Diversity and Distribution of Polychaetes Associated with Macroalgae along the Alexandria Coast, Egypt

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Abstract. The relationship between benthic macroalgae and associated polychaetes was studied monthly from October 2014 to October 2015 along the Alexandria coast, Egypt. A total of 56 polychaete species were found among 28 macroalgal species, which belonging to green, brown and red algae. The red algae hosted pronouncedly higher number of polychaete species than the brown and green algae, particularly during winter and spring, while green algae were associated with higher number of polychaete species in January, April, August and October 2015. In contrast, the average count of polychaete individuals associated with the green algae was higher in winter and autumn than that recorded with the red algae, while low with both red and green algae in spring and summer, and very poor within the brown algae. The present study revealed that the structure of algal species may affect the diversity and abundance of the associated polychaetes and the diversity of these worms varied among the hosting algal species.

Keywords: Egyptian coast, Benthic fauna, Macroalgae, Red algae, Green algae, Annelida.

1. Introduction

The coastal benthic habitats are the most productive areas in the marine ecosystems, because of the great amount of nutrients received from the terrestrial system causing the increase of macroalgal biomass (Kelaher and Castilha, 2005). Macroalgal communities of coastal ecosystems play a key role in maintaining overall coastal biodiversity (Ba-Akdah *et al.*, 2016) as different marine invertebrates are frequently associated with them, such as polychaetes, amphipods, isopods, gastropods and mussels (Christie *et al.*, 1998; Sanchez-Moyano *et al.*, 2007; Cunha *et al.*, 2013). Macroalgae provides significant feeding, shelter, refuge, and nursery ground for numerous animal assemblages in the coastal zone, and can

affect their distribution and abundance (Gil *et al.*, 2006; Bracken *et al.*, 2007). In addition, coastal macroalgae can protect the benthic organisms from wave action, heat and desiccation (Moore, 1978; Hicks, 1980). The structure of the macroalgal thallus provides different habitat complexity that enhances diverse macrofaunal assemblages (Jeffries, 1997). Algal coverage enhances habitat variation, supporting a higher number of polychaete species than less complex habitats (Abbiati *et al.*, 1987; Giangrande, 1988). For example, *Jania rubens* coverage was among the variables affecting the distribution of hard bottom assemblage, and might represent a suitable habitat for polychaetes due to its structural complexity (Dorgham *et al.*, 2014). Similarly, the calcified complex algae are

suitable as polychaete habitats (Tena *et al.*, 2000). However, other algae with less complex thalli (i.e. *Enteromorpha* sp., *Petalonia* sp., *Ulva rigida*, *Colpomenia sinuosa*) contributed significantly to explain the variation of Alexandria hard bottom polychaete assemblages, as observed elsewhere (Musco, 2012). Furthermore, variation in the distributions of some crustaceans were positively related to variations in the cover of some dominant algal species, while no relation was observed with the animal components of fouling communities (Hamdy *et al.*, 2018).

Polychaetes are the most diverse and abundant benthic communities and are considered good indicator of species richness of benthic invertebrate assemblages (Van Hoey *et al.*, 2004). Polychaetes represent an essential component of the marine benthic fauna, with pronouncedly high biodiversity as well as numerical density (Fauchald, 1977). They are important diet for many marine fishes and invertebrates (Gambi and Giangrande, 1986), in commercial uses (Gambi *et al.*, 1994) and in aquaculture (Pausoao *et al.*, 1995). Further, polychaete community are used in assessing the environmental health (Gopalakrishnar and Nair, 1998; Sarkar *et al.*, 1999) and in biological criteria for the water quality (Lardicci *et al.*, 1997; Giangrande and Frascchetti, 1996; Samuelson, 2001), as they act as good bioindicators of environmental conditions, particularly of organic matter in the sediments (Méndez *et al.*, 1998; Simboura and Nicolaidou, 2001).

Numerous studies have been done on the polychaete community in the Egyptian Mediterranean coast, with high stress on the Alexandria coast, the majority of these studies were carried out during the past two decades (Selim, 1996 a,b,c; Abd El-Naby, 1999; 2005; Selim *et al.*, 2006a,b, Dorgham

et al., 2013; 2014; Dorgham and Hamdy, 2015). However, the majority of these studies were concentrated on the species composition and abundance of polychaetes either along the Alexandria coast or in the Eastern Harbour, while some of them recorded new coming species to the area.

The present study aims to follow up the relationship between the macroalgal cover and the composition and abundance of the associated polychaetes on hard bottoms along the Alexandria coast.

2. Materials and Methods

3.1 Study Area

The coast of Alexandria extends about 35 km along the Egyptian Mediterranean coast. It is mostly sandy, with some natural rocky areas and intensive shore armoring structures, extending both along the shore and inside the sea.

The present study was carried out at four sites, representing different habitats of the study area (Fig. 1).

1. Abu Qir (AQ) (31°20'16.80"N - 30°04'52.12"E) is an exposed area lying east of Alexandria City with sandy bottom alternating with large natural rocky patches.

2. Gleem (GL) (31°14'30.68"N - 29°57'38.98"E): Rocky sheltered area protected by concrete blocks, has small pieces of natural rocks.

3. El Kashafa (EK) (31°12'62.74"N - 29°54'23.91"E): Sheltered area inside the Eastern Harbour, with concrete blocks.

4. El-Mex (MX) (31°09'14.93"N - 29°50'52.38"E) is an exposed rocky area within El-Mex Bay, receiving brackish water effluents of agricultural, industrial, and sewage discharge from the adjacent Lake Mariut.

Fig. 1. The coast of Alexandria including the sampling sites (after Dorgham *et al.*, 2014).

2.2 Sampling

Macroalgal samples were collected on monthly basis from October 2014 to October 2015 from the selected sites. Water samples were also collected for the analysis of physico-chemical parameters. Water temperature was measured in situ, using a simple thermometer, graduated to 100°C; salinity was determined by a calibrated Beckman Induction Salinometer (Model RS-7C), and pH was measured in situ by digital portable pH-meter (Cyberscan 10pH; pH - °C Meter). Dissolved oxygen (DO) was determined according to the method described by Strickland and Parsons (1972). Nitrate and phosphate were determined following Moorcroft *et al.*, (2001) using spectrophotometer (HACH-DRL 2000).

Biological samples were collected in three replicates within the depth range of 0.5m by removing the macroalgae and the associated fauna by careful scraping the hard substrates within a metallic quadrat of 25x40 cm and the collected samples were fixed in 4% neutralized formalin. In the laboratory, the collected macroalgae were placed in big plastic container, washed carefully to free the attached polychaetes, which were then isolated in plastic jars and finally preserved in 70% ethanol. Polychaete identification was

done according to Fauvel (1923, 1927), Fauchald (1977) and San Martin (1984, 2003). The wet weight of the algae was taken after removing any visible sessile invertebrates or other epiphytes, and the algal species were identified to species level, following Taylor (1945), Nasr and Aleem (1949), Duerden and Jones (1981), Campbell (1982), El-Zayat (2012) and Diaz-Tapia and Barbara (2014).

3. Statistical Analysis

3.1 Diversity Indices

The Shannon index was calculated according to the equation of Shannon & Weaver (1949), Pielou's evenness index was found as a ratio of observed diversity to maximum diversity (Magurran, 2003), and species richness (SR) was determined according to the equation given by Margalef (1958). Dominance (CDI) was calculated using the community dominance index described by Mc-Naughtn (1968).

Variations in species composition and abundance, number of species and diversity were analyzed with PERMANOVA and ANOVA. The model consisted of two orthogonal factors: "algal type" (two levels fixed: green algae, red algae) and "month" (13 levels random). Each term in the

PERMANOVA and ANOVA was tested using 999 random permutations of the appropriate units.

Non-metric multi-dimensional scaling (nMDS) analysis was performed in order to obtain a graphic visualization of similarities (Bray-Curtis) among polychaete assemblages of the two algal habitats (red and green algae). Environmental variable vectors were over imposed in order to highlight their correlation with the polychaete assemblages of the two different algal types and of the four sampling sites.

SIMPER (Similarity percentage) analysis was performed in order to highlight the species mostly contributing to differentiate the assemblages associated to the two algal habitats analyzed. The analyses were performed using the PRIMER v6 software, including the add-on package PERMANOVA.

4. Results

4.1 Physical Chemical Conditions

The physical chemical parameters are given in Table 1 indicate that water temperature displayed clear seasonal variation between the winter minimum in February and the summer maximum in August. Surface salinity varied within a narrow range at most of the sampling sites, except for a wide range at MX due to the huge amount of brackish water discharged from Lake Mariut through El-Umoum Drain. Both pH and dissolved oxygen experienced narrow monthly variations at most sites except at MX, where pH was relatively low and DO displayed wide variation. Nitrate sustained low concentration over the whole area of study, with the lowest values during spring and summer and comparatively high values during autumn and winter. Phosphate showed little spatial differences most of the year,

especially during the period from October to April.

Table 1. Annual average values of the physical chemical parameters at the sampling sites from October 2014 to October 2015.

	Salinity (‰)	Temp. (°C)	pH	Dissolved oxygen (mg /l)	Nitrate conc. (µM)	Phosphate conc. (µM)
AQ	38.3 ± 0.52	23.61 ± 4.41	7.96 ± 0.42	5.91 ± 0.81	11.54 ± 13.04	0.68 ± 0.34
GL	37.54 ± 1.20	23.76 ± 4.30	7.87 ± 0.31	5.11 ± 1.14	7.22 ± 8.05	0.81 ± 0.20
EK	28.07 ± 2.13	23.60 ± 4.61	7.60 ± 0.30	4.57 ± 1.32	9.94 ± 6.84	0.84 ± 0.31
MX	10.37 ± 7.12	23.09 ± 4.61	7.45 ± 0.29	2.97 ± 0.98	12.97 ± 8.45	0.84 ± 0.32

4.2 Macroalgal Community

A total of 28 macroalgal species were recorded, including 8 species of green algae (Chlorophyceae), 3 species of brown algae (Phaeophyceae) and 17 species of red algae (Rhodophyceae). The majority of the red algae (15 species) were recorded at AQ and the lowest number (4 species) at EK, with the dominance of *Corallina* spp. and *Jania* spp. The species composition of green algae showed little spatial differences, whereas 6 species existed at AQ against 4-5 species at the other sites, with the dominance of *Ulva* spp. along the study area. The brown algae were represented by three species only, namely *Petalonia fascia*, *Dictyota dichotoma* and *Colpomenia sinuosa*.

4.3 Polychaetes

The polychaete community comprised 56 species, belonging to 44 genera and 19 families. Syllidae (16 species) appeared as the most diverse family, followed by Nereididae (5 species). However, family Serpulidae was represented by the highest number of individuals constituting 72% of the total polychaetes count, against (14.6%) for Syllidae and (9.7%) for Nereididae. The polychaetes diversity experienced clear spatial differences along the Alexandria coast, where 53 species were recorded at AQ,

dropped to 41 species at EK (Table 2). In contrast, their numerical abundance demonstrated pronounced variations among the sampling sites, attaining the lowest count (annual average: 243 ind/m²) at AQ and the highest count (annual average: 3880 ind/m²) at EK (Table 2), with the dominance of *Spirobranchus triqueter* over the whole area.

Table 2. Algal diversity and number of polychaetes species and abundance (Annual average: ind/m²) among the algal groups at different stations.

Type of algal group	No. of algal species	Polychaetes	
		No. of species	abundance (ind/m ²)
AQ			
Green Algae	6	19	54
Red Algae	15	34	189
Brown Algae	3	0	0
Total	24	53	243
GL			
Green Algae	4	16	400
Red Algae	9	30	737
Brown Algae	1	0	0
Total	14	46	1137
EK			
Green Algae	5	16	2693
Red Algae	5	24	1186
Brown Algae	2	1	1
Total	12	41	3880
MX			
Green Algae	4	23	1852
Red Algae	6	25	528
Brown Algae	2	0	0
Total	12	48	2380

The present study revealed that the red algae hosted pronouncedly higher number of polychaete species (53) than the green algae (39), while the abundance of polychaetes associated with green algae (annual average 1250 ind/m²) was pronouncedly higher than that (annual average 660 ind/m²) with the red algae (Fig. 2). The brown algae hosted extremely poor polychaetes as 4 individuals only were found in one sample. Regarding the temporal pattern, the number of polychaete species with the red algae were the highest during winter and spring and

deceased during summer, while those with green algae appeared to be the highest in January, April, August and October (Fig. 2). However, the average count of polychaete individuals among the green algal mats was higher in winter and autumn than that in the red algae, but this count was low in spring and summer among both red and green algae (Fig. 2). The Shannon diversity index for polychaetes in the red algae was more than one during most of the study period and less than one in the green algae except August, 2015 (Fig. 2).

The correlations among the green algae biomass was low and negative with the number of species ($r = -0.167$) and number of individuals ($r = -0.451$) but positive with reference to the Shannon diversity ($r = 0.282$). The correlations among the red algae biomass was low and negative with the number of individuals ($r = -0.089$) but it was positive when considering the total number of species ($r = 0.211$) and the Shannon diversity ($r = 0.22$).

The multivariate Analyses (PERMANOVA) of temporal variation of polychaete distribution between the algae (Table 3) revealed significant temporal variation as well as clear differences between the polychaete species associated to the red and the green algae. The nMDS plot (Fig. 3) showed some differences in temporal distribution of polychaete assemblages in the two algal groups, while the nMDS plot (Fig.4) revealed no clear differences among polychaete assemblages from different sites since symbols tend to mix on the plot. However, it is possible to see a tendency of EK, GL and AQ polychaete assemblages to separate from each other, whilst no clear differences can be seen as far as MX is concerned.

Table 3. PERMANOVAs testing temporal (monthly) differences in polychaete assemblages associated to red and green algae in the study area. Significant p values are given in *italics*. Test by permutations (999) based on Bray-Curtis similarity. Data fourth-root transformed.

	PERMANOVA table of results					
	df	SS	MS	Pseudo-F	P(perm)	Uniqueperms
Algal type	1	15075	15075	7.6862	<i>0.001</i>	999
month	12	38489	3207.4	1.4067	<i>0.004</i>	996
Algal type x month	12	23515	1959.6	0.85941	0.846	998
Res	76	173290	2280.2

Fig. 2. The monthly average number of polychaete species, individuals and Shannon diversity (the error value indicate SE).

Fig. 3. Monthly relationship between the polychaete abundance and the wet weight of green algae from October 2014 to October 2015.

Fig. 4. Monthly relationship between the polychaete abundance and the wet weight of red algae from October 2014 to October 2015.

Fig. 5. Non-metric multi-dimensional scaling (nMDS) showing a graphic visualisation of similarities (Bray-Curtis) among polychaete assemblages of the two algal habitats (red and green algae). Environmental variable is over imposed in order to highlight their correlation with the polychaete assemblages.

Fig. 6. Non-metric multi-dimensional scaling (nMDS) showing a graphic visualisation of similarities (Bray-Curtis) among polychaete assemblages of the four analyzed sites. Environmental variable is over imposed in order to highlight their correlation with the polychaete assemblages.

5. Discussion

It is well known that habitat structure is considered as an important determinant of the diversity and abundance of species present in biological communities (Commito and Rusignuolo, 2000) algae such as calcareous species could have binder and baffler functional role which expand and unite the components of the framework and the settling sediment (Cocito, 2004) since the structure of algae and the leaf surface strongly affects the composition and abundance of the associated fauna (e.g. Bates, 2009; Jones and Thornber, 2010; Cacabelos *et al.*, 2010), and consequently enhance significant correlation between the abundance and diversity of polychaete assemblages with the algal groups (Giangrande *et al.*, 2003). This statements may explain the significant correlation between the number of polychaete species and the red algae and between the polychaete abundance and green algae during the present study. Similar observations were found earlier along the Alexandria coast (Dorgham *et al.*, 2014).

The present study revealed that the several polychaete species preferred red algae as suitable refuge, particularly those of Syllidae, while Nereididae seems to prefer green algae may be due to the algal consumption by these worms (Raffaelli, 2000), while decrease of nereidids diversity among coralline algae is due to the dense accumulation of the epifauna on their thalli that prevents the feeding efficiency of these worms (Menge, 1978). However, Musco (2012) supposed no feeding relationship between polychaetes and macro algae as polychaetes usually feed on detritus.

Our results indicated the occurrence of few specimens of the polychaetes *Polyophthalmus pictus* and *Capitella capitata* in association with the green algae *Cladophora gracilis*, *C. pellucida*, *C. dalmatica* and *Enteromorpha intestinalis*. Similarly, Bolam and Fernandes (2002) found that *Enteromorpha* and *Cladophora* were poor species and dominated by trimmer species such as *C. capitata* and oligochaetes.

The dominance of the red algal species *Coralline officinalis*, *Jania* sp., *Amphiroa*

compressa, and *Amphiroa rigida* at AQ was accompanied by the most diversified polychaete community along the Alexandria coast, particularly the Syllidae and other small size species. Similar observations were reported by Giangrande (1988) who noticed an association between the red algal species, *Corallina elongata*, *Jania rubens*, and *Laurencia obtusa* and the polychaetes of the superficial infralittoral zone such as *Platynereis dumerilii*, *Syllis prolifera*, *Eunice harassii*, *Spirobranchus polytrema*, *Ceratonereis costae*, *Syllis gracilis*, *S. prolifera* and *Nereis zonata*, which were also found at AQ. These algal species play significant role in habitat heterogeneity, due to the combination of their rough branched habit and the sessile invertebrates growing directly on the algae (Raffaelli *et al.*, 1999; Nyberg *et al.*, 2009). Furthermore, the calcareous branches of red algae were found to allow the accumulation of sediment and detritus influencing the distribution and composition of associated polychaetes such as Syllid species (Serrano *et al.*, 2006; Tena *et al.*, 2000), and also favoring for the presence of other interstitial species to face both physical stresses (decreasing desiccation and wave force) and biotic stresses (providing refuge from predators and increased niches to reduce competition) (Bradshaw *et al.*, 2003; Quirós-Rodríguez and Campos, 2013). Although Abbiati *et al.*, (1987) and Serrano *et al.* (2006) stated that the variation in abundance of habitat-forming taxa is one of the most important factors influencing the distribution of Syllidae, Musco and Giangrande (2005) found no significant relationship between red alga and Syllidae distribution.

6. Conclusion

The present study indicated that increased biomass of algal cover enhanced the increase polychaete diversity species and consequently other sessile fauna, algal morphology play a significant role in the

diversity and abundance of associated polychaete species.

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تنوع وتوزيع الديدان عديدة الأشواك المصاحبة للطحالب على طول ساحل الإسكندرية،

مصر

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المستخلص. تمت دراسة العلاقة بين الطحالب والديدان عديدة الأشواك المصاحبة لها شهرياً خلال الفترة من أكتوبر ٢٠١٤ إلى أكتوبر ٢٠١٥ عند أربعة مواقع على امتداد ساحل الإسكندرية. سجلت الدراسة ٢٨ نوعاً من الطحالب القاعية يصاحبها ٥٦ نوعاً من الديدان عديدة الأشواك. شملت الطحالب سبعة عشر نوعاً من الطحالب الحمراء، ثمانية أنواع من الطحالب الخضراء، وثلاثة أنواع من الطحالب البنية مع تغير واضح في عدد الأنواع عند المواقع المختلفة. استضافت الطحالب الحمراء العدد الأكبر من أنواع الديدان مقارنة بالطحالب الخضراء والبنية، إلا أن عدد أنواع الديدان أظهر تبايناً واضحاً مع تغير الغطاء الطحلي في أوقات العام المختلفة، حيث كانت الديدان الأكثر تنوعاً مع الطحالب الحمراء خلال الشتاء والربيع، في حين بدت الديدان أكثر تنوعاً مع الطحالب الخضراء خلال يناير، أبريل، أغسطس، أكتوبر ٢٠١٥. وعلى النقيض سجلت الديدان كثافة عددية أكبر مع الطحالب الخضراء عنها مع الطحالب الحمراء، خاصة خلال فصلي الشتاء والخريف، بينما انخفضت تلك الكثافة مع كل من الطحالب الخضراء والحمراء على السواء خلال فصلي الربيع والصيف، في حين استضافت الطحالب البنية عدداً قليلاً جداً من الديدان عديدة الأشواك، وقد أوضحت الدراسة الحالية أن تركيب الطحالب يمكن أن يؤثر على تنوع وكثرة الديدان عديدة الأشواك المرتبطة بها وأن تنوع هذه الديدان قد يختلف تبعاً لنوع الطحالب الذي تعيش فيه.

كلمات مفتاحية: الطحالب، الطحالب الحمراء، الطحالب الخضراء، الديدان عديدة الأشواك.