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SEASONAL DYNAMICS OF EPIPHYTIC MICROALGAE AND THEIR HOST SEAWEEDS FLORIDEOPHYCEAE AT JEDDAH COAST, THE RED SEA, SAUDI ARABIA

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Abstract

Algae play a very important role as feed and shelter for fish, crustacean and gastropods. Thus, this study was carried out to know dynamics of epiphytic microalgae and their host macroalgae of Florideophyceae at Jeddah coast, the Red Sea. The water temperature, salinity, pH and dissolved oxygen varied from 21.6 to 32.30°C, 36.40 to 39.70 ppt, 8.04 to 8.60, and 3.00 to 8.90 mg/L, respectively. A total of 10 seaweeds species of Florideophyceae was found, and among them *Gracilaria corticata* was found throughout the year. *Gracilaria tikvahiae* and *Digenea simplex* occurred from spring to autumn, and *Acanthophora muscoides* occurred from winter to summer. A total of 108 taxa of epiphytes were identified; 95 belong to Bacillariophyceae, 9 Cyanophyceae, 2 Dinophyceae, 1 Chlorophyceae and 1 Raphidophyceae. The epiphytes on *A. muscoides* varied from 9.50 to 66.10×10^5 cells/100 g of *A. muscoides*, and the highest cell abundance was in spring. Epiphytic cell abundance on *Amphiroa* sp., fluctuated from 5.38 to 40.78×10^5 cells/100 g of *Amphiroa* sp. Similarly, for *Digenea simplex*, epiphytes varied from 27.56 to 51.69×10^5 cells/100 g of *D. simplex*. Epiphytic cell abundance on *Gracilaria corticata* varied from 7.28 to 74.21×10^5 cells/100 g of *G. corticata*, and the lowest and highest cell abundance were in winter and summer, respectively. Among the microalgae, the contribution of Bacillariophyceae was highest (87.96%), followed by Cyanophyceae (8.33%) and Dinophyceae (1.85%). A total of 32 species contributed above 10% in epiphytic microalgae, and *Licmophora* sp., *Navicula* sp., *Leptocylindrus* sp., *Nitzschia* sp., *Tabellaria* sp., and *Thalassionema* sp., were the dominant species.

Key words: Seasonal dynamics, Epiphytic microalgae, Seaweeds, Environmental factors, Jeddah coast.

Introduction

Seaweeds are multicellular and macroscopic macro-algae, which are abundant in intertidal zones of coastal environments. Primarily they grow in near-shore coastal waters with suitable substrates for attachment. Seaweeds or macroalgae possess very simple vegetative structure called 'Thallus' and, therefore, do not possess stems and roots like other plants. Different species of seaweeds occupy different habitats based on depth, degree of exposure to wave action, shore beds and other environmental factors (Ballesteros, 1992, Sales & Ballesteros, 2009). Moreover, seaweeds assemblages serve as nursery habitats for many littoral fishes (Aburto-Oropeza *et al*., 2007; Cheminee *et al*., 2010). The leaves of seaweeds provide substrates suitable for the attachment and growth of various numbers of microalgae (Mazzella & Russo, 1989). The microalgae grow attached or associated to other plants are known as epiphyton (Round, 1971). Epiphytic microalgae are common components of aquatic systems and they are important in terms of productivity (Burkholder & Wetzel, 1990), and also a suitable food source for higher trophic levels (Kitting *et al*., 1984: Sullivan & Moncreiff, 1990). Epiphytic floras of microalgae grow on seaweeds either loosely, tightly attached or as an adnate component (Burkholder *et al*., 1990; and Cattaneo & Kalff, 1978). The dynamics, abundance and community structure of epiphytic microalgae are influenced by biotic factors such as leaf age, seasonal cycle of the host, and grazing pressure by herbivores, and also by the abiotic factors such as light, temperature, nutrients and water motion (Mazzella & Russo, 1989; Prado *et al*., 2007; Mabrouk *et al*., 2011). The abundant and diverse epiphytic microalgae include diatoms, dinoflagellates and cyanobacteria which make a significant contribution to food webs.

Studies of macro and microalgae are very few at the Jeddah coast of the Red Sea, though macro and microalgae are important for food source and good indicator of pollution. Long time ago, Aleem (1978) studied the presence of algae and he recorded some new species at Obhur creek at Jeddah. Recently, some studies have been made in relation to the effect of environmental factors on chlorophyll and phytoplankton abundance near desalination plant, marine fouling and marine polluted area of Jeddah coast (Abdul Aziz, 2000; Khomayis, 2002; Khomayis & Haibi, 2003; Abdulwassi, 2006). There is no report on the study of epiphytic microalgal dynamics in relation with environmental factors along the cost of Saudi Arabia. Thus, an investigation on epiphytic microalgae was carried out on Coast off Jeddah, the Red Sea, Saudi Arabia. Jeddah is the second biggest city of Saudi Arabia, located on the Coast off the Red Sea and is extending rapidly.

It receives huge waste water from fish farms, industry and domestic use. The Red Sea is narrow oceanic basin, which is lying between the African and the Asian continental shelves. The northern end of the Red Sea connects with the Mediterranean Sea through the Suez Canal, and the southern region exchanges its waters with the open ocean (Gulf of Aden and the Arabian Sea) through Bab-el-Mandeb strait (Sofianos & Johns, 2002). The Red Sea is a unique area in the tropics for several reasons which having the highest saline water body in the world's seas with the deep water salinity of 40.06 ppt while the surface water salinity ranged from 40.10 to

40.65 ppt (Marcos, 1970; Plähn *et al*., 2000; Manasrah *et al*., 2004). The high salinity phenomenon occurs due to its location in an arid and hot climatic zone, isolation from Open Ocean, without riverine inputs, the high evaporation rate (> 210 cm/yr), and scant rainfall which is restricted from October to May, resulting in a negative hydrological budget. The Red Sea is considered as an oligotrophic water body due to deficient of several major nutrients such as nitrate, ammonium, phosphate, and silicate (Acker *et al*., 2008). The required nutrients for photosynthetic activity come through water intrusion (from the Gulf of Aden), the sub-surface (below the nutricline), or via aerial deposition. Higher nutrient concentrations occur in the southern areas, and gradually decline towards the north Weikert (1987). The reservoirs of nutrients in the Red Sea are trapped below the stratified zone due to the persistent pycnocline. The deep water renewal is generally prevented by high stratification levels and the resulting homogeneity of the northern Red Sea deep waters which limits nutrient availability and biological productivity in the euphotic zone. The nutrients supply occurred through the convergence zone formed by the Eastern and Western coastal currents collision. These two currents (one heading northwards and the other southwards) collision brings cold nutrients rich water from deeper parts of the water column to rise to the surface (Acker *et al*., 2008). Temperature is increasing abruptly since mid-90's to present (Raitsos *et al*., 2011), therefore, the oceanic warming may have a direct and/or indirect impact on marine algae, thus, it is important to monitor epiphytic microalgae association dynamics of the relatively unexplored Red Sea. This study was conducted to investigate the seasonal dynamics of epiphytic microalgae community attached to host seaweeds species of Florideophyceae at Jeddah Coast, Saudi Arabia.

Materials and Methods

Sampling was done in March (Spring), June (Summer), September (Autumn) and December (Winter) in 2013 at Jeddah coast, the Red Sea, Saudi Arabia. Jeddah City is being expanded northward towards another marine inlet which is a creek (Obhur creek) located on the east coast of the Red Sea, 35 km north of Jeddah. The surface area of the creek is about 7.79 km^2. The sampling sites were; (i) Obhur-1 (21°44´58.1 N and 39°09´58 E) is a beach where thousands of people gathered in weekend for recreation, such as swimming, bathing etc.,(ii) Obhur-2 (21°44´56.1 N and 39°07´58 E) near the creek entrance to the Red Sea, (iii) Salman-1 (21°53´19 N and 38º 58´29 E), and (iv) Salman-2 (21°51´36 N and 38°58´45 E), the domestic waste water discharge area of the major city Jeddah, (v) Fish market (21°30´28 N and 39°09´49 E) and (vi) Corniche (2°38´57.90 N and 39°06´02.90 E) (Fig. 1).

The water temperature, salinity and pH were measured on spot with HACK Multi mode Salinometer. The water sample was also collected from the respective stations to estimate the nutrients concentration. The concentration of NO_3-N, NO_2-N, NH_3-N, PO_4-P and SiO_3-S were determined with a spectrophotometer (Shimadzu UV-1201, Japan) according to Parsons *et al*. (1984). Seaweeds samples were collected randomly from the above mentioned sites. The wet seaweeds leaves (except stalk and rhizoids) were kept in polyethylene bags and transferred to laboratory. Hundred gms wet sea weeds were put in plastic bottle with filtered seawater, and separation of epiphytic algae from their host was performed by manual shaking by intense and regular manual shaking (10 min at 80 beats/min) (Gosselain *et al*., 2005). Then, the epiphytic microalgal samples were preserved with 2% of logul's solution.

For quantitative study, a 1 mL sample was taken after mixing and counted in a Sedgewick-Rafter (S−R) counter chamber with a light microscope. Counted results were summarized as cells per liter, and finally the results were converted to cells per 100g and used for graphical presentation. For species identification, the sample was observed under the phase-contrast microscope (Zeiss Axioplan, Germany) at 400x magnification. Identifications were made with reference to Prescott (1973), Tomas (1993), Shim (1994) and Kobayasi *et al*. (2006).

Results

The water temperature showed three distinct seasonal cycles characterized by a maximum in summer-autumn, followed by spring and winter. Temperature varied from 21.60 to 32.30°C with an average of 28.05°C (Fig. 2A). Salinity fluctuated from 36.40 to 39.70 ppt with an average of 38.40 ppt. The salinity was lowest in spring at fish market and the highest was in summer at salman-2 (Fig. 2B). Salinity did not show difference during same sampling time among all stations throughout the study, except fish market where the salinity was about 1.00 ppt lower than that of other stations in spring. The pH varied from 8.04 to 8.60, average of 8.39. The minimum and maximum pH were in winter and spring at Salman-2 and fish market, respectively (Fig. 2C). Concentration of dissolved oxygen (DO) varied from 3.00 to 8.90 mg/L with an average of 6.18 mg/L. The minimum and maximum DO concentration were recorded in autumn at Fish-market and in spring at Obhur-2, respectively (Fig. 2D). Among nutrients, the concentrations of NO_3-N, NO_2-N, NH_3-N, PO_4-P and SiO_3 were 0.26-2.99, 0.22-5.14, 0.13-4.70, 0.49-3.52 and 0.22-14.63 µg/L, respectively among the stations of Jeddah coast of the Red Sea, from winter to autumn 2013 (Table 1). The abundance of epiphytic microalgae showed strong positive correlation with temperature (r = 0.76), NO_2-N (r = 0.80), PO_4-P (r = 0.76) and SiO_3-S (r = 0.70).

A total of 10 seaweeds species belonging to Floriedophyceae was found throughout the year. *Gracilaria corticata* was recorded throughout the year. *Gracilaria tikvahiae* and *Digenea simplex* were found from spring to Autumn, and *Acanthophora muscoides* was found from winter to summer (Table 2). A total of 108 taxa of epiphytic microalgae were identified during the study, among them 95 belonged to Bacillariophyceae, 9 Cyanophyceae, 2 Dinophyceae, 1 Chlorophyceae and 1 Raphidophyceae (Table 3). Among the microalgae the contribution of

Bacillariophyceae was highest (87.96%), followed by Cyanophyceae (8.33%) and Dinophyceae (1.85%) (Table 4).

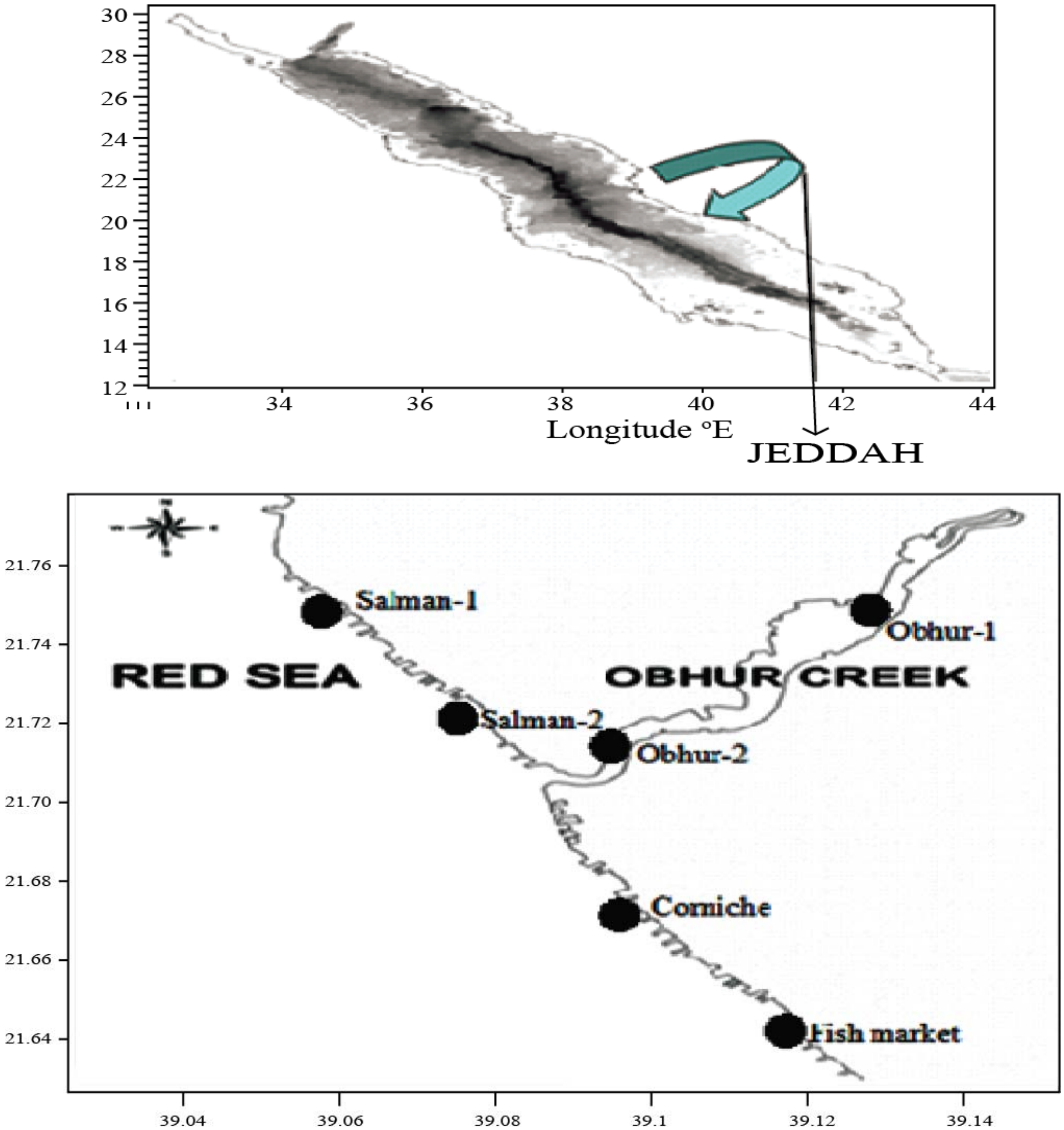

Fig. 1. Map of the Jeddah Coast, Red Sea, Saudi Arabia, and location of the study sites (Obhur-1, Obhur-2, Salman-1, Salman-2, Corniche and Fish market).

Acanthophora muscoides was found from winter to summer and its associated epiphytic microalgae abundance varied from 9.50 to 66.10×10^5 cells/100 g of *A. muscoides*. The average cell abundance was 28.45×10^5 cells/100 g of *A. muscoides* and the highest cell abundance was in spring. *Amphiroa* sp. was found from spring to autumn, and the epiphytic cell abundance fluctuated from 5.38 to 40.78×10^5 cells/100 g of *Amphiroa* sp. The lowest cell abundance was in autumn, and the highest cell abundance was found in summer. Similarly, *Digenea simplex* was also found from spring to autumn. The epiphytic cell abundance varied from 27.56 to 51.69×10^5 cells/100 g of *D. simplex*, with an average of 39.86×10^5 cells/100 g of *D. simplex*, and the highest cell abundance was found in spring. *Gracilaria tikvahiae* was found from spring to summer and its epiphytic microalgae showed highest abundance in summer which was 53.60×10^5 cells/100 g of *G. tikvahiae*. However, among 10 species of seaweeds, *Gracilaria corticata* was found throughout the year, and it's epiphytic cell abundance varied from 7.28 to 74.21×10^5 cells/100 g of *G. corticata*, with an average of 41.24×10^5 cells/100 g of *G. corticata*, and the lowest and highest cell abundance were in winter and summer, respectively (Fig. 3).

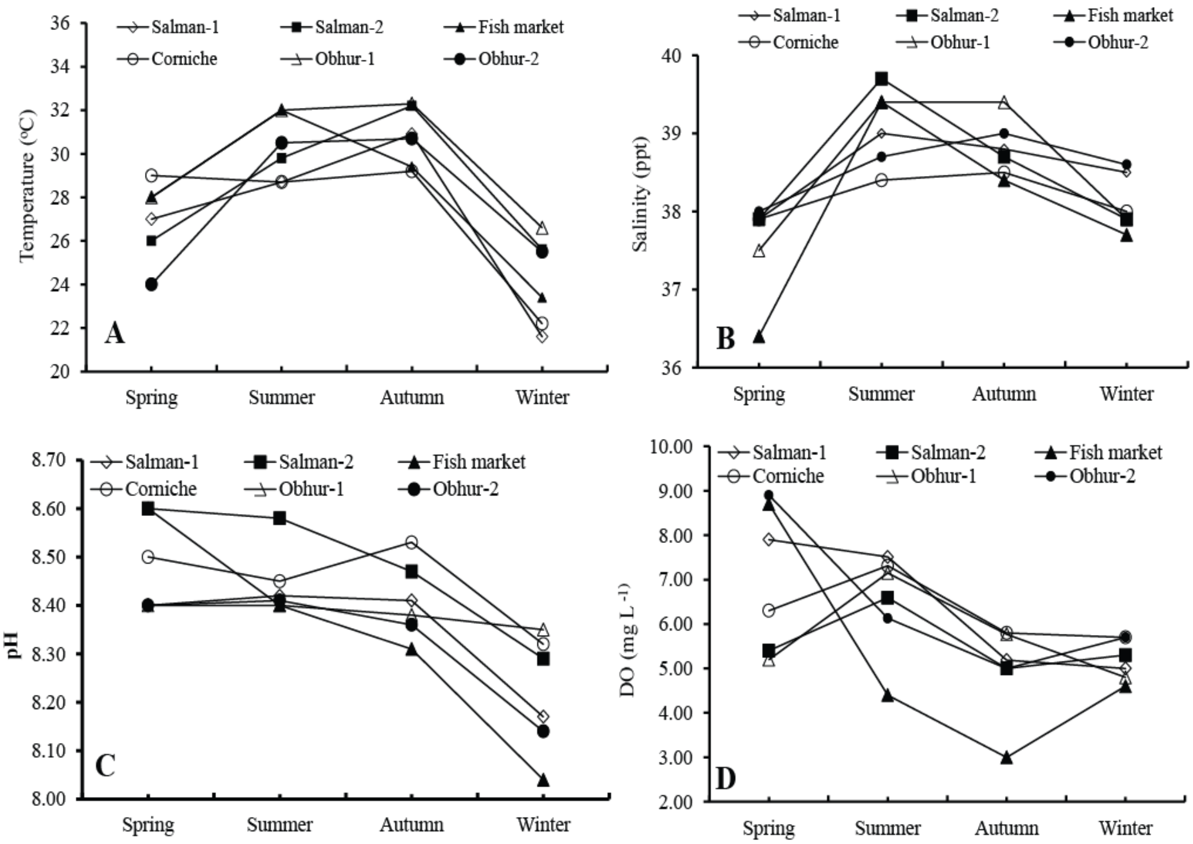

Fig. 2. Variation of temperature (°C) (A), salinity (ppt) (B), pH © and dissolved oxygen (DO) (D) at Jeddah coast of Saudi Arabia, the Red Sea from spring to winter 2013.

Table 1. Dynamics of nutrients (μg.L^{-1}) from spring to winter 2013 at Jeddah coast of the Red Sea, Saudi Arabia.

Stations	NO_3-N				NO_2-N				NH_3-N				PO_4-P				SiO_3			
	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut
Salman-1	0.54	0.92	1.47	0.65	0.22	3.52	0.52	0.72	1.02	0.19	0.53	1.18	0.83	0.90	0.51	0.44	1.16	6.24	1.64	0.22
Salman-2	1.05	0.86	1.28	0.75	0.32	1.54	0.61	0.85	0.76	0.21	0.52	0.36	0.64	3.22	0.50	0.75	2.35	5.31	1.99	0.26
Fishmarket	1.06	1.65	1.93	2.99	0.74	5.14	0.99	1.38	0.44	2.27	3.84	4.70	1.94	2.18	2.11	1.11	4.49	14.63	5.38	5.39
Corniche	0.32	1.93	2.96	1.03	0.28	1.58	0.57	0.80	0.49	0.20	0.68	0.41	0.61	3.52	1.10	0.75	2.27	5.62	2.81	1.29
Obhur-1	0.67	0.94	1.67	2.35	0.43	2.10	0.71	0.99	0.13	0.25	0.45	1.19	0.49	2.01	0.66	0.51	2.35	8.70	1.17	1.69
Obhur-2	0.26	0.87	0.56	2.61	0.27	1.98	0.57	0.79	0.58	0.39	0.48	0.42	0.71	0.93	0.57	0.53	3.21	6.39	1.87	1.60

Table 2. List of seaweeds found at different sites at Jeddah Coast, Red Sea, Saudi Arabia from spring to winter 2013.

Species name	Spring	Summer	Autumn	Winter
Florideophyceae				
Acanthophora muscoides	S-1, S-2, CO & OB-1	OB-1	–	CO
Amphiroa sp.	OB-2, S-2 & CO	OB-2 & CO	OB-2 & S-2	–
Chondrus armatus	–	OB-2	–	–
Digenea simplex	S-1, CO	CO	S-1 & OB-1	–
Gracilaria chilensis	–		–	OB-2
Gracilaria corticata	S-2, CO & OB-1	CO & OB-1	S-1 & OB-1	CO
Gracilaria spinulosa	–	S-2	OB-2	–
Gracilaria tikvahiae	S-1 & OB-2	S-1 & OB-2	–	–
Laurencia minuta	–	–	–	CO
Laurencia papilosa	–	–	–	S-1

S-1, Salman-1; S-2, Salman-2; CO, Corniche; OB-1, Obhur-1; OB-1, Obhur-2; FM, Fish market

Table 3. List of epiphytic microalgae taxa and frequency of occurrence on the seaweeds Florideophyceae at the Cost off Jeddah from spring to winter in 2013.

Florideophyceae	Winter	Spring	Summer	Autumn
Epiphytic of Bacillariophyceae				
Pennate Diatoms				
Amphiprora paludosa		X		
Amphora sp.		C	X	R
Amphora arcus				R
Amphora astrearia		R		
Amphora coffeaeformis		R	X	F
Amphora commutata			R	
Amphora exigua	X		X	
Amphora karyana		X		
Bacillaria paradoxa		C		
Bacillaria paxillifer	X	R		
Closterium moniliferum	X			
Closterium navicula	R	X		
Cocconeis granii			X	
Cocconeis heteroidea			R	H
Cocconeis limosa		X		
Cocconeis placentula			R	
Cocconeis scutellum			X	
Cocconies lineatus			X	
Cyclotella meneghiniana				R
Cylindrotheca closterium	R	H	H	F
Cymbella tumida				R
Diatoma mesodon				F
Entomoneis punctulata				R
Grammatophora angulosa	X			
Gyrosigma sp.		C	X	
Gyrosigma balticum	X			
Gyrosigma fasciola				R
Licmophora abbreviata	X		X	F
Licmophora flabellata	C	H	F	H
Licmophora gracilis	R		X	
Licmophora grandis		H		R
Licmophora juergens			X	
Licmophora paradoxa	X		R	R
Licmophora remulus			H	F
Licmophora suergensii	X	X		
Mastogloia sp.		X		
Navicula sp.		C		
Navicula cuspidata	X	F	C	R
Navicula distans	R	R	H	F
Navicula gregaria		X		
Navicula incerta		F		
Navicula laneeolate	X	X		
Navicula longissima		H	R	
Navicula peregrina		C	X	
Navicula ramosissima		R		
Navicula transitans	H	X	H	H
Navicula vanhoeffenii	X			
Nitizschia frigida		X		
Nitzschia acicularis	X			
Nitzschia hungarica	C	R	F	H
Nitzschia longissima	C	X	X	H
Nitzschia reversa				R
Nitzschia seriata		X	X	R
Nitzschia sigma	X			
Nitzschia socialis			C	
Pinnularia gibba	F			H

Table 3. (Cont'd.).

Florideophyceae	**Winter**	**Spring**	**Summer**	**Autumn**
Pinnularia viridis	R		R	
Pleurosigma angulatum		X	F	R
Pleurosigma directum		X		
Pleurosigma elongatum	X		R	
Pleurosigma formosum	R			
Pleurosigma normanii	F	X	F	H
Pseudo-nitzschia multistriata			X	
Pseudo-nitzschia multistriata				R
Striatella unipunctata		R	F	
Synedra gaillonii				R
Tabellaria fenestrata	R		X	
Tabellaria flocculosa	R			
Thalassionema bacillare			R	R
Thalassionema costatum	X			
Thalassionema frauenfeldii			R	F
Thalassionema nitzschioides			X	H
Toxonidea insignis		X		
Centric Diatoms				
Buddlphia alternans		X		
Buddulphia sp.			X	
Chaetoceros curvisetus		C	X	
Chaetoceros decipiens		X		
Chaetoceros fragile	X	X		
Chaetoceros radicans	R		X	
Chaetoceros socialis			X	R
Coscinodiscus asteromphalus			X	
Coscinodiscus centralis				H
Coscinodiscus concinnus				R
Coscinodiscus lineatus		X		
Coscinodiscus radiates	X		R	R
Coscinodiscus wailesii			R	
Leptocylindrus adriaticus		C		
Leptocylindrus danicus	X	F	C	F
Leptocylindrus minimus	X		X	F
Melosira nummularioides			X	
Rhizosolenia sp		R		
Rhizosolenia delicatula			X	
Rhizosolenia pungens			X	
Rhizosolenia setigera			X	R
Rhizosolenia stolterfothii				R
Cyanophyceae				
Anabaena collarcito				H
Merismopedia sp				*R*
Microcystis aeruginosa				F
Oscillatoria sp.		X		
Oscillatoria formosa	R			
Oscillatoria sancta		R		
Spirulina subsalsa			H	R
Trichodesmium sp.	C	R	C	F
Trichodesmium erythraeum			X	
Dinophyceae				
Prorocentrum lima		R	R	
Prorocentrum micans			X	R
Chlorphyceae				
Tetraselmis cordiformis			X	
Raphidophyceae				
Heterococcus akashiwo			X	

Legend of occurrence frequency: Sporadically (X=1- 20%), Rarely (R= 21- 40%), Commonly (C = 41-60%), Frequently (F = 61-80%) and High frequently (H = 81-100%)

Table 4. List of seaweeds (written in bold) and epiphytic microalgae abundance above 10% at Jeddah Coast, from spring to winter 2013.

Seaweeds and phytoplankton	Winter	Spring	Summer	Autumn
Acanthophora muscoides				
Chaetoceros radicans	11			
Licmophora flabellata		24	14	
Licmophora grandis		23		
Navicula ramosissima		10		
Navicula transitans			10	
Pinnularia gibba	11			
Prorocentrum micans			11	
Tabellaria fenestrata	15			
Tetraselmis cordiformis			55	
Chondrus armatus				
Nitizschia longissima			28	
Navicula sp.			16	
Licmophora grandis			13	
Digenea simplex				
Licmophora flabellata		14		
Licmophora grandis		13		
Leptocylindrus danicus			28	
Pleurosigma angulatum			11	
Thalassionema frauenfeldii			14	
Gracilaria chilensis				
Oscillatoria formosa		10		
Navicula transitans		10		
Nitzschia longissima		10		
Pleurosigma normanii		12		
Heterococcus akashiwo			63	
Navicula distants			11	
Navicula transitans			12	
Leptocylindrus danicus				19
Licmophora flabellata				25
Gracilaria corticata				
Closterium navicula	12			
Cocconeis placentula			19	
Leptocylindrus danicus	31			23
Licmophora abbreviata	21			
Licmophora flabellata				30
Licmophora grandis		37		
Navicula delicatula		26	10	
Gracilaria spinulosa				
Baciilaria paxillifer			13	
Striatellales delicatula			11	
Cocconies heteroidea			10	
Pleurosigma normanii				11
Thalassionema nitzschioides				19
Anabaena collarcito				11
Gracilaria tikvahiae				
Leptocylindrus danicus		43	13	
Licmophora grandis			10	
Licmophora paradoxa			11	
Navicula sp.		17		
Tabellaria fenestrata			12	
Laurencia minuta				
Leptocylindrus danicus	18			
Pinnularia gibba	18			
Tabellaria fenestrata	18			
Laurencia papilosa				
Nitzschia longissima	15			
Gyrosigma balticum	18			
Trichodesmium sp.	12			
Amphiroa sp.				
Leptocylindrus danicus		10	11	
Leptocylindrus minimus				13
Licmophora flabellata			11	
Licmophora grandis		31		
Navicula directa			10	

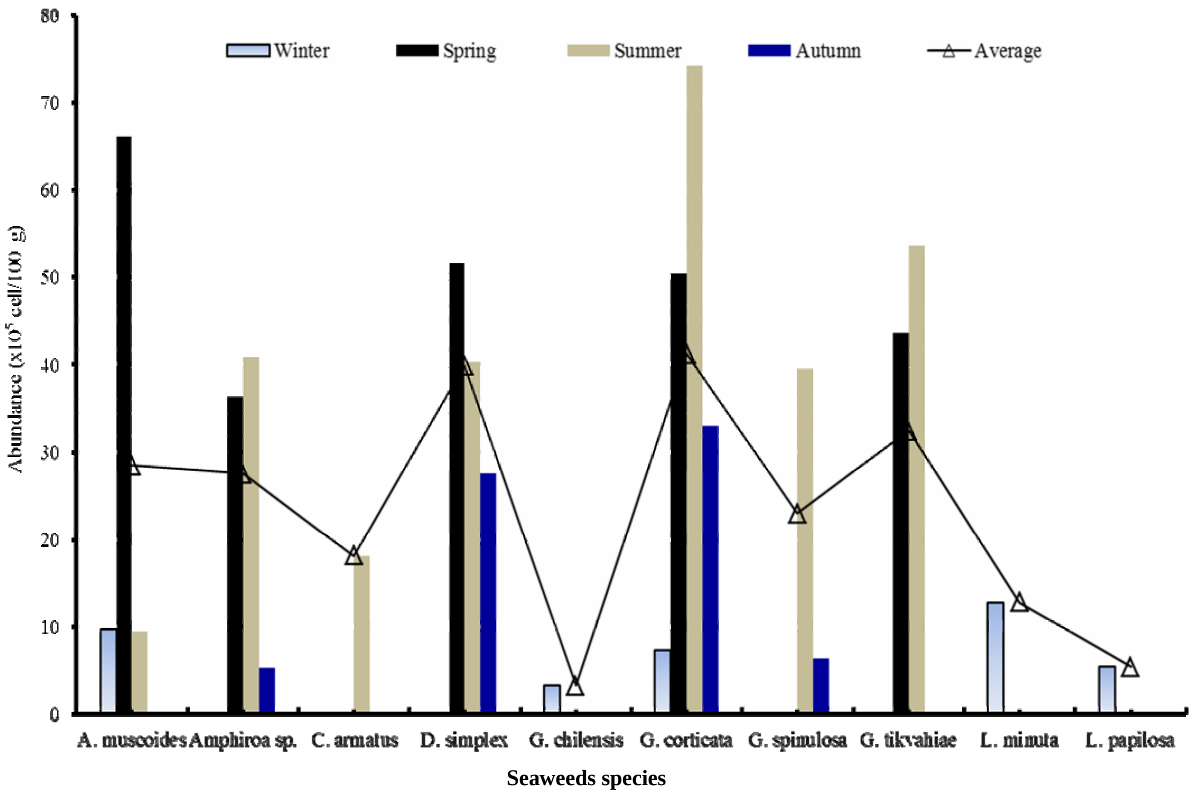

Fig. 3. Variation of epiphytes cell abundance associated with seaweeds available at Jeddah Coast from spring to winter 2013.

Among themicroalgae, the contribution of Bacillariophyceae was highest (87.96%), followed by Cyanophyceae (8.33%) and Dinophyceae (1.85%). Among Bacillariophyceae, the abundance of pennate was more than that of centric diatoms. The contributions of pennate and centric diatoms were 67.59 and 20.37%, respectively among microalgae and 76.84 and 23.16%, respectively among Bacillariophyceae. However, a total of 32 species contributed above 10% to the total microalgae throughout the study period. *Licmophora* sp., *Navicula* sp., and *Leptocylindrus* sp., were found more frequently than that of other species. *Leptocylindrus danicus* was found to contribute 31, 43 and 63% in winter, spring and summer, respectively as single species to the totalmicroalgae. *Licmophora flabellata* was found in all four seasons while *Licmophora grandis* was found only from spring to summer (Table 4). *Nitzschia* sp., *Tabellaria* sp., and *Thalassionema* sp., were also found to be dominant above 10% to the total microalgae population though they were not found throughout the year.

Discussion

Ten species of Florideophyceae were found at six sampling stations. They occurred in different seasons and different areas which made different habitats for epiphytic microalgae depending on local environmental conditions (nutrient, substratum, current, etc.). The epiphytic abundance and composition are the results of the interaction between the lifespan of the host and the reproductive lifespan of the epiphytes (Borowitzka *et al*., 2006) although environmental factors and predators control the abundance of epiphytic microalgae. In this study, 8 species of seaweeds among 10 species of Florideophyceae were found from spring to autumn as host for epiphyticmicroalgae. These long life span seaweeds might have provided substrate for diatoms species for long time since diatoms species occurrence and abundance were above 87%. Vegetative ecosystems are ideal habitats for benthic diatoms and other epiphytes as seaweeds leaves and algal thalli may provide greater surface area for the colonization and growth of diatoms (Zieman *et al*., 1989). Previous studies have showed that diatoms and bacteria are the first organisms which make colony on the submerged objects or organisms, and they shape a biofilm (Novak, 1984). Therefore, it could be said that seaweeds species of Florideophyceae might be the suitable substrate for diatoms.

The physico-chemical factors, NO_2-N (r = -0.34), NH_3-N (r = - 0.76) and PO_4-P (r = - 0.34) showed negative correlation with epiphytic microalgal abundance in summer, and in autumn PO_4-P and NO_3-N showed negative correlation which were r = -0.54 and r = - 0.49. The temperature showed highly positive correlation in summer (r = 0.59) and autumn (r = 0.78). These relationships indicated that the nutrients were highly taken up by epiphytic microalgae in summer and autumn when temperature was favorable for proliferation and growth of epiphytic microalgae. Among the epiphytic smaller diatoms, *Licmophora flabellata*, *L. grandis*, *Navicula distant*s, *N. transitans Leptocylindrus danicus* were found as most dominant species throughout the year. These smaller microalgae may be more efficient in the utilization of nutrients for their growth. Chisholm (1992) found that the smaller microalgae possess lower sinking velocity and a higher surface area to volume ratio, thereby optimizing light and nutrients absorption efficiencies. Diatoms also have another advantage because of their high fucoxanthin content. Fucoxanthin is the most efficient photosynthetic carotenoid absorbing light in the green waveband (Ondrusek, 1991). In coastal waters, where particulate and dissolved organic matter are in high concentrations, blue light is rapidly attenuated with preferential transmission of the green-to- yellow wavelengths for photosynthesis (Gin *et al*., 2003). The diatoms dominated the summer and autumn due to available of nutrients and favorable temperature.

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