-1}, Mean ± SD (5995±4656.42) at station A and 1.17-61.67$\times 10^3$ cells l^{-1}, Mean ± SD (10657.18±12518) at station B (Table 1). The total phytoplankton community was dominated by diatoms and the mean proportion was 69% at station A and 56% at station B. Highest percentage of diatoms 97% were observed in the month of February, 2003 at station A and in September, 2002 and May, 2003 at station B. Lower diatoms percentage 5% was recorded in the month of October, 2002 at station A. Similarly at station B lower diatoms 10% was recorded in the same month of October, 2002 (Fig. 5). The maximum and minimum average abundance of pennate and centric types of diatom cells were recorded at both stations (Table 2).

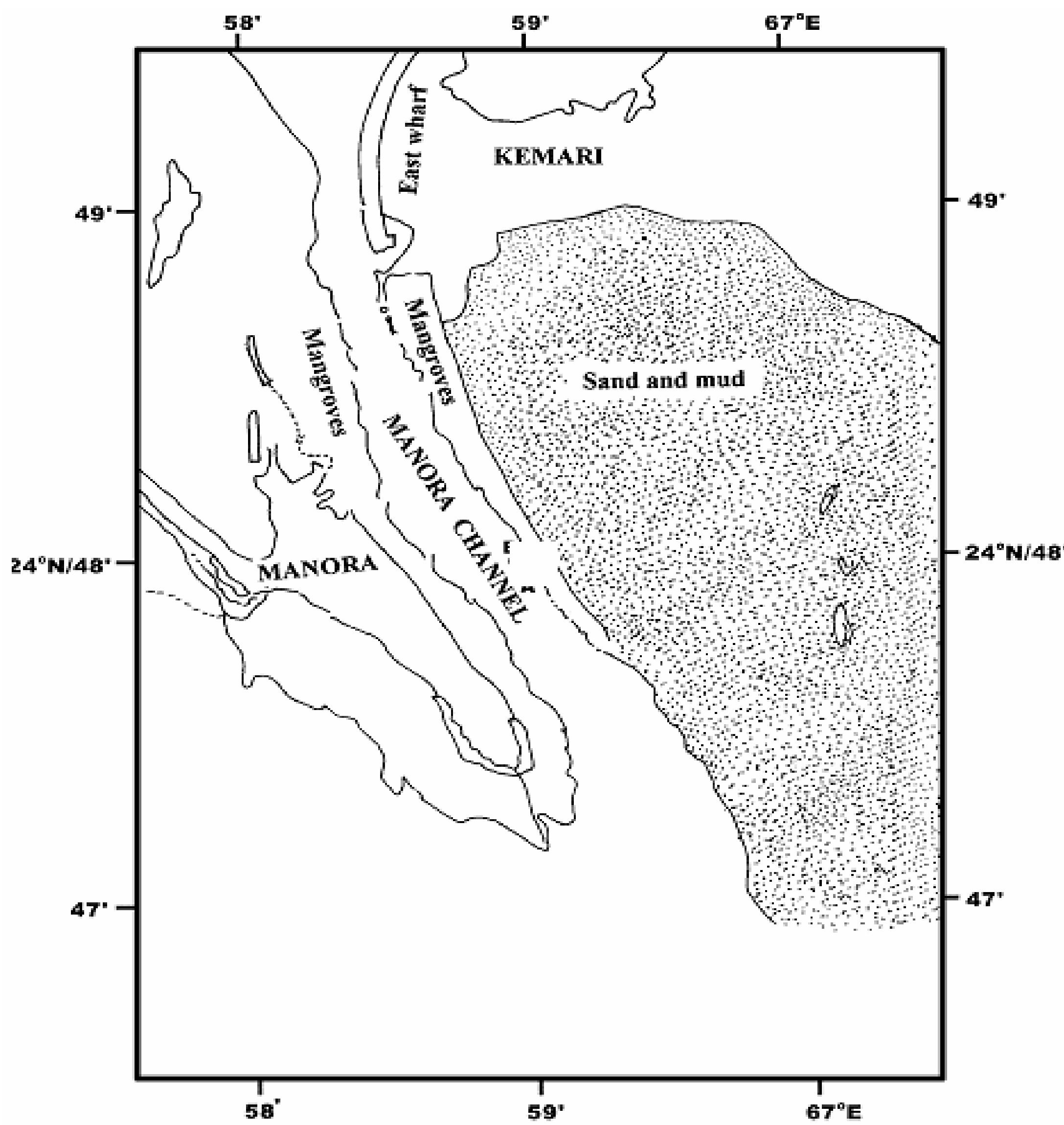

Fig. 1. Map showing the study area.

Table 1. Average (Mean ± SD) of total cell abundance of phytoplankton , diatoms (×10^3 cells l^{-1}), salinity (psu),temperature (◦C), dissolved oxygen (DO, mg/L), chlorophyll a (µg/L), pH and transparency (cm) from stations A, B.

Stations	Total phytoplankton (×10^3 cells l^{-1})	Diatoms (×10^3 cells l^{-1})	Salinity (psu)	Temperature (◦C)	Dissolved oxygen (mg/L)	Chlorophyll a (µg/L)	Transparency (cm)	pH
A	2.41-16.82	0.85-13.09	34-40	23.5-31.8	0.7-5.1	2.3-73.5	22-81	6.3-8.3
	5.995±4.656	4.24±3.62	37.1±1.5	27.3±2.8	3.0±1.4	14.9±14.3	43.4±17.0	7.4±0.4
B	1.17-61.67	0.67-30.07	34-41	22.3-31.1	2.3-5.2	0.4-103.2	27-207	6.6-8.1
	10.6578±1.251	6.310±6.694	37±1.6	27.3±2.6	4.0±0.9	13.3.±20.2	83.7±49.3	7.6±0.4

Table 2. Maximum and minimum range of diatom abundance (×10^{-3}cells l^{-1}) from stations A, B of Manora Channel.

Diatom	Stations	Abundance (×10^3 cells l^{-1})
Pennate	**A**	0.3×10^3-29.8×10^3
Centric		0.007×10^3-2.8×10^3
Pennate	**B**	0.3×10^3-29.8×10^3
Centric		0.1×10^3-4.3×10^3

Total diatoms abundance appears to vary seasonally. Diatoms were present throughout the year under all temperatures and salinities constituting major part of phytoplankton. The seasonal variability of diatom abundance observed was high in different months and ranged 0.85-13.09×10^3 cells l^{-1}, Mean ± SD (4239.69±3622.65) at station A and 0.67-30.0709 ×10^3 cells l^{-1}, Mean ± SD (6310.39±6694.34) at station B (Table 1). Diatoms had low abundance from August to December with a peak in the month of September 2 2002 was 29.8×10^3 cells l^{-1} at station B. On the other hand high abundance of diatoms was recorded during January to April/May at both stations. Second highest cell abundance 16.48 ×10^3 cells l^{-1} was recorded in the month of April 2 2003 at station B. Cell abundance was also high in the month of February-1-2003 with 16.22×10^3 cells l^{-1}. Total cell abundance observed was also high in the months of May 1 2003 with 10.9×10^3 cells l^{-1} at same station. On the other side at station A a peak of cells was observed in the month of February 1 2003 with cell abundance of 13.093×10^3 cells l^{-1}. Cell abundance remains high at the end of the same month which was 11.46×10^3 cells l^{-1}. This cell abundance was also high in the month of March 1 2003 with cell abundance recorded 11.72 ×10^3 cells l^{-1}. Lowest cell abundance was 0.84×10^3 cells l^{-1} recorded in Aug 1 2002 at station A which was similar as recorded at station B. Second Lowest cell abundance was observed in the month of October 2 2003 and was 0.90×10^3 cells l^{-1}. In contrast cell abundance was high 5.9×10^3 cells l^{-1} at station B in the same month. Total Cell abundance observed at station A also lower in the month of May, 2003 as compared to station B (Fig. 2). There were about 847 to 13093 average cells l^{-1} encountered at the polluted station A and 667 to 30067 cells l^{-1} at non-polluted station B (Fig. 2). This shows that polluted station A had low abundance compared to non-polluted station B.

Total average abundance for pennate and centric groups was calculated (Table 2). Highest total average abundance of pennate diatoms was observed at both stations. As compared to pennate centric diatoms have lower abundance at station A but higher at station B (Fig. 4). The cell abundance for pennate diatoms observed ranged from station A 0.3×10^3 to 29.8×10^3 cells l^{-1} and for centric diatoms 0.007×10^3 to 2.8×10^3 cells l^{-1}. From station B the total abundance ranged 0.3×10^3 to 29.8×10^3 cells l^{-1} and 0.1×10^{3}to4.3×10^3 cells l^{-1} respectively (Table 2).

Water parameters

Chlorophyll a: Chlorophyll a concentration showed great variation during study period. It was ranged from 2.3 to 73.5µg/L, Mean ± SD (14.9±14.3) at station A and 0.4 to 103.2µg/L, Mean ± SD (13.3±20.2 at station B in the upper 2m depth (Table 1). High values of Chlorophyll a was 73.50µg/L and 30.47µg/L also observed during the southwest monsoon period in the month of Oct. 2002 and Sept. 2 2002 respectively from station A. Chlorophyll a values were also high 50.51 µg/L in the month of Oct. 2 2002 at station B. At both stations chlorophyll a concentration recorded was high in the month of May 2 2003 (Fig. 3).

Temperatures, salinity, dissolved oxygen, pH and Secchi depth: Temperature was high all the year except in winter months of November, December and January at both stations. It was ranged from 23.50°C to 31.83°C, Mean ± SD (27.3±2.8) at station A and 22.3°C to 31.1°C, Mean ± SD (27.3±2.6) at station B (Table 1). Minimum temperature recorded was 22.00°C in the month of December, 2002 and maximum was 31.17°C in the month of July, 2003 (Fig. 3b).

Salinity was ranged from 34 to 40psu, Mean ± SD (37.1±1.5) at station A and 34 to 41psu, Mean ± SD (37±1.6) at station B (Table 1). Salinity showed highest value at station B recorded 41psu in the month of January, 2003 and lowest value observed was 34.67psu in the month of July, 2003. Maximum value was observed at station A was 40.00psu in the months of July, 2002, November, 2002 and January, 2003. Minimum value recorded was 34.33psu in the month of August, 2002 (Fig. 3a).

Dissolved oxygen values were ranged from 0.7-5.1mg/L, Mean ± SD (3.0±1.4) from station A and 2.3-5.2mg/L, Mean ± SD (4.0±0.9) from station B (Table 1). From station A highest dissolved oxygen concentrations were found 5.2mg/L in the month of July 02 2003. Lowest values of dissolve oxygen 0.7mg/L were observed in the month of September and October, 2002. At station B dissolved oxygen values recorded were also high5.6mg/L in the months of July, 2002 and January, 2003. Lower values 2.6-2.3mg/L were recorded in the month of October, 2002 and May, 2003 respectively (Fig. 3c).

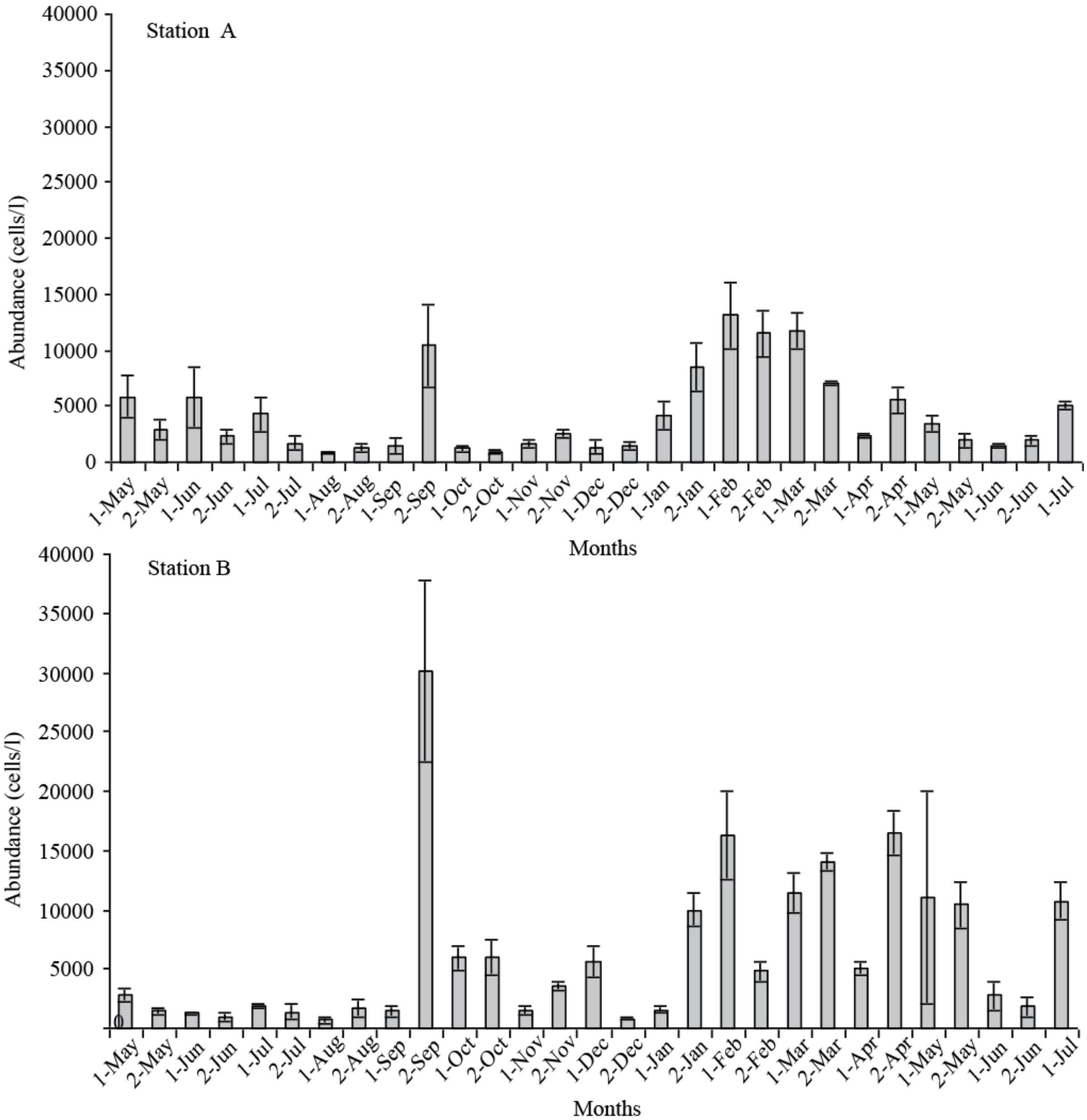

Fig. 2. Total abundance (cells l^{-1}) of diatom assemblage from stations A, B of Manora Channel.

Transparency was ranged from 22 to 81cm, Mean ± SD (43.4±17.0) at station A and 27 to 207cm, Mean ± SD (83.7±49.3) at station B (Table 1). pH was ranged from 6.3 to 8.3, Mean ± SD (7.4±0.4) at station A and 6.6 to 8.1, Mean ± SD (7.6±0.4) (Table 1). pH reached its maximum 8.1 in the month of March and April, 2003 at both stations. Low values 6.3 were observed in the month of August, 2002 at both stations. Secchi depth was minimum 28cm in the month of June-02 at station B and maximum 207cm in January-03. Minimum value 22cm at station A was observed in the months of August, 2002, April and May, 2003 (Table 1).

Statistical analysis: The functioning of a biological community can be analyzed by their diversity, species richness and equitability (evenness). It has a great impact on the production and stability of an ecosystem because it provides information about the environmental changes that are taking place along the related area. The community diversity (H′), Equitability (j) and species richness (D″) were calculated according to (Shannon & Weaver, 1949).

Shannon and weaver diversity index (H′): Shannon and Weaver (1949) diversity index (H) was calculated by the equation:

$H' = -\Sigma \, Pi \; 1n \; Pi$

where,

H′ = Diversity Index, pi = Relative percentage of species.

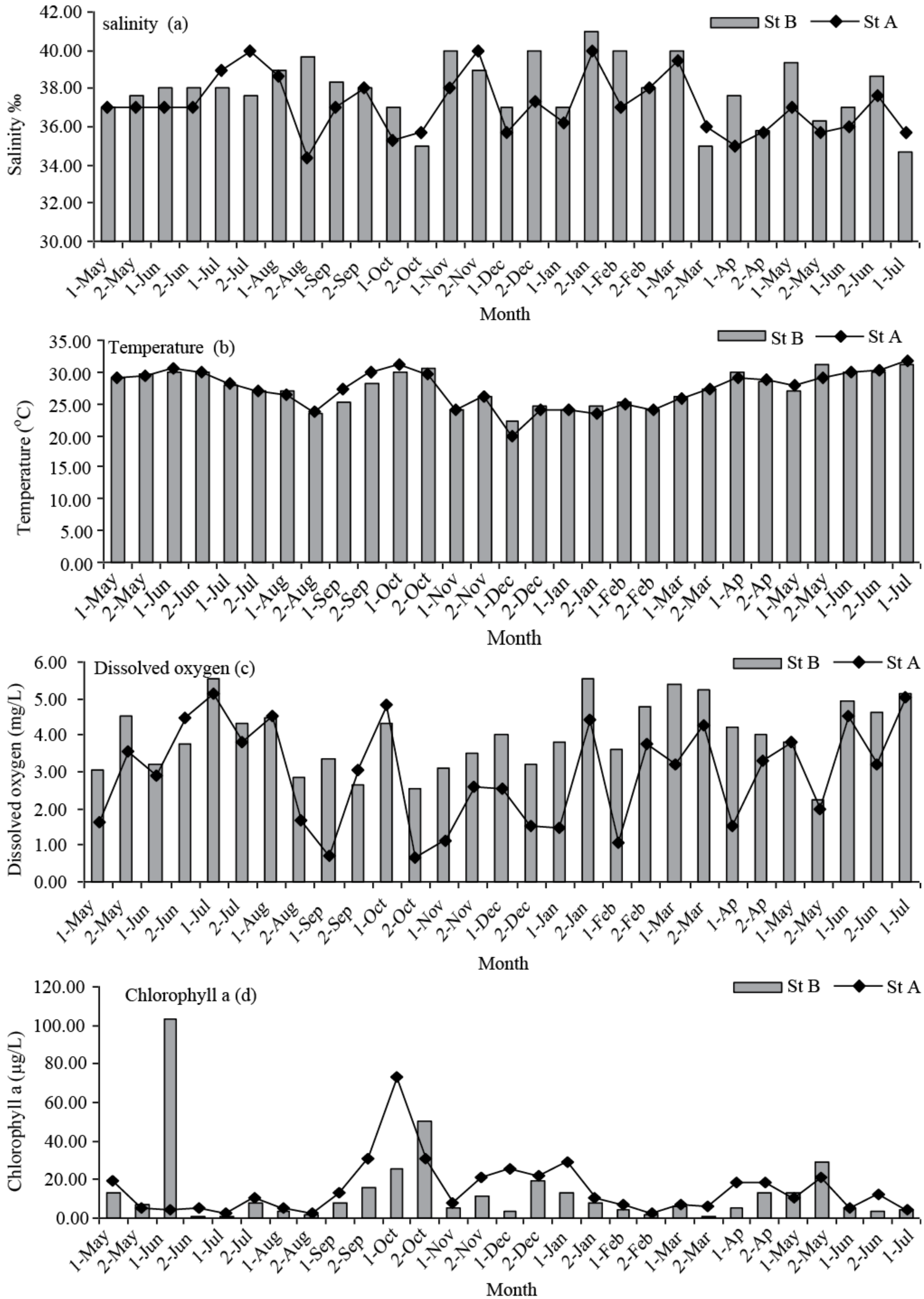

Fig. 3. Seasonal variation in (a) salinity (‰), (b) temperature (ºC), (c) dissolved oxygen (mg/L) (c) and (d) chlorophyll a (µg/L) at stations A, B.

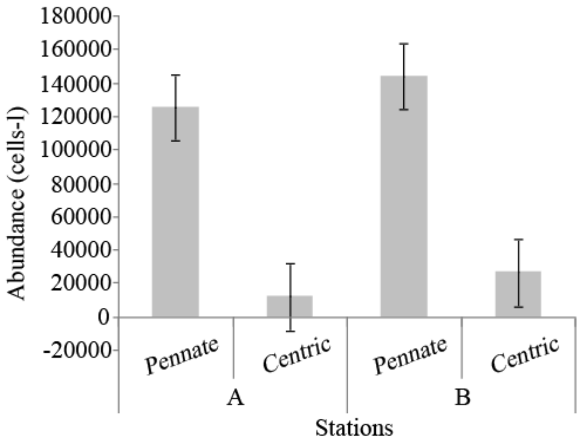

Fig. 4. Total abundance (cells l^{-1}) of pennate and centric diatoms at stations A, B.

Species richness index (d): The equation below was used for calculating species richness.

d = (S – 1)/ Log N

where,

d= Species richness index, S = Number of species in a population, N = Total number of individuals in species.

Species equitability

j = H´ / Log2 S

where,

J = Equitability index, H´ = Shannon and weaver index, S = Number of species in a population.

Seasonality in diversity, equitability and species richness has observed at both stations (Table 5). High values of diversity observed were 3.2 and 3.6 in the month of July, 2002 at both stations. Lowest values 0.1 were recorded in the month of September, 2002 at both stations. Equitability showed similar pattern as high values 13 and 14.8 were seen in the month of July, 2002 at both stations. Lowest values 0.4 and 0.5 were recorded in the month of September, 2002 at both stations. Highest species richness was in the month of October, 2002 at station B. At station A highest species richness was observed in the month of July, 2002 (Table 5). Diversity and equitability both showed similar trends and similar positive correlation values 0.6 was observed at both stations.

Pearson's correlation was used to highlight the relationship between total abundance of diatoms and the environmental parameters (Tables 3, 4). Correlation of chlorophyll a with total abundance calculated was negative -0.218 at station A and -0.054 at station B. Pearson's correlation calculated for temperature was negative at station A -0.124 and positive but insignificant 0.080 at station B. Salinity was inversely related with abundance at station B -0.140 and positively 0.294 at station A. Dissolve oxygen was positively related 0.082 at station A but negative -0.053 at station B. pH was positive 0.337 at station A and 0.209 at station B (Tables 3, 4).

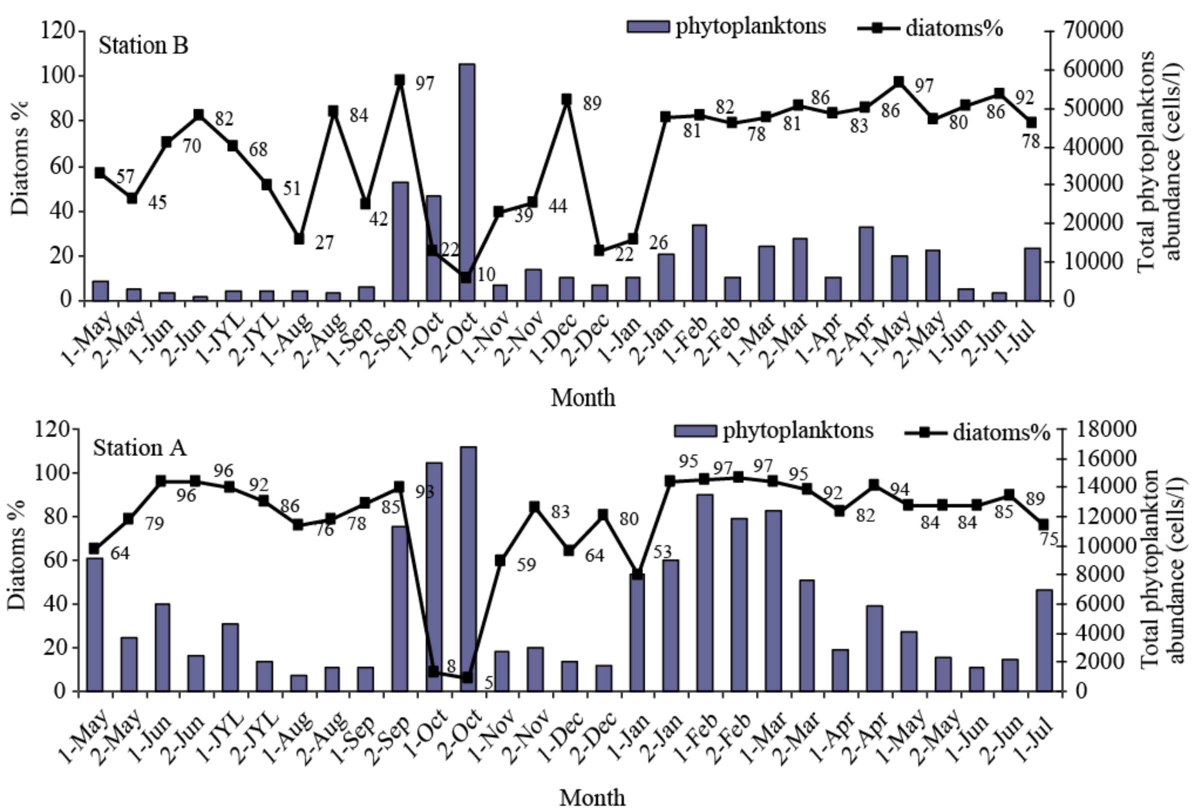

Fig. 5. Percentage % contribution of diatoms in total phytoplankton abundance (cells l^{-1}) at A and B satations.

Table 3. Correlations (Pearson) of total abundance of diatoms with water parameters at station A.

Abundance	Salinity	Temp.	Chlo	DO	pH	Trans
Salinity	0.294					
Temp	-0.122	-0.122				
Chlo	-0.218	-0.226	0.144			
DO	0.082	0.246	0.322	-0.117		
pH	0.337	-0.135	-0.002	0.078	0.155	
Trans	0.369	0.08	-0.378	-0.084	0.05	0.505

Chl a, DO, Temp, Trans refer to chlorophyll a, dissolved oxygen, transparency respectively
*=Significant at probability 0.05

Table 4. Correlations (Pearson) of total abundance of diatoms with water parameters at station B.

Abundance	Salinity	Temp.	Chlo	DO	pH	Trans
Salinity	-0.14					
Temp	0.08	-0.55				
Chlo	-0.05	-0.165	0.366			
DO	-0.053	0.011	-0.007	-0.421		
pH	0.208	-0.149	0.043	-0.126	0.369	
Trans	0.238	0.331	-0.606	-0.264	0.379	0.424

Chl a, DO, Temp, Trans refer to chlorophyll a, dissolved oxygen, transparency respectively
*=Significant at probability 0.05

Table 5. Diversity (H´), equitability (J) and species richness (D) of diatoms from stations A, B.

Months	Diversity (H´)	Equitability (J)	Sprichness (D)	Diversity (H´)	Equitability (J)	Species richness (D)
	Station	A		Station	B	
MY1	0.8	3.5	55.37	0.7	2.6	41.19
MY2	0.9	3.6	47.45	0.8	3.9	27
JU1	2	7.7	47.47	1.7	6.2	29.94
JU2	1.1	4.1	40.43	2.7	10.5	39.41
JY1	3.2	13.2	58.03	3.6	14.8	51.42
JY2	3.3	13	44.91	3	10.7	35.35
AG1	2.9	10.6	31.6	3.5	14.4	51.42
AG2	3.2	11.6	34.74	3.2	12.8	48.21
SP1	2.6	8	18.68	2	10.5	39.94
SP2	0.1	0.4	35.82	0.1	0.5	40.3
OC1	2.6	8.7	28.84	2.5	11.1	71.27
OC2	2.7	9.6	28.89	2.1	8.6	55.18
NV1	1.7	6.4	38.68	2	8	43.6
NV2	1.8	6.6	37.71	1.9	6.7	35.24
DC1	2	7.7	41.14	1.5	5.8	44.55
DC2	1.3	3.9	22.04	2.1	7.2	26.04
JA1	0.3	0.7	14.46	1.1	4	38.18
JA2	1.6	6.4	50.08	2.6	9.7	40.61
FB1	0.1	0.4	16.49	0.2	0.8	67.36
FB2	0.6	2.5	48.74	2.7	10.8	51.44
MC1	0.6	2.2	36.61	1.2	4.7	56.77
MC2	0.9	3.5	43.19	2	7.9	57.98
AP1	1.7	4.7	27.14	1.5	5.9	51.82
AP2	1.5	5.4	37.13	0.6	2.3	50.64
MY1	0.8	2.9	35.31	0.3	1.3	48.51
MY2	2.4	9.1	42.01	2	6.9	36.15
JU1	2.5	8.8	31.14	2.1	7.6	38.27
JU2	2.3	8.1	32.39	2.4	8.8	35.93
JU1	2.3	9.4	55.29	0.6	2.5	68.45

Discussion

In the present study seasonal abundance of diatoms in relation with the environmental parameters were investigated. This is the first attempt for the assessment of seasonal abundance of diatom population from coast of Karachi at Manora Channel. Two stations were selected for analysis. One was inside the channel **A** and other was outside at the mouth of the channel **B**. Diatoms were found as a dominant group in phytoplankton community but total numbers of cells l^{-1} observed were different at both stations. The significant seasonal variation in the total abundance and chlorophyll a has observed during the study period. This variation was due to the influence of Asian monsoon system exist in the region. Primary productivity and hydrographical parameters in the northern Arabian Sea is greatly affected by the monsoon system that prevails from May to October for southwest monsoon and between November and March for northeast monsoon (Brock *et al.*, 1991; Tegen & Fung, 1995). High upwelling is evident in the central and northern Arabian Sea. This upwelling brings the nutrient rich cold water to the surface results high primary productivity in the area (Tarran *et al.*, 1999). The diatoms always gathered in the zone where nutrients rich conditions present. These dynamic changes in the environment affect on the abundance of diatoms all the year. The seasonal change in total number of cells was not similar at both stations. The total abundance of cells was higher at station **B** as compared to station **A**. Similar observation was reported from the southeastern Arabian Sea by Jyothibabu *et al.,* (2008). The peak of cells noted in the month of September, 2002 because of a single species of *Navicula* at station B during southwest monsoon which is well known for high growth rate period for diatom from northern Arabian Sea. High diatoms densities also reported in the month of September from Central Arabian Sea, Oman (Barlow *et al.*, 1999).

There is no previous data available on the seasonal distribution of chlorophyll a from northern part of Arabian Sea except one report by Saiffullah (1994) in which the seasonal data of southwest monsoon was lacking. The analysis of chlorophyll during the study period shows highest value in the season of summer in the month of June, 2002. This was the onset period of southwest monsoon. Similar high values of chlorophyll were noted in the month of June by Saifullah (1994) from Pakistan shelf. During this time total abundance of diatom population abundance was very low 1.26×10^3 cells l^{-1}. High values of chlorophyll a and low abundance suggests that Picoplanktons were dominating component at that time.

Previously during the southwest monsoon phytoplankton blooms were reported linked with the heavy upwelling in the region (Banzon *et al.*, 2004). During our studies a bloom of *Navicula directa* has observed with the cell densities of 29.567×10^3 cells l^{-1} in the month of September 2002 at station B. A bloom of *Nitzschia longissima* was also observed with the highest cell abundance of 15.293×10^3 cells l^{-1} in the month of February 2003 from station **B** and 12.973×10^3 cells l^{-1} from station **A**. High abundance of *Nitzschia* species was also reported from other nutrient rich coastal waters (Brown *et al*., 1999; Jyothibabu *et al*., 2006). The high cell densities of small diatoms are a conspicuous feature in many upwelling regions. It is also because of the small diatoms always found in stratified water columns (Burkill *et al.*, 1993). It is well known that Arabian Sea develops intense stratification of water column during monsoon period. It causes severe nitrate depletion in the upper layers of water and only small diatom species can survive in nitrate depleted conditions.

Our findings have shown diatom in lower numbers of species but some species and peaks of their cell abundance during summer or spring times. The similar observations were recorded from other parts of the world like Adriatic Sea, Caroppo, (2000); Spanish waters, Gilabert, (2001); Saudi Arabia, Abdul-aziz *et al.*, (2003). The same observations of phytoplankton bloom conditions were seen from subtropical Pacific Ocean Hawaii, North Atlantic Ocean and central Arabian Sea (Takashi & Bienfang, 1983; Weeks *et al.*, 1993; Tarran *et al*, 1999). The similar observations evident from Daya Bay, South China Sea a subtropical area which is also dominated by the South Asian monsoon system (Wang, 1999; Peng *et al*., 2002). Wang, 2006 reported blooms of phytoplankton in the inshore areas (Zhong *et al*., 2002).

The results explored relationships between diatoms that associated with specific water parameters. At station B diatoms abundance has a good inverse correlation -0.140 between diatom abundance and salinity which shows the mixing of two different water masses resulting the dilution of water at station B. One the other side at station A this relation is giving positive values 0.294 but insignificant. Chlorophyll a is thought to be the indicator of diatom abundance including both pennate and centric diatoms but Chlorophyll a and diatoms concentrations at both stations showed strong inverse correlations -0.218 at station A and -0.054 at station B. It shows that chlorophyll a can not be considered as a single factor for the prediction of diatom abundance because it is the physiology of a cell which changes the chlorophyll a concentrations. Physiological activities of cells depends on the environmental influences specially availability of light which is controlled by the seasonal variations in the region. It suggests that diatom have different survival adoptions like resting stages at that time. Similar observations were reported by Mitbavker & Anil (2000) from Dona Poula Bay, India.

High species diversity and richness was observed at station **B** as compared to station **A**, which has pollution free environment. It shows that diatoms species can flourish in stress free environment. It also suggests that diatom communities able to grow in healthy and favorable conditions. High biological diversity usually shows the good water quality which was seen in the month of October, 2002 at station **B**. In contrast lowest species richness was clearly seen at station **A** which is a polluted station and providing less favorable environment for the survival of diatoms species.

Total cell abundance was high for pennate diatoms compared to centric types from both stations suggested that these pennate diatoms have great tolerance for environmental variables. Similar results were observed from Bay of Bengal which is located in the eastern arm of the northern Indian Ocean (Paul *et al.*, 2007). They also found high abundance of pennate diatoms as compared to centric diatoms.

Eutrophication is the phenomenon constantly affecting the ecosystem of Manora channel. The increasing nutrient loads through the Layari River into the Channel can cause the change in the nature of ecosystem and shifting of diatoms community to heterotrophs and flagellates (personal communications). These studies provides for the first time baseline data suggesting further assessment of diatoms diversity and their impact on the ecosystem of the region.

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