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Dynamics of Macroalgae at Two Different Ecological Sites in Alexandria Coastal Waters

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Abstract. A year cycle investigation of the macroalgae dynamics in Alexandria coastal waters was conducted at two selected stations that maximize possible differences in seawater characteristics. Eleven genera, including seventeen species were identified at the Eastern Harbour (EH) and Abou Talat (AT). The total species richness was higher at EH, but the algal species composition was highly similar at the two sites. The floristic ratio at EH indicates a mixed flora of warm temperate nature. The prevalence of red and brown algae was detected at relatively high salinities, and green opportunistic algae at lower salinities, and with nutrient pulses indicate its importance as ecological factors regulate the structure of the macroalgae communities in Alexandria waters. The changes in algal proportion reflected the anthropogenic influence and/or improvement in environmental quality at times. Incidents of massive green macroalgae proliferation occurred at a wide range of environmental variations, and with the sharing of other red species. *Ulva fasciata* represented a perennial species and the spring warming and nutrient enrichment seem to interact with its massive growth. The study is yet the first attempt to measure the algal biomass of different species under different physical and chemical ecological stresses.

Key words: macroalgae, abundance, production, mass proliferation, environmental factors.

Introduction

Macroalgae represent one of the major primary producers in coastal marine systems (Valiela *et al.*, 1997). Its diversity maintains ecosystem's stability (Parker *et al.*, 2001), and are widely utilized to characterize and monitor coastal systems (Leliaert *et al.*, 2000). Macroalgae have great ecological and biological importance as providing nutrition, protection, and accommodation to other living organisms (Bernecker & Wehrtmann, 2009; Pedersen *et al.*, 2012; Guidone & Thornber, 2013). They act as biological indicators for detecting an anthropogenic impact on the coastal ecosystems (Vasquez & Guerra, 1996). The broad fluctuations of ecological processes are strong stress inducers in macroalgae diversity, production and geographical distribution (Borges *et al.*, 2006). Database about marine macroalgae along the coast of Alexandria is very preliminary; the previous work based on collections at specific locations (Khalil, 1987; Aleem, 1993). Hence, the present study is an attempt to detect influences of abiotic factors in fostering temporal and regional dynamics of macroalgal abundance, assemblage structure and production during a year cycle.

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Materials and Methods

The Eastern Harbour (N31˚12′-31˚13′/E29˚53′-29˚54′) is a sheltered semi-enclosed area (about 2.53 km^2) in the central urban area of Alexandria City. It has an intense long-term process of eutrophication. The harbour is a site of different man activities as fishing, Yachts sports, boat building, and recreation, particularly at its northwestern part. Abou Talat at the west of Alexandria is fully exposed to wave action and not heavily inhabited, but situated in the neighbor of highly polluted regions (El-Mex Bay and El-Noubaria Canal (Fig. 1). The study extends for eight months between March 2014 to February 2015, when each site was visited twice per season.

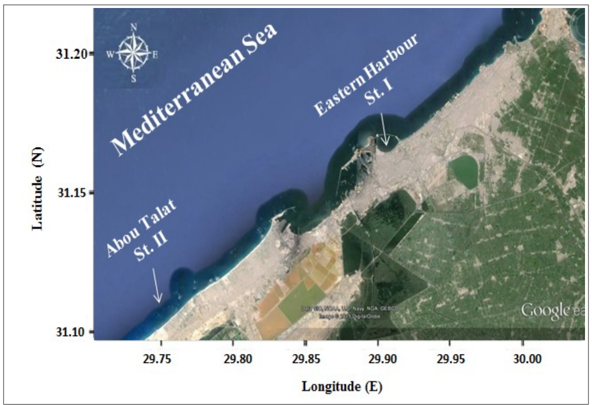

Fig. 1. Location of the sampling stations.

The environmental factors; water temperature (ºC), salinity, dissolved oxygen (mg l^{-1}), and pH values were measured in the field using the hydro lab. (HANA, Model HI 9828). Nutrient concentrations of the dissolved NH_4, NO_2, NO_3, SiO_4 and PO_4 were determined following STRICKLAND & PARSONS (1972). Each time at each site, living macroalgae samples were taken from a depth of about 20 cm at two marked areas of different dimensions following the seaweeds field manual (DHARGALKAR & KAVLEKAR, 2004), carefully separated from the substrate under the hold fast using a knife and/or handpicked. The seaweed samples of about 100 g fresh weights were kept in a labeled plastic bag filled with local seawater and vigorously shaken to dislodge any extraneous matters as stones, sand particles, animals and epiphytic microalgae, and brought back to the laboratory in icebox containing frozen gel cold packs. The specimens of each species were gently scrubbed under running tap water, rinsed with distilled water. The taxonomic guides consulted for identification include ALEEM (1993), and ABBOTT & HUISMAN (2004) and JHA *et al*. (2009). The abundance of macroalgae community at the two sites was estimated by following the scale of JAMES (2007), and TREVOR (2007), which is a broad estimate of frequency.

Chlorophyll content based on certain weights was extracted in 90% acetone, and measured spectrophotometrically and calculated applying the equation of WELLBURN (1994).

The floristic similarity between the number and percentage of taxa shared by the different sites was calculated as percent similarity (C) (MATHIESON & PENNIMAN, 1986), and the floristic ratio according to CHENEY (1977).

Multiple regression analysis was done using Excel software version 4.

Results

The physical and chemical characteristics of the surface water at the two sites are given in Table 1.

Temperature oscillated normally between a minimum in winter (February) and a maximum in summer (August), showed clear seasonality. The surface water started to be warmer by April. The changes in salinity were irregular, and not as obviously seasonal, comparatively higher during June. The abrupt drop in salinity at AT in October might reflect clear signs of discharged water influence. The water was well oxygenated, and the levels never fell down below 5.5 mg O_2 l^{-1}, Abou Talat waters appeared richer, with highest between August and October. The pH values differ slightly between the two stations, but, all in the alkaline side (mean 8.06±0.12 and 8.15±0.09, respectively), its lowest in September and October.

Table 1. Physical and chemical parameters of the surface water.

	Temp. (°C)	Salinity	pH	D. O. (mg l-1)	NO_2 (µM)	NO_3 (µM)	NH_4 (µM)	TN (µM)	SiO_4 (µM)	PO_4 (µM)
Eastern Harbour										
March	17.70	36.36	8.17	10.55	0.40	5.72	2.97	9.09	2.22	0.23
April	24.09	35.59	8.73	7.50	0.20	1.57	0.59	2.35	0.46	0.32
June	28.60	38.85	8.03	10.71	0.83	7.24	3.29	11.35	1.08	0.54
August	30.30	35.23	7.89	7.11	0.78	5.35	7.61	13.73	1.48	0.41
September	27.70	34.06	7.68	5.52	2.10	7.75	2.75	12.59	2.68	1.85
October	24.10	35.02	7.64	6.33	1.48	11.99	3.38	16.84	1.31	1.13
December	21.00	35.77	8.09	6.17	1.08	11.93	1.98	14.99	0.63	0.59
February	17.30	36.51	8.23	10.65	0.23	3.11	1.08	4.41	0.63	0.23
Mean	23.85±6.5	35.92±2.9	8.06±0.12	8.07±2.5	0.88±0.6	6.38±3.7	2.95±1.4	10.67±6.2	1.31±1.3	0.66±0.41
Abou-Talat										
March	18.2	35.99	8.32	10.10	0.23	3.75	0.18	4.16	0.68	0.09
April	24.51	37.26	8.57	6.80	0.13	2.57	0.90	3.59	0.63	0.18
June	28.90	38.46	8.09	7.46	0.25	4.43	0.23	4.90	0.97	0.50
August	29.80	33.38	8.16	10.31	4.28	17.31	2.16	23.74	1.77	0.54
September	25.00	34.28	7.78	10.60	0.28	7.53	1.53	9.34	0.74	0.36
October	23.3	32.22	7.81	8.11	1.88	23.22	5.72	30.81	2.79	1.88
December	20.2	34.95	8.23	9.41	0.68	19.73	3.42	23.83	6.21	0.23
February	16.4	37.41	8.25	10.55	0.10	5.72	0.27	6.09	0.63	0.05
Mean	23.29±6.5	35.5±2.9	8.15±0.09	9.17±1.4	0.975±0.6	10.5±9.68	1.8±1.6	13.3±7.5	1.8±1.2	0.48±0.4

The seawater was characterized generally by high levels of the measured nutrients, indicating influences of discharged water at times arrival. No particular seasonal trend was detected. The total nitrogen (NO_2 + NO_3 + NH_4 concentrations) showed distinct changes in terms of the relative proportion of the dominant nitrogen forms; nitrate at EH contributed 64.38% of the total nitrogen and 82.21% at the latter station. It's concentrations at the harbour (mean 6.83±1.33 µM) fall down at a level < 2 µM in April, and it was around 12 µM in October and December, while, higher levels were measured at AT with its extreme in October. The seasonal variations of the nitrite concentrations followed the patterns of NO_3 and NH_4. Ammonium values gained two major peaks in August and October at the two stations, respectively. Silicate exhibited erratic value changes with a minimum in April, and relatively higher levels in September (EH), and highest in October (AT). Phosphate levels were relatively higher at EH than AT, the lowest levels were measured in the cold periods, and the highest in autumn and with no adhere to a clear seasonal pattern. The calculated nutrient ratio in EH indicated high N:P ratio most of the year with two major peaks. Such values signal Si and P limitation at times (Fig. 2).

Macroalgae community structure and composition

Eleven genera, including 17 species were identified at EH and AT, as 3 genera with 7 species of Chlorophyta, 3 genera with 3 species of Phaeophyta and 5 genera with 7 species of Rhodophyta. The regional distribution indicated Chlorophyta and Rhodophyta of permanent existence at the two stations, with the highest species richness at EH in early spring and lowest in mid-autumn and early winter (Table 2).

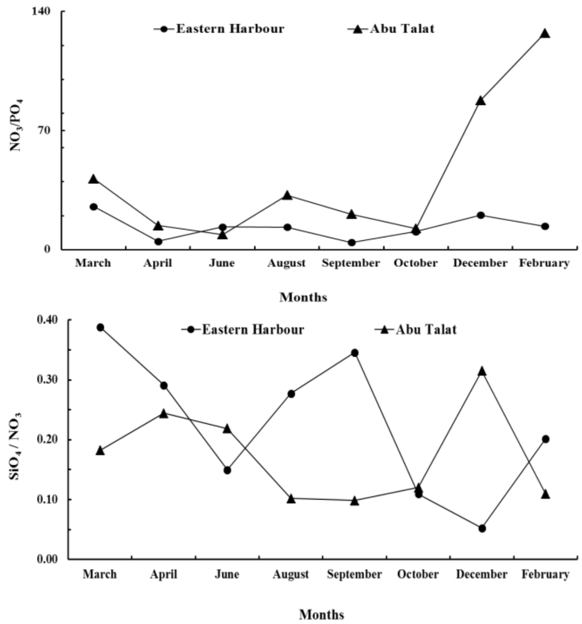

Fig. 2. Nutrient ratios at the Eastern Harbour and Abou Talat.

The succession showed *U. fasciata* Delile contributes a perennial form with different degrees of dominance, *U. compressa* Linnaeus with exclusive occurrence at AT, and *U. lactuca* Linnaeus and *U. linza* Linnaeus at EH during February and April as well. Other Chlorophyta species; *Cladophora pelluceda* (Hudson) Kützing contributed the major at AT in August and September, and the Rhodophyta *Corallina officinalis* Linnaeus at EH between June and December. The Phaeophyta species, *Petalonia fascia* (O.F. Müller) Kuntze, *Padina pavonica* (Linnaeus) Thivy and *Sargassum vulgare* C. Agardh detected at EH in February and March with relatively lower sharing.

Mass proliferation of macroalgae species

Four incidents of massive macroalgae blooms occurred at EH in February, April, August, and September, and other three events at AT during the first two months and in October as well. The blooms covered > 40% of the marked area, maintaining a wide range of environmental variations. The bloom at EH occurred at the lowest water temperature (February) compared with others in August and September. However, all the bloom periods, particularly in August characterized by relatively low salinity and high NO_3 and NH_4 concentrations. Moreover, SiO_4 and PO_4 reached the highest accompanying the algal bloom in September. The causative bloom species and the accompanied ones were different during the bloom periods. In February, *U. fasciata* dominated, followed by *U. lactuca*, while, the Phaeophyta "*Padina pavonia* and *Sargassum vulgare*" were of much lower existence. During August, *U. fasciata* remained the major; yet, *C. officinalis* shared actively the degree of dominance. Other accompanied Rhodophyta were *Cladophora pelluceda* and *Antithamnion nageli*. During September, *U. fasciata* was still the leader, and *C. lehmanniana* ranked the second significant constituent. Other existed species of rare occurrence were *C. pelluceda* and *C. elongata*. At Abou Talaat, the algal blooms attributed mainly to the proliferation of *U. compressa* and *U. fasciata*, particularly in February under almost equal contributions. However, in October *Cl. pelluceda* considerably shared the bloom.

Biomass of the recorded macroalgae species

Chlorophyll *a* content of the recorded species (Table 3) indicates the minimum value registered for *C. elongata* at EH in September and the maximum for *Cl. pellucida* in August. The latter species gained its highest value at AT in September, and the minimum for *U. compressa* in June. The common green *U. fasciata* exhibited higher chlorophyll *a* content most of the period at EH compared with AT, particularly during winter and with varied nutrient concentrations.

Discussion

The measured physico-chemical parameters conformed to previously reported ranges (El-Zayat, 2012), although large inter-annual variability has been recognized, particularly for NO_3 and PO_4. The exceeded values of N/P ratio above the Redfield ratio in March and December at EH attribute to human activity (Lapointe *et al.*, 2004), might indicate the overall growth is often N limited.

Table 2. Temporal and regionalabundances of recorded macroalgae.

Spp. / Months	March	April	June	August	September	October	December	February
	2014							2015
Eastern Harbour								
Chlorophyta								
Chaetomorpha linum								+
Cladophora lehmanniana					+++			
Cladophora pellucida				++	+			
Ulva fasciata	++	+++	++	+++	+++	+++	++	+++++
Ulva linza		+++						
Ulva lactuca								++
Phaeophyta								
Petalonia fascia	+							
Padina pavonia								+
Sargassum vulgare								+
Rhodophyta								
Amphiroa fragilissima	+++							
Antithamnion nägeli				+				
Corallina elongata	++				+			
Corallina officinalis		++	+++	+++	+	+++	+++	
Gigertina teedi	+							
Griffithsia equisetifolia			+					
Griffithsia flosculosa								
Abou Talat								
Spp. / Months	**March**	**April**	**June**	**August**	**September**	**October**	**December**	**February**
	2014							2015
Chlorophyta								
Cladophora pellucida				+++	+++	++		
Ulva compressa	++	+++	++	+	+	+++	+++	+++
Ulva fasciata	++	+++	+	++	+++	+++	+++	++
Rhodophyta								
Corallina officinalis		+						

+, 1–5% cover; ++, 5–25% cover; +++, 25–50% cover; ++++, 50–75% cover; +++++, >75% cover.

Seaweeds community structures were analyzed by functional form groups, coverage, species composition, and biomass. Such items are the main focusing of worldwide investigations for seasonal distribution of macroalgae communities and their ecological patterns (PRATHEP, 2005; WELLS *et al.*, 2007; CHOI, 2008). Surprisingly, little is known about these patterns in Alexandria waters. Referring the taxonomical works of KHALIL (1987) and ALEEM (1993), the present checklist of the marine algae at the two coastal areas of Alexandria is yet a part of their checklist.

A very strong similarity within 70 % of the algal species composition was found between the two sites.

The calculated floristic ratio at EH (4.33) indicated a mixed flora of warm temperate, yet, the limited community structure at AT hindered such definition. KHALIL (1987) defined the nature of vegetation along the coastal area of Alexandria as rather boreal as subtropical.

Table 3. Chlorophyll *a* content (mg g^{-1} DW) in the collected macroalgae species.

Eastern Harbour	Chl a	Abou Talat	Chl a
March			
Corallina elongata	0.08	*Ulva compressa*	0.71
Griffithsia flosculosa	0.17	*Ulva fasciata*	0.17
Ulva fasciata	0.40		
April			
Corallina officinalis	0.07	*Corallina officinalis*	0.19
Corallina elongata	0.07	*Ulva compressa*	0.10
Ulva fasciata	0.34	*Ulva fasciata*	0.67
Ulva linza	0.11		
Ulva lactuca	0.85		
June			
Corallina officinalis	0.06	*Ulva compressa*	0.04
Ulva fasciata	0.24	*Ulva fasciata*	0.35
August			
Cladophora pellucida	1.35	*Cladophora pellucida*	0.19
Corallina officinalis	0.07	*Ulva fasciata*	0.32
Ulva fasciata	0.40		
September			
Cladophora lehmanniana	0.04	*Cladophora pellucida*	1.32
Cladophora pellucida	1.32	*Ulva fasciata*	0.18
Corallina elongata	0.02		
Ulva fasciata	0.65		
October			
Ulva fasciata	0.56	*Cladophora pellucida*	0.51
Corallina officinalis	0.07	*Ulva compressa*	0.46
		Ulva fasciata	0.28
December			
Ulva fasciata	0.70	*Ulva compressa*	0.61
Corallina officinalis	0.03	*Ulva fasciata*	0.40
February			
Ulva lactuca	0.95	*Ulva compressa*	0.80
Chaetomorpha linum	0.44	*Ulva fasciata*	0.07
Ulva fasciata	0.74		

The present study showed that seaweeds in Alexandria coastal waters exposed to a variety of environmental stresses, offering some evidences about the relative influence of the measured factors on the spatiotemporal macroalgae structure and production. Such changes are regarded a consequence of habitat modification mediated by a combination of physical and chemical disturbances (WORM *et al.*, 2006; WERNBERG & CONNELL, 2008).

The current data might confirm the role of temperature as driving regulating factor that mainly recognized during spring and summer, affecting negatively the species diversity and positively algal production

(SZÉCHY & NASSAR, 2005). This role became more important when nutrients were in excess regardless the geographical locality. The observed extremely high pH values during the macroalgae bloom periods might represent an ecological factor affecting the species diversity. Recent studies in coastal areas documented pH can reach levels up to 10 during microalgae and macroalgae dense blooms (HANSEN, 2002; BJÖRK *et al.*, 2004; MIKHAIL & LABIB, 2013).

The present prevalence of the red and brown algae at relatively high salinities and the green opportunistic algae at relatively low salinities and under nutrient pulses particularly with the massive algal growth supports others (NIELSEN *et al.*, 1995; VALIELA *et al.*, 1997; BENEDETTI-CECCHI, 2001) for their importance as ecological factors regulate the structure of the macroalgae communities in Alexandria waters.

Since the changes of macroalgae biomass at Alexandria near-coastal areas received a very rather limited attention, and according to the available literatures and knowledge, the present study throughout a year cycle is yet the first attempt to measure algal biomass of different macroalgae species under different physical and chemical ecological stressors. Despite the relatively limited data, the calculated regression analyses indicate the variability in temperature, salinity, pH, NO_3, and NH_4 explains about 53% and 92% of the algal abundance at EH and AT stations, respectively, and 85% and 71% of chlorophyll *a* changes.

The present data confirm the occurrence of incidents of the massive green macroalgae proliferation at a wide range of environmental variations, and with the sharing of other Rhodophyta species. Although the distinct inter-annual variations and the different response of the different species to variable environmental conditions hinder definition and prediction of principle factor/factors control *Ulva* abundance and growth, the study stresses the importance of the spring-increased temperature that interacts with the growth and abundance of opportunistic macroalgae at AT when nutrient enrichment occurs. Slight seasonal variations of seawater temperature with the algal growth were reported (HURTADO & RAGAZA, 1999; LEE, 1999). The study also revealed the strong contribution of salinity on the proliferation of *U. fasciata* and *U. compressa* in accordance with others (ERIKSSON & BERGSTROM, 2005; LARSEN & SAND-JENSEN, 2006).

The present regional and temporal distribution of algal community structure explains relative reduction in the number of Phaeophyta and increased Chlorophyta, indicating changes in the environment status. Brown algae were scarcely recorded at EH, while, both brown and red algae were almost absent at AT. The changes in proportion have been considered to be indicative of anthropogenic influences and shifts in quality status (GIACCONE & CATRA, 2004; WELLS *et al.*, 2007; CORZO *et al.*, 2009). The brown algae are not as tolerant as the green algae, they are very sensible to pollution. The significant difference between the two sites confirms the previously discussed geographical sensitive characteristics of seaweed communities (KAREZ *et al.*, 2004). The highest species number of red algae in March at EH attributed to lack of competition with green algae, and might indicate some improvement in environment quality and stability at times. The presence of *C. elongata* in March as indicator for intermediate quality (SOLTAN *et al.*, 2001; BENEDETTI-CECCHI, 2001) supports the above-mentioned result. The dominance of green species explains their ability to adapt more readily to changes in the environment whereby proportions increase with decreasing quality status. Cormaci et al. (2003) pointed out that increased/decreased red/green/brown species proportions indicate degradation and/or environmental stability.

Macroalgae dynamics and the factors influencing their variability are important aspects of the ecological, environmental, aesthetic, and socio-economic value of Alexandria ecosystems. The results can increase the overall success of management strategies, helping decision makers.

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