concentrations occur in the southern areas, and gradually decline towards the north [22]. 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 [21]. Moreover, Jeddah Coast is receiving huge waste water from fish farms, industries and domestic use as it is the second biggest city of Saudi Arabia, located on the Coast off the Red Sea and is extending rapidly.

There are few reports on the study of microalgae ecology, community and primary productivity on the Jeddah Coast of the Red Sea. Aleem [23] studied on community composition of microalgae at Obhur, Jeddah Coast of the Red Sea and he recorded 16 species of Cyanophyta and 27 species of Chlorophyta. Khomayis [24] studied on phytoplankton abundance with annual nutrients recycle was conducted in tourist resort area from South Corniche to North Obhur of Jeddah Coastal water. Diatom composition in marine fouling area of Obhur was studied by Khomayis and Haibi [25] in which they recorded 22 species of diatoms. Recently, Harbi and Affan [26] studied on seasonal dynamics of epiphytic microalgae and their host seaweeds Florideophyceae at Jeddah Coast, the Red Sea, and Saudi Arabia. In this study, brown seaweeds (Phaeophycease) and their epiphytic microalgal association was studied in relation with environmental factors at the northern part of Jeddah Coast. The aim of this study was to investigate the community composition and seasonal dynamics of leaf epiphytic microalgal abundance of host seaweeds species of *Phaeophyceae* at the northern coast of Jeddah, the Red Sea.

Materials and Methods

Study area, sampling and sample analysis

The sampling was done seasonally at the peak of season which was in March (spring), June (summer), September (autumn) and December (winter) in 2015. The sampling was conducted at the northwest coast of Jeddah, Saudi Arabia, the Red Sea. The sampling sites were; (i) Yambu (23°59´45″N and 38°10´35″ E) am one of major sea port of the Red Sea in the Al Madinah province of western Saudi Arabia. It is approximately 300 kilometers northwest of Jeddah. There are oil refineries and petrochemical industry. (ii) Ar-Riyas (23°33´55″N and 38°36´17″E) is an industrial city of Madinah province, (iii) Mastura (23°08´80″N and 38º47´14″E) is famous for fishing, (iv) Rabigh (22°41´35″N and 39°00´34″E) has several industries such as cement factory, electricity station, large refinery, Petro Rabigh and (v) Thuwal (22°16´44″N and 39º05´21″E) had long been a fishing center. The town is experiencing an increase in industries due to its proximity to the King Abdullah Economic City (Figure 1).

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 grams wet sea weeds were put in plastic bottle with filtered seawater, and separation of epiphytic algae from their host was performed by manual

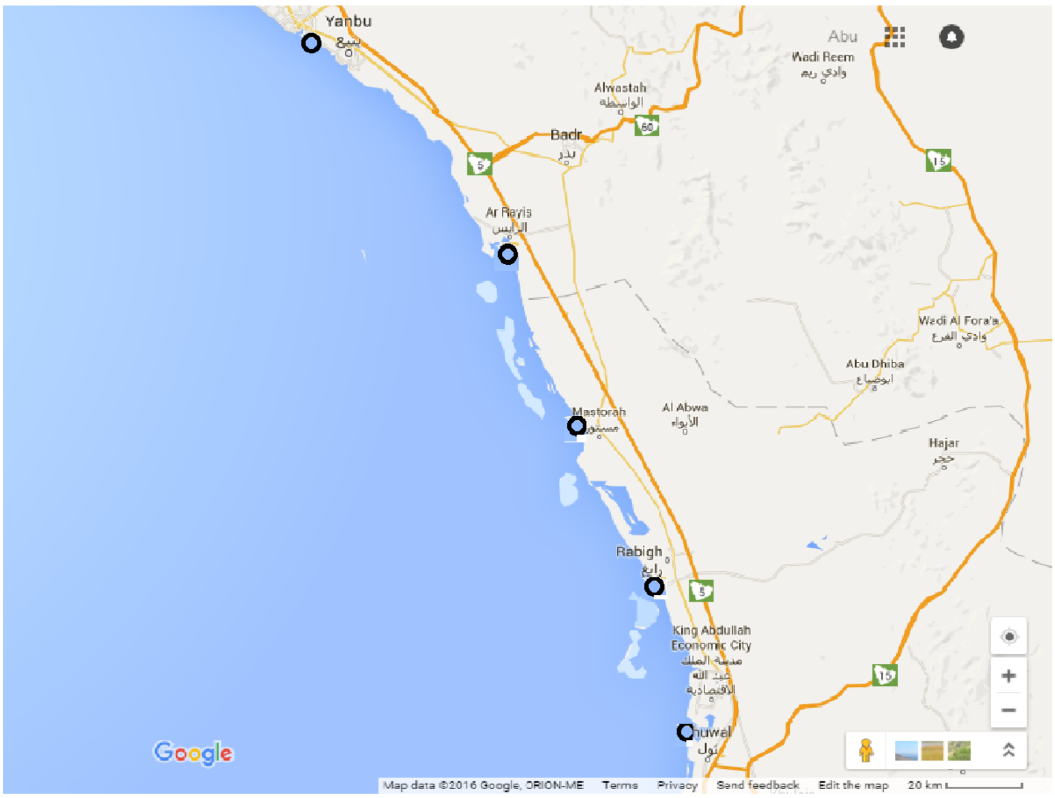

Figure 1: Location of the study sites; Northwest coast of Jeddah, Saudi Arabia, namely Yambu, Ar-Rayis, Mastorah, Rabigh and Thuwal, the Red Sea.

shaking method. Then, the epiphytic microalgal samples were preserved with 2% of logul's solution for further study. For taxonomical study, the sample was observed under the phase-contrast microscope (Zeiss Axioplan, Germany) at 400X magnification. Taxonomic identifications were made with reference to Prescott [27], Tomas [28,29], Shim [30], Kobayasi [31] and Round et al. [32]. For quantitative study, a 1 mL sample was taken after mixing of the preserved sample and counted in a Sedgewick-Rafter (S-R) counter chamber with same microscope as mentioned above. Counted results were summarized as cells per 100 grams of seaweeds, and used for graphical presentation (Figure 2). The water temperature, salinity and pH were measured on spot with portable meter HACH (Model HQ14d).

Results

The water temperature was found to be highest in summer-autumn, followed by spring and winter. Temperature varied from 22.10-32.02°C with an average of 28.48°C, showing minimum and maximum in winter and summer at Yambu and Rabigh, respectively. Salinity fluctuated from 38.72-39.35 psu with an average of 38.92 psu. The salinity was lowest in spring at Ar-Rayis and the highest was in summer at Yambu (Figure 3). The pH varied from 8.40 to 8.63 throughout the study with an average of 8.52. The highest and the lowest pH was recorded at Rabigh and Mastorah in spring and summer, respectively. The high pH was in spring, followed by winter among all the stations (Figure 4).

Seaweeds and epiphytic microalgal species composition

Total 4 species seaweeds of *Phaeophyceae* were found throughout the year among different sites. *Padina fraseri* was found in four seasons at stations Thuwal, Masturah, Rabigh and Yambu. *Laminaria* sp. was found in spring and summer at Ar-Riyas and Rabigh. *Sargassum muticum* was found spring and autumn at Ar-Riyas, Masturah and Rabigh. *Turbinaria ornata* was found in winter, spring and autumn at Rabigh and Thuwal (Table 1). A total of 83 epiphytic microalgae were identified, including 76 belong to *Bacillariophyceae*, 5 belong to *Cyanophyceae,* 1 belongs to *Chlorophyceae* and 1 belongs to *Dinophyceae* which were grown on different species of seaweeds of *Phaeophyceae*. Among the identified epiphytic microalgae of the host seaweeds of *Phaophyceae*, the percent contribution of epiphytic *Bacillariophyceae, Cyanophyceae, Chlorophyceae* and *Dinophyceae* were 91.57, 6.02, 1.20 and 1.20%, respectively. Within Diatoms, the pennate and centric diatoms were 72.37% and 27.63%, respectively (Table 2). The cell abundance of epiphytes on host *Laminaria* sp. of seaweeds varied from 16.00×10^5 to 73.00×10^5 cells/100 g *Laminaria* sp. with an average of 45.00×10^5 cells/100 g *Laminaria* sp. The highest and lowest cell abundance of epiphytes was found in summer and spring, respectively (Figure 5). Three species of epiphytes were found to occur in high frequently during the study. *Cylindrotheca closterium* was found to be occurred in high frequently in spring, *Licmophora flabellata* was in spring and summer, and *Navicula transitans* was in winter (Table 2).

Seasonal dynamics of epiphytes on host seaweeds

On seaweeds of *Laminaria* sp., the dominant epiphytes were *Leptocylindrus danicus, Licmophora flabellata* and *Navicula ramosissma* in winter. The abundance of *Leptocylindrus danicus, Licomophora flabellata* and *Navicula ramosissma* were 16.01×10^5, 16.01×10^5 and 14.11×10^5 cells/100 g of *Laminaria* sp. and their percent contribution (21.93, 21.93, 19.33)% to the total epiphytic microalgae. Similarly, in spring, the dominant species of epiphytes were *Cylindrotheca clostridium* and *Leptocylindrus danicus* which contributed 12.18% and 51.11%, respectively to the total epiphytic microalgae (Table 3). On seaweeds of *Padina fraseri*, a total five dominant epiphytic microalgae were found and among them *Cylindrotheca closterium*, *Navicula* sp.,

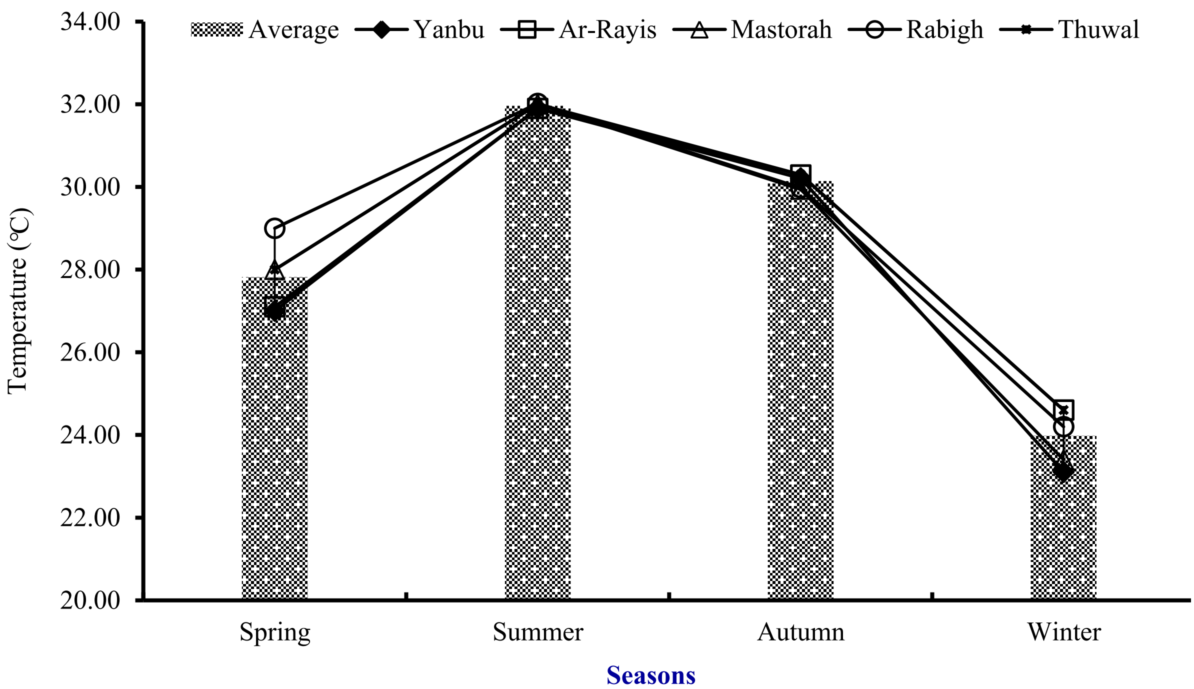

Figure 2: Seasonal variation of water temperature (°C) at the Northwest coast of Jeddah, namely Yambu, Ar-Riyas, Mastorah, Rabigh and Thuwal, the Red Sea, Saudi Arabia from spring to winter 2015.

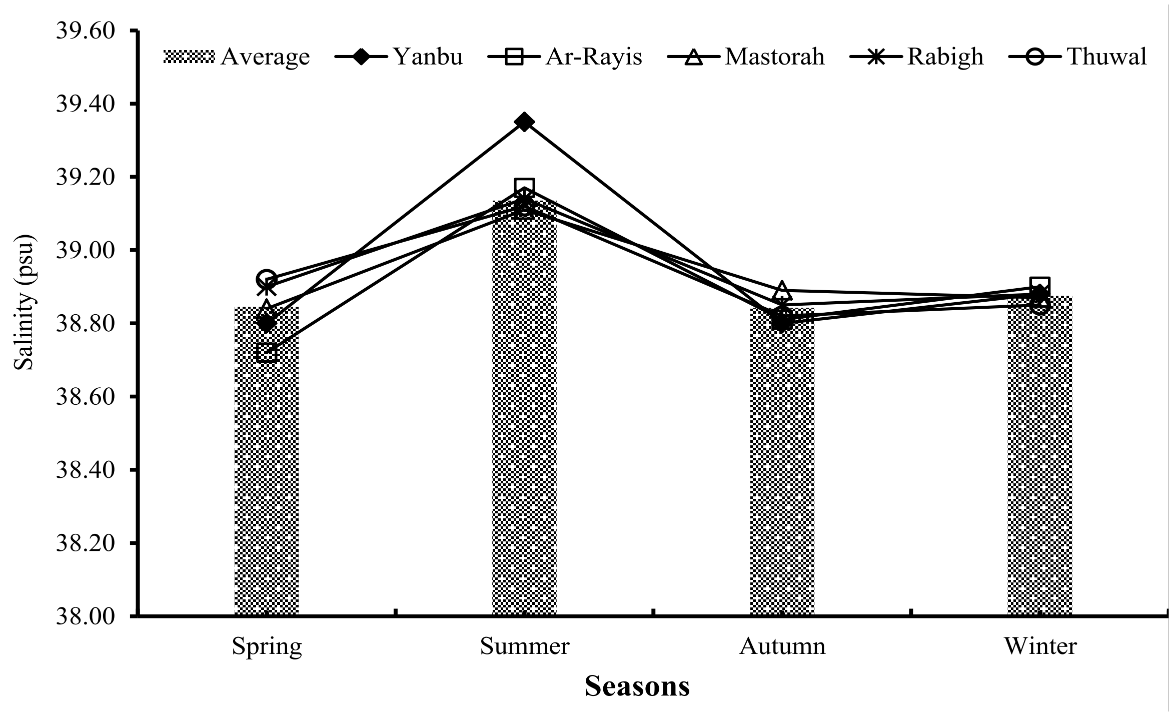

Figure 3: Seasonal variation of salinity (psu) at the Northwest coast of Jeddah, namely Yambu, Ar-Riyas, Mastorah, Rabigh and Thuwal, the Red Sea, Saudi Arabia from spring to winter 2015.

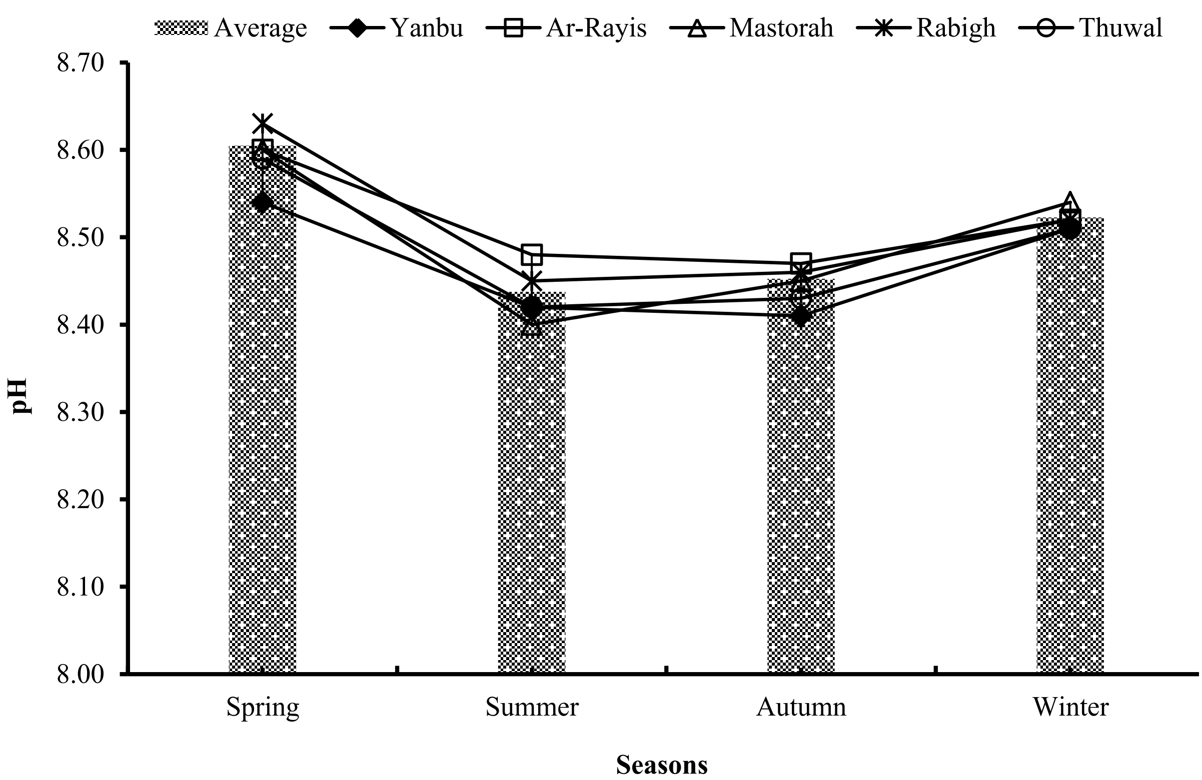

Figure 4: Seasonal variation of pH at the at the Northwest coast of Jeddah, namely Yambu, Ar-Riyas, Mastorah, Rabigh and Thuwal, the Red Sea, Saudi Arabia from spring to winter 2015.

Phaeophyceae	**Winter**	**Spring**	**Summer**	**Autumn**
Species name				
Laminaria sp.	–	R, A	R	–
Padina fraseri (Greville, 1830)	M, R, T	M, R, T	R, M	M, R, T, Y
Sargassum muticum (Fensholt, 1955)	–	R, M, A	M	M, R, A
Turbinaria ornata (Agardh, 1848)	R, T	R	–	R, T

*Legend of location; M, Masturah; R, Rabigh; T, Thuwal; Ar-Riyas; and Y, Yanbu.

Table 1: List of seaweeds found at different sites of Northwest coast of Jeddah, Saudi Arabia, namely Yanbu, Ar-Riyas, Mastorah, Rabigh and Thuwal, the Red Sea from spring to winter 2015.

	Spring	**Summer**	**Autumn**	**Winter**	**%**
Bacillariophyceae					91.57
Pennate diatoms					72.37
Amphiprora alata Kützing				X	
A. angustata Hendey				X	
A. paludosa Smith	X	X		X	
A. paludosa Smith	R				
Amphora arcus Gregory 1855				X	
A. coffeaeformis Kützing	X	X			
A. commutata Grunow		X			
A. exigua Levkov			X		
Bacillaria paradoxa Gmelin	X		X		
B. paxillifer Müller		X	R	X	
Closterium jenneri Ralfs			R		
C. moniliferum Ehrenberg				R	
C. pronum Brébisson				X	
Cocconeis heteroidea Hantzsch		X	X		
C. heteroieda Hantzsch				X	
C. pediculus Ehrenberg	X				
C. pellucida var. minor Grunow	R				
Cylindrotheca closterium Ehrenberg	H	F	X	F	
Entomoneis paludosa var. subsalina Cleve			X		
Fragilaria crotonensis Kitton		X			
Gyrosigma acuminatum Kützing				R	
G. balticum Ehrenberg				X	
Licmophora paradoxa Lyngbye				X	
L. abbreviata Agardh		F	F	C	
L. flabellata Greville	H	R	H		
L. gracilis Ehrenberg		X		R	
L. paradoxa Agardh				R	
Navicula delicatula Cleve	F	X			
N. didyma Ehrenberg		X			
N. distans Smith	C	F	C	X	
N. granii Gran				X	
N. incerta Grunow	C		X		
N. jejunoides f. longissima Van	F	R			
N. peregrine Ehrenberg			R		
N. ramosissma Agardh	X			X	
N. transitans Cleve		F	F	H	
Navicula vanhoeffeni Smayda		X		C	
Nitzschia closterium Ehrenberg				X	
N. hungarica Grunow	X	R			
N. longissima Brébisson			F	C	
N. longissima Brébisson	X				
N. reversa Smith.			R	R	
N. seriata Cleve		X	R		
N. sigma Kützin				R	
N. socialis Gregory		R			
Pinnularia brebissonii Kützing				X	
P. viridis Nitzsch		X	R	R	

P. viridis Nitzsch	X				
Pleurosigma angulatum Smith	X	C		X	
P. directum Grunow				X	
P. normanii Ralfs	R	R	F	R	
Synedra ulna Nitzsch			X		
Tabellaria fenestrata Nitzsch	X	R		X	
Thalassionema frauenfeldii Grunow		X	R		
T. nitzschioides Grunow		X		X	
Centric diatoms					27.63
Biddulphia sp. Gray	X				
Chaetoceros affinis Lauder				X	
C. curvisetus Cleve	R				
C. socialis Lauder		R			
C. turgidus Kützing			X	X	
Coscinodiscus sp.	X				
C. lineatus Ehrenberg		X			
C. wailesii Gran & Angst		X			
Cyclotella meneghiniana Kützing			X		
Guinardia delicatula Cleve		X			
Hyalosynedra laevigata Grunow			X		
Leptocylindrus minimus Gran	X	R	F	C	
L. adriaticus Schroder	R				
L. danicus Cleve	F	F	C	C	
Melosira nummuloides Agardh	X				
Rhizosolenia delicatula Cleve	X	X		X	
R. lineola Cleve			X		
R. pungens Clev		X			
R. setigera Cleve		X	X	X	
R. stolterfothii Peragallo		X	X		
Striatella delicatula Kützing		X	R		
Chlorophyceae					1.20
Tetraselmis cordiformis Carter				X	
Cyanophyceae					6.02
Anabaena collarcito Thomas		X	R		
Merismopedia sp.			X		
Oscillatoria sp.	X	C			
O. formosa Gomont			X	C	
Trichodesmium sp.	R	F	F	R	
Dinophyceae					
Prorocentrum lima Ehrenberg	C	R	R	R	1.02

[**]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 2: List of epiphytic microalgal taxa, frequency of occurrence and percent (%) contribution of each class on the seaweeds Phaeophyceae at the northern coast of Jeddah from spring to winter, 2015.

Nitzschia sp. and *Prorocentrum lima* were dominant in spring, and in summer the dominant epiphytic microalgae was *Cocconeis lineatus*. In winter, the highest percent contribution was 19% by *Cylindrotheca closterium,* followed by *Navicula* sp. (17%) and *Nitzschia* sp. (13%). Similarly, in summer the percent composition of *Cocconeis lineatus* and *Trichodesmium* sp., 10 and 10% to the total epiphytes (Table 3). On seaweeds of *Sargassum muticum*, four epiphytes were found to be dominated in spring, and another two epiphytes were found to be dominant autumn. In spring, *Navicula distans* and *Nitzschia sociales* contributed 23.00 and 23.00%, followed by *Navicula vanhoeffeni* (11.04%) and *Leptocylindrus minimus* (10.00%) in epiphytic microalgae. In autumn, *Leptocylindrus minimus* and *Navicula transitans* were the dominant species which contributed 37.00 and 10.00%, respectively to the total epiphytes (Table 3). On seaweeds of *Turbinaria ornata*, six species of epiphytes were found to be dominant from winter to autumn. In winter the highest percent contribution was 59.00% by *Leptocylindrus minimus*, followed by *Bacillaria paxillifer* (15.00%). *Leptocylindrus danicus* contributed 20.65 and 10.32% to the total epiphytes in spring and summer, respectively. In autumn, the highest contribution was 17.00% by *Nitzschia hungarica*, followed by *Leptocylindrus danicus* (14.00%) and *Thalassionema frauenfeldii* (12.00%) to the total epiphytes (Table 3).

Discussion

Four species seaweed of *Phaeophyceae* were identified at the study area in different seasons in different stations. Different types of epiphytic microalgae were also found on same seaweeds of *Phaeophyceae* which might be occurred depending on local environmental conditions (nutrient, substratum, current, etc.). The epiphytes abundance and composition are the results of the interaction between the lifespan of the host and the reproductive lifespan of the epiphytes although

	Winter		Spring		Summer		Autumn	
	10^5 cell	%	10^5 cell	%	10^5 cell	%	10^5 cell	%
Laminaria sp.								
Cylindrotheca closterium	-	-	1.95	12.18	-	-	-	-
Leptocylindrus danicus	16.01	21.93	8.18	51.11	-	-	-	-
Licomophora flabellata	16.01	21.93	-		-	-	-	-
Navicula ramosissma	14.11	19.33	-		-	-	-	-
Navicula sp.	-	-	3.22	20.11	-	-	-	-
Padina fraseri								
Cocconeis lineatus	-	-	-	-	3.90	10	-	-
Cylindrotheca closterium	-	-	1.93	19	-	-	-	-
Navicula sp.	-	-	1.73	17	-	-	-	-
Nitzschia sp.	-	-	1.33	13	-	-	-	-
Prorocentrum lima	-	-	1.00	10	-	-	-	-
Trichodesmium sp.	-	-	-	-	3.90	10	-	-
Sargassum muticum								
Leptocylindrus minimus	-	-	9.20	10	-	-	-	-
Leptocylindrus minimus	-	-	-	-	-	-	6.36	37
Navicula distans	-	-	23.00	25	-	-	-	-
Navicula transitans	-	-			-	-	1.69	10
Navicula vanhoeffeni	-	-	11.04	12	-	-	-	-
Nitzschia socialis	-	-	23.00	25	-	-	-	-
Turbinaria ornata								
Bacillaria paxillifer	0.74	15	-	-	-	-	-	-
Leptocylindrus minimus	2.94	59	-	-	-	-	-	-
Leptocylindrus danicus	-	-	39	20.65	10.32	10.32	-	-
Leptocylindrus minimus	-	-	-	-	-	-	4.53	14
Nitzschia hungarica	-	-	-	-	-	-	5.36	17
Thalassionema frauenfeldii	-	-	-	-	-	-	3.71	12

Table 3: List of dominant (10% or above) epiphytes cell abundance (10^5 cell/100 g of seaweeds) and host seaweeds found from winter to autumn 2015 at northwest coast of Jeddah, the Red Sea.

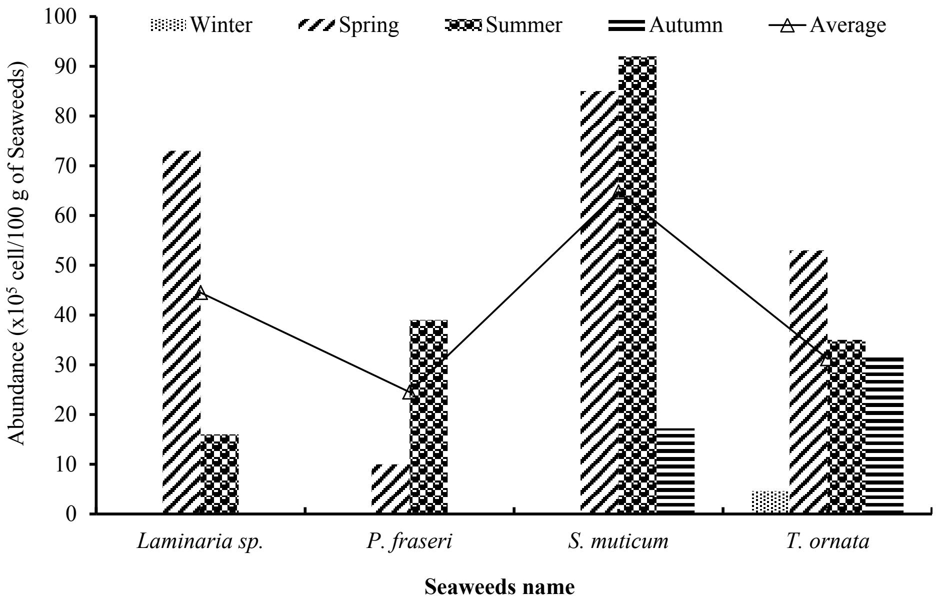

Figure 5: Variation of epiphytes cell abundance associated with seaweeds of Phaeophyceae available at northwest coast of Jeddah from winter to autumn 2015.

environmental factors and predators control the abundance of epiphytic microalgae [33]. In this study, some of the species diatoms among 78 species of diatoms might be obligatory to be epiphytic in habitat. It is reported that the genera *Cocconeis*, *Achnanthes*, and *Tabularia* are obligate diatoms [32,34]. Among the epiphytic smaller diatoms, the genera of *Leptocylindrus* sp., *Licmophora* sp., *Cocconeis* sp., and some species *Navicula ramossima*, *Navicula distans*, *Navicula transitans*, *Navicula vanhoeffeni* and *Nitzschia socialis* were found to be obligate epiphytes at different seasons on different type of seaweed of *Phaeophyceae*. There is evidence that tube forming species of *Navicula*, *Nitzschia* and *Amphora* which create cells masses within a gelatinous matrix are epiphytes [32]. Thus, the species which showed 10% or more abundance among the microalgae found on the leaves of seaweeds of *Phaeophyceae* can be consider as real epiphytic microalgae though they occurred in different seasons on same or different genus of seaweeds of *Phaeophyceae*.

Diatoms were the most dominant epiphyte though some also from Dinophyta, Chlorophyta and Cyanophyta. Diatoms have advantage over other group of epiphytes because of their high fucoxanthin content. Fucoxanthin is known as the most efficient photosynthetic carotenoid absorbing light in the green waveband [35]. Thus, diatoms become dominant on the seaweeds in coastal waters with effect of available of particulate and dissolved organic matter and blue light. The blue light can rapidly attenuated with preferential transmission of the green-to- yellow wavelengths for photosynthesis [36]. Additionally, it is well know that vegetative ecosystems are ideal habitats for benthic diatoms and other epiphytes since seaweeds leaves provide greater surface area for the colonization and growth of diatoms [37,38] found that diatoms and bacteria are the first organisms which make colony on the submerged objects. Therefore, dominancy of diatoms on submerged seaweeds of *Phaeophyceae* from spring to autumn might be occurred due to suitable circumstance with favorable temperature and light as those seasons day length is longer in Saudi Arabia than that of winter.

However, Ramm [39] reported that the reasons for a specific dependency of epiphytic microalgae on the substratum might be related with the shape of the thalli surface. The diatoms with small attaching area like *Licmophora* sp., is predominant on fine branched thalli while think branched thalli are preferred by diatoms with a large attaching area like *Cocconeis* sp., and tube living diatoms like *Navicula* sp., [39]. In this study, the seaweeds of *Phaeophyceae* having larger and branched thalli which provided suitable substratum for small and large attaching diatoms. In all seasons, almost same species (*Leptocylindrus* sp., *Licmophora* sp., *Navicula* sp. and *Nitzschia* sp.) of epiphytic microalgae were found to be dominant on the four species of seaweeds of *Phaeophyceae*. Thus, it can be said that these epiphytes are obligate on the seaweeds (*Laminaria* sp., *P. fraseri*, *S. muticum* and *T. ornata)* of *Phaeophyceae*. Except diatoms, a species of dinoflagellates (*Prorocentrum lima*) was found to be epiphytic on *Padina fraseri* seaweed and it was found to be dominant above 10% to the total epiphytic microalgae. It is well known that dinoflagellates are planktonic species, thus its presence as a dominant species might be related with the occurrence of its bloom and it attached with seaweeds temporarily during spring.

Conclusion

The host seaweeds influenced the associated diatoms mainly through its morphology and surface texture and roughness, providing a point of attachment and shelter for host-adapted species. Depth affected diatom community growth form structure. The seaweeds were collected from intertidal zone where the water depth was around half meter. Four species seaweeds of *Phaeophyceae* were found at the study area throughout the year. Most of the dominant epiphytes were in smaller cell size diatoms, except *Cylindrotheca closterium*. The findings of the study focused on the need for further, long-term and spatially extensive investigations to gather the necessary information about individual species of benthic marine diatoms associated with specific seaweeds species even in different regions of the Red Sea in different seasons of Saudi Arabia. These findings could be the important source for future explanation of marine eco-biogeographical phenomena in the Red Sea.

Acknowledgement

This project was funded by the Deanship of Scientific Research (DSR), King Abdulaziz University, Jeddah, under grant no. 468/150/1434. The authors, therefore, acknowledge with thanks DSR technical and financial support.

References

1. Murphy S, Eunice H, Pinn, Paul DJ (2013) The short-beaked common dolphin (*Delphinus delphis*) in the north-east Atlantic: distribution, ecology, management and conservation status. Oceanogra Mar Biol 51: 193-280.
2. Ballesteros E (1992) The coastal zoning and vegetables: That factors influencing species and communities in their distribution. Institute of Catalan Studies, Barcelona 101: 613.
3. Sales M, Ballesteros E (2009) Shallow Cystoseira (Fucales: Ochrophyta) assemblages thriving in sheltered areas from Menorca (NW Mediterranean): relationships with environmental factors and anthropogenic pressures. Estuar Coast Shelf Sci 84: 476-482.
4. Jacobi CM, Langevin R (1996) Habitat geometry of benthic substrata: effects on arrival and settlement of mobile epifauna. J Exp Mar Biol Ecol 206: 39-54.
5. Heck KL, Orth RJ (1980) Seagrass habitats: the role of habitat complexity, competition and predation in structuring associated fish and motile macroinvertebrate assemblages. In: V. Kennedy (ed.), Estuarine perspectives. Academic Press, San Diego, pp: 449-464.
6. Stoner AW, Lewis FG (1985) The influence of quantitative aspects of habitat complexity in tropical seagrass meadows. J Exp Mar Biol Ecol 94: 19-40.
7. Mazzella L, Russo GF (1989) Grazing effect of two Gibbula species (Mollusca, Archaeogastropoda) on the epiphytic community of *Posidonia oceanica* leaves. Aquatic Botany 35: 357-373.
8. Burkholder JM, Wetzel RG, Komparens KL (1990) Direct comparison of phosphate uptake by adnate and loosely attached microalgae within an intact biofilm matrix. Appl Environ Microbiol 56: 2882-2890.
9. Cattaneo A, Kalff J (1978) Seasonal changes in the epiphyte community of natural and artificial macrophytes in Lake Memphremagog (Que. and Vt.). Hydrobiol 60: 135-144.
10. Frankovich TA, Zieman JC (1994) Total epiphyte and epiphytic carbonate production on Thalassia testudinum across Florida Bay. Bull Mar Sci 54: 679-695.
11. Burkholder JM, Wetzel RG (1990) Epiphytic alkaline phosphatase on natural and artificial plants in an oligotrophic lake: re-evaluation of the role of macrophytes as a phosphorus source for epiphytes. Limnol Oceanogr 35: 736-747.
12. Kitting CL, Fry B, Morgan MD (1984) Detection of inconspicuous epiphytic algae supporting food webs in seagrass meadows. Oecology 62: 145-149.
13. Sullivan MJ, Moncreiff CA (1990) Edaphic algae are an important component of salt marsh food-webs: evidence from multiple stable isotope analyses. Mar Ecol Prog Set 62: 149-159.
14. Aburto-Oropeza O, Sala E, Paredes G, Mendoza A, Ballesteros E (2007) Predictability of reef fish recruitment in a highly variable nursery habitat. Ecology 88: 2220-2228.
15. Cheminee A, Sala E, Pastor J, Mangialajo L, Cottalorda JM, et al. (2010) Algal forests and the replenishment of Mediterranean rocky fishes. Consequences of the decline of Cystoseira forests on Mediterranean juvenile fish populations. ICES (ASC edn.), p: Q17.
16. Prado P, Alcoverro T, Mart´ınez-Crego B, Verg´es MA, P´erez, et al. (2007)

Macrograzers strongly influence patterns of epiphytic assemblages in seagrass meadows. J Expt Mar Biol Ecol 350: 130-143.

17. Mabrouk L, Hamza A, Brahim MB, Bradai MN (2011) Temporal and depth distribution of microepiphytes on *Posidonia oceanica* (L.) Delile leaves in a meadow off Tunisia. Mar Ecol 32: 148-161.

18. Sofianos SS, Johns WE (2002) An Oceanic General Circulation Model (OGCM) investigation of the Red Sea circulation, 1. Exchange between the Red Sea and the Indian Ocean. J Geophys Res 107: 3196.

19. Marcos SA (1970) Physical and chemical oceanography of the Red Sea. Oceanogr Mar Biol Ann Rev 8: 73-202.

20. Manasrah R, Badran M, Lass HU, Fennel WG (2004) Circulation and winter deep-water formation in the northern Red Sea. Oceanology 46: 5-23.

21. Acker J, Leptoukh G, Shen S, Zhu T, Kempler S (2008) Remotely-sensed chlorophyll a observations of the northern Red Sea indicates seasonal variability and influence of coastal reefs. J Mar Sys 69: 191-204.

22. Weikert H (1987) Plankton and the pelagic environment. In: Edwards AJ, Head SM (eds.) Key Environments: Red Sea. Pergamon Press, Oxford, pp: 90-111.

23. Aleem AA (1978) Contributions to the study of the marine algae in the Red Sea. III. Marine algae from Obhur in the Vicinity of Jeddah, Saudi Arabia. Bull Facul Sci KAU Jeddah 2: 99-118.

24. Khomayis HS (2002) The annual cycle of nutrient salts and chlorophyll a in the coastal waters of Jeddah, Red Sea. J KAU: Mar Sci 13: 131-145.

25. Khomayis HS, Harbi SMA (2003) Pcriphyton flora in the coastal water of Jeddah, Saudi Arabia. J KAU: Mar Sci 14: 3-18.

26. Harbi SMA, Affan MA (2016) Seasonal dynamics of epiphytic microalgae and their host seaweeds florideophyceae at jeddah coast, the Red sea, Saudi Arabia. Pak J Bot 8: 1289-1298.

27. Prescott GW (1973) Algae of the western Great Lakes area. Dubuque, W.C. Brown.

28. Tomas CR (1993) Marine Microalgae, a guide to naked flagellates and coccolithophorids. Academic Press, Harcourt Brace, San Diego, California, USA.

29. Tomas CR (1997) Identifying marine microalgae. Academic Press, Harcourt Brace, San Diego, California, USA.

30. Shim JH (1994) Illustrated encyclopedia of fauna and flora of Korea, vol. 34 Marine microalgae. Ministry of Education, Seoul, Korea, p: 487.

31. Kobayasi H, Idei M, Mayama S, Nagumo T, Osada K, et al. (2006) Atlas of Japanese Diatoms based on electron microscopy. Uchida Rokakuho Publishing Co. Ltd., Tokyo.

32. Round FE, Crawford RM, Mann DG (1990) The diatoms: biology & morphology of the genera. Cambridge University press, Cambridge, p: 747.

33. Borowitzka MA, Lavery P, Keulen M (2006) Epiphytes of seagrasses, in Seagrasses: Biology, Ecology and Conservation. In: Larkum AWD, Orth RJ, Duarte CM (eds.) Springer, Amsterdam, The Netherlands.

34. McIntire CD, Moore WW (1977) Marine littoral diatoms: ecological considerations. In: Werner D (ed.) The Biology of Diatoms. Blackwell, Oxford, pp: 333-371.

35. Ondrusek ME, Bidigare RR, Sweet ST, Defreitas DA, Brooks JM (1991) Distribution of phytoplankton pigments in the North Pacific Ocean in relation to physical and optical variability. Deep-sea Res 38: 243-266.

36. Gin KYH, Zhang S, Lee YK (2003) Phytoplankton community structure in Singapore's coastal waters using HPLC pigment analysis and flow cytometry. J Plankton Res 25: 1507-1519.

37. Zieman JC, Fourqurean JW, Iverson RL (1989) Distribution, abundance and productivity of seagrasses and macroalgae in Florida Bay. Bull Mar Sci 44: 292-311.

38. Novak R (1984) A study in ultra-ecology: microorganisms on the seagrass *Posidonia oceanica* (L.) Delile. Mar Ecol 5: 143-190.

39. Ramm G (1976) Structure of epiphytic diatom populations of the phytal of the Kiel Bight (Western Baltic). In: Simonsen R. (ed.) Proceedings of Fourth Symposium on Recent and Fossil Marine Diatoms. Ganter Verlag KG, Germany, pp: 379-387.