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Full length article

Phytoplankton abundance in relation to the quality of the coastal water – Arabian Gulf, Saudi Arabia

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ABSTRACT

Phytoplankton abundance in relation to some physicochemical characters of the costal water of Arabian Gulf (Saudi Arabia) was studied for one year. The sampling program included 15 locations in Dammam, Saihat, Al-Qatif, Al-Awamia and Safwa. Water samples were analyzed monthly for these parameters; temperature, pH, salinity, dissolved oxygen, nitrite, nitrate, ammonia, carbon dioxide, total chloride, reactive orthophosphate and total phosphorus and alkalinity, also phytoplankton communities were identified and Chlorophyll *a* was estimated. The results showed that, the high phytoplankton density attaining the maximum ($190.3 \times 10^4/m^3$) during May and June, and the minimum ($10.4 \times 10^4/m^3$) during November and December. Forty Five species belonging to 5 phytoplankton groups were recorded. *Bacillariophyceae* was the first dominant group forming 48% of the total phytoplankton communities (23 species). The dominant species of *Bacillariophyceae* were *Pleurosigma strigosum*, *Pleurosigma elongatum*, *Lyrella clavata*, *Rhizosolenia shrubsolei*, *Cylindrotheca closterium*, *Nitzschia panduriform*, *Nitzschia longissimia*, *Amphora sp* and *Stephanopyxis*. *Dinophyceae* was the second dominant group and formed 31% of the total phytoplankton communities (10 species); the dominant species were *Ceratium fusus*, *Heterosigma sp*, *Ceratium furca*, *Prorocentrum triestium*, *Protoperidinium sp*, *Gyrodinium spirale*, *Noctiluca scintillans* and *Scrippsiella trochoidea*. Cyanophyceae formed 13% (5 species) where *Nostoc sp*, *Oscillatoria* and *Merismopedia sp* were the dominant species. *Chlorophyceae* had 8% (6 species); *Scendesmus sp*., *Chlorella sp*., *Chlamydomonas sp*., *Dunaliella salina* and *Nannochloropsis sp* were the dominant species. The *Euglinophyceae* was rare only one species (*Euglina sp*). The relationship was positive between the phytoplankton, chlorophyll *a* and carbon dioxide while negative amongst dissolved oxygen and total nitrogen. This research indicated that the relation between water quality and phytoplankton organisms at the coast of Arabian Gulf (Saudi Arabia) was extremely overlapping and interdependent; any changes in the one component may significantly affect those of the other components.

Introduction

The Arabian Gulf speaks to one of the harshest marine environments on the planet because of checked changes in seawater temperatures and high levels of salinities. These natural extremes may meddle with ordinary functioning of marine environments and influence physiological parts of marine life forms and their differences, plenitude and spatial dissemination.

Phytoplankton, weighed as the intrinsic division of an maritime food cycle, is the beginning of oxygen and the convention aboriginal elementary producers (Shams, et al., 2012). The floristic variety in phytoplankton group relies on upon the accessibility of supplements, temperature, and light force and on other limnological elements (Ghosh et al., 2012). Phytoplankton swing the dominant biological components utilized for the appraisal of the natural condition of exterior water bodies, and the variety in the biological parameters gives a decent sign of vitality upheaval in amphibian conditions, because of its affectability to any adjustment in the environment (Forsberg, 1982; Reynolds, 2006).

The seasonal variation of the algal vegetation in the distinctive water foundations in Saudi Arabia in relation to physico-chemical properties specially in the Arabian Gulf had been studied by Abdel Mohsen and Bokary (1969) and Aleem et al. (1982). Recently,

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Abdulaziz et al. (2000) documented 35 genera of phytoplankton speaking to diatoms, Dinoflagellates and cyanobacteria prosperity of waters Arabian Gulf, Saudi Arabia. They recorded that, flourishing of phytoplankton occurred at the time May and August, caused by changes in heat and nutrients notably in the interim summer seasons. Khomayis (2002) reported that, high nutrient content was accompanied by low phytoplankton biomass during summer. In addition, inorganic micro-nutrients considered as limiting factors affecting the growth of phytoplankton. Seeberg-Elverfeldt et al. (2004) described that, the genres *Bacteriastrum*, *Chaetoceros*, *Nitzschia* and *Rhizosolenia* were the most overwhelming genera of the diatom. The diatoms dominate the diverse planktonic and benthic algal amid winter time, in Jeddah Coast, Saudi Arabia. Moreover, hotter waters can likewise prompt to oxygen exhaustion and lack of oxygen of oceanic living beings. More temperatures were ascribed to the massive fish deaths along the shorelines of Qatar, Al-Ansi et al. (2002). Estimations of pH, focus in superficial waters done a four year (2007–2010) demonstrated that waters turn sour by period, Uddin et al. (2012). In spite of exclusive requirements of discharge treatment, substantial amounts of regional discharge are released to shore Arabian Gulf, Sheppard et al. (2010). These discharges portray by nitrogen and phosphate compounds, Naser (2011). Sewage are the most part joined by pathogen microbes and heavy metals contaminations, Shatti and Abdullah (1999). Phytoplankton is fantastic pointers to ecological changes in coastal environments (Rimet and Bouchez, 2012). Monitoring inspect depicts as a technique to perception and evaluation of physico-chemical and biological factors to detect ecological changes, Lovett et al. (2007).

The aim of this work consider to follow the status of phytoplankton groups diversity in light of changes in the physico-chemical parameters in the coastal waters of Arabian Gulf.

Materials and methods

Physical, chemical and biological parameters

Phytoplankton succession relevant to some physico-chemical characters of some water bodies in the coastal Arabian Gulf (Saudi Arabia) was studied for one year (2014). The sampling program included 15 coastal locations, at Dammam, Saihat, Al-Qatif, Al-Awamia and Safwa. Three water samples from surface water and three samples from the bottom had collected from every location (90 samples every month).

Water temperature, salinity, dissolved oxygen (DO) and pH were measured monthly in situ at each site utilizing a pH/ISE/conductivity/RDO/DO Meter Thermo Scientific Orion Star A329 Portable. Duplicate Water samples for water quality factors were gathered (surface samples of 0.25-m depth below surface water) and above sediment 0.25-m (bottom samples), using a PVC Niskin bottle. Physico-chemical parameters were carried out monthly according to Standard Methods For Examination of the Water and Wastewater (APHA, 1992) which including NO_2, NO_3-N, NH_3, CO_2, PO_4, TP_4, alkalinity, total chloride and chlorophyll *a*.

Phytoplankton

Water samples were collected using 60 liter from surface water filtered through a plankton net mesh size 20 μm, 50 cm mouth diameter, and 2 m total length. The samples were preserved in lugol's solution. Preserved samples were shaken well before examination. One ml was applied for Sedgwick- Rafter counting divided chamber and identification of phytoplankton species from different samples. Counting and identification were carried out using AmScope microscope at magnification of x100 and x400 provided with a digital camera. Phytoplankton counts were expressed as number of cells $\times 10^4$ per m^3 for all phytoplankton groups. Identification was carried out according to Starmach (1966), Cornelius (1971), Garcia-Baptista (1993), Silva and Pienaar (2000) and Botes (2003). At that point, the phytoplankton species are overhauled by the taxonomic database sites as: algaebase.com (ab), World Register of Marine Species (WoRMS), Canadian Register of Marine Species (CaRMS), Nordic Microalgae and Aquatic Protozoa (NOD), and Integrated Taxonomic Information System (ITIS).

Statistical analysis was run utilizing the Statistical Package for the Social Science (SPSS 22). One ways ANOVA were employed to find the significant differences of physicochemical parameters, and phytoplankton between sites, also, means ± standard errors and Duncan were derived from all data. Phytoplankton analysis was performed using Microsoft Excel and Pearson Correlation coefficients (r) for the ecological parameters and phytoplankton groups and species Table 1.

Results and discussion

The species composition of phytoplankton component follows a distinct succession regulated by physico-chemical characters of water, such as pH, Do, temperature, salinity and nutrients (Touliabah et al., 2016; Buzzi, 2002). Water temperatures in the present study were relatively lower in winter (21.6 °C) than summer (29.3 °C). The temperature values recorded during last spring and beginning of summer seemed to be appropriate for phytoplankton growth, where the phytoplankton standing crop reached its maximum value. These data are in accordance with those of Kebede and Ahlgren (1996), who reported that the ideal temperature for phytoplankton development is 30 °C. The present study reveals also the pH values of the investigated sites lie on the alkaline side (Table 2), where it ranged between 8.0 in autumn and 8.2 in winter. These values appropriate for phytoplankton development, particularly, the phytoplankton standing crop which achieved its maximum value in the same season where *Bacillariophyceae*, *Dinophyceae*, and *Cyanophyceae* have their maximum growth at pH 8. These data are in agreement with the findings of Toulibah et al. (2010) in the coastal water near Jeddah, Red Sea.

The dissolved oxygen "DO" average values ranged from 10 to 6.2 mg/l during winter and summer, respectively. As a general trend, the lowest concentration of DO were detected in summer, and the negative correlation ($r = -0.76$) at $p < .01$ between dissolved oxygen and temperature. This may be due to increased water temperature and decomposition of detritus, plankton and

Table 1
GPS points of the study locations samples, at Dammam, Saihat, Al-Qatif, Al-Awamia and Safwa (The star sign * means the location near from drainage source).

Locations	Site	GPS
1	Dammam	N 26°26.461′ E050°11.718′
2		N 26°29.439′ E050°08.056′
3*		N 26°28.286′ E050°05.087′
4	Saihat	N 26°28.757′ E050°05.733′
5*		N 26°28.167′ E050°04.138′
6		N 26°28.105′ E050°04.573′
7	Al-Qatif	N 26°28.500′ E050°04.018′
8		N 26°29.332′ E050°03.603′
9*		N 26°32.042 ′E050°20.999′
10	Al-Awamia	N 26°30.202′ E050°02.685′
11		N 26°33.188′ E050°01.403′
12*		N 26°33.218′ E050°01.389′
13	Safwa	N 26°36.594′ E050°01.017′
14		N26°36.454′ E050°01.052′
15*		N 26°40.042′ E049°59.527′

Table 2
Means and Standard error (SE) of Physico-chemical parameters of the coastal water of Arabian Gulf (Saudi Arabia) in Different season.

Season		Temperature Cº	DO mg/l	DO%	PH	EC	Salinity %º	TDS mmhos/cm	chlorophyll *a* µg/L	NH_3 mg/l	NO_2 mg/l	NO_3 mg/l	sulfide µg/L	Active PO_4 mg/l	Total PO_4 mg/l	Total chloride mg/l	Total Alkalinity mg/l	CO_2 mg/l	TN
Winter	Mean	21.58	9.99	110.31	8.2	56.43	38.25	28.97	13.71	0.46	0.03	1.09	3.91	0.35	0.56	0.08	108.73	2.26	1.21
	SE	0.54	0.46	5.39	0.04	2.84	2.06	1.37	2.19	0.11	0.01	0.07	0.33	0.04	0.05	0.05	8.88	0.38	0.15
Spring	Mean	25.5	8.37	104.44	8.09	55.3	37.41	27.41	19.85	0.79	0.04	0.74	3.16	0.46	0.48	0.04	153.12	1.52	1.48
	SE	0.7	0.44	6	0.04	2.61	1.8	1.28	3.27	0.15	0.01	0.06	0.61	0.07	0.07	0.01	7.08	0.08	0.17
Summer	Mean	29.26	6.15	80.36	8.06	59.02	40.53	29.01	28.66	0.03	0.01	0.51	1.94	0.31	0.33	0.03	176.97	2.12	0.54
	SE	0.44	0.29	4.94	0.06	1.51	1.25	0.72	3.84	0	0	0.04	0.28	0.06	0.05	0	4.48	0.09	0.04
Autumn	Mean	28.97	6.47	79.82	8.03	56.86	37.96	27.9	24.59	0.05	0.05	0.64	9.6	0.89	0.83	2.45	146.83	2.82	0.7
	SE	0.48	0.24	2.68	0.04	1.82	1.29	0.9	2.88	0.01	0.01	0.04	1.03	0.11	0.1	1.34	2.59	0.13	0.05
Annual	MAX	29.26	9.99	110.31	8.2	59.02	40.53	29.01	28.66	0.79	0.05	1.09	9.6	0.89	0.83	2.45	176.97	2.82	1.48
Range	MIN	21.58	6.15	79.82	8.03	55.3	37.41	27.41	13.71	0.03	0.01	0.51	1.94	0.31	0.33	0.03	108.73	1.52	0.54

Table 3
Correlation between physico-chemical and phytoplankton groups in the coastal water of Arabian Gulf (Saudi Arabia).

Parameters	Chlorophyll *a*	NH_3	NO_2	NO_3	sulfide	PO_4	TPO_4	Total Chloride	Total. alkalinity	CO_2	Temperature	DO	DO%	pH	EC	salinity	TDS	TN
NH_3	−0.47	1																
NO_2	−0.17	0.01	1															
NO_3	−0.26	−0.09	0.36	1														
sulfide	0.19	−0.32	0.37	0.23	1													
PO_4	0.17	−0.05	0.1	0.37	0.31	1												
TPO_4	0.26	−0.17	0.24	0.52*	0.60*	0.70**	1											
Total Chloride	−0.14	−0.3	0.2	0.27	0.87**	0.49	0.39	1										
Total. alkalinity	0.23	0.05	−0.48*	−0.60*	−0.77**	−0.35	−0.66*	−0.60*	1									
CO_2	0.14	−0.08	−0.35	0.1	0.39	0.1	0.1	0.31	−0.19	1								
Temperature	0.63*	−0.3	−0.27	−0.75	−0.2	−0.15	−0.4	−0.04	0.58*	0.03	1							
DO	−0.74	0.64**	0.12	0.35	−0.17	−0.04	0.12	−0.18	−0.27	−0.04	−0.77**	1						
DO%	−0.71	0.73**	0.09	0.16	−0.3	−0.05	−0.01	−0.19	−0.09	−0.14	−0.61*	0.96**	1					
pH	−0.46	0.43	−0.22	−0.01	−0.27	0.26	0.26	−0.2	−0.04	−0.22	−0.4	0.65**	0.68**	1				
EC	0.35	−0.53	−0.11	−0.44	0.18	0.19	−0.11	0.51	0.22	0.80**	0.56*	−0.53	−0.41	−0.38	1			
salinity	0.3	−0.46	−0.29	−0.57*	−0.01	0.05	−0.27	0.38	0.4	0.70*	0.61*	−0.48	−0.31	−0.22	0.97**	1		
TDS	0.01	−0.43	−0.05	−0.54	0.08	0	−0.38	0.45	0.21	0.31	0.45	−0.43	−0.3	−0.04	0.83**	0.86**	1	
TN	−0.58*	0.83**	0.26	0.49*	−0.14	0.14	0.14	−0.16	−0.3	−0.05	−0.70**	0.77**	0.74**	0.36	−0.80**	−0.82**	−0.76**	1
Bacillariophyceae	−0.15	0.31	0.602*	0.24	−0.22	0	−0.11	−0.11	0.02	−0.13	−0.15	0.31	0.36	−0.11	−0.14	−0.15	−0.12	0.43
Dinophyceae	0.1	−0.26	−0.2	−0.36	−0.08	−0.47	−0.53*	−0.1	0.17	0.09	0.35	−0.15	−0.13	−0.35	0.42	0.41	0.38	−0.41
Cyanophyceae	0.1	−0.26	−0.2	−0.36	−0.08	−0.47	−0.53*	−0.1	0.17	0.09	0.35	−0.15	−0.14	−0.35	0.42	0.41	0.38	−0.41
Chlorophyceae	0.17	0.48*	−0.50*	−0.24	−0.27	0.47	0.13	−0.16	0.28	0.14	0.09	0.15	0.26	0.52*	0.06	0.14	0	0.25
Euglinophyceae	0.32	0.04	−0.46	−0.46	−0.36	−0.07	−0.47	−0.4	0.58*	−0.11	0.33	−0.16	−0.05	0.03	0.32	0.43	0.38	−0.24

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

organic matter where oxygen becomes consumed and carbon dioxide is produced. This result agrees with the fact that oxygen solubility decreases with increasing temperature and salinity (Calliari et al., 2005). Wide fluctuations in temperature were seen between winter and summer. The expansive seasonal variety in temperature in coastal water (Basson et al., 1977) is somewhat an impression of the severe climate, and harsh condition of the Gulf region. The range is higher than in practically identical scopes on the grounds that the Gulf is shallow and practically landlocked Price (1979).

The Arabian Gulf is a semi-enclosed system in which evaporation is one of the most important factors affecting salinity. Salinity, EC and TDS are characterized by a remarkably variation, showed the highest average values (40.5‰ – 59.1–29.0) during summer and the lowest average values (37.4‰ – 55.3–27.4) during spring (Table 2). Higher values during the summer may be attributed to the high evaporation rate as reported by Schumann et al. (2006) and Khomayis (2002). In the present study (Table3), the positive relationship between salinity and *Dinophycea* and *Cyanophyceae* was ($r = 0.69 - r = 0.71$) at $p < .05$, Schumann et al. (2006), concluded that salinity affects the phytoplankton diversity. As shown in the present investigation data revealed that the highest PO_4 and TPO_4 levels of (0.89–0.93 mg/l) were observed during autumn, while the lowest levels during summer (0.31–0.33 mg/l) (Table 2). This could be related to reduced uptake rates by phytoplankton in autumn than summer; this was confirmed by the reduced phytoplankton standing crop recorded during autumn compared with summer where P attained its lowest value (Toulibah et al., 2016).

Nitrite (0.05–0.79 mg/l) and ammonia (0.01–0.03 mg/l) attained their maximum values, while nitrate reached its maximum and minimum values (1.09–0.51 mg/l) during winter and spring, (Table 2). During the present study, higher levels of nitrite, nitrate and ammonia were due to the domestic wastewater discharge in some area. This is in agreement with the findings of El-Bassat and Taylor (2007), who reported that, nitrogen and phosphorus compounds are always present in domestic wastewaters.

The negative correlation between TN and chlorophyll *a* (Table3) indicates the importance of the nitrogen source for phytoplankton growth. This phenomenon was found in the present study during summer, where the nitrate concentration showed its lowest value and the total phytoplankton standing crop recorded the highest flourishment. Camargo and Alonso (2006) reported that inorganic nitrogen contamination in aquatic ecosystems animates the advancement, support and multiplication of primary producers bringing about eutrophication of aquatic environments. In additions, they reported that the *Cyanophyceae*, *Dinophyceae* and diatoms were being the major groups that might be empowered by inorganic nitrogen contamination. This finding was in agreement with that of the present dominant groups.

The concentrations of chlorophyll *a* ranged between 28.7 μg/l during summer and 13.7 μg/l during winter (Table 2). Total chlorophyll *a* revealed an increase in summer at all locations through the investigation period. This result agrees with that of Khomayis (2002).

The phytoplankton community in the investigated areas was represented by a total of 45 species belonging to 5 groups. The most abundant groups were, *Bacillariophyceae, Dinophyceae, Cyanophyceae and Chlorophyceae* (48%, 31%, 13% and 8%) respectively, (Fig. 2). *Euglinophycea* is a rare group in the investigated areas with a percentage 0.09% of the total phytoplankton. The highest count of phytoplankton was $190.3 \times 10^4/m^3$ during May and June, while the minimum was $10.4 \times 10^4/m^3$ during November and December. In general this result agrees with Abdulaziz et al. (2000) in the coastal water Gulf in Saudi Arabia. The abundance of total phytoplankton along the investigated area followed the same trend of chlorophyll *a* showing their maximum during summer (the most productive season). Summer peaks of the phytoplankton were mainly due to flourishing of *Dinophyceae, Cyanophyceae* and *chlorophyceae* (Fig. 1) this result agrees with Turkoglu (2010). The phytoplankton community composition in the study showed high standing crop values, although it is poor to some extent in the species number, which may be attributed to the presence of some stressors that have limited the species diversity to only tolerant species to these environmental conditions (Parnell, 2003). During the period of investigation, *Dinophyceae* remained the fully elaborated group during winter. Twenty-three species belonging to *Bacillariophyceae* were identified. The maximum abundance of *Bacillariophyceae* was detected in winter and spring (Figs. 1 and 2). The dominant species of *Bacillariophyceae* in the most of sites were *Pleurosigma strigosum*, *Pleurosigma elongatum*, *Lyrella clavata*, *Rhizosolenia shrubsolei*, *Cylindrotheca closterium*, *Nitzschia panduriform*, *Nitzschia longissimia*, *Amphora sp* and *Stephanopyxis sp* (Table 5, Fig. 3).

The high nutrient load in the sewage water was the main reason for the diatoms flourishment at this period. Varela and Prego (2003) attributed the dominance of diatoms in the Coruna Harbour (NW Spain) to the nutrient loaded sea water. Morais et al. (2003)

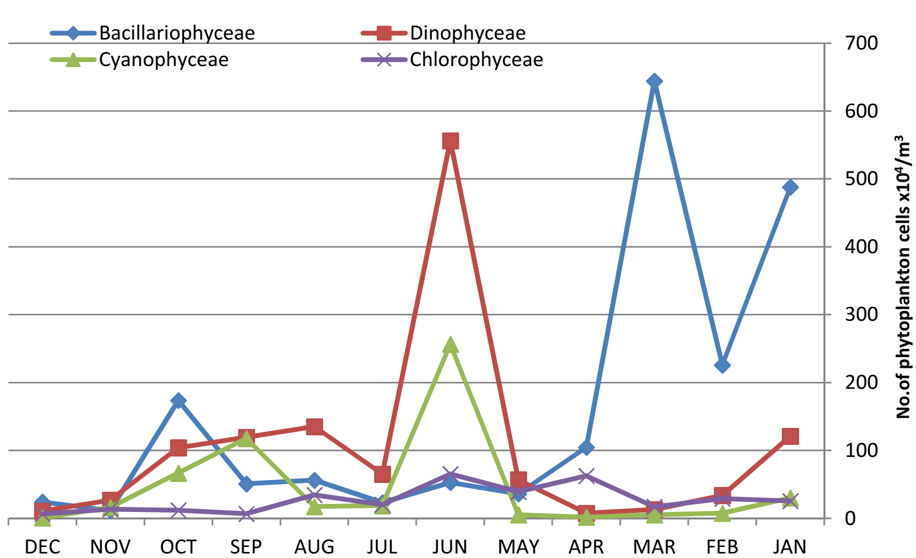

Fig. 1. Monthly variation in the density of phytoplankton (total average of phytoplankton groups during the investigation period).

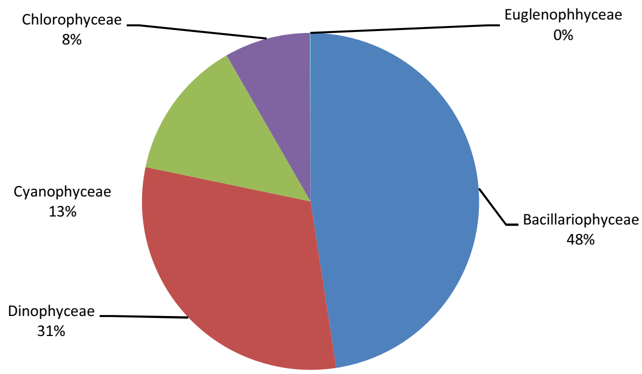

Fig. 2. Diversity of phytoplankton groups during the investigation period.

found that the increase in water temperature might have allowed phytoplankton to optimize its growth and productivity. *Dinophyceae* was the second dominant group in phytoplankton community, the prevailing species in most sites were *Ceratium fusus*, *Heterosigma sp*, *Ceratium furca*, *Prorocentrum triestium*, *Protoperidinium sp*, *Gyrodinium spirale*,*Noctiluca scintillans* and *Scrippsiella trochoidea* (Table 5, Fig. 4). Cyanophyceae was the third dominant group during the period of study, forming 13% of the total phytoplankton crop (Fig. 2). Five species were identified in this study, the dominant species were *Nostoc sp*, *Oscillatoria* and *Merismopedia sp*. Chlorophyceae were rarely recorded during the present study, and this result coincides with Chen (2005), for the South China Sea. The presence of Chlorophyceae was restricted to few sites, the study of dominant species were *Scendesmus sp*, *Chlorella sp*, *Chlamydomonas sp*, *Dunaliella salina* and *Nannochloropsis sp* (Table 5).

Cyanophyceae have a positive significant relationship with CO_2 (r = 0.77) at p < .01, EC (r = 0.72), Salinity (r = 0.71) and TDS (r = 0.64) at p < .05, while a negative relation is reported between Cyanophyceae and dissolved oxygen (r = −0.56) and total nitrogen (r = −0.63) at p < .05, some (Table 4). *Cyanophyceae* species maybe fixed the nitrogen from the air, reduced oxygen and using the CO_2 through photosynthesis.

Dinophyceae have a positive significant relationship with chlorophyll *a* (r = 0.62), CO_2 (r = 0.66) and salinity (r = 0.69) at p < .05 (Table 4). The total phytoplankton appeared as floating parameters which is affected by most environmental parameters. It was negatively correlated to total nitrogen and positively with water temperature. Water quality and phytoplankton dynamics mirrored seasonal hydrologic and salinity administrations throughout the Arabian Gulf Coast. The pearson relationship in the present work may give a sign that the dissolved compounds are not only predominantly identified with the anthropogenic materials, but also they are related with the first material here and mirror the composition way of the organic matter. The positive significant relationship between TN and Chl-a (r = 0.57 at P < .05) revealed that generally a great amount of nitrogen may be due to decomposition of living organisms. The important role of PO_4-P and NO_3-N for increasing of phytoplankton were observed from the relationship between Chlorophyll *a* and both phosphate and nitrate, the negative correlation identified with the consumption of these nutrients in the growth of phytoplankton. While the dominant species showed varied correlation with physico-chemical parameters as seemed in Table 4. The impact of the environmental conditions on the harmful algae was investigated. *Ceratium furca* was dominated in sites 9 and 12 and common in sites 4 and 5. *Ceratium furca* was positive significant with NO_2 (r = 0.76) at p < .01 and temperature (r = 0.74) p < .05 and negative with TDS (r = −0.80) p < .05 (Table 4). The *Ceratium fusus* was common in sites

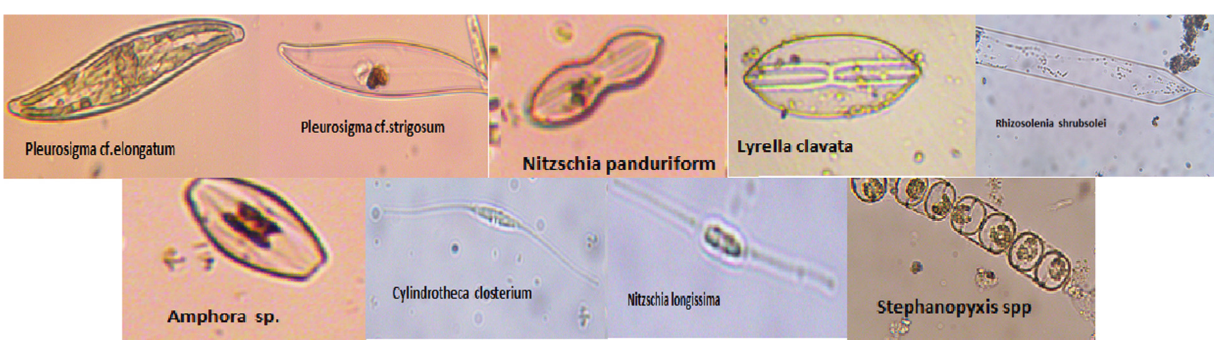

Fig. 3. Photos of some dominant species of *Bacillariophyceae* in the water of Arabian Gulf (Saudi Arabia). Photos were taken by Am Scope light microscope provided with a digital camera at magnification ×400.

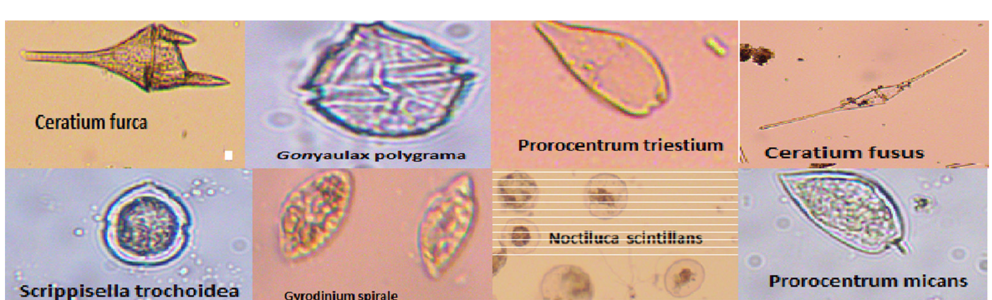

Fig. 4. Photos of some dominant species of Dinophyceae in the water of Arabian Gulf (Saudi Arabia). Photos were taken by Am Scope light microscope provided with a digital camera at magnification ×400.

Table 4
Correlation between physico-chemical parameters and phytoplankton species in the coastal water of Arabian Gulf (Saudi Arabia).

Phytoplankton Species	Chlorophyll	NH_3	NO_2	NO_3	sulfide	PO_4	TPO_4	T chloride	T Alkalinity	CO_2	Temperature	DO	DO%	pH	EC	Salinity	TDS
Bacillariophyceae1																	
Rhhizosolenia imbricata	−0.59	−0.96	.c	0.1	.c	−0.41	−1.00*	0.91	0.55	.c	−0.68	−0.78	−0.74	0.7	0.04	−0.02	−0.41
Grammatophora oceanica	0.23	−0.03	−0.11	−0.01	0.46	−0.07	−0.1	−0.4	0.21	−0.04	−0.13	0.11	0.09	0.13	0.13	0.12	0.12
Pleurosigma strigosum	0.32	−0.23	−0.2	−0.12	0.18	−0.2	−0.2	−0.58*	0.07	−0.19	−0.25	0.35	0.34	0.34	0.2	0.2	0.21
Pleurosigma elongatum	0.36	0.05	0.2	0.24	0.16	0.02	−0.02	−0.02	−0.05	−0.06	−0.12	−0.21	−0.25	0.23	0.06	0.08	0.04
Proboscia alata	0.32	0.72*	0.41	0.18	0.53	0.7	0.66	0.44	0.62	0.53	0.65	−0.48	−0.41	−0.59	−0.69	−0.71	−0.67
Mastogloia exigua	−0.22	0.56	0.04	−0.06	0.63	0.45	0.51	0.59	0.49	0.89**	0.44	−0.69*	−0.71*	−0.54	−0.33	−0.3	−0.43
Lyrella clavata	−0.09	−0.26	−0.16	−0.21	−0.33	−0.3	−0.29	−0.07	−0.17	−0.18	−0.26	−0.07	−0.11	0.48	0.23	0.23	0.21
Thalassiosira oestrupii	0.43	0.56	0.45	0.3	0.73*	0.47	0.31	0.3	0.33	0.13	0.25	−0.52	−0.49	−0.51	−0.15	−0.21	−0.15
Plagiotropis lepidoptera	−0.31	0.18	0.68	0.17	0.61	−0.05	0.3	0.37	0.12	−0.01	0.54	−0.03	−0.01	0.11	−0.35	−0.27	−0.35
Cyclotella striata	0.08	0.25	0.35	0.34	0.07	0.34	0.46	0.68*	0.28	0.64*	0.45	−0.68*	−0.72**	−0.19	−0.49	−0.42	−0.53
Donkinia	0.24	0.02	0.19	0.31	0.1	0.21	0.3	−0.07	0.41	0.42	0.29	−0.26	−0.29	−0.01	−0.33	−0.27	−0.35
Rhizosolenia shrubsolei	0.4	0.80**	0.36	−0.08	0.15	0.67*	0.44	−0.15	0.56	0.01	0.37	−0.39	−0.28	−0.51	−0.46	−0.58	−0.4
Guinadia sp	−0.77	.c	.c	.c	.c	.c	.c	.c	.c	.c	.c	.c	.c	.c	.c	.c	.c
Haslea sp	0.13	0.13	0.03	−0.19	0.79*	0.05	0.01	0.12	0.04	−0.06	0.02	0.06	0.09	−0.07	0.08	0.06	0.08
Oestrupia musca	−0.07	0.69*	−0.13	0.07	0.45	0.61*	0.3	0.36	0.39	0.27	0.11	−0.57	−0.55	−0.70*	−0.16	−0.24	−0.17
Licmophora gracitis	−0.48	−0.55	−0.07	0.29	−0.3	−0.49	−0.64	−0.05	−0.55	−0.64	−0.62	0.63	0.62	0.61	0.42	0.39	0.49
Cylindrotheca closterium	0.19	−0.22	−0.19	0.05	−0.09	−0.25	−0.31	−0.59	0	−0.22	−0.31	0.12	0.09	0.45	0.23	0.22	0.23
Diploneis	−0.21	0.48	−0.26	−0.43	−0.36	0.21	0.02	−0.41	0.5	−0.17	0.03	0.02	0.12	−0.16	−0.24	−0.39	−0.16
Nitzschia panduriform	0.24	0.53	−0.06	−0.07	0.54	0.33	0.12	0.24	0.41	0.19	0.09	−0.56	−0.55	−0.47	−0.07	−0.14	−0.08
Nitzschia longissimia	−0.01	−0.34	−0.25	−0.21	−0.17	−0.34	−0.34	−0.25	−0.06	−0.18	−0.29	−0.01	−0.06	0.53	0.26	0.27	0.25
Amphora turgida	0.17	0.07	−0.14	−0.06	0.22	0.05	−0.02	−0.5	0.33	−0.02	−0.09	0.09	0.08	0.06	0.01	−0.02	0.02
Amphora sp	−0.35	−0.2	−0.15	−0.26	−0.33	−0.18	−0.13	−0.32	−0.24	−0.13	−0.09	0.14	0.12	0.07	0.19	0.19	0.19
Stephanopyxis	0.52	−0.07	−0.14	0.19	0.25	−0.06	−0.08	0.08	0.04	−0.06	−0.07	−0.12	−0.13	0.1	−0.01	−0.01	0.06
Cyanophyceae																	
Nostoc sp	0	0.5	0.3	−0.35	−0.25	0.45	0.46	−0.08	0.44	−0.25	0.55	−0.16	−0.02	−0.19	−0.70*	−0.70*	−0.67*
Chroococcus	−0.24	0.76*	−0.19	−0.2	0.33	0.52	0.42	0.71*	0.65	0.56	0.33	−0.67*	−0.69*	−0.45	−0.45	−0.5	−0.46
Oscillatoria	−0.06	0.68*	−0.14	−0.47	−0.34	0.59	0.47	−0.28	0.66	0.1	0.36	−0.16	−0.05	−0.39	−0.67*	−0.77*	−0.58
Lyngbya	0.09	−0.14	−0.14	−0.24	0.08	−0.29	−0.16	0.12	−0.25	−0.1	−0.21	0.39	0.36	0.33	0.12	0.14	0.12
Merismopedia sp	0.72	0.05	0.79	0.3	0.95*	−0.12	0.25	0.5	0	.c	0.55	−0.17	−0.22	0.2	−0.07	−0.02	−0.13
Chlorophyceae																	
Scendesmus sp	0.09	0.66*	0.54	0.28	0.62*	0.58	0.42	0.14	0.41	0.17	0.35	−0.49	−0.45	−0.6	−0.24	−0.3	−0.24
Eudorina sp	0.16	−0.19	−0.2	−0.09	0.12	−0.25	−0.18	−0.49	0.21	−0.07	−0.14	0.24	0.21	0.33	0.11	0.12	0.12
Chlorella sp	0.25	−0.01	0.53	0.46	0.14	0.29	0.59	0.06	0.52	0.63*	0.68*	−0.36	−0.37	−0.24	−0.53	−0.41	−0.58
Chlamydomonas sp	0.24	0.06	−0.01	0.12	0.3	0.1	0.17	0.33	0.27	0.26	0.19	−0.34	−0.35	−0.06	−0.23	−0.21	−0.21
Dunaliella salina	0.27	0.65*	−0.12	−0.1	0.57	0.65*	0.51	0.36	0.62*	0.51	0.35	−0.71*	−0.70*	−0.67*	−0.4	−0.43	−0.4
Nannochloropsis sp	0.53	0.55	0.19	0.2	0.52	0.37	0.35	0.38	0.57	0.48	0.4	−0.58	−0.59	−0.47	−0.38	−0.4	−0.37
Dinophyceae																	
Ceratium fusus	−0.42	−0.24	0.21	−0.28	0.09	−0.23	−0.15	0.32	−0.38	−0.23	−0.05	0.29	0.31	0.3	0.19	0.21	0.16
Heterosigma sp	0.17	0.6	0.33	0.18	0.737*	0.6	0.57	0.63*	0.5	0.58	0.5	−0.77**	−0.77**	−0.72*	−0.37	−0.36	−0.42
Ceratium furca	0.06	0.05	0.80**	0.06	−0.2	0.28	0.59	0.54	0.56	0.76*	0.74*	−0.58	−0.58	−0.19	−0.66	−0.55	−0.72*
Prorocentrum micans	0.35	0.06	−0.06	−0.31	0.3	−0.13	−0.15	−0.18	0.14	−0.28	0	0.1	0.15	0.14	0.07	0	0.11
Prorocentrum triestium	0.13	0.06	0.21	0.28	0.23	0.4	0.65	0.09	0.68*	0.79*	0.64	−0.52	−0.55	−0.34	−0.59	−0.48	−0.64
Protoperidinium sp	0.04	0.97**	−0.06	−0.29	0.25	0.89**	0.69*	0.35	0.80**	0.46	0.52	−0.64*	−0.55	−0.83**	−0.69*	−0.78**	−0.66*
Gonyaulax polygrama	−0.22	0.09	0.12	0.04	−0.03	0.05	0	0.18	0.02	0	−0.01	−0.36	−0.37	0.15	−0.01	−0.01	−0.03
Gyrodinium spirale	0.38	−0.18	0.03	0.37	0.21	−0.14	−0.14	−0.64*	0.08	−0.11	−0.17	0.21	0.18	0.25	0.16	0.18	0.16
Noctiluca scintillans	−0.09	0.48	−0.09	−0.2	0.03	0.59	0.70*	0.6	0.80**	0.81**	0.67*	−0.722*	−0.70*	−0.5	−0.76*	−0.71*	−0.79**
Scrippsiella trochoidea	0.61*	−0.01	0.18	−0.09	0.27	−0.02	0.14	0.22	0.21	0.18	0.4	−0.13	−0.1	−0.04	−0.18	−0.17	−0.19
Euglenophyceae																	
Euglena sp	−0.21	0.19	−0.14	−0.58	0.13	0.23	0.25	−0.1	0.16	−0.13	0.09	0.32	0.41	−0.06	−0.28	−0.28	−0.24

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed). c. Cannot be computed because at least one of the variables is constant (Not found).

Table 5
The dominant species of phytoplankton in different sites in the coastal water of Arabian Gulf (Saudi Arabia).

Species	Site1	Site2	Site3	Site4	Site5	Site6	Site7	Site8	Site9	Site10	Site11	Site12	Site13	Site14	Site15
Bacillariophyceae															
Rhhizosolenia imbricata	+	–	–	–	–	–	–	–	+	–	–	–	+	+	+
Grammatophora oceanica	–	–	+	+	+	+	++	+	+	+	+	+	+	+	+
Pleurosigma strigosum	+	+	+++	++	+	+	+++	+	++	+	+	++	+	+	+
Pleurosigma elongatum	+	+	+	+	++	+	++	+	++	++	+	+	+	+	–
Proboscia alata	–	+	+	+	+	+	–	–	–	+	+	–	+	+	+
Mastogloia exigua	–	+	+	+	+	+	+	+	+	–	+	–	++	+	+
Lyrella clavata	+	+	+	+	+	+	–	+	+++	+	+	+	+	+	+
Thalassiosira oestrupii	+	+	+	+	+	+	–	+	+	–	+	+	+	+	+
Plagiotropis lepidoptera	+	+	+	–	+	+	–	–	–	–	+	–	+	+	+
Cyclotella striata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Donkinia	+	+	+	+	+	+	++	+	+	++	+	++	–	+	–
Rhizosolenia shrubsolei	+	+	++	+++	+++	+++	–	–	+++	–	+	+++	+	+	+
Guinadia sp	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–
Haslea sp	–	–	+	–	+	+	–	–	+	+	+	+	–	+	+
Oestrupia musca		+	+	+	++	+	+	+	+	–	+	+	+	+	–
Licmophora gracitis	+	+	+	+	+	+	–	+	–	–	+	–	+++	++	++
Cylindrotheca closterium	+	+	+	+++	+	+	+++	+	+++	–	+	+	–	+	+
Diploneis	+	+	+	++	+	+	–	+	+	+	+	+	–	+	+
Nitzschia panduriform	+	+	+	+++	+++	++	–	+	+++	++	+	+	+	+	++
Nitzschia longissimia	+	+	+	+	+	+	++	++	+++	+	+	+	++	+	+
Amphora turgida	+	+	++	+	+	+	++	+	+	+	+	+	+	+	+
Amphora sp	+	+++	+	+	+	+	++	+	++	–	+	++	–	–	–
Stephanopyxis	+	+	+	++	+	–	–	+++	+	–	+	–	+	+	+
Cyanophyceae															
Nostoc sp	+	–	+	++	+	++	+	–	+	–	+	–	++	+	+
Chroococcus	–	+	+	–	+	+	–	+	+	–	+	+	+	+	+
Oscillatoria	–	+	+	++	+	+	–	+	–	–	+	+	–	+	+
Lyngbya	+	+	+	+	+	+	+	+	+	+	+	–	–	–	–
Merismopedia sp	–	+	–	+	–	++	–	–	–	–	+	–	–	–	+
Chlorophyceae															
Scendesmus sp	–	+	+	+++	+++	+++	++	+	+	–	+	+	+++	+++	+
Eudorina sp	+	+	+	++	+	++	+++	+	–	+	+++	++	+++	–	+
Chlorella sp	+	–	+	+	+++	+++	+++	+	++	–	+	+++	+++	+++	+++
Chlamydomonas sp	+	–	+++	+++	+++	+++	–	+++	+++	–	+++	+++	+++	+	++
Dunaliella salina	++	+++	+++	+++	+++	+++	+++	+++	+++	–	+++	+++	+++	++	++
Nannochloropsis sp	++	+++	++	+++	+++	+++	–	+++	+++	+++	+++	–	+	–	–
Dinophyceae															
Ceratium fusus	+	+	++	+	+	+	+	+	++	–	+	–	++	++	++
Heterosigma sp	+	–	–	+	+++	+++	+	+	+	–	++	+++	+++	++	–
Ceratium furca	+	+	+	++	++	–	–	+	+++	–	++	+++	+	++	+
Prorocentrum micans	+	+	+	++	+	++	+	++	+	+	+	+	++	+	+
Prorocentrum triestium	+	+	–	+	–	++	+++	+	+	–	+	+++	+++	+	+
Protoperidinium sp	+	+	+	+++	+++	+	+	–	+	–	+	++	+	+	++
Gonyaulax polygrama	+	+	+	+	++	++	+	+	+++	++	+	+	++	+	+++
Gyrodinium spirale	+	+	+	+	++	+++	+++	+	++	–	++	++	+++	++	++
Noctiluca scintillans	+	+	+++	+++	++	+	–	+	+++	–	+++	+++	–	–	+
Scrippsiella trochoidea	–	+	++	+++	++	+++	+	++	++	++	+++	+++	–	–	+
Euglenophyceae															
Euglena sp	+	+	++	++	+	+	+	+	+	–	–	–	+	+	+

+ = Rare, ++= Common, +++ = Dominant, – = Negative; The frequency of occurrence of different phytoplankton species is represented as: rare (below 10%), common (between 10% and 50%) and dominant (50% or more).

3,9,13,14 and 15 whereas, *Noctiluca scintillans* was dominant in site5. The *Gonyaulax polygrama* was dominant in sites 9 and 15 and common in sites 4 and 5, *Noctiluca scintillans* was positively correlated with TPO_4 (r = 0.70), CO_2 (r = 91), temperature (r = 0.67), total alkalinity (r = 80) and negative correlation with DO (r = −0.72) and also with ES, Salinity and TDS (r = −0.76, −0.71, −0.79) respectively; the harmful dominant species algae appeared in discharge of raw sewage wastes, agricultural drainage sites which polluted with nitrogen, organic and inorganic compounds (Mohamed and Mesaad, 2007). The harmful algae cause either ecological impacts or mass mortality of marine organisms. May be cause fish kills due to drop of oxygen, or direct taking of toxic algal species, the drop of oxygen occurs in the ecosystem when the phytoplankton release CO_2 and consumption O_2 at night during the phytoplankton bloom period. Also, more O_2 is utilized at the time of organic matter decomposition, these agree with Omar et al. (2013) and Thangaraja et al. (2007).

Conclusion

The present study results revealed that temperature, salinity, DO, nitrogen compounds, phosphor compounds and chlorophyll *a* were playing important roles as limited factors to phytoplankton diversity. The variation in the phytoplankton groups reflects the seasonal dynamics and the impact of water quality. The appearance of potentially harmful algae species even in low counts, make the region of the coastal water Arabian Gulf susceptible to harsh effects at flourishing of these species during favorable conditions. Thus, monitoring continuously of this area is imperative, to follow probable bloom of these species, to predict negative effects resulting from increasing land activities, So the goal is the keeping to shield the water Arabian Gulf from any undesirable change.

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