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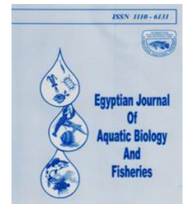

An Ecological Study of Seaweeds Along the Eastern Coast of Alexandria, Egypt, Mediterranean Sea, with Emphasis on the Newly Recorded Alga *Phyllymenia gibbesii* (Harvey) Showe M. Lin *et al.*

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ABSTRACT

An ecological study of seaweeds was carried out bimonthly from April 2015 until June 2016 at five sites located along the Eastern Coast of Alexandria, Egypt (Mediterranean Sea) by examining the conspicuous seaweed community structure and function using percentage cover in addition to the physical and chemical variables of their habitats. This study focused on the newly introduced *Phyllymenia gibbesii* and its distribution for the first time. A total of 18 seaweed species were identified, which is among them, the opportunistic *Ulva lactuca* recorded the highest average percentage cover (35.26-80.22%). *Phyllymenia gibbesii* appeared twice during the study period, with a very low total average cover (0.63%), contributing very little to the main bulk at the time of sampling, thus it cannot be considered as an invasive species. Principal Component Analysis demonstrated that the percentage cover of the algal assemblage was influenced to different degrees by the physical and chemical variables of the ambient seawater. The ecological status of the five sites revealed that they fall between bad and moderate, while the dominance of the opportunistic species and the high load of nutrients in the study area reflected signs of pollution.

INTRODUCTION

Seaweeds play a significant role in aquatic and global ecosystems **(Filbee-Dexter & Wernberg, 2018; Duffy *et al.*, 2019)**. According to the Water Framework Directive (WFD 2000/60/ EC), macroalgae are one of the biological quality elements used for evaluating the ecological quality status of a water body. They are valuable indicators of water quality since they respond to changes in nutrient concentrations and hydrographic conditions **(Orfanidis *et al.*, 2021)**. Notably, coastal areas are the most subjected to intensive human activities such as tourism, agricultural drainage, industrial effluents, and particularly domestic sewage, causing deterioration in water quality **(Zheng & Liu, 2021)**. All these activities affect the structure and function of macroalgal communities on rocky shores, with drastic changes in seaweed diversity in many regions worldwide **(de Faveri *et al.*, 2015; Kostamo *et al.*, 2019)**. Climate change is another consequence of human activities, resulting in several adverse impacts on marine ecosystems, including being threatened by a number of invasive species **(SCBD, 2009)**. A significant question being asked right now is how invasive species will affect native species in their habitats. Consequently, studies of the algal flora are necessary to acquire the distributional data concerning each species, either considering them as native or alien and to provide ecological information on local communities in response to environmental conditions **(D'Archino & Piazzi, 2021)**.

In Egypt, the Mediterranean coastal areas suffer from deterioration in water quality, with several hot spot zones being identified **(Dorgham, 2011)**. This is because of the large amounts of wastewater received each year, which are discharged bearing different kinds of contaminants in addition to nitrogenous and phosphorous chemicals, leading to a high level of pollution and/or eutrophication. Consequently, the entire coastal biota was impacted by these unfavorable conditions **(Dorgham, 2011)**.

The Egyptian Mediterranean coast was previously highly diversified in seaweeds (244 species) **(Aleem, 1993)**. Since 1993, very few studies were carried out on seaweed diversity and the ecological conditions of their habitats **(Labib *et al*., 2015; El-Dahhar *et al*., 2017; Khalil *et al*., 2020)**. These studies highlighted the decrease in seaweed diversity and the drastic change in seaweed communities, coupled with the degradation of the water quality at many sites at the coast. On the other hand, there are rare studies concerning alien species or the newly recorded ones in the Egyptian Mediterranean Sea **(Garreta *et al*., 2001; Madkour & El-Shoubaky, 2007; El-Shoubaky, 2013)**. A recent study by **Rodriguez-Prieto *et al*. (2021)** revealed the presence of the newly introduced species *Grateloupia gibbesii* Harvey, which was previously misidentified as *Grateloupia doryphora* **(Shafik & Taha, 2008; Shams El-Din & Aboul-Ela, 2017)**. The species was originated from South Carolina **(Rodriguez-Prieto *et al.*, 2021)** and is currently regarded as *Phyllymenia gibbesii* **(Rodríguez-Prieto *et al*., 2022)**.

This study investigated the distribution of the conspicuous seaweeds along the Eastern Coast of Alexandria to track the changes that might take place in the macroalgal assemblages in response to changes in the physical and chemical variables of their surrounding water. The study aimed to gather reliable information that could be incorporated into monitoring strategies and future plans for sustainable management. In addition, the study focused, for the first time, on the distribution of the alien red alga *P. gibbesii*.

MATERIALS AND METHODS

1. Study area

Algal and water samples were collected bimonthly from April 2015 until June 2016 from five different sites across the coast of Alexandria, Egypt (Mediterranean Sea), representing different environmental conditions. The chosen sites were as follows: Abu-Qir, Miami, El-Saraya, Gleem, and Eastern Harbor (Fig. 1).

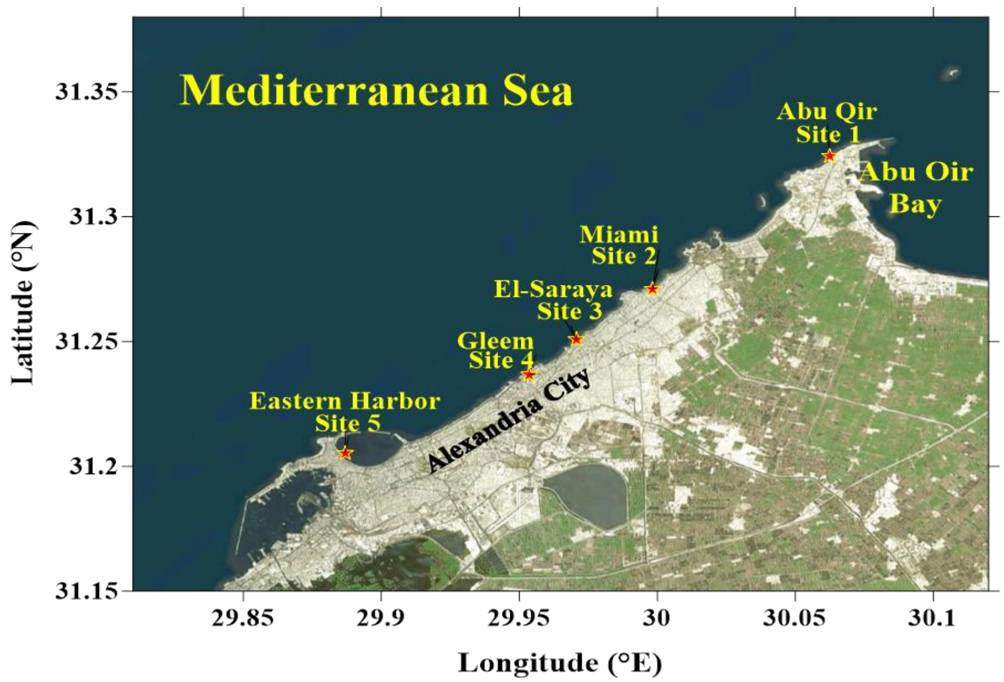


Fig. 1. Alexandria coast line map showing the locations of the five sites

Abu-Qir Bay (Site 1) is a heavily polluted part of the Egyptian Mediterranean, as it suffers from numerous pollution sources **(Waheed *et al.*, 2013)**. It is subject to freshwater discharge loaded with industrial and domestic wastes, and oil pollution **(Shams El-Din & Dorgham, 2007)**, as well as nutrients **(Shreadah *et al*., 2019)**.

Miami (Site 2) is a sandy-rocky shore with shallow depths dedicated to tourism activity. El-Saraya (Site 3) is entirely composed of artificial concrete rocks, and it is subject to human activities and environmental pressures **(Ismael, 2014)**.

Gleem (Site 4) is a sandy-rocky shore consisting of outcrops of rocky islets aligned parallel to the shoreline acting as natural wave breakers **(Iskander, 2016)**. This site is subject to nutrient enrichment **(Nabih, 1989)**.

The Eastern Harbor (Site 5) is considered a eutrophic area **(Halim *et al*., 1980; Madkour & El-Shoubaky, 2007)**, recording high algal blooms associated with fish mortality due to excessively high nutrients **(Ismael & Halim, 2007; Ismael, 2012)**.

2. Collection of water samples

Water samples were collected from the same sites and at the same depth (0.5-1.0m) as the seaweeds. The samples were collected in 1-liter plastic bottles to determine all the studied parameters. Temperature, pH, and salinity of seawater were measured *in situ* by the Hydrolab (Crison model MM+40). Dissolved oxygen (DO) was measured according to Winkler's method as modified by **Strickland and Parsons (1968)**. Ammonium (NH_4-N) was determined according to the Intergovernmental Oceanographic Commission **(IOC, 1983)**. Nitrate (NO_3-N) and nitrite (NO_2-N) were determined according to **Strickland and Parsons (1968)**. Reactive soluble phosphate (PO_4-P) was measured according to **Murphy and Riley (1962)** as modified by **Grasshoff *et al*. (1983)**. Silicate (SiO_4-Si) was assessed according to **Grasshoff (1964)**. All of these nutrients were estimated spectrophotometrically by using a T60 UV/VIS spectrophotometer. Three replicates for each nutrient sample were prepared for measurement. The values of all nutrients were expressed as µM.

3. Collection of seaweeds

3.1. Qualitative sampling

Specimens of conspicuous seaweeds were hand-collected whole from the substrata to which they were adhering. The samples were washed with seawater at the sampling site to remove adhered sediments and impurities, and were put in polyethylene bags in an ice box for further identification. In the laboratory, quick rinsing of the algae with tap water was carried out on the same day to eliminate the remaining impurities and epiphytes. Samples were preserved in 4% formalin-seawater and/or pressed for herbarium specimen sheets. The algae were identified by morphological traits using identification guides and keys for identification according to **Riedel (1970)**, **Aleem (1993)**, and **Cabioch *et al*. (2014)**. The identification of *Grateloupia gibbesii* was undertaken according to **Rodriguez-Prieto *et al*. (2021)**. The taxonomic position of *G. gibbesii* was updated to *Phyllymenia gibbesii* according to **Rodriguez-Prieto *et al*. (2022)**. In addition, the other recorded macroalgal species were updated according to the taxonomic database (www.algaebase.com) created by **Guiry and Guiry (2024)**.

3.2. Quantitative sampling

Non-destructive samples investigating the percentage cover of seaweeds, using ten replicate quadrats with an area of 0.25m^2, were randomly taken from the littoral zone of each site from 0.5 to 1.0m under the water surface. Thus, the value of the percentage cover is the average of 10 replicas. Seaweed percentage cover for each subdivision in each quadrat was estimated in the field according to **Litter and Litter (1985)**.

The ecological evaluation index (EEI) designed by **Orfanidis *et al*. (2001)** was applied in the current study using the percentage cover of the conspicuous algae to estimate the ecological status of the five sites located along Alexandria's coastline. The EEI quantifies shifts in the marine ecosystem structure and function, evaluated by classifying the recorded seaweeds in two Ecological State Groups I & II (ESGs I, II). These groups represent pristine and degraded ecological states, respectively. According to the classification adopted by **Orfanidis *et al*. (2001)**, ESG I includes seaweed species with thick or calcareous thalli, low growth rates, and long-life cycles, whereas ESG II includes sheet-like and filamentous seaweed species with high growth rates and short life cycles (opportunistic).

4. Multivariate analysis

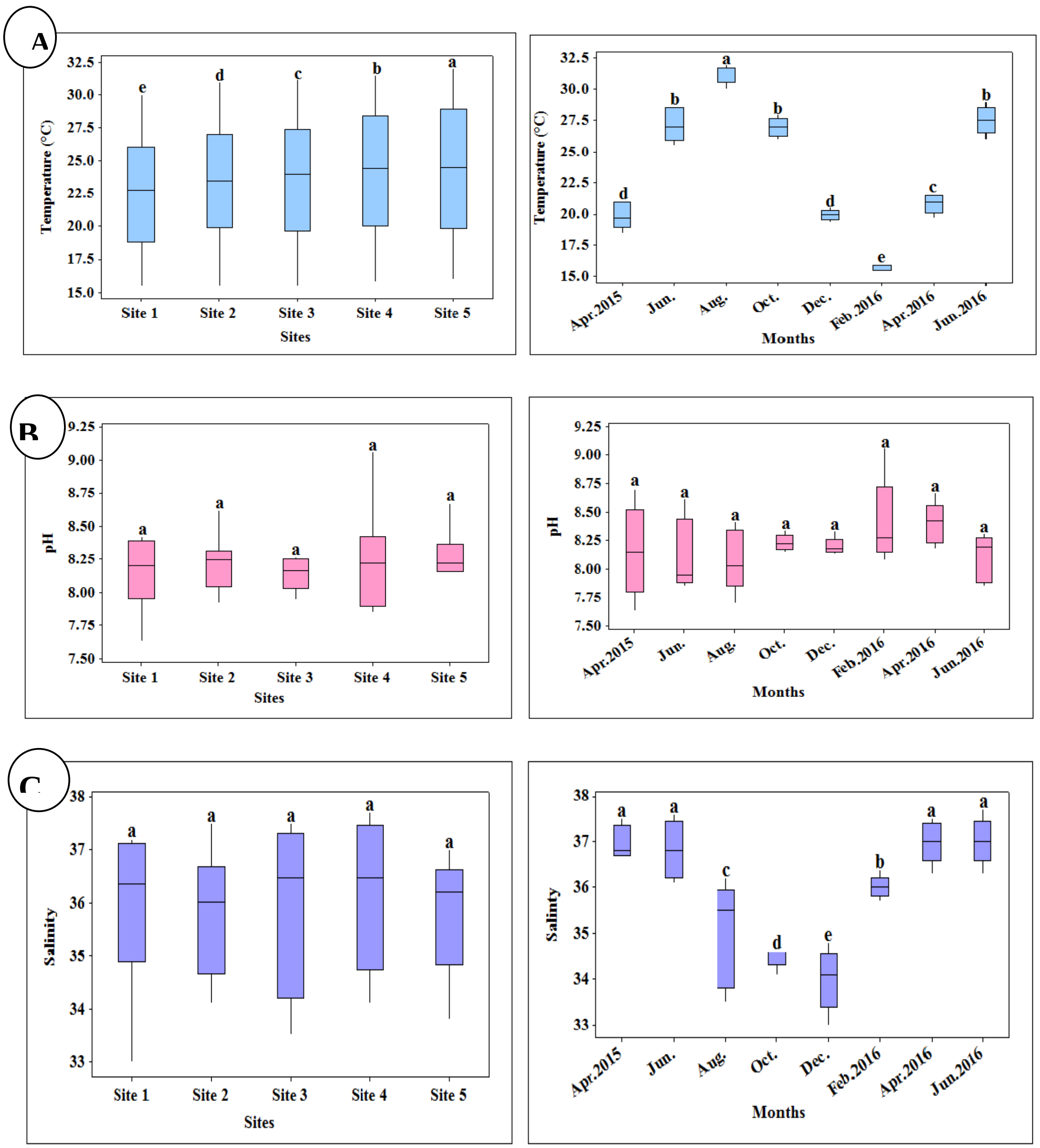
The box plot graphs show the spatial and temporal variation of the physical and chemical variables as well as variation of percentage cover of the two dominant macroalgae using Minitab (Version14) software, while a two-way ANOVA showed the statistical significance of these variations using Minitab (Version14) software. The two-way ANOVA was applied on three replicates only for the chemical variables. Principal Component Analysis (PCA), on the other hand, was conducted between the percentage cover of the algal assemblages and the physical and chemical variables using Minitab-14 in order to find out the effect of these variables on the algal species.

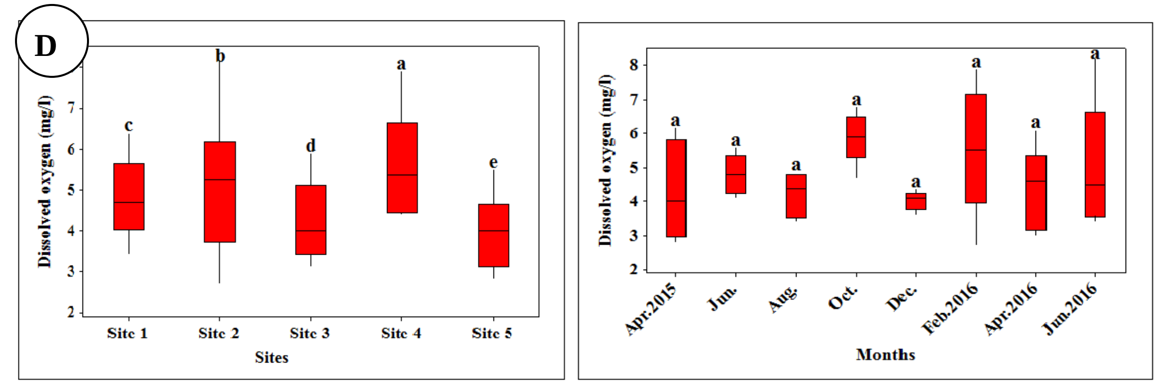
3. RESULTS

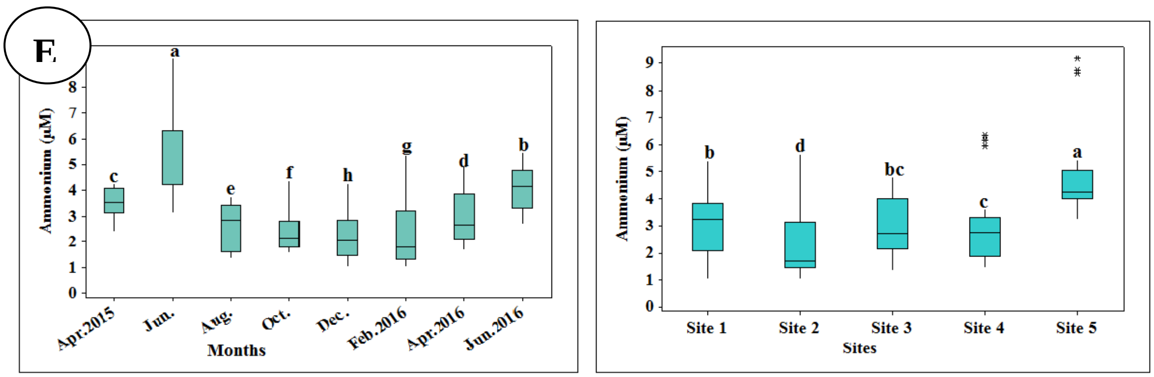
1. Water quality

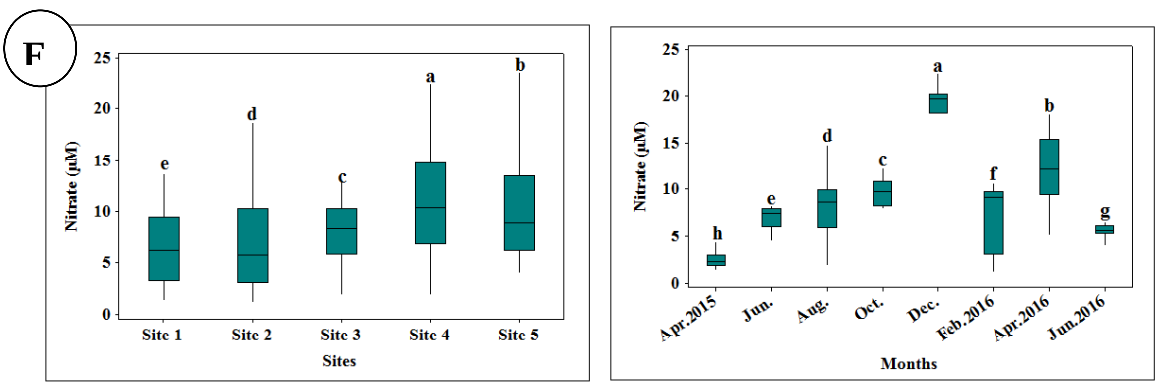
In the current study, the results of the two-way ANOVA showed that temperature differed significantly between months (F=386.44, $P\leq 0.05$) and among the five sites (F= 10.15, $P\leq 0.05$). Temperature values ranged from a minimum of 15.5°C during February 2016 to a maximum of 32°C during August 2015 (Fig. 2A). For pH values, they were mostly alkaline ranging from 7.63 at Site 1 to 9.06 at Site 4 (Fig. 2B). The two-way ANOVA showed that there was no significant difference between sites or between months (Fig. 2B). Water salinity varied between 33 at Site 1 and 37.7 at Site 4, showing only significant monthly variation during the course of the study (F= 20.76, $P\leq 0.05$; Fig. 2C). The levels of dissolved oxygen (DO) showed that the study area could be considered well ventilated, except for the values recorded at Sites 2 and 5 (2.70 and 2.80 mgO_2l^{-1}, respectively; Fig.2D). The two-way ANOVA assessed that the variability was significantly different only between sites (F=2.80, $P\leq 0.05$; Fig. 2D). Ammonium concentrations were maximal at 9.17µM during June 2015 and at a minimum of 1.02µM during December 2015 and February 2016 (Fig. 2E). Noticeably, Site 5 showed the highest ammonium median (4.24µM) (Fig. 2E). The ANOVA results showed that ammonium concentrations differed significantly between months (F= 267.75, $P\leq 0.05$) and among the five sites (F=293.32, $P\leq 0.05$; Fig. 2E). In general, nitrate concentrations were high during the study period (1.15-23.51µM) (Fig. 2F) and differed significantly between months (F= 182, $P\leq 0.05$) and among the five sites (F= 38.98, $P\leq 0.05$; Fig. 2F). The nitrite concentrations were at their lowest (0.20µM) during August 2015 and at the highest value (4.73µM) during December 2015 (Fig. 2G). The ANOVA results showed that nitrite concentrations differed significantly between months (48.31, $P\leq 0.05$) and among the five sites (F=10.95, $P\leq 0.05$;

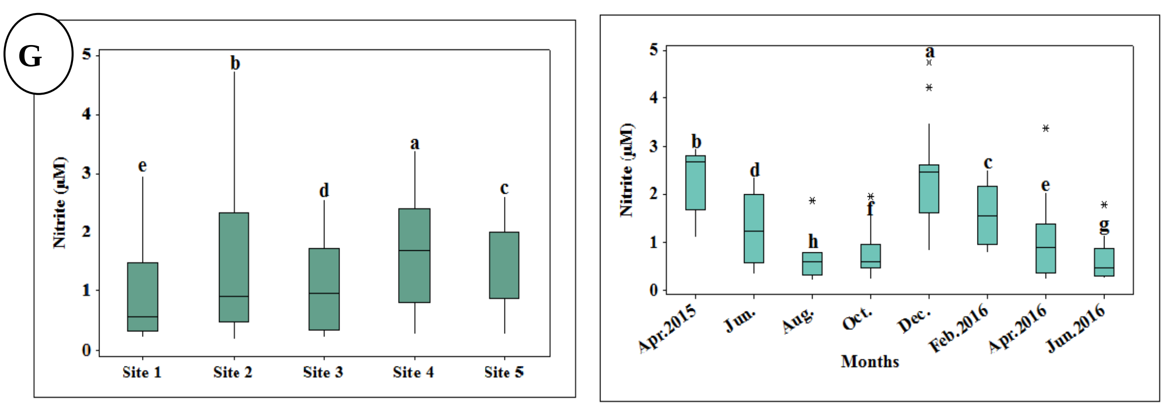
Fig. 2G). The concentrations of phosphate were at their highest values at Site 5 during June 2016 (4.61µM), and their lowest at Site 3 during April 2015 (0.12µM; Fig. 2H). The ANOVA results showed that phosphate concentrations differed significantly temporally (F= 569.64, $P\leq 0.05$; Fig.2H) and spatially (F= 175.15, $P\leq 0.05$; Fig. 2H). There were great temporal variations in silicate values from 0.12µM during February 2016 to 18.50µM during December 2015 (Fig. 2I). Site 1 exhibited more variations (0.51 -18.50µM) than the other sites. The temporal and spatial variations were confirmed by ANOVA test (F= 42.63, $P\leq 0.05$ and F= 22.06, $P\leq 0.05$; Fig. 2I), respectively.




D
Dissolved oxygen (mg/l)
Site 1
Site 2
Site 3
Site 4
Site 5
Sites
Apr.2015
Jun.
Aug.
Oct.
Dec.
Feb.2016
Apr.2016
Jun.2016
Months


E
Ammonium (µM)
Apr.2015
Jun.
Aug.
Oct.
Dec.
Feb.2016
Apr.2016
Jun.2016
Months
Site 1
Site 2
Site 3
Site 4
Site 5
Sites


F
Nitrate (µM)
Site 1
Site 2
Site 3
Site 4
Site 5
Sites
Apr.2015
Jun.
Aug.
Oct.
Dec.
Feb.2016
Apr.2016
Jun.2016
Months


G
Nitrite (µM)
Site 1
Site 2
Site 3
Site 4
Site 5
Apr.2015
Jun.
Aug.
Oct.
Dec.
Feb.2016
Apr.2016
Jun.2016
Months

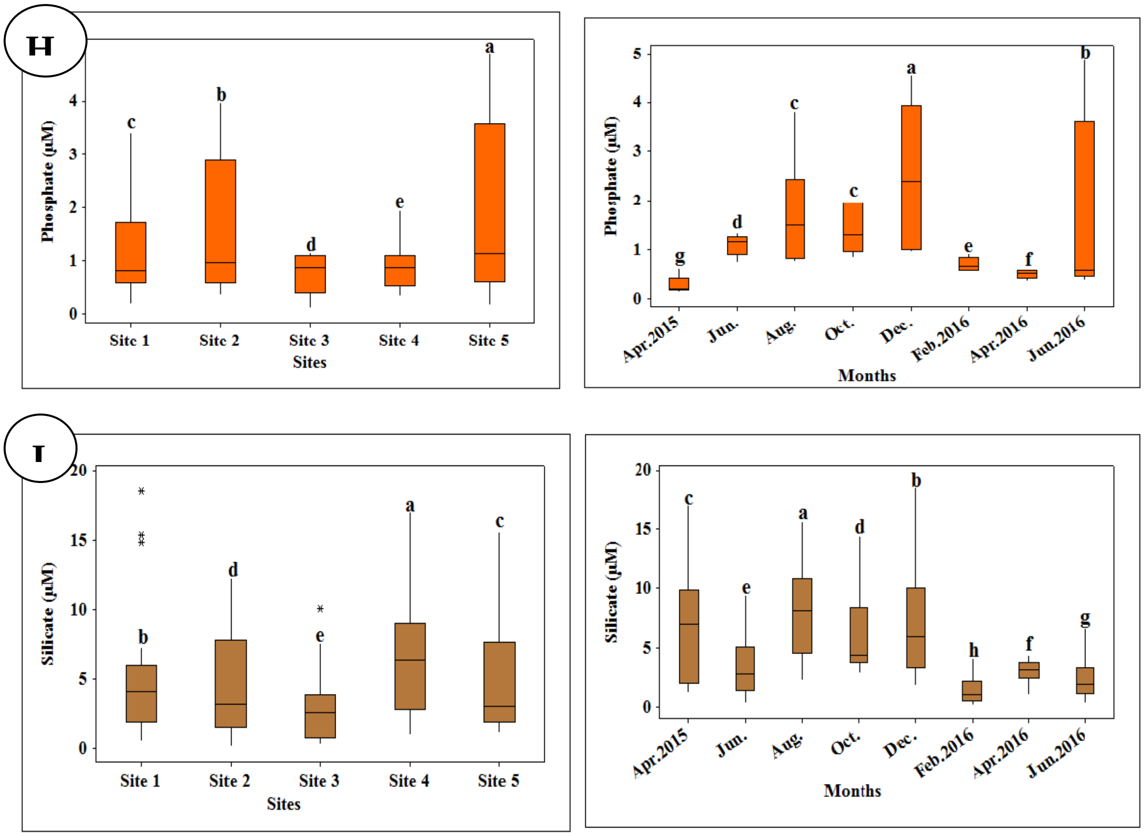


Fig. 2. The spatial and temporal variations of the physico-chemical parameters in the five sites along the Eastern Coast of Alexandria during (2015-2016). Different letters indicate significant differences, while similar letters indicate no significance ($P \leq 0.05$).

2. Characteristics of seaweed communities

2.1. Macroalgal structure

A total of 18 macroalgal taxa were collected and identified from the five sites along the Alexandrian Eastern Coast from April 2015–until June 2016. The collected seaweeds belong to three phyla: Chlorophyta (6 taxa), Rhodophyta (9 taxa), and Ochrophyta (3 taxa). However, 4 taxa represented the pristine (ESC, I), while 14 taxa represented the degraded ecological status class (ESC, II) **(Orfanidis *et al.*, 2001 & 2003)** (Table 1). All the sites experienced low diversity, with one species at Sites 3, 4, and 5, while a maximum of 10 taxa was recorded at Site 4 during June 2015 (Table 2). In fact, the number of seaweed taxa showed both marked temporal (F= 7.67, $P \leq 0.05$) and spatial variations (F= 4.96, $P \leq 0.05$).

Table 1. The recorded seaweed taxa, with their mean percentage cover at each site and their Ecological State Groups (ESG I &II) during 2015- 2016

	Cover %				
Taxa	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**
ESGI					
Phylum: Rhodophyta					
Class: Florideophyceae					
Order: Corallinales					
Family: Corallinaceae					
Ellisolandia elongata (J. Ellis &Solander) K.R. Hind & G.W. Saunders.	19.56	2.88	3.43	5.69	15.24
Corallina officinalis Linnaeus	14.85	34.40	6.86	46.88	44.18
Jania rubens (Linnaeus) J.V. lamouroux	4.85	4.95	0	2.17	0.01
Phylum: Ochrophyta					
Class: Phaeophyceae					
Order: Dictyotales					
Family: Dictyotaceae					
Padina pavonica (Linnaeus) Thivy	0.09	0	0	0	0
ESGII					
Phylum: Chlorophyta					
Class: Ulvophyceae					
I-Order: Bryopsidales					
Family: Bryopsidaceae					
Bryopsis sp.	0	1.73	0	0.12	0.10
Family: Caulerpaceae					
Caulerpa racemosa (Forsskål) J. Agardh	0.69	0	0	0	0
Family: Codiaceae					
Codium vermilara **(Olivi) DelleChiaje**	0	0.39	0	0	0
II- Order: Cladophorales					
Family: Caldophoraceae					
Chaetomorpha linum(O.F. Müller) Kützing	0	0	0	0	0.08
III-Order: Ulvales					
Family: Ulvaceae					
Ulva intestinalis Linnaeus	15.52	14.24	5.12	2.90	0.16
Ulva lactuca Linnaeus	39.21	38.60	80.22	35.26	36.27
Phylum: Rhodophyta					
Class: Florideophyceae					
I- Order: Ceramiales					

Family: Ceramiaceae					
Ceramium ciliatum (J. Ellis) Ducluzeau	0.34	0	0	0.26	0
Ceramium diaphanum (Lightfoot) Roth	0	0	0	1.29	0.26
Family: Rhodomelaceae					
Osmundea pinnatifida (Hudson) Stackhouse	0.43	0	0	0.22	0
II- Order: Gelidiales					
Family: Gelidiaceae					
Gelidium sp.	0	0	0	0	0.15
Family: Pterocladiaceae					
Pterocladiella capillacea (S.G. Gmelin) Santelices & Hommers	0.37	2.42	0	4.10	0.56
III- Order: Halymeniales					
Family: Halymeniaceae					
Phyllymenia gibbesii (Harvey) ShoweM.Lin, Rodríguez-Prieto, De Clerck & Guiry.	0	0	0	0.13	3.00
Phylum: Ochrophyta					
Class: Phaeophyceae					
Order: Ectocarpales					
Family: Scytosiphonaceae					
Colpomenia sinuosa (Mertens ex Roth) Derbès &Solier	3.91	0	4.37	0	0
Petalonia fascia (O.F. Müller) Kuntze	0.19	0.40	0	0.99	0

2.2. Macroalgal abundance

In the present study, the opportunistic species *Ulva lactuca* had a high cover percentage at all sites (Fig. 3A), overwhelming at Site 3 (100%) during August 2015, December 2015, February 2016, and April 2016 (Table 2). Furthermore, the species recorded the highest average percentage cover (35.26-80.22%) (Table 1). The ANOVA results showed that there is only a significant spatial variation (F= 3.68, $P\leq 0.05$) (Fig. 3A). The second dominant species was *Corallina officinalis* recording an average percentage cover (6.86-46.88%), followed by *Ellisolandia elongata* (2.88-19.56%) (Table 1). The percentage cover of *C. officinalis* showed the maximum (100%) at Site 5 during October 2015 and December 2015, while it attained only a 0.61% cover during April 2016 (Table 2). The ANOVA results revealed that there were significant temporal (F= 2.71, $P\leq 0.05$) and spatial significant differences (F= 3.85, $P\leq 0.05$; Fig. 3B). On the other hand, there are five occasional species that appeared once during the study period, *Chaetomorpha linum*, *Caulerpa racemosa*, *Codium vermilara*,*Gelidium* sp. and *Padina pavonica* (Table 2). Noticeably, the newly recorded species *P. gibbesii* appeared twice during the study period and experienced relatively low percentage cover, where it recorded a 23.29% at Site 5 during April 2015, 1.04 and 0.68% at Sites 4 and 5 during June 2015, respectively (Table

2). Thus, the species contributed to the main algal bulk with very low average percentage cover (0.63%).

Table 2. Number of seaweed taxa and their cover percentage at the five sites during 2015- 2016

Taxa/ Site	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Apr-15					
Ulva intestinalis	10.85	6.69	1.38	1.12	1.36
Ulva lactuca	37.29	66.24	63.57	26.7	47.55
Corallina officinalis	14.99	14.01	27.47	34.61	6.83
Ellisolandiae longata	17.41	6.53		20.02	19.76
Gelidium sp.					1.16
Jania rubens	11.54	2.23		9.64	0.05
Pterocladiella capillacea	0.86	1.12			
Phyllymenia gibbesii					23.29
Colpomenia sinuosa	5.51		7.58		
Petalonia fascia	1.55	3.18		7.91	
No. of taxa	**8**	**7**	**4**	**6**	**7**
Jun-15					
Bryopsis sp.		8.24		0.99	0.8
Caulerpa racemosa	5.51				
Codium vermilara		3.09			
Ulva intestinalis	0.73	6.7	25.16		
Ulva lactuca	22.52	76.30	74.84	49.8	56.34
Ceramium cilliatum				2.08	
Ceramium diaphanum				10.3	2.05
Corallina officinalis	7.11	1.5		6.34	1.02
Ellisolandia elongata	33.77	1.5		8.71	39.11
Jania rubens	9.58	1.16		7.72	
Osmundea pinnatifida				1.73	
Pterocladiella capillacea	1.6	1.5		11.29	
Phyllymenia gibbesii				1.04	0.68
Colpomenia sinuosa	18.43				
Padina pavonica	0.76				

No. of taxa	**9**	**8**	**2**	**10**	**6**
Aug-15					
Bryopsis sp.		5.63			
Ulva intestinalis	24.9	65.04		2.1	
Ulva lactuca	51.9	28.03	100	87.37	42.44
Ceramium cilliata	2.7				
Corallina officinalis	0.8	1.3		9.15	44.79
Ellisolandia elongata	13.8			1.38	10.22
Jania rubens	2.0				
Osmundea pinnatifida	3.4				

Table 2. Continued

Taxa/ Site	Site 1	Site 2	Site 3	Site 4	Site 5
Pterocladiella capillacea	0.5				2.55
No. of taxa	**8**	**4**	**1**	**4**	**4**
Oct-15					
Ulva intestinalis	57.35		14.46	20.00	
Ulva lactuca	42.65	57.35	85.54	33.33	
Corallina officinalis		12.09		46.67	100
Jania rubens		16.6			
Pterocladiella capillacea		13.96			
No. of taxa	**2**	**4**	**2**	**3**	**1**
Dec-15					
Ulva intestinalis		17.1			
Ulva lactuca	9.8		100		
Corallina officinalis	47.4	63.3		100	100
Ellisolandia elongate	27.1				
Jania rubens	15.7	19.6			
No. of taxa	**4**	**3**	**1**	**1**	**1**
Feb-16					
Ulva intestinalis	21.01				
Ulva lactuca	3.5	38.5	100	12.9	59.20
Corallina officinalis	47.86	61.5		87.1	34.70
Ellisolandia elongate	27.63				6.10
No. of taxa	**4**	**2**	**1**	**2**	**3**
Apr-16					
Chaetomorpha linum					0.63
Ulva intestinalis		3.36			
Ulva lactuca	62.64	0.53	100	6.59	58.56
Corallina officinalis	0.61	96.11		56.5	17.31
Ellisolandia elongate	36.75			15.41	23.5
Pterocladiella capillacea				21.5	
No. of taxa	**3**	**3**	**1**	**4**	**4**
Jun-16					
Ulva intestinalis	9.26	15			

Ulva lactuca	83.37	41.82	17.8	65.3	26.11
Corallina officinalis		25.38	27.4	34.7	48.79
Ellisolandia elongate		15.0	27.4		23.19
Pterocladiella capillacea		2.8			1.91
Colpomenia sinuosa	7.37		27.4		
No. of taxa	**3**	**5**	**4**	**2**	**4**

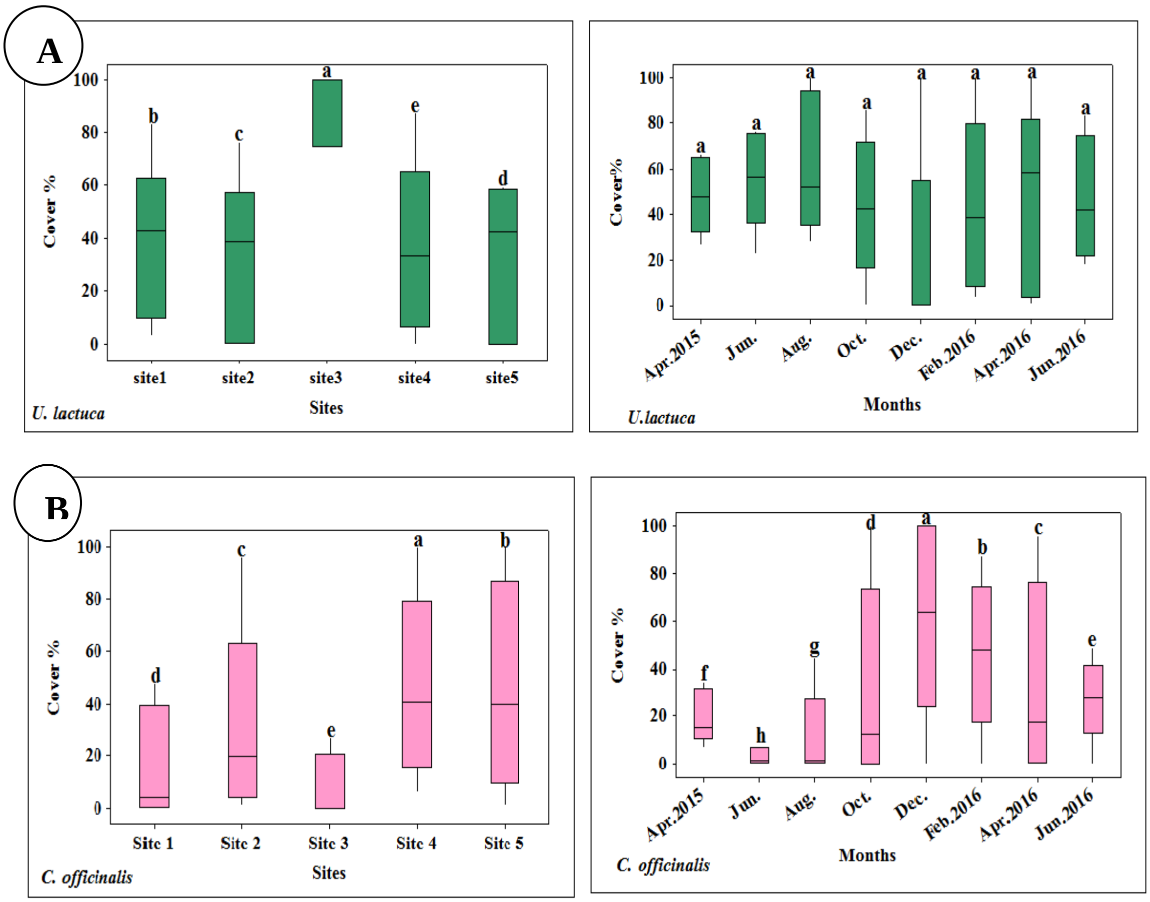


Fig. 3. The spatial and temporal variations of the two-dominant species (*Ulva lactuca* and *Corallina officinalis*) in the five sites along the Eastern Coast of Alexandria during (2015-2016). Different letters indicate significant differences, while similar letters indicate no significance ($P \leq 0.05$).

Using the numerical scoring system for the evaluation of the ecological status of transitional and coastal waters adopted by **Orfanidis *et al*. (2001)**, Site 3 can be classified as having a bad ecological status, followed by Site 1, which showed a low status. Then, Sites (2, 4 and 5) displayed a moderate status (Table 3).

Table 3. Ecological evaluation of the five sites along the coast of Alexandria during 2015-2016

Site	Month	ESG I	ESG II	Ecological status category
Site 1	Apr-15	43.94	56.06	Moderate
	Jun-15	51.21	48.79	Moderate
	Aug-15	16.60	83.40	Bad
	Oct-15	0	100	Bad
	Dec-15	90.2	9.8	High
	Feb-16	75.49	24.51	High
	Apr-16	37.36	62.64	Low
	Jun-16	0	100	Bad
	Mean	**39.35**	**60.65**	**Low = 4**
Site 2	Apr-15	22.77	77.23	Bad
	Jun-15	4.16	95.84	Bad
	Aug-15	1.30	98.70	Bad
	Oct-15	28.66	71.31	Bad
	Dec-15	82.90	17.10	High
	Feb-16	61.50	38.50	Good
	Apr-16	96.11	3.89	High
	Jun-16	40.38	59.62	Moderate
	Mean	**42.22**	**57.78**	**Moderate= 6**
Site 3	Apr-15	27.47	72.53	Bad
	Jun-15	0.00	100	Bad
	Aug-15	0.00	100	Bad
	Oct-15	0.00	100	Bad
	Dec-15	0.00	100	Bad
	Feb-16	0.00	100	Bad
	Apr-16	0.00	100	Bad
	Jun-16	54.80	45.20	Moderate
	Mean	**10.28**	**89.72**	**Bad = 2**
Site 4	Apr-15	64.27	35.73	Good
	Jun-15	22.77	77.23	Bad
	Aug-15	10.53	89.47	Bad
	Oct-15	46.67	53.33	Moderate
	Dec-15	100	0.00	High
	Feb-16	87.10	12.90	High
	Apr-16	71.91	28.09	High
	Jun-16	34.70	65.30	Bad
	Mean	**54.74**	**45.26**	**Moderate = 6**
Site 5	Apr-15	26.64	73.36	Bad
	Jun-15	40.13	59.87	Moderate
	Aug-15	55.01	44.99	Moderate
	Oct-15	0.00	100	Bad
	Dec-15	100	0.00	High
	Feb-16	40.80	59.20	Moderate
	Apr-16	40.81	59.19	Moderate
	Jun-16	71.98	28.02	High
	Mean	**46.92**	**53.08**	**Moderate = 6**

3. Multivariate analysis

Principal Components Analysis (PCA) was performed between the percentage cover of the algal assemblage and the physical and chemical variables of the seawater (Fig. 4). The results revealed three algal categories: the first category included: *Bryopsis* sp., *Chaetomorpha linum*, *Codium vermilara*, *Ulva lactuca*, *U. intestinalis*, *Ceramium ciliatum*, *C. diaphanum*, *Osmundea pinnatifida* and *Pterocladiella capillacea*, the second category included: *Corallina officinalis*, *Jania rubens*, and *Petalonia fascia*, and the last category included: *Caulerpa racemosa*, *Gelidium* sp., *Ellisolandia elongata*, *Phyllymenia gibbesii*, *Colpomenia sinuosa*, and *Padina pavonica*, which were influenced in different degrees by the physical and chemical variables (Fig. 4).

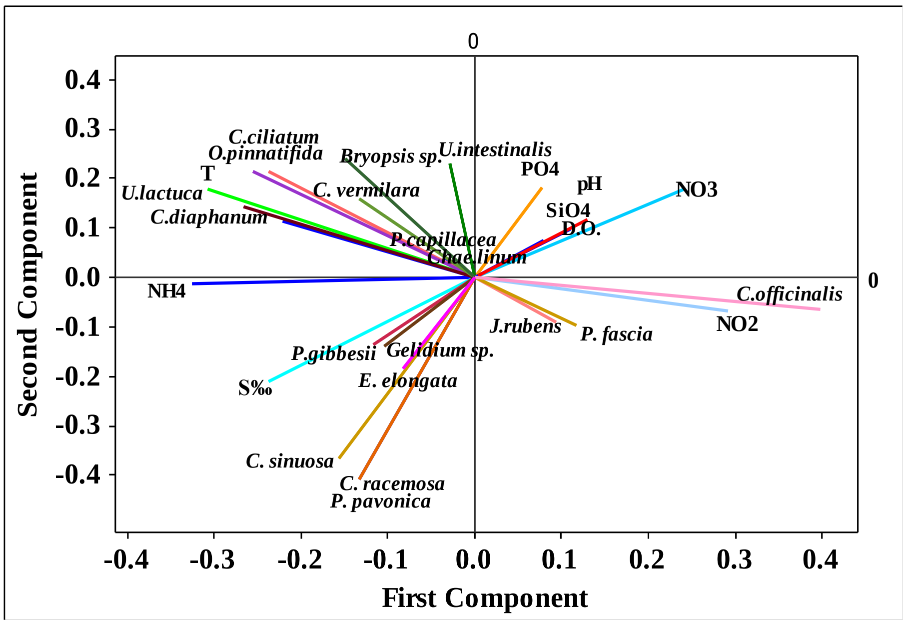


Fig. 4. Principle Component Analysis (PCA) between the percentage cover of the algal species and the physical and chemical variables along the Eastern Coast of Alexandria during 2015-2016

DISCUSSION

1. Water quality

Most ecological studies of seaweeds have emphasized that the amount and type of suitable substrata **(Kautsky & Van der Maarel, 1990)**, turbidity **(Balata *et al*., 2007)**, nutrient supply **(Harley *et al*., 2012)**, and bed stability, all play a significant role in algal growth. For instance, temperature has a significant impact on the nutrients transported to the surface water affecting the metabolism of marine algae photosynthesis, reproduction, and growth **(Barber & Chavez, 1983)**. Salinity is also known to affect macroalgal growth, and a shift in salinity may influence macroalgal compositions **(Larsen & Sand-Jensen**

2006). However, temperature has increased about five degrees in the last few decades along the coast of Alexandria. Many studies have documented this rise (from 25- to 30ºC) and its effects on seaweed communities **(Nasr & Aleem, 1948; Negm, 1976; Nabih, 1989; Soliman, 1997; Khalil *et al*., 2020)**. In the present study, temperature reached a maximum value of 32.00ºC, while salinity reached a maximum value of 37.70, which is lower than the typical values of the Mediterranean Sea and those of the previous studies (39, 39.04, 38.71) **(Nasr & Aleem, 1948; Nabih, 1989; Khalil *et al.*, 2020)**, respectively, affecting seaweed biodiversity and species composition. The first dominant species was the opportunistic species *Ulva lactuca*, which was also listed among eurythermal and euryhaline species and among dominant species in the aforementioned studies. Principle Component Analysis (PCA) revealed that percentage cover of *U. lactuca* was positively influenced by temperature, NH_4-N, and salinity, while the second dominant species, *Corallina officinalis* was sensitive to these three parameters. Dissolved oxygen (DO) is considered one of the most useful parameters for estimating the degree of pollution, which affects marine life through oxygen reduction or depletion, influencing the growth of marine flora **(Shaltout & Abd-El-Khalek, 2014)**. In the present study, the concentration of DO ranged from 2.7- 8.2mg O_2 l^{-1}, whereas all nutrients experienced high concentrations spatially and temporally, with the values of ammonium ranging from 1.02- 9.17µM and nitrate 1.15-23.51µM, exceeding the values adopted by **Vucak and Stirn (1982)** for eutrophic areas (> 2.0µM for NH4-N and > 4.0µM for $N0_3$-N). Accordingly, and despite the fact that the five sites studied are well-oxygenated, they can be classified as polluted due to the high loads of nutrients.

2. Characteristics of seaweeds communities

2.1. Macroalgal structure

The results showed that the five sites were low diversified, and the number of recorded taxa (18 taxa) diminished dramatically compared with the previous study of **Aleem (1993)** (244 species) along Alexandria's coastline. **Khalil (1987)** recorded in Abu-Qir 76 species, against only 16 species recorded later by **Khalil *et al*. (2020)**, who attributed the decline in algal biodiversity to several factors such as temperature, light intensity, salinity, and nutrients of ambient water. Similarly, **Labib *et al.* (2015)** reported a low number of species at Abu Qir (25 species), while **El-Dahhar *et al*. (2017)** recorded 17 species in the East Harbor site. In the present study, such low diversity may be attributed to the continuity of the destruction of the natural reefs due to tourism and other anthropogenic activities.

2.2. Macroalgal abundance

Comparing the five sites, Site 4 was the most diversified site (10 taxa) against the lowest diversified one (Site 3). This is attributed to this site being made of artificial concrete rocks, which act as a limiting factor for the survival of many algal species. The difference between the site's levels of diversity was confirmed by the two-way ANOVA test.

The green alga *Ulva lactuca* was the dominant species at the five sites (35.26-80.22%), followed by *Corallina officinalis* and *Ellisolandia elongate*. **Boderskov and Krause-Jensen (2022)** considered the species of the genera *Enteromorpha*, *Ulva*, *Chaetomorpha*, and *Cladophora* among the opportunistic species, in addition to being classified as the group representing degraded ecological status (ESGI) **(Orfanidis *et al*., 2001, 2003)**. Such opportunistic species can outcompete other seaweeds **(Pihl *et al*., 1999)** since they are able to tolerate harsh environmental conditions **(Messyasz, 2011)**, and are at the same time characterized by high rates of nutrient uptake **(Boderskov & Krause-Jensen, 2022)**. Therefore, they are reliable indicators of polluted and/or eutrophicated areas **(Høgslund *et al*., 2022)**, and they reflect pollution levels at the five sites of the study area. However, the bloom of *U. lactuca* caused the regression of *C. officinalis* and *E. elongate* (ESGI) in the second order in the community structure, although the main feature of the intertidal rock surfaces is a dense carpet-like turfs dominated by corallinates **(Stewart, 1989)**. This regression was confirmed by PCA, where the percentage cover of *C. officinalis* was inversely correlated with *U. lactuca*.

In fact, the occasional species: *Chaetomorpha linum*, *Caulerpa racemosa*, *Codium vermilara*, and *Gelidium* sp., have a meager contribution to the community structure. Moreover, the three phaeophytes *Colpomenia sinuosa*, *Padina pavonica*, and *Petalonia fascia* recorded a very low percentage cover, indicating that the study area suffers from pollution as reported previously by **Mannino and Sara (2007)**. This was confirmed by our PCA results, which showed a negative influence of nutrients on these species.

The newly recorded red alga, *Phyllymenia gibbesii* appeared only during April 2015 at (Site 5) and during June 2015 at Sites (4 and 5), contributing a very low percentage (0.63%) to algal bulk, and so far, it cannot be considered as an invasive species, just an introduced one. In the current study, the species was recorded at a temperature of 21 and 28.5°C. Our results are consistent with the findings of **Shams El-Din & Aboul-Ela (2017)** and **Rodriguez-Prieto *et al.* (2021)**. This was also confirmed by our PCA results, revealing that the percentage cover of the alga was positively influenced by temperature, salinity and NH_4. According to **de la Hoz *et al.* (2018)**, shifts in temperature over the previous 50 years were a significant factor in the arrival and settlement of hundreds of alien species in the Mediterranean basin.

By applying the Ecological Evaluating Index (EEI) adopted by **Orfanidis *et al*. (2001)**, seaweed communities on the Eastern Coast of Alexandria suffer from pollution.

CONCLUSION

According to the percentage cover of the recorded conspicuous species and the Ecological Evaluating Index (EEI), seaweed communities on the Eastern Coast of Alexandria suffer from pollution. This was confirmed by the dominance of the opportunistic alga *Ulva lactuca* and the low number of associated species. On the other hand, the newly recorded alga *Phyllymenia gibbesii* contributed at a negligible rate to the main bulk and based on our data is considered an introduced species in the study area rather than an invasive one. Thus, Alexandria's coastline should be monitored periodically to assess the real impact of *P. gibbesii* in time and space and to predict any potential effects that may be caused by this alien alga on native species.

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REFERENCES

Aleem, A.A. (1993). The Marine Algae of Alexandria, Egypt. 1st ed., Alexandria, ISBN-10: 9770052817, 138 p.

Balata, D.; Piazzi, L. and Cinelli, F. (2007). Increase of sedimentation in a subtidal system: effects on the structure and diversity of macroalgal assemblages. J. Exp. Mar. Biol. Ecol., 351: 73-82.https://doi.org/10.1016/j.jembe.2007.06.019.

Barber, R.T. and Chavez, F.P. (1983). Biological consequences of El Nino. Science 222: 1203-1210. https:// doi: 10.1126/science.222.4629.1203**.**

Boderskov, T. and Krause-Jensen, D. (2022). Literature review of general responses of macroalgae to light, nutrient, salinity and temperature variations relevant to Danish waters. Aarhus University, DCE - Danish Centre for Environment and Energy, 32s. *Scientific briefing* No. 2022|30. Available at: https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Notater_2022/N2022_30.pdf (Accessed 27 April 2022).

Cabioch, J.; Folch, J.Y.; Le Toquin, A.; Boudouresque, J.F.; Meinesz, A. and Verlaque, M. (2014). Algues des mers d'Europe. 3st edition, Delachaux et Niestlé Sa, Paris, 272p.

D'Archino, R. and Piazzi, L. (2021). Macroalgal assemblages as indicators of the ecological status of marine coastal systems: A review. Ecological Indicators**,** 129: 107835.https://doi.org/10.1016/j.ecolind.2021.107835

de Faveri, C.; Schmidt, É.C.; Simioni, C.; Martins, C.D.; Bonomi-Barufi, J.; Horta, P.A. and Bouzon, Z.L. (2015). Effects of eutrophic seawater and temperature onthe physiology and morphology of *Hypnea musciformis* JV Lamouroux (Gigartinales, Rhodophyta). *Ecotoxicology***,** 24**:**1040–1052.

de la Hoz, C.F.; Ramos, E.; Puente, A.; Méndez, F.J.; Menéndez, M.; Juanes, J.A. and Losada, I.J. (2018). Ecological typologies of large areas. An application in the Mediterranean Sea. Journal of Environmental Management, 205: 59-72. https://doi.org/10.1016/j.jenvman.2017.09.058.

Dorgham, M.M. (2011). Eutrophication problem in Egypt. In: Ansari, A., Singh Gill, S., Lanza, G., Rast, W. (Eds), Eutrophication: causes, consequences and control (171-194p) Dordrecht: Springer.

Duffy, J.E.; Benedetti-Cecchi, L.; Trinanes, J.; Muller-Karger, F.E.; Ambo-Rappe, R.; Bostrom, C.; Buschmann, A.H.; Byrnes, J.; Coles, R.G.; Creed J., *et al*. (2019). Toward a coordinated global observing system for seagrasses and marine macroalgae. Frontiers Marine Science, 6: 317. https://doi.org/10.3389/fmars.2019.00317.

El-Dahhar, A.A.; Diab, M.H.; Ismail, M.M. and Labib, W. (2017). Dynamics of macroalgae at two different ecological sites in Alexandria coastal waters. Journal of Ecologica Balkanica, 9(2):57-66.

El-Shoubaky, G.A. (2013). Comparison of the impact of climate change and anthropogenic disturbances on Arish coast and seaweed vegetation after ten years in 2010, North Sinai. Oceanologia, 55: 663-685.https:// doi:10.5697/oc.55-3.663.

Filbee-Dexter, K. and Wernberg, T. (2018). Rise of Turfs: A New Battlefront for Globally Declining Kelp Forests. Bioscience, 68: 64-76. https://doi.org/10.1093/biosci/ bix147.

Garreta, A.G.; Gallardo, T.; Riberaa, M.A.; Cormaci, M.; Furnari, G.; Giacconc, G. and Boudouresque, C.F. (2001). Checklist of Mediterranean Seaweeds III. rhodophyceae. Rabenh. 1.Ceramiales Oltm. Botanica Marina, 44(5): 425-460. https://doi.org/10.1515/BOT.2001.051.

Grasshoff, K. (1964). On the determination of silica in sea water. Deep-Sea Res.11: 597-604

Grasshoff, K.M.; Ehrhardt, M. and Kremling, K. (1983). Determination of nutrients. In: *Methods of Seawater Analysis*. p 143.

Guiry, M.D. and Guiry, G.M. (2024). Algae Base. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org. (Accessed on July 2024).

Halim, Y.; khalil, A. and Al-Handhal, A.Y. (1980). Diatoms flora of a eutrophic bay, the Eastern Harbour of Alexandria. Acta Adriatica, 21(2): 271-298.

Harley, C.D.G.; Anderson, K.M.; Demes, K.W.; Jorve, J.P.; Kordas, R.L.; Coyle, T.A. and Graham, M.H. (2012). Effects of climate change on global seaweed communities. Journal of Phycology, 48(5):1064–1078.

Høgslund, S.; Krause-Jensen, D. and Carstensen, J. (2022). Macroalgae indicators for assessing ecological status in the Baltic and North-East Atlantic. Aarhus University, DCE - Danish Centre for Environment and Energy, 26 pp. - Scientific briefing no. 2022|31.

Intergovernmental Oceanographic Commission (IOC) (1983). Chemical Methods for Use in Marine Environmental Monitoring. Manuals and Guides, UNESCO.

Iskander, M.M. (2016). Development, vulnerability and resilience capacity of Alexandria coastal zone: a review. Research and Technology Development for Sustainable Water Resources Management conference, (REDWARM), Cairo, Egypt.

Ismael, A.A. and Halim, Y. (2007). Potentially harmful microalgae epiphytic on macroalgae along the coast of Alexandria. First IOC/HANAWorkshop on Harmful Algal Blooms in North Africa. Casablanca, Morocco pp. 18–20.

Ismael, A.A. (2012). Benthic bloom of cyanobacteria associated with fish mortality in Alexandria waters. Egyptian Journal of Aquatic Research, 38:241-247.http://doi.org/10.1016/j.ejar.2013.01.001.

Ismael, A.A. (2014). Coastal engineering and harmful algal blooms along Alexandria coast, Egypt. Egyptian Journal of Aquatic Research, 40: 125-131.https://doi.org/10.1016/j.ejar.2014.07.005.

Kautsky, H. and van der Maarel, E. (1990). Multivariate approaches to the variation in phytobenthic communities and environmental vectors in the Baltic Sea. Marine Ecology Progress Series, 60: 169-184.

Khalil, A.N. (1987). A list of the marine algae from the Alexandria coast, Egypt. Bulletinof Institute of Oceanography and Fisheries, 13 (1): 229-241.

Khalil, A.N.; Ismael, A.A.; Halim, Y. and El-Zayat, F.M. (2020). Is the change in biodiversity of macro-algae in Alexandria coastal waters related to climate?.Egyptian Journal of Aquatic Biology and Fisheries, 24: 435 - 457.

Kostamo, K.; Arponen, H.; Eloranta, P.; Kiviluoto, S.; Koistinen, M. and Leskinen, E. (2019). Algae. In: Hyvarinen, E., Juslen, A., Kemppainen, E., Uddstrom, A., Liukko, U.-M. (Eds.). *The 2019 Red List of Finnish Species.* Ministry of the Environment; Finnish Environment Institute, Helsinki, pp. 149-156 (In Finnish, with English summary).

Labib, W.; Abou Shady, A.M.; Mohamed, L.A.; El Shafaay, S.M. and Hosny, S. (2015). Ecological Studies of Macroalgae in Alexandria Mediterranean Waters. Egyptian Journal of Experimental Biology (Botany), 11: 169 - 180.

Larsen, A. and Sand-Jensen, K. (2006). Salt tolerance and distribution of estuarine benthic macroalgae in the Kattegat-Baltic Sea area. Phycologia, 45: 13-23. https://doi.org/10.2216/03-99.1.

Littler, M. M. and Littler, D.S. (1985). Handbook of phycological methods. Ecological field methods: macroalgae. Cambridge University Press 617pp.

Madkour, F.F. and El-Shoubaky, G.A. (2007). Seasonal distribution and community structure of macro-algae along Port Said coast, Mediterranean Sea, Egypt. Egyptian Journal of Aquatic Biology and Fisheries, 11:221-236.

Mannino, A.M. and Sara, G. (2007). Effects of fish-farm biodeposition on periphyton assemblages on artificial substrates in the southern Tyrrhenian Sea (Gulf of Castellammare, Sicily). Aquatic Ecology, 42:575-581. http://doi.org/10.1007/s10452-007-9131-1.

Messyasz, B. and Rybak, A. (2011). Abiotic factors affecting the development of *Ulva sp*. (Ulvophyceae; Chlorophyta) in freshwater ecosystems. Aquatic Ecology, 45(1):75-87.

Murphy, J.A. and Riley, J.P. (1962). A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta, 27:31-36. DOI: 10.1016/s0003-2670(00)88444-5.

Nabih, S. (1989). Composition and distribution of some algal association along Alexandria coast. M. Sc. Thesis (Biological Oceanography) Faculty of Science, Alexandria Univ., Egypt 214 pp.

Nasr, A.H. and Aleem, A.A. (1948). Ecological studies of some marine algae from Alexandria. Hydrobiologia, 1: 251-280.

Negm, S.N. (1976). Studies on some algal plants along the Egyptian Mediterranean Coast of Alexandria with special reference to the genus *Codium.* M.Sc. Thesis, Faculty of Science, Alexandria University 102 pp.

Pihl, L.; Svenson, A.; Moksnes, P.O. and Wennhage, H. (1999). Distribution of green algal mats throughout shallow soft bottoms of the Swedish Skagerrak archipelago in relation to nutrient sources and wave exposure. Journal of Sea Research, 41: 281-295. http://doi. org/10.1016/S1385-1101 (99) 00004-0.

Orfanidis, S.; Panayotidis, P. and Stamatis, N. (2001).Ecological evaluation of transitional and coastal waters: A marine benthic macrophytes-based model. Mediterranean Marine Science, 2: 45-65.https://doi.org/10.12681/mms.266.

Orfanidis, S.; Panayotidis, P.; Stamatis, N. (2003). An insight to the ecological evaluation index (EEI). Journal of Ecological Indicators, 3: 27-33.http://doi:10.1016/S1470-160X (03)00008-6.

Orfanidis, S.; Rindi, F.; Cebrian, E.; Fraschetti, S.; Nasto, I.; Taskin, E.; Bianchelli, S.; Papathanasiou, V.; Kosmidou, M.; Caragnano, A. *et al*. (2021). Effects of Natural and Anthropogenic Stressors on Fucalean Brown Seaweeds Across Spatial Scales in the Mediterranean Sea. Frontiers in Marine Science, 8:658417. doi: 10.3389/fmars.2021.658417.

Riedel, R. (1970). Fauna und Flora der Adria. Verlag Paul Parey, Hamburg, 702 pp.

Rodríguez-Prieto, C.; Shabaka, S.H.; Shams El-Din, N. and De Clerck, O. (2021). Morphological and molecular assessment of *Grateloupia* (Halymeniales, Rhodophyta) from Egypt revealed a new introduced species in the Mediterranean Sea, *Grateloupia gibbesii*. Phycologia, 60: 83-95. https://doi.org/ 10.1080/00318884.2020.1857113.

Rodríguez-Prieto, C.; De Clerck, O.; Guiry, M.D. and Lin, S. M. (2022). Revisiting the systematic of the genera *Grateloupia*, *Phyllymenia*, and *Prionitis* (Halymeniaceae, Rhodophyta) with a description of a new species -*Prionitis taiwani-borealis.* Journal of Phycology, 58: 1-17. https://doi.org/ 10.1111/JPY.13226.

Secretariat of the Convention on Biological Diversity (SCBD)(2009). Connecting biodiversity and climate change mitigation and adaptation: Key messages from the Report of the Second Ad Hoc Technical Expert Group on biodiversity and climate change. Secretariat of the Convention on Biological Diversity, Montreal. Technical Series No. 41.

Shafik, M.A. and Taha, H.M. (2008). The first record for the invasion of the red alga *Grateloupia*to the Egyptian coasts in Alexandria. Egyptian Journal of Biotechnology, 29: 309-328.

Shaltout, N.A. and Abd-El-Khalek, D.E. (2014). Assessment of Seawater Quality of El-Dekhaila Harbor, Alexandria, Egypt. Asian Journal of Advanced Basic Science, 3: 206-216.

Shams El-Din, N.G. and Dorgham, M.M.(2007). Phytoplankton community in Abu-qir bay as a hot spot on the southeastern Mediterranean coast. Egyptian Journal of Aquatic Research, 33: 163-182.

Shams El-Din, N.G. and Aboul-Ela, H.M. (2017). The new record of *Grateloupia doryphora* (Halymeniaceae, Rhodophyta) alga in the Egyptian Mediterranean Sea recognized by morphological and molecular integrative approach. Plant Cell Biotechnology and Molecular Biology,18: 432-449.

Shreadah, M.A.; El-Sayed, A.A.M.; Taha, A.A.S; Ahmed, A.M. and Abdel Rahman, H.H. (2019). Evaluation of Different Anthropogenic Effluents Impacts on the Water Quality Using Principal Component Analysis: A Case Study of Abu-Qir Bay-Alexandria-Egypt. International Journal of Environmental Monitoring and Analysis, **7**: 56-67. https://doi: 10.11648/j.ijema.20190703.11.

Soliman, M.M.Y. (1997). Ecological and biological studies of some benthic communities along Alexandria coast. M.SC. Thesis (Biological Oceanography) Faculty of Science, Alexandria University, Egypt 193 pp.

Stewart, J.G. (1989). Establishment, persistence and dominance of *Corallina* (Rhodophyta) in algal turf. Journal of Phycology, 25: 436-446. https://doi.org/10.1111/j.1529-8817.1989.tb00248.x

Strickland, J.D.H. and Parsons, T.R. (1968). A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada Bulletin, 167: 71-75.

Vucak, Z.A.S. and Stirn, J. (1982). Basic physical chemical and biological data reports. R.V. A Mohorov ICIC Adriatic cruises 1974-76. Hydrograhic Institute of Yugoslav Navy split, 175 pp.

Waheed, M.E.; El-Moselhy, K.; Saad, A.E. and Owen, N.A. (2013). Evaluation of water quality of Abu-Qir Bay, Mediterranean coast, Egypt. International Journal of Environmental Science and Engineering, 4: 47-54.

Zheng, Y. and Liu, D. (2021). Research on Marine Pollution Problems and Solutions in China from the Perspective of Marine Tourism. Journal of Marine Science, 3:19-28. https://doi.org/10.30564/jms.v3i1.2599.