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Investigation of physicochemical factors, chl-a and primary production in Mahshahr Creeks (Northwest Persian Gulf)

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Abstract

The study on physicochemical factors and primary production of the aquatic ecosystems is important to know the characteristics of the environment and capacity of recharge. Mahshahr Creeks are the most important creeks in the Northwest Persian Gulf, Iran. In this study, variations in physicochemical factors, chl-a, and primary production in creeks of Mahshahr, Zangi, and Moussa were evaluated for 2 months of every season of 2014. The following variables were analyzed: nitrate, phosphate, nitrite, silicate, temperature, salinity, DO, pH, conductivity, turbidity, light, chl-a, primary production and phytoplankton abundance. The maximum amount of chl-a (1.6 mg m-^{3}) was observed in Moussa Creek in April while the minimum amount (0.1 mg m^{-3}) was seen in Moussa in July. The highest (1.19 gc m^{-2} day^{-1}) and lowest (0.1gc m^{-2} day^{-1}) amount of primary production were observed at the entrance of Moussa Creek in April and in Zangi Creek in November, respectively. The maximum and minimum abundance of phytoplankton was observed in April and October, respectively in all study areas. The results of correlation test between the studied factors revealed that primary production has a significant relationship with nitrite, chl-a, phytoplankton abundance and light. Primary production in these creeks is relatively high in April and is attributed to the uptake of nutrients including nitrate and phosphate from shallow waters entering these creeks, sufficient light and suitable temperature, but in other months the production is low.

Keywords: Physicochemical factors, Chl-a, Primary production, Mahshahr Creeks, Persian Gulf

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Introduction

Tidal creek ecosystems are the primary aquatic link between storm water runoff from the land and estuaries. Small tidal creeks begin in upland areas and drain into larger creeks forming a network. The upper regions or headwaters of tidal creeks are the first responders to storm water runoff and are an important habitat for evaluating the impacts of coastal development on aquatic ecosystems. The biological productivity in coastal areas is always related to the abundance of planktonic organisms (Carvalho *et al*., 2010). Phytoplankton plays two important roles in the world: the first role is as the basis of food network in the sea (Chiu *et al*., 1994) and the second is stabilization of inorganic carbon through their ability to convert solar energy to chemical energy at the top of the water column (Tundisi and Tundisi, 1976). Primary production is the manufacturing of organic compounds taking from atmospheric or aquatic carbon dioxide, mainly through the process of photosynthesis by the chlorophyll bearing organisms by trapping solar energy (Shrotriy *et al*., 2014). Primary production in aquatic ecosystems, especially in coastal areas, and also determination of physico-chemical factors are an important tool to know the characteristics of the environmental and the recharge capacity and sustainable use of living resources, especially in environments that suffer extraction or natural and artificial eutrophication (Santos, 2002). The analysis of primary production and environmental factors may provide knowledge about the functional structure of aquatic ecosystems. The dynamic of the phytoplankton community, such as species composition, biomass and primary productivity are controlled by physical, chemical and biological factors (Herrera-Silveira, 1998).

In this region, a few studies were conducted to study the primary production and chlorophyll (KhalfehNilsaz, 1998; HabibiKhaledi, 1999; Moabed *et al*., 2006). As a result of economic, social, political and military significance of Mahshahr Creeks and their environmental values, it is important to apply integrative management for their preservation and protection. The present research aimed at measuring the phytoplankton abundance, primary production and chl-a relationship with physicochemical parameters of water in various stations within various months in Mahshahr Creeks.

Materials and methods

The study area is located in three important creeks in the northwest Persian Gulf consisting of Zangi Creek, Mahshahr Creek, and Moussa Creek entrance (Table 1, Fig. 1).

Table 1: The position of sampling stations in present study.

	Stations	Longitude	Latitude
1	Mahshahr Creek	49° 02′ 18″E	30° 27′ 44″ N
2	Zangi Creek	49° 03′ 19″E	30° 25′ 27″ N
3	Moussa Creek entrance	49° 08′ 12 ″E	30° 26′ 13″N

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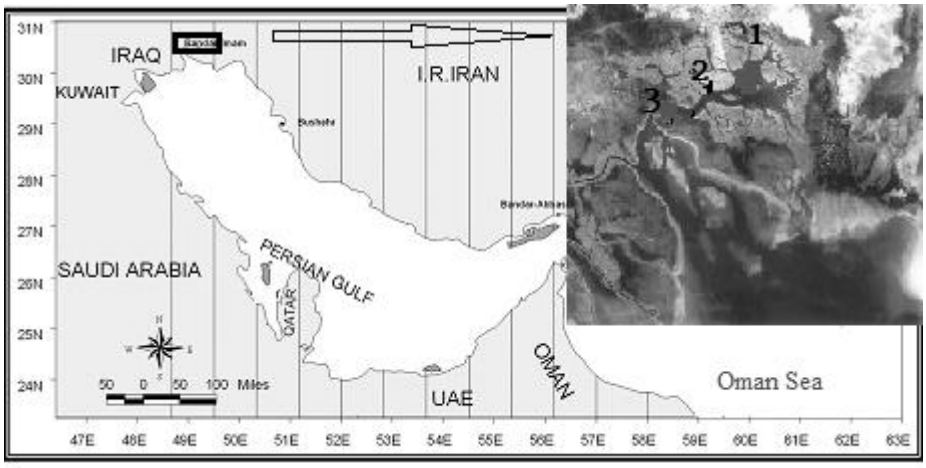

Figure 1: The position of sampling stations: 1. Zangi Creek 2. Mahshahr Creek, 3. Moussa Creek entrance.

Samples were taken in two months of every season including February, March, April, May, July, August, October and November in 2014. One liter of water was transferred to the laboratory from each target creek using special bottles in standard conditions to investigate nutrients. In the laboratory, water nutrients such as nitrate, nitrite, ammonium, phosphate and silicate were measured using Chromometric Techniques (Levinton, 1995). To measure the chl-a, Ruttner sampler was used to take samples from each depth. The water was passed through GF/F 2.5 cm filters and analyzed using a spectrophotometer (Levinton, 1995). Direct estimation of phytoplankton cell abundance and diversity was performed by cell counting method. Phytoplankton samples were collected by using sterilized, one-liter wide mouth plastic container at each sampling station (Boyd, 1981). The filtered samples were washed into the sterilized collecting bottles and immediately fixed in 4% formalin. Identification and enumeration was done by using a leitzuezier binocular microscope and keys by Perry (2003) and Tomas (1997). Primary production was measured by the light-dark bottle method (Wetzel and Likens, 1991). The average depth of the region is about 45 m so 1, 2, 4 and 8m depths were chosen for the collection of water samples with Niskin bottles. Then integrated primary production in the euphotic zone (1, 2, 4, 8m) was calculated. After sampling water samples were transferred to the light-dark bottles (three light bottles and one dark bottle), preliminary oxygen was measured and the bottles were placed in selected depths according to standard method for 4 h (APHA, 1998). Thereafter, dissolved oxygen was measured by Winkler (1888) method and determined with the following formula:

$GPP=3/5\ (L-D)\times depth/PQ$

$R=375(I-D)\times RQ\times depth$

$NPP=GPP-R$

Where:

GPP = gross primary production (mg of C $m^{-2}h$)

R = respiration (mg of C $m^{-2}h$)

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NPP = net primary production (mg m^{-2} h)

L = light bottle dissolved oxygen (mg l^{-1})

D= dark bottle dissolved oxygen (mg l^{-1})

PQ= Photosynthetic Quotient (molecules of O2 produced/molecules of CO2 taken up)

RO= Respiratory Quotient (molecules of CO2 produced/molecules of O2 taken up)

Differences between factors in months and stations were tested by ANOVA (significance level $p \leq 0.05$). Principal Component Analysis (PCA) was used to determine the relationship between the above measured environmental factors, as well as chlorophyll and primary production. Statistical analyses were performed using SPSS (IBM, 23) software.

Results

The results reveal that the maximum amount of nitrate (2 ppm) was observed in May and March in Mousaa Creek, while the minimum (0.2 ppm) was observed in November in Zangi Creek (Table 2). The highest (0.3 ppm) and lowest (0.05 ppm) levels of nitrite were observed in February in Zangi Creek and April in Mousaa Creek, and, respectively (Table 2). The highest (3.8 ppm) and lowest (1.15 ppm) levels of phosphate were observed in October in Mahshahr Creek and in July in Zangi Creek, respectively (Table 2). The highest (0.46 ppm) and lowest (0.25 ppm) levels of ammonium were observed in July in Mahshahr Creek and in April in Moussa Creek, respectively (Table 2). Silicate was highest (4.8 ppm) in Zangi Creek in May and lowest (0.2 ppm) in Moussa Creek in April (Table 2). The highest (8.8) and the lowest (7.4) pH levels were observed in Moussa Creek in March and in Moussa and Mahshahr Creeks in Nov, respectively (Table 2). The highest (47 g L^{-1}) and lowest (38 g L^{-1}) salinity levels were observed in Zangi and Mahshahr Creeks in October and in Moussa Creek in February, respectively (Table 2). The highest (31°C) and lowest (15.1°C) temperatures were observed in Moussa and Mahshahr Creeks in July and in Zangi Creek in February, respectively (Table 2). Conductivity was highest (73.8 ms cm^{-1}) in Zangi Creek in July and lowest (45.5 ms cm^{-1}) in Moussa Creek in February (Table 2). The highest turbidity value (233.8 NTU) was observed in Zangi Creek in May and the lowest was observed (64 NTU) in Mahshahr Creek in April (Table 2). Amount of PAR was highest (26.8 e/m2/d) in Mahshahr Creek in July and was lowest (12 e/m2/d) in Moussa Creek in November (Table 2). The highest level of oxygen (8.56 ppm) was observed in Moussa Creek in February and the lowest level (6.7 ppm) was observed in Zangi Creek in May (Table 2).

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Table 2: The concentration of different factors in the water column in the northwest Persian Gulf.

Factor	Station	Feb	March	April	May	July	August	Oct	Nov
Nitrate (ppm)	1	0.2	0.28	0.09	0.1	0.18	0.11	0.21	0.26
	2	0.28	0.17	0.08	0.9	0.11	0.12	0.12	0.19
	3	0.25	0.19	0.05	0.09	0.12	0.09	0.13	0.2
Nitrite (ppm)	1	0.3	0.28	0.09	0.1	0.18	0.11	0.21	0.26
	2	0.28	0.17	0.08	0.2	0.11	0.12	0.12	0.19
	3	0.25	0.19	0.05	0.09	0.12	0.09	0.13	0.2
Phosphate (ppm)	1	2.4	2.3	2.8	1.9	1.3	2	3.8	3.2
	2	2.4	1.9	2	1.5	1.15	1.5	3	2.8
	3	2.1	2	2.5	1.7	1.25	1.8	3.7	3.1
Silicate (ppm)	1	1.7	2.1	0.3	4	0.45	1.3	1.3	1.1
	2	1.9	1.8	0.5	4.8	0.3	1.7	1.4	1.5
	3	1.8	2.2	0.2	3.8	0.42	1.2	1.3	1.2
Ammonium(ppm)	1	0.42	0.37	0.35	0.38	0.45	0.37	0.4	0.39
	2	0.31	0.27	0.4	0.39	0.46	0.38	0.31	0.34
	3	0.32	0.29	0.25	0.3	0.42	0.29	0.41	0.35
Salinity (gl^{-1})	1	42	45	42.5	45	45	45	47	46
	2	39.9	45	42	46	45.5	46	47	46.6
	3	38	44	42	45	45	45	46	46
Temperature (°c)	1	15.2	17.4	25	30	31	30	30	21.4
	2	15.1	15.7	25	30.2	30	29.9	30	21
	3	15.8	18.8	24.9	29.5	31	30	29.8	20
DO (ppm)	1	8.32	7.3	8.4	6.8	8.1	8.2	8.3	7.1
	2	7.98	7	8.4	6.7	8	8.1	8.1	6.9
	3	8.56	7.4	8.5	6.81	8.2	8.3	8.4	7.2
pH	1	8.02	8.2	8.3	7.45	8.1	7.6	7.8	7.4
	2	8.01	8.24	8.4	7.46	8.25	7.7	8	7.45
	3	8.02	8.8	8.2	7.46	8.2	7.7	7.9	7.5
Conductivity (ms c^{-1})	1	46.7	69.4	63.4	72.4	73.6	61.9	55.6	51.4
	2	48.1	70.8	66.6	73.4	73.8	62.9	56.8	50.7
	3	45.5	68.5	64.3	72.7	70.4	60.2	54.4	48.4
Turbidity (NTU)	1	27	29	38	54.3	41	35	29	42
	2	32	35	40	70	45	40	30	44
	3	29	30	48	41.3	38	35	28	40
Light (e/m2/d)	1	17.1	20.4	19.4	25.2	25.6	20.3	14	15.5
	2	16.4	19.6	18.6	24.7	26.8	18.9	13.4	14.8
	3	17.9	17.4	15.3	20	22.9	19.5	12.2	12

The maximum amount of chl-a (1.6 mg m^{-3}) was observed in Moussa Creek in April while the minimum amount (0.1 mg m^{-3}) was seen in Moussa in July (Fig. 2).

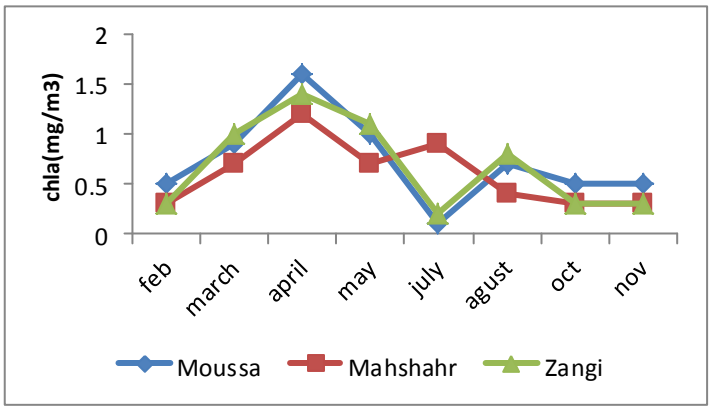

Figure 2: Monthly variation of chl-a during the period analyzed.

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The highest (1.19 gc m^{-2} day^{-1}) and lowest (0.1gc m^{-2} day^{-1}) amount of primary production were observed in Moussa Creek entrance in April and in Zangi Creek in November, respectively (Fig. 3).

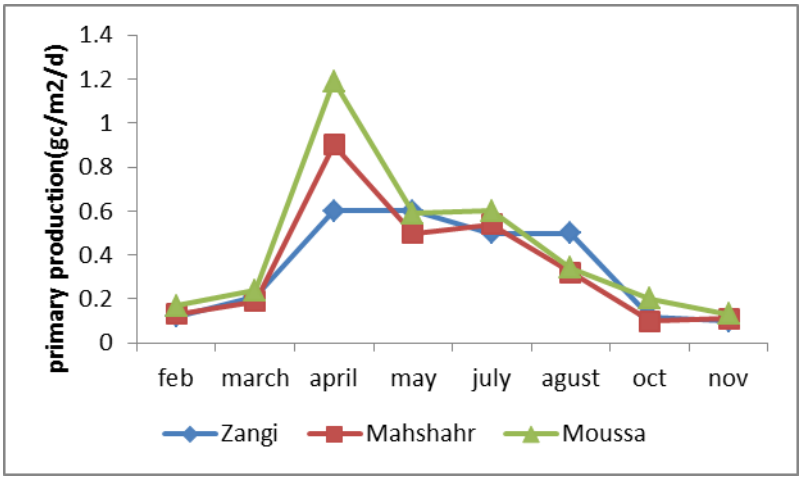

Figure 3: Monthly variation of primary production in the northwest Persian Gulf.

The highest amount of phytoplankton abundance was observed in April in Moussa and the lowest amount was observed in July in all three Creeks (Fig. 4).

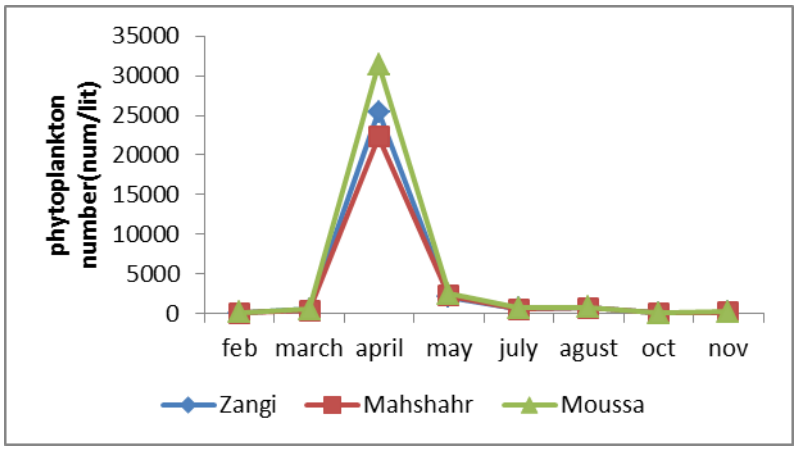

Figure 4: Monthly variation of phytoplankton abundance in the northwest Persian Gulf.

The results of ANOVA between the stations, months and factors showed that there were no significant differences between sampling stations but there are significant differences between the different months (Table 3).

Table 3: The results of ANOVA between the stations and months and factors in the northwest Persian Gulf.

Parameters	Correlation in various station	Correlation in various months
Nitrate	0.87	0.001
Phosphate	0.65	0.01
Nitrite	0.55	0.05
Silicate	0.45	0.045

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Table 3 continued:		
Temperature	0.32	0.006
Salinity	0.11	0.002
DO	0.12	0.05
pH	0.54	0.000
Conductivity	0.67	0.006
Turbidity	0.98	0.003
Light	0.88	0.000
chl-a	0.73	0.001
Primary production	0.32	0.01
Phytoplankton abundance	0.87	0.001

The results of PCA indicated that the first principal component is associated with nitrate, nitrite, temperature, phytoplankton abundance, light, and conductivity and second principal component is associated with DO, silicate, pH, salinity and phytoplankton abundance and third principal component is associated with turbidity and ammonium and PC4 is associated with phosphate (Table 4).

Table 4: Principal component weights in the present study.

parameters	PC1	PC2	PC3	PC4
PAR	**0.882**	-0.075	-0.373	0.196
nitrate	**-0.866**	-0.324	-0.067	0.246
nitrite	**-0.863**	-0.233	0.098	0.297
chlorophyll	**0.841**	0.428	0.005	0.270
Primary production	**0.769**	0.372	0.239	0.064
temperature	**0.737**	-0.211	-0.463	-0.260
conductivity	**0.736**	-0.145	-0.218	0.539
DO	-0.034	**0.811**	-0.273	-0.235
silicate	-0.086	**-0.733**	0.477	0.226
pH	-0.072	**0.713**	-0.190	0.477
Phytoplankton frequency	**0.523**	**0.655**	0.390	-0.076
salinity	0.262	**-0.601**	-0.486	-0.330
turbidity	0.441	0.297	**0.717**	-0.092
ammonium	0.055	-0.181	**-0.602**	0.188
phosphate	-0.335	0.051	0.109	**-0.816**

From these data, 4 principal components explain 83% of the total variance. A scree plot shows the eigenvalues sorted from large to small as a function of the principal components number. After the forth PC (Fig. 5), starting the elbow in the downward curve, other components can be omitted.

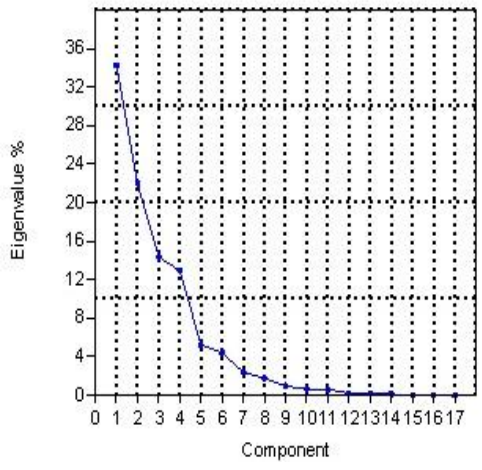

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Figure 5: Scree plot of the eigenvalues in the northwest Persian Gulf.

The scatter plot, composed from the first and second principal components, for sample score as a result of the PCA analysis on the 14 factors (12 physico-chemical factors plus, chlorophyll and primary production) is shown in Fig. 6.

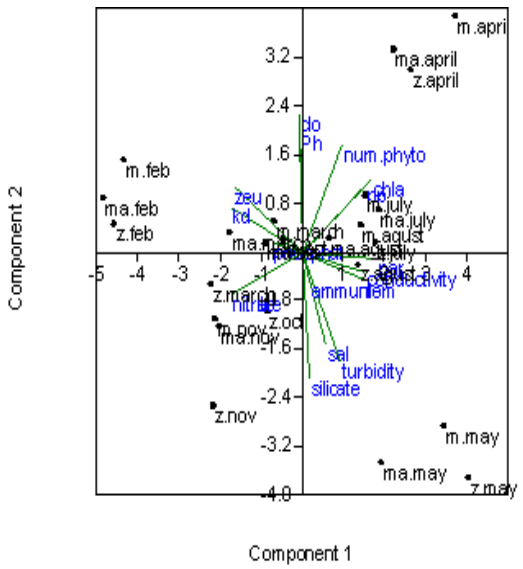

Figure 6: Biplot based on Principal Component Analysis (PCA) of chlorophyll-*a*, primary production and 12 environmental parameters for 3 stations for the period Feb 2014 till Nov 2014 along Khuzestan's waters (ma: Mahshahr Creek, m: Moussa Creek and z: Zangi Creek).

Discussion

The use of physicochemical and biological variables is a powerful tool for water resource management being essential to guide research. With the results obtained in this study, we can conclude that phosphate concentration in creeks is several times greater than the amount of phosphorus in other estuary regions (Gruber *et al*., 2008). Silicate concentration is lower in creeks than in other estuary regions which might be due to higher consumption by diatoms for building their skeleton (Kimmerer, 2002). pH is one of the most important factors that changes with the degree of pollutant dissolution. Most shallow waters have a pH between 5 and 10. The highest degree of pH fluctuation can be seen in pH values between 6.5 and 9.0 (Boyd, 1981). Accordingly, the pH values obtained from the studied regions is within the normal range for this parameter in other coastal waters. At a pH between 6 and 9, the growth of aquatic creatures is optimal, between 9 and 11 it is low and is lethal at higher pH (Edwards and Richardson, 2004). The reason for the difference can be attributed to factors such as precipitation in various months, monthly evaporation level and tidal conditions of the stations during sampling.

Turbidity was significantly different in the studied months. This can be due to the difference between the amounts of precipitation and currents causing turbulence in water and thereby affecting turbidity (Lazzari *et al*., 2012).Turbidity values lower than 100 mg L^{-1} have a very low impact on most creatures (Leymarie *et al.*, 2010). Since dissolved oxygen concentrations lower than 4 ppm are alarming for an aquatic environment (Gruber *et al*., 2008), it can be stated that all creeks should have a desirable level of oxygen during the year. The reason for increased oxygen in February is naturally due to increased oxygen solubility in response to temperature reduction in cold months. As a result of increased precipitation and water turbulence in cold seasons, turbidity is greater in winter months than in summer, thus this factor is one

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of the limiting factors of primary production (HabibiKhaledi, 1999). Another limiting factor of primary production is the availability of solar energy in winter (Amin, 2010).

In temperate waters, there is usually a certain period of phytoplankton growth during the year that hardly changes regularly in response to variations in specific aquatic conditions of this period. Production and distribution of phytoplankton usually vary according to geographical latitude and longitude. Regions situated in higher latitudes have typically higher phytoplankton production since they have longer light period during summer, however in contrast regions located in lower latitudes such as temperate and warm regions have less phytoplankton production because of variability in length of day and night (O´Reilly *et al*., 1998). PCA analysis was used to identify those environmental factors, as well as primary production that contain the most information. These results indicated that primary production has a significant relationship with nitrite, nitrate, light energy, phytoplankton abundance and chl-a. The combination of phytoplankton strains, species richness, population density and primary production in various coasts and seas is highly dependent on variations in water hydrobiology. Changes in temperature, light penetration, nutrients, and zooplankton grazing are the most important factors (Prabhahar *et al*., 2011). Nutrients affect primary production and they are always directly related to each other (Le Que´re, 2005). In creeks, both nitrogen and phosphate levels can be limiting agents, the degree of limitation of each is dependent on the season and local conditions of the ecosystem (Le Que´re´, 2005). In the present study, phytoplankton flourished abundantly in April, when the highest level of primary production and chl-a were recorded. Blooms are not high in winter but are at a maximum level in spring (Shrotriy *et al*., 2014). Joint and and Groom (2000) reported a high level of primary production during phytoplankton growth. In spring when the waters are turbulent, biogenic elements revived in winter are transferred to superficial layers, where increased light and temperature leads to algal growth (KhalfehNilsaz, 1998). In May primary production decreases because of zooplankton grazing on phytoplankton (Dallolmo and Gitelson, 2005).

A brief investigation of all these results reveal that since creeks did not show significant differences among each other in terms of amount of various factors, it can be stated that these creeks are similar in terms of physico-chemical and biological conditions. Nevertheless, the existence of a significant difference in different months is absolutely natural. It is caused by atmospheric and climatic conditions and is inevitable and unchangeable. The level of nutrients and oxygen in creeks exhibits that it can sustain living creatures. The comparison of primary production levels in the studied regions with other regions of the world for example some of the coastal waters off the Barrier

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Island, the southwest coast of India, and Venezuela coastal waters (Tada *et al*., 1998; Radhakrishna, 2000; Fernandez and Penoth, 2003) indicates that primary production is highest in the creeks in April but is low in other locations (Shrotriy *et al*., 2014). Definitely, high production level in this month can be attributed to of the uptake of nutrients including nitrate and phosphate from shallow waters entering into these creeks, sufficient light and suitable temperature. Water mixing and inhibition from precipitation of nutrients on the floor of the creeks may result in higher production in these regions. The comparison of this study with other investigations in previous years (KhalfehNilsaz, 1998; HabibiKhaledi, 1999; Moabed *et al*., 2006), (e.g. maximum primary production was 10.39 in July and minimum primary production was 0.04gc/m^2/d in May), has revealed reduction of primary production, the amount of phytoplankton, and chl-a. It might be due to increased toxic contamination caused by petrochemical and industrial factories located in the region and elevated turbidity stemming from these industries together with a high level of regional debris throughout the years (Fikslin, 1999; Moll, 2012).

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