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Monitoring for the abundance and distribution of macroalgae along Suez Canal, Egypt

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ABSTRACT
Suez Canal is a vital navigational passageway linking between east and west. The present study monitored both water quality and macroalgal groups, in five sites (Port Said, Qantara, Ismailia, Fayed and Suez) along Suez Canal, throughout one year. Physico-chemical properties of water exhibited local variations, giving noticeable maximum concentrations of most parameters at Suez. Total of 34 macroalgal species were recorded (14 Chlorophyta, 12 Phaeophyta and 8 Rhodophyta). Species of Phaeophyta dominated the three middle sites (Qantara, Ismailia and Faied), Chlorophyta had the superiority within Suez and Port Said. Meanwhile, regarding the abundance of macroalgal groups, Chlorophyta dominated over Phaeophyta and Rhodophyta in three sites (Suez, Fayed and Port Said), where, it formed 89% of the total macroalgal vegetation at Suez and 51% at Fayed, however at Port Said it represent 44% . Meanwhile, Rhodophyta dominated over the other macroalgal group at Ismailia. Multivariate analysis revealed the relation between macroalgal distribution and environmental parameter, also clarified the relations between the algal species, providing baseline information along the Suez Canal. The low number of recorded species indicating the importance to follow up the rapid increase in human activities in Suez Canal to improve the situation through regular monitoring.
Keywords: Macroalgal distribution, Suez Canal, Monitoring, Multivariate analysis.

INTRODUCTION

Suez Canal is an artificial waterway linking between the east and the west. It was opened for international navigation on17th November 1869. Due to its unique geographic location; it is an important international navigation canal to Egypt and to the world as well, linking between the Mediterranean Sea at Port Said and the Red Sea at Suez. This importance is getting augmented with the evolution of maritime transport and world trade. The maritime transport is the cheapest transportation method, so that more than 80 % of the world trade volume transported via waterways. Suez Canal not only considered as a main navigation road but also as a road for migration of invasive aliens organisms between Red Sea and Mediterranean Sea. Hundreds of alien Indo-Pacific marine species have migrated to the eastern Mediterranean Sea via the Suez Canal since the canal's opening (Goren and Aronov, 2002 and Hoffman and Dubinsky, 2010), this is known as ''Lessepsian migration'' (Por, 1978). Where, the north-flowing current in the Suez Canal, high salinity in the region and rising temperatures as a result of global warming have facilitated this process. Besid this natural factor, shipping as well as the other anthropogenic activeties in Suez Canal are changing, directly and indirectly the ecosystem and community structure, where there is considerable reduction of macroalgal species within the general decline of biodiversity took place (Larned, 1998 and Chang & Tseng, 2010). At the same time, it is well known that the habitat may determine the type of algal flora present and allow the dominance of particular species at the expense of others (Issa, 2014).

Macroalgae, or seaweeds as they are sometimes called, are one of the most important biological resources in marine ecosystems. They can support some of the most diverse and productive communities in the marine environment by performing the important role of primary producers. They also can provide the food and shelter for different generations of marine organisms. Mushler (1908) recorded the first macroalgae (8 species) in the primitive initial Suez Canal, then Cambridge Expedition 1924, collected 25 species (Fox, 1926). During seventies Lipkin (1972) recorded additional 45 species to the list. Some additions of species had been published occasionally by Farghaly *et al*. (1988), El-Manawy (2000) and Farghaly and El-Shoubaky (2015).

Recently, human activities, including agriculture, urbanization, and tourism have led to increased anthropogenic nutrient loading into shallow shores and caused these fragile ecosystems to shift to different phases (Wielgus et al., 2004, McClanahanet *et al*., 2007 & Chang and Tseng, 2010). Additionally, direct and indirect effects of overfishing activities may also strongly affect biological interactions among coastal organisms such as decreasing the abundance of marine organism, changing population structures and distributions of certain species within the ecosystem (Lenzi, 2015). Moreover, disturbance in salinity, hydrogen ion concentration, temperature and alkalinity are strong selective factors in aquatic habitats (Comeau *et al.*, 2015). Liu *et al.* (2014) reported that, chloride ion concentration and organic carbon affected reversibly on the growth rate of some marine algae. Replacement of variables between sites was responsible for the presence of new functional groups of macroalgae (Issa *et al.*, 2014). Monsoonal variation is also a major factor affecting seasonality and standing crop of algae (Trono and Azana-Carrales, 1981). The fact which reflect the presence of insufficient number of researches have been carried out to establish the major modifications that occurred in the state of macroalgae, under the influence of harmful factors that disturbed the quality of marine environment and biodiversity. Considering the significance of macroalgal communities, both as an indicator of pollution and as a rich economic source, it is important to follow up the variations and distribution in these communities within time and place.

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The objectives of this study are to provide baseline knowledge about macroalgal prevalence in the Egyptian Suez Canal, and to identify macroalgal species that are the most susceptible by water variables. Also, the study aims to give information on the composition and abundance of the macroalgae inhabiting the studied area at Suez Canal shoreline, and the factors that may potentially influence their growth.

MATERIALS AND METHODS

The study area

Five sites, named Port Said, Qantara, Ismailia, Fayed and Suez, were selected as a study area along Suez Canal-Egypt (Fig. 1). The sample collected at each site from three locations with symmetrical separation fixed distances (2 km). Generally, the study area characterized by arid climate and rocks, sand and / or mud substratum. It is exposed to disturbance and pollutant due to increasing the number and activity of ships and containers, beside the agricultural, domistic run- off and industrial effluent, especially the petroleum pollutants in the canal.

Sample collection

The surface water samples (for physico- chemical analysis) and the seaweeds samples (for phycological analysis) were monthly collected throughout one year (January 2014 - January 2015).

Physico- chemical analysis of water

A total of 18 Physico-chemical parameters were determined within each water samples to detect the values of dissolved oxygen, carbone dioxide, ortho-phosphate, total phosphorus, nitrate-N, nitrite-N, ammonia-N, chlorosity, total alkalinity, dissolved organic nitrogen, silicates, total hardness and cations (Na, K) beside water temperature, salinity, total dissolved solids (TDS) and pH according to Parsons and Strikland (1965).

Phycological analysis

For macroalgae investigation, in each site, 10-15 quadrates (1m x 1m) were used to determine the cover percentage and distribution pattern of each species throughout the study period "quadrat method" according to Londo- scale (Londo, 1984). Marine macroalgae were sampled thoroughly by wading or snorkelling. Complete thalli of live specimens were uprooted by hand or with paint-scraper, placed in plastic bags, labelled by location and date of collection, and transported to laboratory. Identification and nomenclature of macroalgae were based on the following references: Fox (1926), Zinova (1953 &1967), Taylor (1960), Papenfuss (1968) Lipkin (1972), Gribb (1983) and Womersley (1984& 1987).

Statistical analysis

One-way analysis of variance (ANOVA) was employed for determination the significant differences between the different habitats in relation to their environmental variables throughout the study period (Anonymous 1993). Person correlation analyses were performed with SPSS version 12.0 (SPSS, Inc., Chicago, IL). Cluster analysis was performed using the MVSP program, where it is a multidimensional analysis classify the data into partition or division of a set and then into subsets (Legendre and Legendre, 1998) to clarify the similarity between sites. Also, the abundance index performed using the MVSP program in order to determine the most common species during the study period.

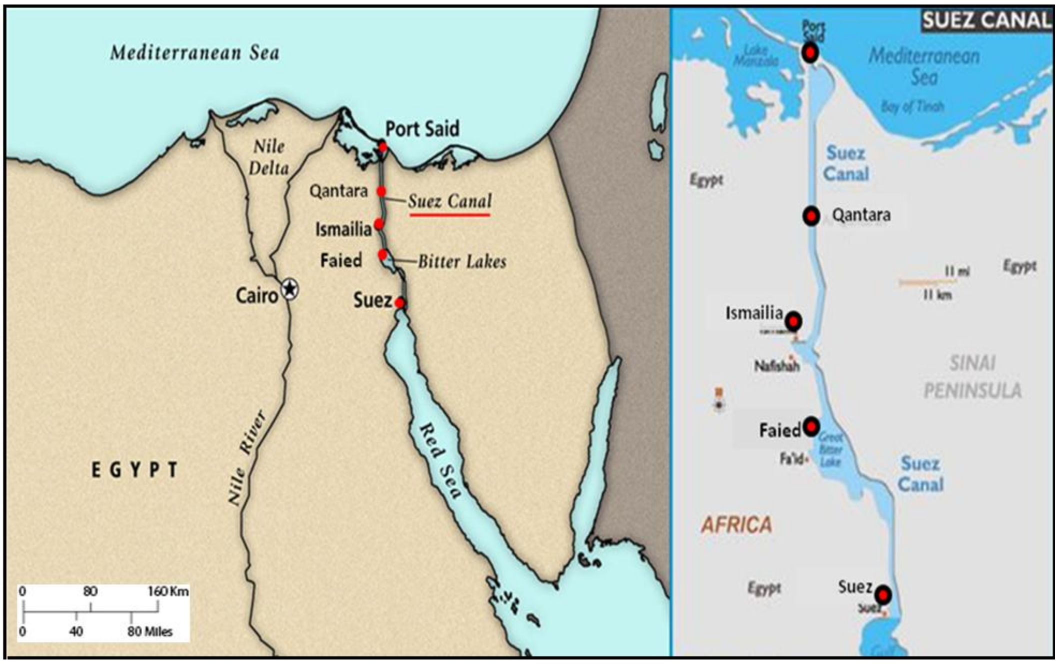


Figure (1): Map shows the sampling sites along Suez Canal- Egypt.

Multivariate analysis of Canonical correspondence analysis (CCA) and Detrended correspondence analysis (DCA) Ordinations were performed using the CANOCO program version 2.1, according to Ter-Braak (1988) to elucidate the relations between the macroalgae species and physicochemical parameters within sites, where the axes are constrained to optimize their relationship with a set of environmental variables. Arrows depict the direction (maximum change) of environmental variables in the ordination, while the length of the arrows shows their proportional influence.

RESULTS

Inspection of Table (1) revealed the mean variation for the tested physico-chemical parameters of water at each site during the entire period of investigation, where the mean seasonal records of surface water temperature at the studied stations varied between (19.5 to 22.5 °C) with relative increase southward (Table1). Meanwhile, the range of water pH (7.59-7.91) exhibited a narrow range of seasonal and local non significant variations (at $p \leq 0.05$). It is noticeable that, the range of mean water salinity, total dissolved salts, total hardness and chloride gave the maximum values within Suez (40.34, 1367g L^{-1}, 253 mg L^{-1} and 22.24 ppm respectively), while, except total dissolved salts, their minimum values were recorded at Qantara. Again, Suez station showed the maximum recorded values of ammonia (0.37mg L^{-1}), nitrate (0.06 mg L^{-1}), nitrite (0.02 mg L^{-1}), dissolved organic nitrogen (2.1 mg L^{-1}), ortho-phophate (0.114 mg L^{-1}) and total phosphorus (1.305 mg L^{-1}) during the entire period of investigation, with a noticeable indication of different ambient conditions, however, their minimum concentrations were recorded within Ismailia and Fayed. On the other hand, the maximum concentration of total alkalinity, dissolved oxygen (348 meq L^{-1} and11.49 mg L^{-1}) and potassium (612.4 ppm) with significant seasonal and local variation (at $P \leq 0.001$) were recorded within the previous sites. Anent Port Said showed the minimum concentrations of dissolved oxygen, silica, sodium and total dissolved solids (10.7, 0.01 mg L^{-1} 14498 and 821 ppm respectively). Meanwhile, both carbon dioxide and silica (0.4 and 0.05 mg L^{-1}) gave its maximum concentrations at Qantara.

The results of Pearson correlation coefficient between physico-chemical are shown in table 2. Reflected that, some variables were either positively high or negatively correlated with each other's. Water temperature showed a significant high positive correlation with chloride (0.55) and total alkalinity (0.49) at $p \leq 0.001$ and a highly negative correlation (-0.71) with dissolved oxygen ($p \leq 0.001$) ($p \leq 0.01$). Water salinity is strongly positively correlated with chloride ($p \leq 0.001$) and negatively correlated with nitrate and dissolved oxygen. On the other hand total alkalinity showed a highly significant positive correlation with ammonia ($p \leq 0.001$) and strong negative correlation with silica ($p \leq 0.01$). However, dissolved oxygen showed significant positive correlation (0.42) with ortho-phosphate ($p \leq 0.01$) and a highly significant negative correlation (-0.52) with chloride ($p \leq 0.001$). Also, nitrite showed a significant positive correlation with nitrate ($p \leq 0.05$).

A total of 34 species of the three representative macroalgal groups (14 Chlorophyta; 12 Phaeophyta and 8 Rhodophyta) were recorded within the studied sites along Suez Canal. The maximum number of species (24 species) was recorded at the Fayed sites (Fig. 2), followed by Ismailia (21 species), Qantara (19 species) and Port Said (13 species). While, only 7 macroalgal species were recorded at Suez.

Table (1): Mean values of the physico-chemical parameters of water along Suez Canal sites.

Water parameters \ Sites	Port Said	Qantara	Ismailia	Faied	Suez	P
Temperature (°C)	19.5±4.5	19.5±4.15	20±3.7	20.5±4.3	22.5±4.2	ns
Salinity (g.L^{-1})	38.78±6.4	37.21±8.3	39.2±5.7	39.00±8.4	40.34±7.4	*
Total dissolved solids (ppm)	821±5.2	841±6.6	984±5.8	1141±3.8	1367±7.5	**
pH.	7.91±0.11	7.8±0.13	7.69±0.08	7.79±0.07	7.59±0.1	*
Total alkalinity (meq L^{-1})	347±11.3	311.38±9.4	328±10.5	348.6±9.4	297 ±6.9	**
Dissolved oxygen (mg L^{-1})	10.7±1.2	11.37±0.9	11.27±1.4	11.49±2.01	10.83±1.1	**
Carbon dioxide(mg L^{-1})	0.3±0.01	0.4±0.04	0.3±0.03	0.2±0.01	0.3±0.03	ns
Ammonia (mg L^{-1})	0.086±0.002	0.093±0.001	0.068±0.001	0.075±0.002	0.37±0.013	**
Nitrate (mg L^{-1})	0.05±0.002	0.04±0.001	0.03±0.0019	0.05±0.005	0.06±0.001	***
Nitrite (mg L^{-1})	0.024±0.002	0.015±0.008	0.01±0.003	0.012±0.003	0.02±0.013	**
Dissolved organic nitrogen (mg L^{-1})	1.04±0.127	1.11±0.088	1.13±0.125	0.85±0.085	2.1±0.131	ns
Ortho-phophate (mg L^{-1})	0.005±0.002	0.002±0.001	0.001±0.001	0.001±0.001	0.114±0.019	***
Total phosphorus (mg L^{-1})	0.01±0.001	0.008±0.003	0.005±0.002	0.003±0.002	1.305±0.016	**
Silica (mg L^{-1})	0.01±0.002	0.05±0.003	0.03±0.002	0.03±0.002	0.02±0.001	ns
Total hardness (mg L^{-1})	224±10.5	194±5.96	203±7.8	175±3.9	253±11.8	*
Chloride (g.L^{-1})	20.1±1.25	19.50±0.8	20.8±2.1	20.9±2.7	22.24±2.6	ns
Sodium (ppm)	14498±17.3	15388±9.8	15128±10.4	15463±9.2	16190±16.2	ns
Potssium (ppm)	446.34±4.6	478.75±2.9	612.4±5.3	504.50±4.8	534.25±3.7	**

Concerning the number of species of different macroalgal groups within each site (Fig. 3), Phaeophyta had the superiority as number of species in the three middel sites (Fayed, Ismailia and Qantara respectively). Meanwhile, lower number of Phaeophyta species (5 and 3 species) were recorded within the two terminal sites (Port Said and Suez respectively), while the superiority in those sites was to green macroalgae (6 and 4 species), which located in the second order within the three middle sites. Anant Rhodophyta showed that, it occupies the third position as number of species within all sites except at Suez site where it completely disappears during the entire period of investigation. In contrast to the above ranking, the situation was different when taking into consideration the abundance percentage of each macroalgal group in the total abundance cover within the studied sites (Fig. 4), where Phaeophyta (46%) occupied the first position only within Qantara site, followed by Chlorophyta (32%) and Rhodophyta (22%), while Chlorophyta was the more representative group in the total cover within Fayed (51%) and Port Said (44%), and it was the most abundant group with cover value 89% over Phaeophyta (11%) in abcence of Rhodophyta within Suez shoreline during the entire period of investigation. It is worth mentioning that, Rhodophyta (36%) occupied the frist position of the total macroalgal cover at Ismailia but with non significant difference with Chlorophyta (35%) and Phaeophyta (29%).

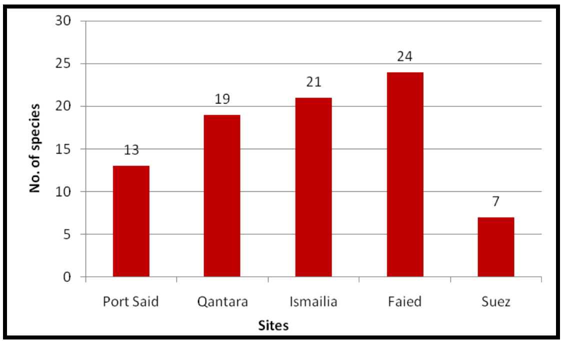


Figure (2): Total number of macroalgal species in the studied sites along Suez Canal.

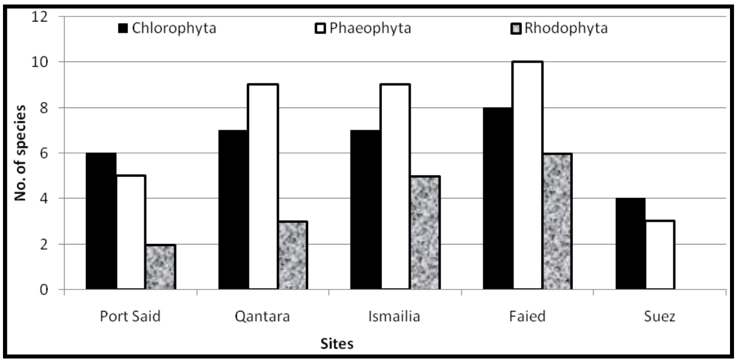


Figure (3): Number of species belonging to each macroalgal group in the studied sites along Suez Canal.

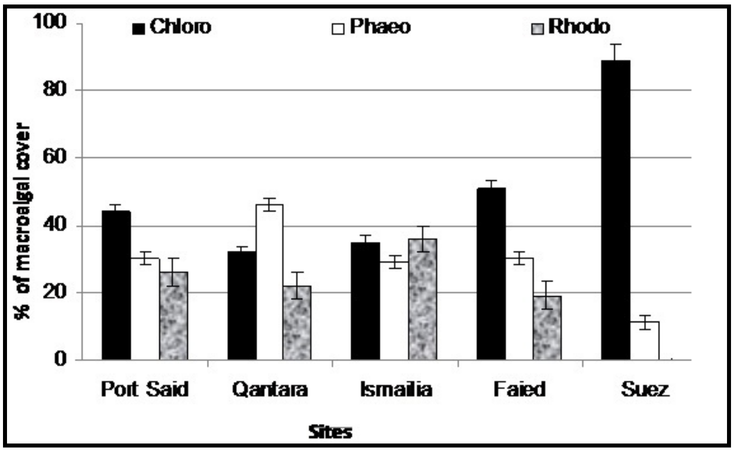
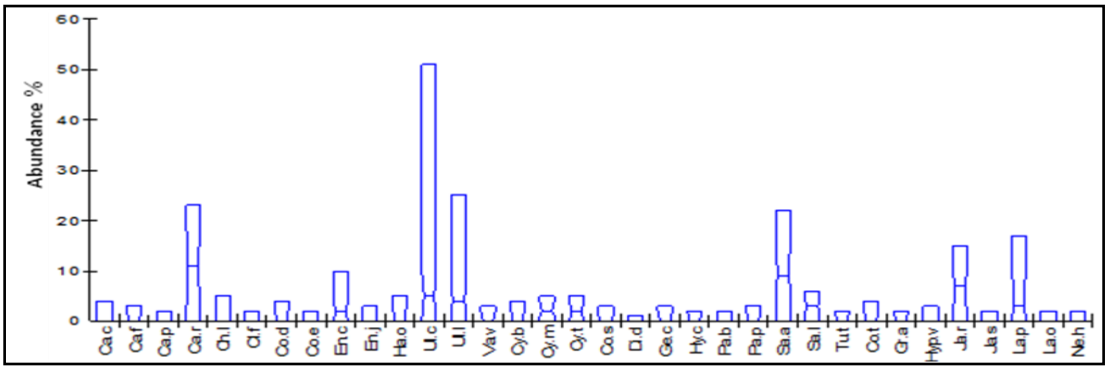


Figure (4): Percentage of abundance for each macroalgal group in the studied sites along Suez Canal.

Table (2): Pearson correlation coefficient between the different water parameters along the Suez Canal sites.

	Temp	Salinity	T. Alk..	DO	CO_2	Amm.	NO_3	NO_2	DON	Ortho-P	Silica	T. Hard.	Na	K	Cl
Temp	1														
Salinity	0.44**	1													
T. Alk.	0.49***	0.12	1												
DO	-0.71***	-0.36*	-0.24	1											
CO_2	-0.31*	-0.18	-0.27	-0.26	1										
Amm.	0.22	-0.12	0.54***	-0.03	0.32*	1									
NO_3	0.02	-0.41**	0.14	0.01	0.15	0.19	1								
NO_2	0.08	-0.29*	0.27	-0.08	0.17	-0.02	0.35*	1							
DON	0.24	-0.12	-0.03	-0.21	0.32*	-0.21	-0.06	0.21	1						
Ortho-P	-0.32*	0.14	-0.26	0.42**	0.22	-0.13	-0.25	-0.17	0.01	1					
Silica	-0.11	-0.2	-0.44**	0.05	-0.19	-0.14	-0.01	-0.09	0.09	0.01	1				
T. Hard.	0.37*	0.28	0.19	-0.34*	0.17	0.12	0.11	0.14	0.25	0.23	0.36*	1			
Na	0.09	0.46**	-0.02	0.14	0.26	-0.19	0.14	0.07	-0.04	-0.06	-0.16	0.42**	1		
k	0.11	0.06	0.18	-0.11	0.19	-0.14	0.14	-0.02	0.04	0.06	-0.04	0.39*	0.2	1	
Cl	0.55***	0.61***	0.11	-0.52***	-0.26	-0.05	0.01	-0.26	-0.16	-0.24	0.08	0.31*	0.2	0.01	1

Regarding the percentage of the mean values of each macroalgal species within the 5 sites, table 3 reflected that, the most dominant species were *Caulerpa racemosa* (23% of the total algal vegetation), *Laurencia papillosa* (17%), *Sargassum asperifolium* (15%) and then *Jania rubens* (9%) within Port Said. Within Qantara *Caulerpa racemosa* (12%) occupied the second position after *Sargassum asperifolium* (22%) and then the two red algae *Jania rubens* and *Laurencia papillosa* (10% for both). With *Ulva clathrata* (9 %), the same previous species were dominate Ismailia but with sovereignty of red algae (*Jania rubens*"15%", *Laurencia papillosa* "13%") over green and brown algae. Again green macroalgae with its species *Caulerpa racemosa* (21%) occupied the first position of the algal cover within Faied shorline followed by *Sargassum asperifolium* and *Ulva clathrata* (10%). The two recorded species of the green alga *Ulva* (*Ulva clathrata* 51% and *Ulva lactuca* 25%) were almost the dominant species over the algal vegetation cover at Suez during the entire period of investigation, with low representation of *Enteromorpha compressa*. Generally, the abundance index (Fig. 5) of all the recorded species within Suez Canal revealed that, the most representative species during the investigation period were *Ulva clathrata* followed by *Ulva lactuca*, *Caulerpa racemosa* and *Sargassum asperifolium*, while *Laurencia papillosa* and *Jania rubens* occupied a lower position. According to the results presented in Fig. 5, abundance index for the recorded species, Cluster analysis for the selected most abundant species (Fig. 6), it was indicated that, both *Ulva clathrata* and *Ulva lactuca* were separated with high dissimilarity factor, while the most common species (*Caulerpa racemosa*, S*argassum asperifolium*, *Jania rubens* and *Laurencia papillosa*) were related in minor sub-group. In other minor sub-group, *Sargassum latifolium*, *Cystoseira myrica* and *Cystoseira trinode* with *Enteromorpha compressa* were relater with low dissimilarity factor.Inspection of ordination diagram produced by the Canonical Correspondence Analysis (CCA) showed the relation between water variables and the recorded species. A glance of Fig. (7) described a noticeable relation between *Ulva clathrata*, *Ulva lactuca* and *Valonia ventricosa* with many water variables (dissolved organic nitrogn, ammonia, nitrite, total hardiness, ortho-Phophate, total phosphorus , total dissolved solid, potassium, sodium and chloride. On the other sid, most of the recorded macroalgal species were related with dissolved oxygen, total alkalinity, pH and silica.



Figure(5): The abundance indix of the recorded species along Suez canal sites.

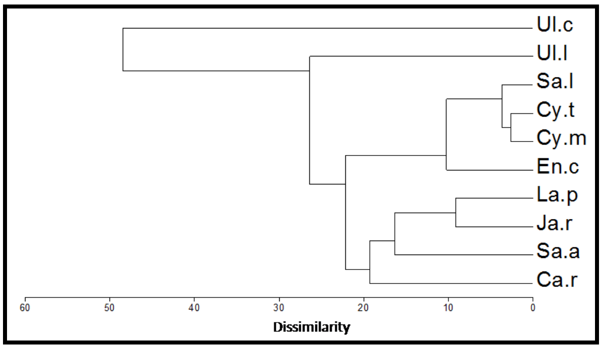


Figure (6): Dendrogram produced by the cluster analysis of the most abundant species along Suez Canal sites. The species names are abbreviated to the first letter of the genus name and the first letter of species name. For full names see table: 3).

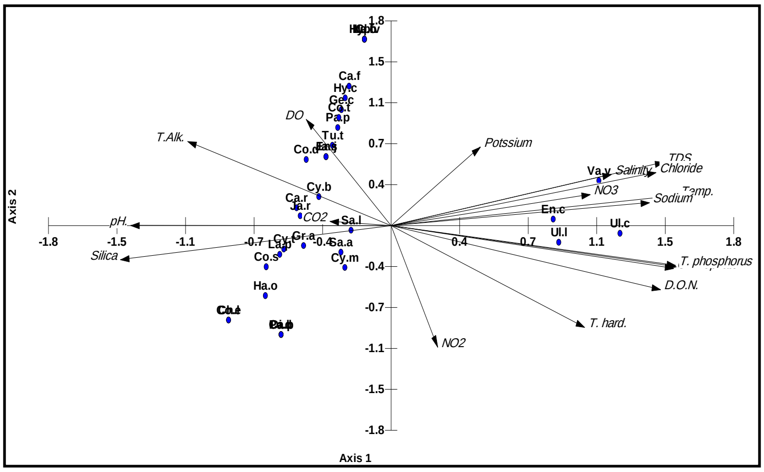


Figure (7): Canonical Correspondence Analysis (CCA) joint plot ordination diagram for macroalgal species (points) with water variables (arrows) along Suez Canal sites (The species names are abbreviated to the first letter of the genus name and the first letter of species name. For full names see table: 3).

A glance on fig. 8 (A & B) revealed that, the similarity between sites differed when classified using the physico-chemical parameter from that classification using the biological parameter in the Cluster analysis, however in both cases Suez was separated from the other sites with high dissimilarity factor. Meanwhile, the other sites were gathered in one sub-group (Fig.8 A&B), with noticeable separation of Port Said in case of classification using physico-chemical parameter, while, Fayed and Qantara were grouped in minor sub-group. Nevertheless, other than Suez, using the biological parameter grouped the four sites in one sub-group with low dissimilarity factor. A somewhat phenomenon was obtained when both environmental physico-chemical variables of water and the biological parameters were used together in one analysis (Fig. 9) to clarify the similarity between the studied sites, by using the Detrended Correspondence Analysis (DCA) ordination. A clear separation of the studied sites obtained, where Suez, that indicated by *Ulva clathrata*, was found on the higher gradient of Axis 1, (on the right of the diagram) in a separet group. On the other hand, there were close interference between Port Said and Qantara, which located along the lower gradient of Axis 1 (on the bottom left side of the diagram) with small interference with the other group containing Ismailia and Fayed.

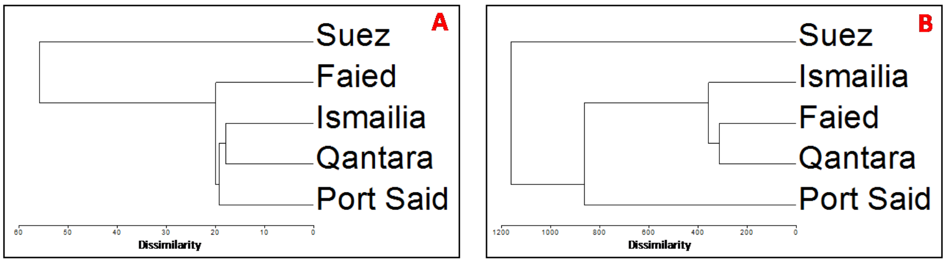


Figure 8 (A&B): Dendrogram produced by the Cluster analysis of the selected sites along the Suez Canal. (A: by using the biological parameter; B: by using the physico-chemical parameter).

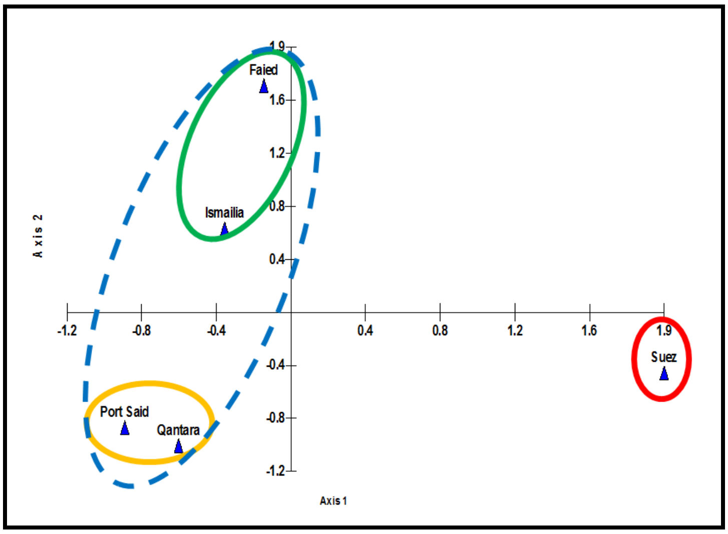


Figure (9): Detrended Correspondence Analysis (DCA) ordination diagram of the selected sites along the Suez Canal.

Table (3): Abundance in percentage cover of the mean values of each macroalgal species within the studied sites along the Suez Canal coast.

	Macroalgae	Abbrev	Port Said	Qantara	Ismailia	Faied	Suez
	Chlorophyta						
1-	*Caulerpa serrulata* (Forsk) Borg.	*Ca.c*		4			
2-	*Caulerpa fastigiata* (Mont.)	*Ca.f*			2	3	
3-	*Caulerpa prolifera* (Roth.) Kutz.	*Ca.p*		2			
4-	*Caulerpa racemosa* (Forsk.) Ag.	*Ca.r*	23	12	11	21	
5-	*Chaetomorpha linum* (Muelb.) Kutz.	*Ch.l*	5				
6-	*Cladophora fascicularis* (Mert.) Kutz	*Cl.f*				2	
7-	*Codium dichotomum* (Huds.) Gray.	*Co.d*	3			4	
8-	*Codium elongatum* (Howc.)	*Co.e*	2				
9-	*Enteromorpha compressa* (Linn) Grev.	*En.c*		2	4	3	10
10-	*Enteromorpha sp.*	*En.j*			3		
11-	*Halimeda tuna* (Lamour).	*Ha.o*		4	2		
12-	*Ulva clathrata* (Roth) C. Agardh	*Ul.c*	5	5	9	10	51
13-	*Ulva lactuca* (Linn) Nasr.	*Ul.l*	6	3	4	6	25
14-	*Valonia ventricosa* (J.Agardh).	*Va.v*				2	3
	Phaeophyta						
1-	*Cystoseira barbata* (Good, Wood).	*Cy.b*		4	2	3	
2-	*Cystoseira myrica* (Gmel.) J.Ag	*Cy.m*	4	5	3	1	2
3-	*Cystoseira trinode* (Forsk.) J.Ag.	*Cy.t*	5	4	3	2	
4-	*Colpomenia sinuosa* (Mert. R.)Der.&Solier.	*Co.s*	3				
5-	*Dictyota dichotoma* (Huds.) Lamour.	*Di.d*		1		1	
6-	*Gelidium corneum (Hudson)* Lamour.	*Ge.c*			3	2	
7-	*Hydroclathrus clathratus* (C. Agardh)	*Hy.c*			2	2	
8-	*Padina boryana* (Thivy.)	*Pa.b*		2			
9-	*Padina pavonica* (Linn.) Thivy.	*Pa.p*		1	2	3	
10-	*Sargassum asperifolium* (Hering) M. Ag.	*Sa.a*	15	22	9	10	7
11-	*Sargassum latifolium* (Turn.) Ag.	*Sa.l*	3	6	3	4	2
12-	*Turbinaria triquetra* (C.Ag.) Ag.	*Tu.t*		1	2	2	
	Rhodophyta						
1-	*Corallina tenella* (Kutz.) Heydr.	*Co.t*			4	2	
2-	*Gracilaria arcuata* (Zanardini.)	*Gr.a*		2	2		
3-	*Hypnea valentiae* (Turn.) Mont.	*Hy.v*				3	
4-	*Jania rubens* (L.) Lamour.	*Ja.r*	9	10	15	7	
5-	*Jenia simplex* (Wulfen.) Ag.	*Ja.s*			2		
6-	*Laurencia papillosa* (Forsk.) Grev.	*La.p*	17	10	13	3	
7-	*Laurencia obtusa* (Huds.) Lamour.	*La.o*				2	
8-	*Nemalion helminthoides* (Vell.) Batt.	*Ne.h*				2	
	Total		100	100	100	100	100

Abbrev.: Abbreviations.

DISCUSSION

Along the study area of Suez Canal coast, man-made modifications in the shoreline throughout the last decades affects on the macroalgae species inhabiting this area. These modifications include the consequences disturbances imposed by the increasing movement of ships navigation, rapid increase in the construction of tourist resorts and villages along the coast with increasing its related touristic activities interrupt macroalgae. Moreover, manual removal of seaweeds and pollution by sewage and industrial discharges, beside the construction of the new eastern branch in the northern Suez Canal might greatly change the habitat of macroalgae (Nyberg, 2007). This may explain the relatively low number of seaweeds (34 taxa) and variations of seaweed's composition in the present study compared with previous survey (Negm, 1988, Farghaly *et al*., 1988 and El-Manawy, 2000). The maximum number of the recorded macroalgal species were belonging to Chlorophyta (14 species), followed by Phaeophyta (12 species) and Rhodophyta (8 species). Considering the relative abundance of macroalgal divisions, Chlorophyta formed the highest coverage throughout the whole year. Chang and Tseng (2010) reported that, Chlorophyta are more tolerant than Rhodophyta and Phaeophyta to water pollution, this would results in an increase of Chlorophyta species number at the expense of Phaeophyta and Rhodophyta. In this respect, El-Manawy and Shafik (2008) also demonstrated that, the growth of Chlorophyta increases vigorously in polluted habitats. The relatively higher number of total seaweed's species (94 taxa) at Halaib and Shalatine may be related to water physical characters e.g. low turbidity and less disturbance caused by human since there is no navigation stress or tourist villages (El-Manawy and Shafik, 2008). These conditions favored high growth of Rhodophyta (53 %) than Chlorophyta (31%) and Phaeophyta (16 %) of the total Seaweeds. These agreed with our results and explains the superiority of Chlorophyta vegetation during the entire period of investigation among the Suez, Faied , Port Said and to certain limit at Ismailia, giving its maximum (89% of the total vegetation cover) at Suez. Only *Ulva (U.clathrata* and *U.lactuca*) dominated (76%) seaweeds vegetation beside a conciderable representation of *Enteromorpha compressa* (10%) at Suez. Such low number of species may be attributed to the high pollution status of water which receive large amount of pollutants as a result of the tremendous activity of the condensed petroleum industrelization, discharged effluent from fertilizer and glass factories beside the organic wastes from city sewage in this site. Aleem (1983) mentioned that, the flourishing growth of *Ulva* spp. was related to the areas exposed to human activities, making a pure community (El-Manawy, 2000).

On the other hand, the relatively higher species number of seaweeds recorded during the entire period of investigation at Fayed (24 species), Ismailia (21 species) and Qantara (19 species) sites may be related to the difference in the quality and quantity of pollutants received in that sites. But actually, that numbers recorded at Qantara, Ismailia and Port Said stell relatively low number of seaweeds species, which might be attributed to the presence of small patches of calcareous substrates, agricultural run- off and the contraction of new infrastructure, projects and facilities along Suez Canal. Moort and Chelliah (2015) supported that, the algal community was affected adversely with the human activities, especially agricultural and industrial discharges.

The abundance cover percentage obviously indicated that, each seaweed species have a specific substrate type and water quality criteria at which higher abundance was achieved. The dominance of cover value of seaweed species depends on the habitat quality and nutritional status of seawater. *Caulerpa racemosa* inhabited all the studied sites "except Suez" with considerable abundance reflecting high ability to adapt in different conditions. According to El-Manawy (2000), *Caulerpa racemosa* was very common in the Red Sea and Suez Canal mixed with other seaweeds and seagrasses or found as pure stands. It inhabited sands or mud in both lagoons and open coasts of a depth varies between 60 cm to several meters.

The most important ecological factors that affect the growth rate of *Caulerpa* are light, substrate nutrients, depth and exposure to waves. Nevertheless Turna and Ertan (2002) mentioned that, the Mediterranean area characterize the photophilic vegetation on rocky substrata, with distinctive presence of *Caulerpa* This interpreted our results where Port said, which support the maximum aboundance (23%) of *Caulerpa* racemosa, considered as the connection point between Mediterranean and Red Seas. Meanwhile, *Laurencia papillosa* and *Jania rubens* (Rhodophyta) were dominant at both Port Said and Qantara sites. This may be due to the relative low temperature (Abou-Aisha *et al*., 1995, Scrosati, 2001 and Agnetta *et al*., 2015), where its abundance decreases with increasing the main value of temperature, and supported at Ismailia by the high concentration of phosphate in water which may be comes from domestic sewage or other liquid wastes discharged into seawater at these sites. It may be attributed to relative increase of dissolved organic nitrogen in water which may be come from agricultural run off, which discharged at north Qantara shores. It is noticeable that, *Ulva* (*Ulva clathrata* and *Ulva lactuca*) and *Sargassum* (*Sargassum asperifolium* and *Sargassum latifolium*) were the only two genra recorded in all the studied sites along Suez Canal. Sanchez & Fernandez (2005) and Zou *et al*., (2014) reported that, *Sargassum* sp. dominates the highly disturbed habitats, the argument which explain the cited results.

The CCA of macroalgal species and water variables revealed that *Ulva clathrata*, *Ulva lactuca*, *Enteromorpha compressa* and *Valonia ventricosa* were found at high position along the gradients with dissolved organic nitrogn, nitrite, nitrate, total phosphorus, chloride, total alkalinity, potassium and sodium concentrations.

These results are supported by conclusions of other researches (Zaid, 1993, Abou-Aisha *et al.*, 1995; Kuwana *et al*., 1998; Larned, 1998 Daniela *et al*., 2011 Agnetta *et al*., 2015). John *et al*. (2013) also stated that, *Ulva* gives its maximum growth rate in enriched seawater by P and N. In other areas total phosphorus and total nitrogen represented a limiting growth and productivity factors of some marine macroalgae (Larned, 1998 and Douglas *et al*., 2014). Also, it was reported that the green alga *Ulva*, that often known as algal turf, was characterized by an enhanced growth in the polluted areas making a pure community with a dark green colour, and showed a higher relative abundance (Turna & Ertan, 2002, John *et al*., 2013 and Yasser *et al*., 2014). On the other side of the CCA joint plot, all the red and brown algae and most green seaweed were in a close relation with dissolved oxygen, total alkalinity, pH and silica. John *et al*. (2013) noted that, dissolved oxygen concentration and pH are important water quality parameters because exposure to low concentration can be physiologically stressful or lethal to aquatic organisms.

Using both environmental physico-chemical variables of water and/or the biological parameters to study the similarity between the studied sites, reflects a more or less the same classification trend. However, the separation was sharp and with high dissimilarity factoring in case of using physico-chemical variables of water than using the biological parameter, which reflects the ability of some algal groups to coexist in different environmental conditions. Elena *et al*. (2012) also reported that, seaweeds in natural systems have the ability to resist and to recover from disturbance, but it is largely dependent on life composition in the aquatic environment. Detrended Correspondence Analysis results again classified Suez in separate group with high dissimilarity compared with the major other group contain Fayed, Qantara, Ismailia and Port Said.

CONCLUSIONS

This study documents the macroalgal species occurrence and prevalence along the Suez Canal and provides important baseline information in this region where limited data exists. The present results indicate a low number of macroalgal species along the study area, with superiority of Chlorophyta over Phaeophyta and Rhodophyta. This lack of species number may refer to the importance of rationing and follow the rapid increase in human activities because of the nature, geography and strategy of Suez Canal. So, because of the importance of Suez Canal for Egypt and for the world, we have future needs for improving the existing situation by continuous and regular biodiversity monitoring in order to enable observations of all changes that might occur in the physical, chemical and biological parameters of water. This will gives valuable information upon the environment quality beside the expected improvement of the marine ecosystem state. Alongside the adoption of a project for rapid and realistic rehabilitation programmes.

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رصـد وفـرة وتـوزيـع الطحـــالب الكبـــيرة على طـول قـناة السـويس، مصر

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الملخص العربي

تعد قناة السويس مجرا ً ملاحياً حيوياً يربط بين الشرق والغرب . عنيت هذة الدراسة برصد التغيرات البيئية للمياه و كذا للتجمعات من الطحالب الكبيرة بسبب الأنشطة البشرية في خمسة مواقع (بور سعيد، القنطرة، الإسماعيلية، فايد و السويس) على إمتداد قناة السويس لمدة عام . أبرز تحليل العوامل الفيزيائية والكيميائية للماء إختلافات ملحوظة بين المواقع قيد الدراسة، حيث سجلت تركيزات عالية في منطقة السويس. و علي الصعيد الأخر تم تسجيل أربع و ثلاثون نوعاً من الطحالب الكبيرة على طول مواقع الدراسة (14 من الطحالب الخضراء و 12 من الطحالب البنية و 8 من الطحالب الحمراء). كان للطحالب البنية السيادة فيى الثلاث مواقع الوسطي (فايد و القنطرة و الا سماعيلية) من حيث عدد الأنواع بينما حققت الطحالب الخضراء الكبيرة أعلي عدد أنواع في السويس وبورسعيد. وفي الوقت نفسه، فيما يتعلق بالنسبة المئوية لمتوسط وفرة كميات كل الأنواع علي إمتداد منطقة الدراسة حققت الطحالب الخضراء تفوقا علي كل من الطحالب البنية و الحمراء في ثلاث مواقع هي السويس و فايد و بورسعيد. حيث شكلت 89% من النسبة الكلية في السويس في حين شكل مجموع الطحالب الخضراء في منطقة فايد 51%. وكان للطحالب الحمراء الغلبة في منطقة الاسماعلية.
إستخدمت الدراسة عدداً من الطرق الإحصائية ذات المتغيرات المتعددة لتوضيح العلاقات المتشابكة بين العوامل البيئية المسجلة في مناطق الدراسة و بين المجموعات الطحلبية المتحصل عليها بأجناسها المتنوعة، و كذا العلاقات بين هذة الأجناس ذاتها ببعض لتقديم صورة واضحة يمكن متابعتها لهذا المجري الملاحي الحيوي. حيث ان ه ذا النقص في عدد الأنواع قد تشير إلى أهمية تقنين و متابعة الزيادة السريعة في الأنشطة البشرية بسبب طبيعة وجغرافية واستراتيجية قناة السويس . لذلك، ونظرا للأهمية قناة السويس العالمية، فإنة اصبح من الضروري تحسين الوضع القائم من خلال رصد مستمر و منتظم للتنوع البيولوجي لإعطاء معلومات قيمة على جودة البيئة و الوقوف علي العوامل المؤثرة عليها.