BIODIVERSITAS
Volume 18, Number 2, April 2017
Pages: 507-513

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d180209

Assessing phytoplankton community structure in relation to hydrographic parameters and seasonal variation (Pre & Post Monsoon)

M. REZA MIRZAEI[1,♥], FERESHTEH SERAJI[2], ELNAZ ERFANIFAR[1], TEYMOUR AMIN RAD[1], ZAHRA AMINIKHOEI[1], BIZHAN AZHANG[1]

[1]Offshore Fisheries Research Center, 9971956663 Chabahar, Sistan and Baluchestan, Iran. Tel./fax.:+98-54-35320450. ♥email: mirzaei.mr@gmail.com
[2]Persian Gulf and Oman Sea Ecological Research Institute, Bandar Abbās, Hormuzgan, Iran

Manuscript received: 9 January 2017. Revision accepted: 20 February 2017.

Abstract. *Mirzaei MR, Seraji F, Erfani E, Rad TA, Aminikhoei Z, Azhang B. 2017. Assessing phytoplankton community structure in relation to hydrographic parameters and seasonal variation (Pre & Post Monsoon). Biodiversitas 18: 507-513.* The present study is conducted to assess hydrographical parameters, phytoplankton composition and the relationship between physicochemical parameters and phytoplankton assemblages along Chabahar coastal waters, South coast of Iran. Based on the collected samples from four stations, all the hydrographical parameters such as sea surface temperature, salinity, pH, DO and nitrate, inorganic phosphate, silicate, and phytoplankton assemblages were studied for five months (from April 2014 to August 2014). A total of 165 phytoplankton groups/taxa were observed in which the Dinophyceae formed the dominant group in all seasons. During the pre-monsoon season, Dinophyceae (56.5%) was the most abundant phytoplankton group followed by Bacillariophyceae (40.8%), Cyanophyceae (1.7 %) and Dictyochophyceae (0.8%). Meanwhile, in the post-monsoon season, Dinophyceae was dominant (49.5%), followed by Bacillariophyceae (46.7%), Cyanophyceae (1.8%), and Dictyochophyceae (1.8%). The highest phytoplankton density was in mid-May (19584953± 345182 cell per litter) and the lowest was in late July (163928± 1790 cells per liter). Salinity, nitrate, phosphate, silicate showed significant variation ($p<0.05$) among seasons while pH, seawater temperature, dissolve oxygen did not show significant differences in all stations over the study periods ($p<0.05$). Phytoplankton density correlated positively with water temperature and salinity. Results showed an increased concentration in phytoplankton density during Pre-monsoon season followed by Post-monsoon and monsoon season.

Keywords: Abundance, diversity, monsoon, physicochemical parameters, phytoplankton

INTRODUCTION

Phytoplankton is one of the most important organisms in marine and coastal environments and are generally comprised of a number of taxonomic groups. These organisms are highly diverse in the vertical stratification of the water column (Mellard et al. 2011). Phytoplankton accounts for most of the primary productions of the global ocean and produce more than 50% of the oxygen and organic materials depending on the season (Helbling and Villafane 2009). In addition to their role as a primary producer, through such processes as photosynthesis (Knoll et al. 2003), calcification (Iglesias-Rodriguez et al. 2008), and nitrogen fixing (Howarth 1988), they are considered as the base of the marine food web, consumed by zooplanktons which are subsequently consumed by large marine life such as fish. Therefore, they are efficient in assessing the fishery potential of different regions (Berglund et al. 2007). However, phytoplanktons can produce powerful biotoxins and cause oxygen depletion, thereby increasing marine mortality rate and threatening the aquaculture industry and human health (Luckas et al. 2005; Rodgers 2008).

Monsoon is a period of the year characterized by changes in wind direction and climate (Kelly et al. 2006). It starts from the southern margins of India and reaches the northern coast of Oman Sea at an advanced stage. In this particular region, also known as Chabahar, monsoonal winds change the weather conditions and hydrographical features in the water column. In fact, the year is divided into pre-monsoon, northeast monsoon, southwest monsoon, and post-monsoon seasons (Fazeli and Zare 2011; Rabbaniha et al. 2014). Environmental changes due to monsoon season further alter the structure and function of biological organisms (Gettelman et al. 2004).

Phytoplankton distribution in the water column is not always uniform and varies at different zones by physicochemical parameters (Loureiro et al. 2006). The knowledge on phytoplankton community is essential to the study of marine biodiversity. The species composition and the population density of phytoplankton are dependent on environmental variables (Macedo et al. 2001). Although extensive research has been carried out on the taxonomic identification of different phytoplankton genera, there is little information on the effect of seasonal variation and phytoplankton composition on water bodies during monsoon seasons, hence of this study is to investigate the impact of hydrographical and environmental parameters on phytoplankton structure and biodiversity along the north coast of Oman Sea during monsoon seasons.

MATERIALS AND METHODS

Study site

The present study was carried out on the north coast of Oman Sea- Chabahar, Iranian waters. Samples were collected every two weeks from four fixed stations during the pre-monsoon (April - May), monsoon (June-July) and post-monsoon (August) of 2014 (Figure 1). These periods were classified according to the onset and ending of the southwest monsoon, which is a factor of climate change in the region.

Sample collection and identification

In order to analyze the phytoplankton, samples were collected from the water column through the use of Niskin bottles. Samples were stored in polyethylene bottles after preservation with Lugol's solution for laboratory analysis. The phytoplankton cells were counted with a Sedgwick rafter-counting chamber under a compound microscope (Nikon Eclipse-E600) with different magnifications. Utermöhl's (1958) method was used for taxonomy and identification of the species. The abundance of phytoplankton is shown as the number of individuals per cubic meter (ind. m^3) according to the following equation (Santhanam and Srinivasan 1994):

$$N = n(v/V) \times 1000$$

Where:

N: Total number of phytoplankton per cubic meter

n: Average number of phytoplankton in 1 mL of the sample

v: Volume of phytoplankton concentrate (mL)

V: Volume of the total filtered water (L)

Field and laboratory measurements

Several hydrographical and environmental parameters were recorded over a period of five months. Sea surface temperature (SST), pH and salinity were measured at the study site through the use of thermometer, moored pH sensors, and hand-held refractometer, respectively. Water samples were then stored in clean polyethylene bottles and transferred to the laboratory for the analysis of hydro-biological parameters. Dissolved oxygen was calculated via Winkler's technique. Furthermore, the collected water samples were filtered and put into nutrient analysis: nitrate (NO_3) was tested by the cadmium reduction method, inorganic phosphate (PO_4) was studied through the ascorbic acid method, and silicate (SiO_4) was analyzed by molybdate method employing a PC-based double beam spectrophotometer.

Data analysis

The correlation coefficient was specified using the SPSS program version 16 so as to determine the association between phytoplankton species and different environmental parameters. A two-way analysis of variance was conducted in order to find out the differences in the density of the Phytoplankton groups in different periods and locations.

RESULTS AND DISCUSSION

Taxa composition

During the study, a total of 165 phytoplankton species were identified in four stations, 85 species belonging to Dinophyceae, 76 species belonging to Bacillariophyceae, 2 to Cyanophyceae, and 2 to Dictyochophyceae (Figure 2). Among the various species *Amphisolenia palmate, Nitzschia sigma, Phormidium abronema, Cochlodinium polykrikoides, Diplopsalis lenticula, Gymnodinium spirale, Heteraulacus polyedricus, Prorocentrum belizeanum, Prorocentrum gracile, Prorocentrum rocentrum, Protoperidinium conicoides* were the dominant species of the phytoplankton obtained from the three study sites.

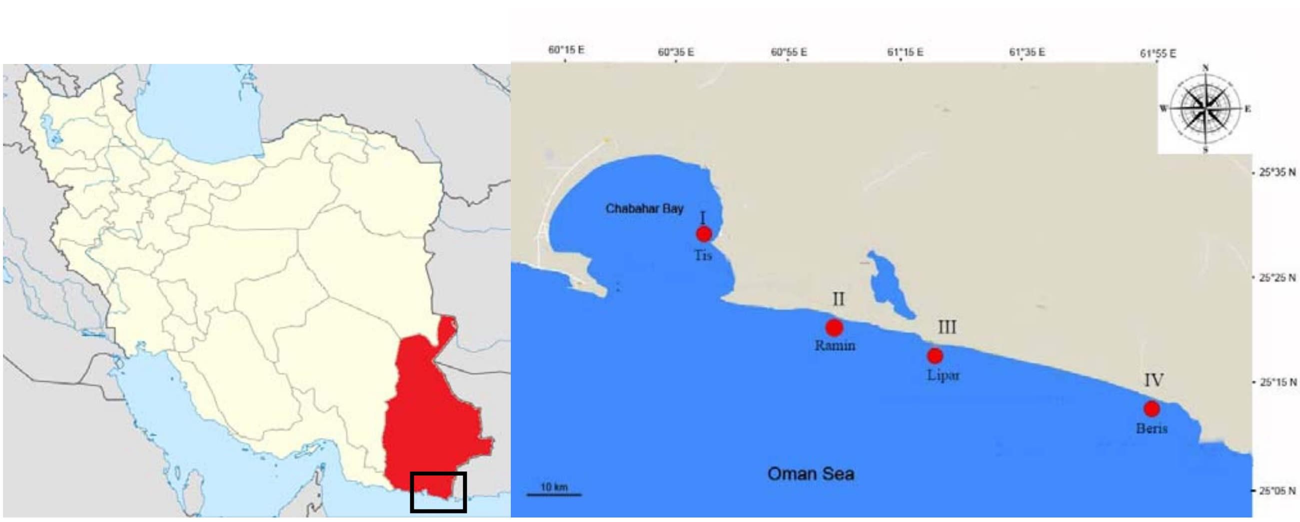

Figure 1. Sampling locations (numerical figures I-IV) in the study area map of Chabahar, Sistan and Baluchestan Province, Iran

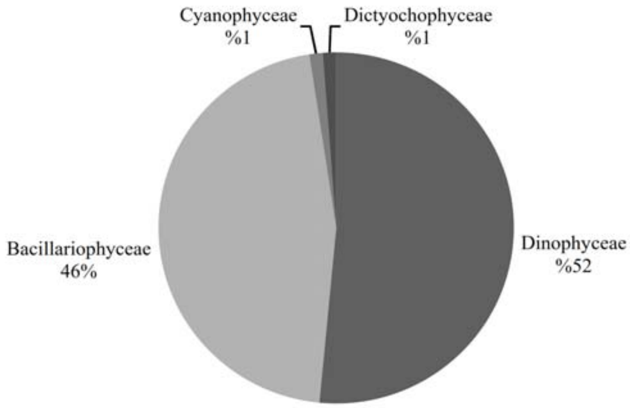

Figure 2. Relative abundance (%) of different groups of phytoplankton from April 2014 to August 2014

Table 1. Number of phytoplankton taxa during pre-monsoon and post-monsoon of 2014

Group	Pre-monsoon	Post-monsoon
Bacillariophyceae	47	51
Dinophyceae	65	54
Cyanophyceae	2	2
Dictyochophyceae	1	2

During the pre-monsoon season, 115 species were observed, consisting of 47 species belonging to Bacillariophyceae, followed by 65 species related to Dinophyceae, two species of Cyanophyceae type and one species belonging to Dictyochophyceae. Meanwhile, in the post-monsoon period, 109 species were observed belonging to Bacillariophyceae (51), Dinophyceae (54), Cyanophyceae (2), and Dictyochophyceae (2) (Table 1).

Density

Seasonally, the mean abundance of phytoplankton varied considerably (Fig. 3). The highest phytoplankton density was in mid-May (19584953± 345182 cell per litter) and the lowest was in late July (163928± 1790 cells per liter). Phytoplankton population density increased from April until the beginning of monsoon (late May), then showed a clear downward trend from the middle of June until the end of July (the onset of monsoon). Phytoplankton density increased once again by the change in phytoplankton density and structure in late August. Dinophyceae and Bacillariophyceae were the most dominant and abundant groups among the four stations during the pre-monsoon and post-monsoon seasons, respectively.

In the pre-monsoon period, among the species of Bacillariophyceae group, *Nitzschia sigma* (53.4%) was the dominant species followed by *Nitzschia pungens* (10.1%), *Stauroneis acuta* (7.5%), *Nitzschia seriata* (5.2%), *Lioloma elongatum* (4.6%), *Diploneis splendid* (4.2%), *Navicula elegans* (3.4%) and the other species (6.7 %).*Cochlodinium polykrikoides* (84.2%), *Prorocentrum belizeanum* (4.2%), and *Prorocentrum rocentrum* (2.5 %) were the most dominant species in Dinophyceae group. With the changes in phytoplankton assemblages (density and species composition) after the monsoon, *Nitzschia seriata* (53.5%), *Lioloma elongatum* (32.3%), *Nitzschia closterium* (4.7%) and *Navicula membrane* (3.9%) were the most abundant species in Bacillariophyceae group. Among Dinophyceae species, *Cochlodinium polykrikoides* was 70.9%, followed by *Prorocentrum gracile* (3.7%), *Prorocentrum rocentrum* (2.8%), and *Ceratium furca* (2.2%). Based on phytoplankton abundance during the study period, *Amphisolenia palmata, Leptocylindrus danicus, Nitzschia closterium* were observed only during the pre-monsoon period. *Heteraulacus polyedricus* and *Prorocentrum sigmoides*, on the other hand, were detected post monsoon and were absent in the pre-monsoon period (Table 2). The differences in the diversity of phytoplankton species in the four study stations were statistically insignificant ($P < 0.05$), with stations I and III having only a difference of three species, meaning that phytoplankton diversity was almost the same in all stations. However, there was a significant difference between the pre- and post-monsoon periods as far as the four study sites are concerned ($P < 0.05$). Dinophyceae and Bacillariophyceae were the dominant groups among the four stations during the pre-monsoon and Post-monsoon seasons, respectively. Furthermore, there were significant differences ($p<0.05$) in the phytoplankton abundance among the sampling months in the study stations. These dramatic differences were apparent in the high and low phytoplankton abundances observed in May and late July, respectively.

Hydrographical and environmental parameters

Hydrographical parameters, with their wide temporal and spatial differences, are considered as significant features that can influence the growth, abundance, and diversity of phytoplankton in the marine environment. Figure 3 demonstrates the variations in surface seawater. As seen, the surface seawater temperature recorded at four different coastal stations ranges from 25.2 °C to 34.3°C. The minimum surface seawater temperature was recorded during June 2014 at the station I and the maximum was recorded late May 2014 at site III. The observed salinity values ranged between 35 ppt (June and July 2014) and 38 ppt (April and August 2014) and there existed a significant difference between the three seasons. Although, did not show much variation among the stations ($P > 0.05$). pH value was more or less constant during the study period and ranged from 8.2 (station III during August 2014) to 8.49 (stations I, II, and III during May 2014). The Dissolved oxygen varied from 3.6 mg/L (Station III, April 2014) to 8.1 mg/L (Station II, June 2014). Nitrate concentration ranged from 0.5 mg/L to 3.9 mg/L reaching a maximum value at station IV in August 2014 and minimum concentration at station II during July 2014. The minimum silica concentration (0.05 mg/L) was recorded during June 2014 at stations I and II while the maximum amount (0.6 mg/L) was observed at the station I in April 2014 (Figure 4). The inorganic phosphate concentration was maximized (0.028 mg/L) during June and July 2014 at stations I, II, and III and the minimum concentration (0.008 mg/L) was seen at the station I during August 2014 (Figure 4). The highest value of silicate was observed during April (0.6 mg/L). Silicate concentrations drop sharply (to values as low as 0.05-0.1 mg/L) until first of monsoon. After a slight increase silicate concentration until the end of June, it remained more or less constant in all the stations until late August (Figure 4).

The correlation between the hydrographical and environmental factors (Independent variables) and phytoplankton density (dependent variable) is shown in Table 6.5. As can be observed, the coefficient (r) ranges from -1 to +1, where -1 and +1 indicate perfect negative and perfect positive relationships and any amount approximating "zero" shows the decrease in the strength of relationship(Pallant 2004, Mirzaei and Shau Hwai 2015). The correlation matrix showed that there was a moderate positive relationship between the phytoplankton density and seawater temperature (+0.46) and salinity (+0.43). Furthermore, a very weak positive relationship was found between phytoplankton abundance and silicate (+0.38), pH (+0.21), and nitrate (+0.27). Finally, the results of correlation matrix indicated that there was a negative relationship between phytoplankton abundance and dissolve oxygen (-0.045) and phosphate (-0.59).

Discussion

In this study, the population dynamics of phytoplankton were compared with the environmental factors. A substantial increase in phytoplankton species composition has been observed as compared to the earlier reports from this locality. Very common phytoplankton species, which were not recorded earlier from this location, were observed during the present study.The results indicated that the monsoon season plays a major role in phytoplankton density and composition. Species composition varied considerably during pre-monsoon, monsoon and post-monsoon periods. Seasonally, the Bacillariophyceae density was found to be highest prior to monsoon, with a decrease to the minimum value by the end of July (monsoon period), Verma and Mohanty (1995); Denisov (2007) and Jagadeeshappa and Kumara (2013) stated that alkaline pH is one of the important factors regulating the abundance of diatomic population. Dinophyceae density was high in the pre-monsoon season, a finding in line with the results of Saravanakumar et al. (2008). Furthermore, in agreement withSaraji's (2014) findings, the abundance of *Prorocentrum rocentrum* and *Prorocentrum belizeanum* was found to be high in the Persian Gulf and Oman Sea before the monsoon. The present study indicated that blue-green algae were regularly observed within the pre-monsoon season; moreover, Cyanophyceae were considerably less abundant throughout the pre-monsoon compared to the post-monsoon season, which is in accordance with Gowda et al. (2001) study at Nethravathi estuary ,India. Dictyochophyceae were observed before and after the monsoon, at high temperatures and relatively alkaline conditions. Dictyochophyceae species, on the other hand, were identified more during the pre-monsoon period than the post-monsoon season.

Table 2. Seasonal variation of major phytoplankton (Nos/L) species recorded at Chabahar Coast (April 2014 -August 2014)

Species	PRM	MON	POM
Alexandrium tamarense	3.449	2.765	5.263
Amphisolenia palmata	0	0.123	9.989
Ceratium furca	6.405	2.875	12.663
Ceratium fusus	6.076	4.654	9.793
ceratium longipes	6.234	4.835	14.869
Ceratium tripos	11.032	1.986	6.776
Chaetoceros costatus	3.598	1.459	9.429
Chaetoceros costatus	7.345	5.936	21.234
Chaetoceros decipiens	2.461	1.546	11.876
Chaetoceros mitra	8.546	2.583	19.546
Chaetoceros simplex	2.765	1.485	8.654
Chaetoceros subtilis	1.957	0.456	3.854
Cochlodinium polykrikoides	3460.674	23.876	404.698
Coscinodiscus granii	9.254	5.234	9.373
Coscinodiscus lineatus	1.686	0	11.893
Dictyocha fibula	4.291	1.657	17.717
Diploneis splendida	9.128	0	0.098
Diplopsalis lenticula	29.897	1.986	5.831
Gymnodinium spirale	42.161	1.734	1.603
Gymnodinium trapeziforme	4.563	1.875	7.342
Gyrosigma acuminatum	6.797	1.546	22.561
Heteraulacus polyedricus	1.858	0.298	11.456
Heteraulacus polyedricus	48.993	1.435	0
Leptocylindrus danicus	0	1.456	303.525
Lioloma elongatum	9.134	3.546	639.268
Navicula elegans	8.429	0	27.076
Navicula membrane	5.684	2.567	77.112
Nitzschia closterium	0	0	93.198
Nitzschia pungens	20.132	0	1.246
Nitzschia seriata	10.318	3.456	1058.953
Nitzschia sigma	105.504	0	0.301
Noctiluca miliaris	9.345	6.567	10.768
Oscillatoria thiebautii	7.007	2.433	3.416
Phormidium abronema	71.743	4.535	7.713
Prorocentrum belizeanum	165.067	0.456	3.535
Prorocentrum gracile	6.435	5.564	9.456
Prorocentrum gracile	32.431	11.875	21.553
Prorocentrum gracile	7.324	2.987	16.234
Prorocentrum lima	9.653	4.657	10.185
Prorocentrum maximum	11.324	2.114	22.657
Prorocentrum maximum	4.324	1.768	13.897
Prorocentrum rocentrum	103.642	0.879	16.132
Prorocentrum rostratum	7.254	4.578	12.765
Prorocentrum rostratum	6.432	0.345	11.897
Prorocentrum sigmoides	3.925	1.435	17.345
Prorocentrum sigmoides	29.666	0.543	0
Prorocentrum triestinum	29.708	1.768	4.912
Protoperidinium conicoides	44.534	3.986	7.097
Protoperidinium latissimum	13.65	1.456	3.424
Protoperidinium leonis	15.237	2.546	5.234
Protoperidinium oblongum	18.543	0.567	2.574
Protoperidinium pentagonum	6.342	2.657	1.568
Protoperidinium steinii	4.095	0.357	6.471
Protoperidinium stellatum	4.0385	2.567	8.9457
Scrippsiella lachrymosa	5.324	0.567	3.658
Scrippsiella precaria	4.768	1.342	5.239
Scrippsiella trochoidea	7.203	0.865	6.377
Stauroneis acuta	14.917	0	41.034

Note: PRM = Pre-monsoon, MON = Monsoon, POM = Post-monsoon

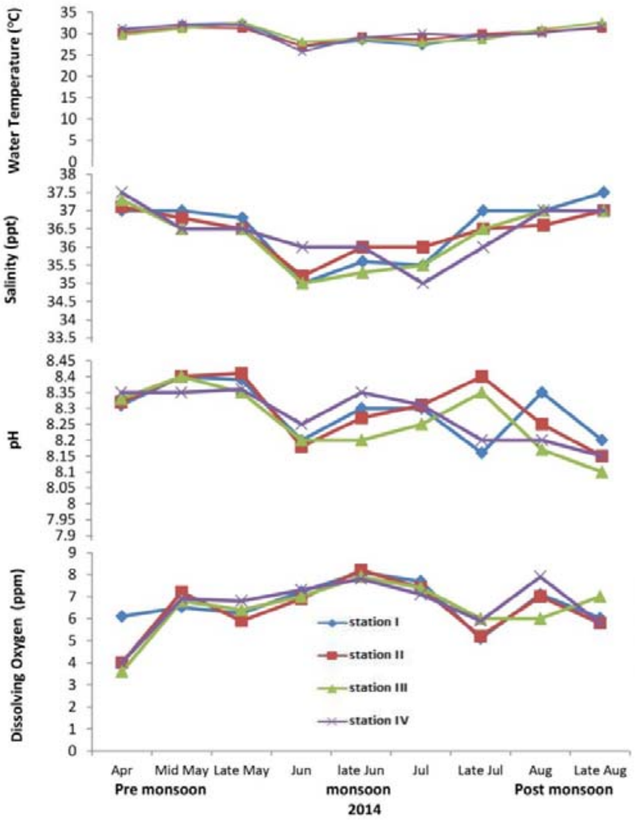

Figure 3. Variation of environmental parameters recorded during sampling period in the Chabahar coast from April 2014 to August 2014

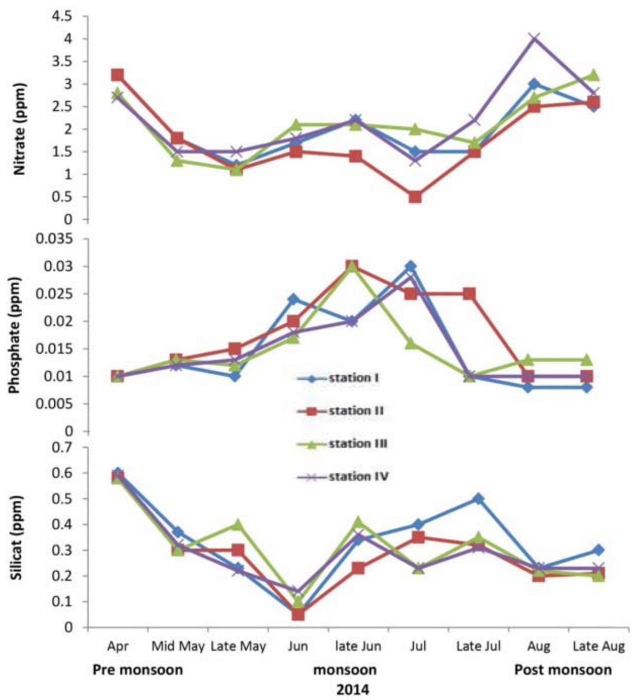

Figure 4. Variation of hydrochemical parameters recorded during sampling period in the Chabahar coast from April 2014 to August 2014

A possible explanation for the high density of phytoplankton prior to the monsoon season might be the prominence of diatoms, the increase in temperature and the subsequent rise in decomposition rate and evaporation, and increase the amount of nutrients and availability of food due to photosynthesis. Another important finding was the low phytoplankton density during monsoon. It seems possible that these results are the outcomes of water stratification due to heavy rainfall, and decrease in temperature; salinity and pH increased turbidity while low transparency and strong currents lowered phytoplankton density. Similarly, Hassan et al. (2010) observed phytoplankton density to be at its lowest during monsoon (in Euphrates River, Iraq) and Devika et al. (2006) found high phytoplankton population after monsoon and extrapolated that this might be owing to the variations in water physicochemical qualities such as temperature and transparency.

All the environmental parameters had clear seasonal patterns and no noticeable variation was observed among the stations. The recorded seawater temperature was between 25.0ºC and36.2ºC. Higher seawater temperatures were recorded during May 2010 due to the increase in sunlight (Balakrishnan et al. 2015) Although surface seawater temperature (SST) can affect such biological aspects as reproduction, growth rate, metabolic processes, and particularly photosynthesis rates, the recorded SST was in the optimal range for phytoplankton growth in the study area. Phytoplankton density was high during the pre- and post-monsoon periods in the north coast of Oman Sea. The abundance of phytoplankton decreased during monsoon season when the water temperature was high, confirming the effect that temperature has on phytoplankton density.

Salinity acts as a reducing variable in the distribution of plankton communities and influences phytoplankton diversity in the coastal ecosystem. Phytoplankton composition was changed by the presence of salinity stratification during the monsoon period and early post-monsoon season due to low rainfall and rise in the rate of evaporation. The pH values were more or less constant during the studied periods. Generally, fluctuations in pH values during pre-monsoon, monsoon, and post-monsoon periods can be related to factors such as the elimination of carbon dioxide by photosynthesis, decrease in salinity and temperature and the dilution of seawater by monsoon currents. High pH values are probably the result of seawater inundation and high phytoplankton density.

The dissolving oxygen level varied between 3.6 mg/L (Station III, April 2014) and 8.1 mg/L (Station II, June 2014). Dissolving oxygen had a positive relationship with phytoplankton biomass and acted as the regulator between photosynthesis and respiration. The increase in DO may be related to the relatively low SST and salinity during monsoon and the vertical mixing of water columns because of turbulent sea currents.

The high silicate values prior to monsoon were due to the heavy inflow of monsoon inputs. Furthermore, suspended-sediment concentration in the biological uptake of silica probably influenced the variation in silica. Results of the current study showed a direct relationship between silicate levels and Bacillariophyceae during and after the monsoon.

Table 3. Correlation coefficient (r) among the physicochemical properties and phytoplanktons of Chabahar Coast from April 2014 to August 2014

	SST	Ph	Salinity	DO	NO_3	PO_4	SiO_4	Phyto-abundance
SST	1							
Ph	0.35*	1						
Salinity	0.82**	0.10	1					
DO	-0.36	-0.12	-0.69	1				
NO_3	0.19	-0.47*	0.61**	-0.38*	1			
PO_4	-0.73	-0.04	-0.91	0.70**	-0.53*	1		
SiO_4	0.29	0.50	0.48	-0.64**	0.22	-0.23	1	
Phyto-abundance	0.46*	0.21	0.43*	-0.45*	0.27	-0.59*	0.38*	1

Note: *Correlation is significant at the 0.05 level, **Correlation is significant at the 0.01 level

Silicate values underwent a significant decrease ($P<0.05$) in the late pre-monsoon season while remaining constant during monsoon and increasing in the early stages of the post-monsoon period. There are two probable reasons why nitrate levels increased during the post-monsoon season, the first one being the organic components in the catchment zone during tidal changes; the second reason is related to the oxidation of ammonia. On the other hand, nitrates were consumed by phytoplankton during photosynthetic activity and that can explain why their values decreased during monsoon.

The nutrient-rich upwelled water is the main reason for high phosphate values during monsoon. In fact, storm turbulence and wind shear are the major monsoon-related factors, launching all phosphor from the muddy bottom. Phosphate values decreased prior to monsoon while reaching their minimum during the post-monsoon season, a fact that can be attributed to the consumption of phosphate by phytoplankton.

Seasonal variations of phytoplankton population density are attributable to a wide range of physical-chemical parameters such as temperature, salinity, nitrate and phosphate. It is obvious in this research that the north coast of Oman Sea has high phytoplankton densities during pre- and post-monsoon seasons; phytoplankton, on the other hand, are least abundant where there is a monsoon.

With this information, the management authorities can monitor the species which exhibit a wide variety of distinguishing morphological and physiological characteristics that control their distribution, population dynamics in relation to hydrographic parameters and seasonal variation. Due to the appearance and increase of potentially harmful species in the pre-monsoon, monsoon and post-monsoon, continuously monitoring of this area is imperative, to estimate the timing of a phytoplankton bloom, to predict negative effects and any undesirable change there. Furthermore, experimental investigations are needed to determine other chemical factors which may have important contributors for the temporal distributions of the phytoplankton population density along the coastal waters of the Sea of Oman.

REFERENCES

Balakrishnan S, Chelladurai G, Mohanraj J, Poongodi J. 2015. Seasonal variations in physico-chemical characteristics of Tuticorin coastal waters, southeast coast of India. Appl Water Sci. DOI: 10.1007/s13201-015-0363-2.

Berglund J, Muren U, Båmstedt U, Andersson A. 2007. Efficiency of a phytoplankton-based and a bacterial-based food web in a pelagic marine system. Limnol Oceanogr 52: 121-131.

Denisov D. 2007. Changes in the hydrochemical composition and diatomic flora of bottom sediments in the zone of influence of metal mining production (Kola Peninsula). Water Resour 34: 682-692.

Devika R, Rajendran A, Selvapathy P. 2006. Variation studies on the physico-chemical and biological characteristics at different depths in model waste stabilisation tank. Pollut Res 25: 771.

Fazeli N, Zare R. 2011. Effect of seasonal monsoons on calanoid copepod in Chabahar Bay-Gulf of Oman. Jordan J Biol Sci 4: 1-170.

Gettelman A, Kinnison DE, Dunkerton TJ, Brasseur GP. 2004. Impact of monsoon circulations on the upper troposphere and lower stratosphere. J Geophys Res-Atmos 109: 1-14.

Gowda G, Gupta T, Rajesh K, Gowda H, Lingadhal C, Ramesh A. 2001. Seasonal distribution of phytoplankton in Nethravathi estuary, Mangalore. J Mar Biol Ass India 43: 31-40.

Hassan FM, Taylor WD, Al-Taee M, Al-Fatlawi HJ. 2010. Phytoplankton composition of Euphrates River in Al-Hindiya barrage and Kifil City region of Iraq. J Environ Biol 31: 343-350.

Helbling E, Villafane V. 2009. Phytoplankton and primary production. Fish Aquacult 5: 206-226.

Howarth RW. 1988. Nutrient limitation of net primary production in marine ecosystems. Ann Rev Ecol Evol Syst 19: 89-110.

Iglesias-Rodriguez MD, Halloran PR, Rickaby RE, Hall IR, Colmenero-Hidalgo E, Gittins JR, Green DR, Tyrrell T, Gibbs SJ, Von Dassow P. 2008. Phytoplankton calcification in a high-CO2 world. Science 320: 336-340.

Jagadeeshappa K, Kumara V. 2013. Influence of physico-chemical parameters on the diversity of plankton species in wetlands of Tiptur taluk, Tumkur dist, Karnataka State, India. Carib J Sci Tech 1: 185-193.

Kelly MJ, Edwards RL, Cheng H, Yuan D, Cai Y, Zhang M, Lin Y, An Z. 2006. High resolution characterization of the Asian Monsoon between 146,000 and 99,000 years BP from Dongge Cave, China and global correlation of events surrounding Termination II. Palaeogeogr Palaeoclimatol. Palaeoecol 236: 20-38.

Knoll LB, Vanni MJ, Renwick WH. 2003. Phytoplankton primary production and photosynthetic parameters in reservoirs along a gradient of watershed land use. Limnol Oceanogr 48: 608-617.

Loureiro S, Newton A, Icely J. 2006. Boundary conditions for the European Water Framework Directive in the Ria Formosa lagoon, Portugal (physico-chemical and phytoplankton quality elements). Estuar Coast Shelf S 67 382-398.

Luckas B, Dahlmann J, Erler K, Gerdts G, Wasmund N, Hummert C, Hansen P. 2005. Overview of key phytoplankton toxins and their recent occurrence in the North and Baltic Seas. Environ Toxicol 20: 1-17.

Macedo M, Duarte P, Mendes P, Ferreira J. 2001. Annual variation of environmental variables, phytoplankton species composition and photosynthetic parameters in a coastal lagoon. J Plankton Res 23: 719-732.

Mellard J. P, Yoshiyama K, Litchman E, Klausmeier C. A. 2011. The vertical distribution of phytoplankton in stratified water columns. J Theor Biol 269: 16-30.

Mirzaei M-R, Shau Hwai AT. 2015. Assessing cockle shells (Anadara granosa) for reconstruction subdaily environmental parameters: Implication for paleoclimate studies. Hist Biol 28: 896-906.

Pallant J. 2004. SPSS Survival Manual: Version 12, Open University Press, Maidenhead, Berkshire. U.K.

Rabbaniha M, Mousavi Golsefid S, Owfi F. 2014. The effect of monsoon on fish larva assemblage changes in Gowatr Bay, North Oman Sea. Iran J Fish Sci 13: 427-436.

Rodgers J. H. 2008. Algal Toxins in Pond Aquaculture. Southern Regional Aquaculture Center, USA.

Santhanam R, Srinivasan A. 1994. A Manual of Marine Zooplankton. Oxford & IBH Pub. Co., UK.

Saraji F. 2014. Phytoplankton Community And Water Quality During Pre And Post Monsoon In The Oman Sea (Part Of Iranian Waters). Universiti Sains Malaysia, Pinang.

Saravanakumar A, Rajkumar M, Serebiah J. S, Thivakaran G. 2008. Seasonal variations in physico-chemical characteristics of water, sediment and soil texture in arid zone mangroves of Kachchh-Gujarat. J Environ Biol 29: 725-732.

Utermöhl H. 1958. Zur Vervollkommnung der quantitativen Phytoplankton-Methodik. Mitt Int Verein Theor Angew Limnol 9: 1-38.

Verma J, Mohanty R. 1995. Phytoplankton and its correlation with certain physiochemical parameters of Danmukundpur pond. Poll Res 14: 233-242.