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Macrofauna Associated with a Recently Described Bryozoan Species in the Eastern Harbour of Alexandria, Egypt

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Abstract

The bryozoan *Calyptotheca alexandriensis* was recorded for the first time two years ago as a new species from the Eastern Harbour of Alexandria, Egypt. Knowledge about the ecology of this bryozoan and the associated fauna is completely lacking. The present study is an attempt to identify the fauna associated with this bryozoan species, through approximately bimonthly sampling from October 2017 to August 2018. A total of 43 animal species were associated with the colonies of *C. alexandriensis*, belonging to nine taxonomic groups, including polychaetes (21 species), crustaceans (13 species), molluscs (3 species), ascidians, bryozoans, cnidarians, echinoderms, sipunculids, and sponges (one species each). Juvenile shrimps, fish larvae, and eggs of different animals were also found. The numerical abundance of the associated fauna fluctuated between 1279.3 individuals/kg in winter and 3041 individuals/kg in autumn. Crustaceans were the most abundant group, constituting 90.5% of the total associated fauna, mainly due to the amphipod *Elasmopus pectenicrus* (75.4%), beside other crustaceans like *Jassa marmorata* (6.2) and *Apohyale perieri* (3.7%). In contrast, polychaetes were markedly less abundant, forming 7.9% of the associated fauna, with the dominance of *Pseudonereis anomala* (3.5%). Spring and summer communities were more diverse (30-32 species) than the autumn and winter communities (16 and 25 species, resp.). The Shannon diversity index presented low diversity of the associated fauna, varying seasonally between 0.56 in summer and 1.6 in winter, with evenness fluctuating from 0.16 in summer to 0.50 in winter.

Keywords: *Calyptotheca alexandriensis*; benthic fauna; polychaetes; amphipods; tanaids.

Introduction

Several groups of marine plants and animals, such as sea grasses (Boström *et al.*, 2006), sponges (Gerovasileiou *et al.*, 2016), polychaetes (Smith *et al.*, 2005; Desroy *et al.*, 2011), oysters (Beck *et al.*, 2011), and heavily calcified bryozoans (Wood *et al.*, 2012; Lombardi *et al.*, 2014), form habitats for numerous marine organisms, from foraminiferans and polychaetes (Stebbing, 1971; McKinney & Jaklin, 2000; Cocito *et al.*, 2002) to larger organisms such as sponges, hydroids, and bryozoans (Jones & Lockhart, 2011). Studies of bryozoan-generated habitats are few and fairly site-specific, while the ecology of these bryozoans is still poorly known (Wood & Probert, 2013).

Benthic biogenic substrata in coastal systems enhance local species diversity by increasing the range of microhabitats for organisms and through adding habitat heterogeneity and structural complexity (Sebens, 1991; Thompson *et al.*, 1996). Colonial organisms such as corals and bryozoans can increase the available secondary substrata in sublittoral systems (e.g., Nalesso *et al.*, 1995; Cocito *et al.*, 2000), since they are used by macrofauna species, such as polychaetes, molluscs, crustaceans, and echinoderms, to hide from predators and to forage for debris and small invertebrates (Porras *et al.*, 1996).

Bryozoans took place in modern tropical carbonate settings mostly in relatively low abundance, while they are dominant outside the tropics, particularly in many temperate areas (Taylor & Allison, 1998). Therefore, the role of bryozoan colonies as habitats has been described mainly in temperate systems (e.g., Maluquer, 1985; Conradi & Cervera, 1995; Ferdeghini & Cocito, 1999; Cocito *et al.*, 2000), while they are scarcely studied in tropical or subtropical regions (Lindberg & Stanton, 1988; Mantelatto & Souza-Carey, 1998). The colonies of several bryozoan species contribute effectively as secondary substrata for local fauna, like *Pentapora fascialis* Pallas, 1766 (Cocito *et al.*, 1998; Ferdeghini & Cocito, 1999); *Cellaria salicornioides* Lamouroux, 1816 (McKinney & Jaklin, 2000); *Schizoporella errata* Waters, 1878 (Cocito *et al.*, 2000); *Celleporaria agglutinans* Hutton, 1873; and *Hippomenella vellicata* Hutton, 1873 (Bradstock & Gordon, 1983). The number of bryozoan species living at present in the Mediterranean is 556 species and is expected to increase by about 280-500 species (Rosso & Di Martino, 2016), due to new records inside the Mediterranean or by intrusion of non-indigenous species from the adjacent regions, whereas 59 out of the 556 spp. living today in the Mediterranean Sea are considered non-indigenous bryozoans (Rosso & Di Martino, *2016)*. Despite the high bryozoan diversity in the Mediterranean when compared with other regions of the globe, bryozoans are still scarcely known in the Eastern Mediterranean (Harmelin *et al.*, 2016; Sokolover *et al.*, 2016). However, Gerovasileiou and Rosso (2016) stated that recent efforts have significantly increased the knowledge on bryozoans in the south-eastern Mediterranean Sea, recording 237 species from the Greek Seas. In the Egyptian Coast, a few studies were conducted about the Bryozoa (Abdel-Salam & Ramadan, 2008 a, b; Abdel-Salam, 2014; Abdel-Salam *et al.*, 2017). Moreover, the fauna associated with bryozoans has not been the subject of any study along the Mediterranean coast of Egypt.

The present study deals with the composition and abundance of the fauna associated with *Calyptotheca alexandriensis*, which was described as follows: colony erect, foliaceous, comprising an open honeycomb of anastomosing bifoliate fronds forming a spheroidal mass, intracolonial overgrowths occasionally developed, uniporous septulae present in lateral and transverse vertical walls, situated close to the basal wall, colour vivid deep orange to red when alive, fading to pale brown in spirit or dry (Abdel-Salam *et al.*, 2017). According to these authors, *C. alexandriensis* represents a new species of unknown original provenance. Its occurrence in the Eastern Harbour of Alexandria, which lies 240 km west of the opening of the Suez Canal at Port Said, raises the possibility that the transfer of this species may not have occurred via the Suez Canal, since the currents along the Egyptian Mediterranean coast are predominantly eastward (Said & Eid, 1994). Therefore, there is no certainty whether this species is a Lessepsian migrant as it may instead have entered the Mediterranean from the Atlantic.

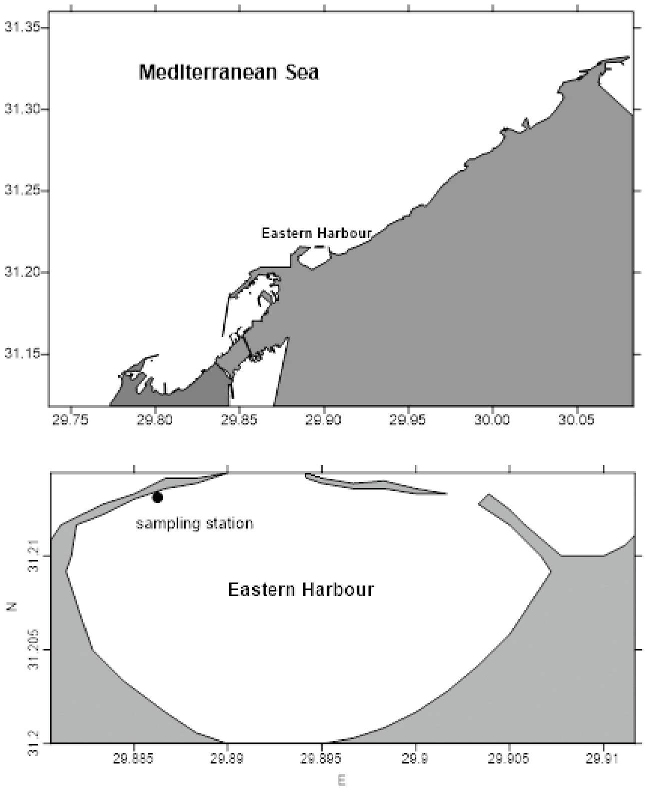

Fig. 1: The Eastern Harbour of Alexandria, including the position of the sampling area station.

Material and Methods

The Eastern Harbour (EH) is located on the Mediterranean Coast of Egypt, and the sampling site lies at 31.212258N and 29.886125 E. The EH is one of the chronically eutrophic coastal basins on the Alexandria coast due to long-term sewage discharge, indirect effect of different types of waste waters from the adjacent Lake Mariout, and several human activities, like shipping, fishing, and recreation, where numerous peoples visit the beach and spend the daytime in swimming snorkeling, sea tours, and sport fishing (Dorgham, 2011).

Three masses of the bryozoan *C. alexandriensis* were collected from a rocky bottom at 1.5 m depth and from metallic stand of a marina (Fig. 1), during October 2017 (autumn), February 2018 (winter), April 2018 (spring), and June and August 2018 (summer). The bryozoan colonies were kept in seawater until reaching the laboratory, where they were carefully broken up by hand and the associated fauna was removed. The bryozoan skeletons were left for one day in the laboratory to dry at room temperature and then they were weighed by analytical balance. The sorted fauna was preserved in 10% neutralized formaldehyde, and the taxa were identified to the lowest possible taxonomic level and counted. The total count per bryozoan sample was estimated as number of individuals/kg of the bryozoan skeleton. Groups like sponges and bryozoans were obtained as small pieces but were not identified. No algal growth was observed on the colonies of *C. alexandriensis.* The environmental parameters (water temperature, salinity, pH, dissolved oxygen, nutrients, and chlorophyll-a) were measured in the area of study following the methods described by Strickland and Parsons (1972).

Statistical Analyses

Statistical analyses were performed using the package PRIMER-E© ver. 6 (Clarke & Gorley, 2006) and MS Excel®.

Diversity Indices

Three diversity indices were calculated: Richness Index (R1), a direct expression of the number of species was estimated according to Margalef (1958). The Diversity Index was determined using the equation of Shannon and Weaver (1949). The fifth Evenness Index (E5), also known as the “modified Hill coefficient” (Alatalo, 1981), was used because it is relatively unaffected by species richness (Ludwig & Renolds, 1988).

BIO-ENV Procedure

The correlation between the associated fauna and water parameters (see below) around the *C. alexandriensis* colonies, at a seasonal basis, was tested with the PRIMER-E© BIO-ENV routine, which is based on the non-parametric Spearman rank correlation coefficient (Clarke & Gorley, 2006).

We tested ten variables, namely, dissolved inorganic phosphorous (DIP), NO_2, NO_3, SiO_4, DO, Chl-a, water temperature (Temp), pH, salinity (Sal), and conductivity (Cond). A Draftsman Plot showed that a log transform was necessary for nutrient variables, that is, DIP, NO_2, NO_3, and SiO_4, in order to reduce a right-skewed distribution, but DO, Chl-a, Temp, pH, Sal, and Cond could remain untransformed.

Interspecific Association

To identify the multivariate patterns of species distribution as derived from different sampling seasons, the method of non-metric multi-dimensional scaling (MDS) (Kruskal, 1964) was adopted. Before that in order to downweight the importance of dominant species, the abundance values were fourth-root transformed prior to similarity coefficient calculation between every pair of samples. Triangular similarity matrices were then produced at monthly scale and season factor was introduced. According to the MDS method, the relative distance of all pairs of species was measured by Bray & Curtis (1957) to define the "stress" that measures the success of the combination obtained in compatibility with the entered data and determines how the points should move to the next repetition. The value of stress close to zero indicates that the duplicates used reached the compatibility of data (Clarke & Warwick, 2001).

ANOSIM

The analysis of similarity (ANOSIM) allows a test of null hypothesis where there are no assemblage differences between groups of samples specified by the levels of a single factor, that is, different times or seasons in the present study. ANOSIM here tests the hypothesis that there are no differences between sampling period dates in the composition of the bryozoan-associated fauna.

Results

Colonies of the bryozoan *C. alexandriensis* were inhabited by a total of 43 benthic animal species belonging to nine higher taxonomic groups, including 21 polychaete species, 13 crustaceans, three molluscs, and one species each for ascidians, bryozoans, cnidarians, echinoderms, sipunculids, and sponges. In addition, juvenile shrimps, fish larvae, and eggs of different animals were found in the samples, but they were not counted (Table 1). The associated fauna in spring and summer was richer in species (30 and 32, resp.) than autumn (16 species) and winter (25 species). However, the diversity indices showed different seasonal patterns. The Shannon diversity index reached the highest value during winter and the lowest in summer, while species richness attained the highest value in summer and the lowest in autumn. Evenness displayed little seasonal variations (Fig. 2), which could be attributed to the persistent dominance of one species, namely, the amphipod *Elasmopus pectenicrus* (Table 1).

The numerical abundance of the associated fauna exhibited wide seasonal fluctuation, as it attained the highest value in autumn (3041.3 ind/kg), followed by pronouncedly lower values (1258.5-1591.5 ind/kg) in winter, spring, and early summer and increasing again in late summer to 2582.3 ind/kg (Fig. 3). Regardless of the crustaceans' lower diversity compared to polychaetes, they greatly sustained higher count, forming 90.5% of the total count of the associated fauna against 7.9% for polychaetes. However, the two groups displayed different

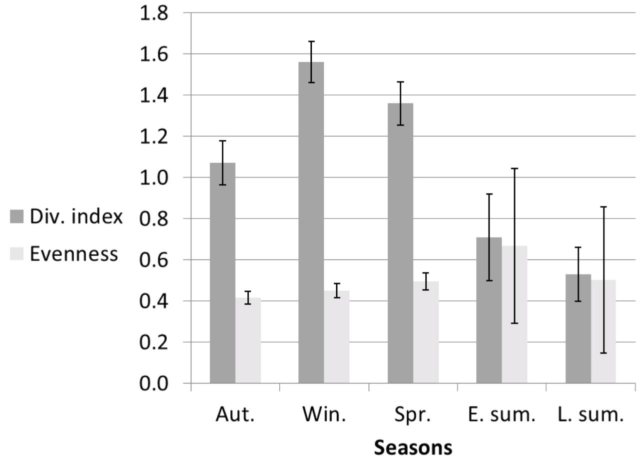

Fig. 2: Seasonal variation of mean diversity, richness, and evenness indices within the community associated with *Calyptotheca alexandriensis* in the Eastern Harbour of Alexandria (E. sum.: early summer; L. sum.: late summer).

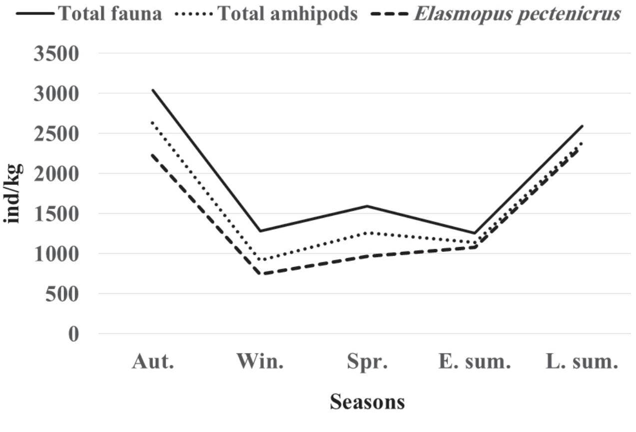

Fig. 3: Seasonal abundance of the total fauna, total amphipods, and the amphipod species *Elasmopus pectenicrus* associated with *Calyptotheca alexandriensis* in the Eastern Harbour of Alexandria (E. sum.: early summer; L. sum.: late summer).

Table 1. Numerical abundance of the fauna associated with the bryozoan *Calyptotheca alexandriensis* in the Eastern Harbour of Alexandria, Egypt.

Group and species	Oct.	Feb.	Apr.	Jun.	Aug.
Class: Crustacea					
Order: Tanaidacea					
Family: Tanaididae					
Tanais dulongii (Audouin, 1826)	80.7	31.7	17.3	8.3	5.3
Family: Leptocheliidae					
Chondrochelia savignyi (Krøyer, 1842)	0	5.3	0	0.7	2.0
Order: Amphipoda					
Family: Maeridae					
Elasmopus pectenicrus (Spence Bate, *sensu* Ruffo 1862) *****	2230	746.7	967	1083.3	2336.7
Family: Ischyroceridae					
Jassa marmorata (Holmes, 1905)	37.3	174.3	291.4	56	48.3
Family: Hyalidae					
Apohyale perieri (Lucas, 1849)	361.3	0	1.3	0	0
Order: Isopoda					
Family: Sphaeromatidae					
Sphaeroma serratum (Fabricius, 1787)	46.3	23.0	10.0	1.7	25.7
Family: Cirolanidae					
Cirolana bovina (Barnard, 1940)	73.3	32.7	16.7	6.6	2.0
Family: Sphaeromatidae					
Dynamene bidentata (Adams, 1800)	0	3.3	4.0	0.7	0
Order: Decapoda					
Family: Eriphiidae					
Eriphia verrucosa (Forskål, 1775)	2.3	0	2.3	2.3	0.3
Family: Portunidae					
Charybdis hellerii (A. Milne-Edwards, 1867) *****	0.3	0	2.3	0	0
Family: Majidae					
Maja sp.	0	*0*	6.3	0.7	0
Family: Alpheidae					
Alpheus lobidens De Haan, 1849 [in De Haan, 1833-1850] *****	0	10.3	15.7	2.0	0.3
Order: Cirripeda					
Family: Sessilia					
Balanus sp.	52	0	2.7	5.7	0.7
Class: Polychaeta					
Order: Amphinomida					
Family: Amphinomidae					
Eurythoe complanata (Pallas, 1766) *****	0	0	1.3	2.7	8.7
Linopherus canariensis (Langerhans, 1881) *****	0	1	0	1.3	0
Family: Dorvilleidae					
Schistomeringos rudolphi (Delle Chiaje, 1828)	0	2.0	0	5	5.3
Family: Chrysopetalidae					
Chrysopetalum debile (Grube, 1855)	0	1	0	**0**	1.0
Family: Hesionidae					
Syllidia armata (Quatrefages, 1866)	0	16.7	1.0	**0**	8.3
Family: Nereididae					
Alitta succinea (Leuckart, 1847)	0	1	6.3	2.7	0
Pseudonereis anomala (Gravier, 1899) *****	57.3	93.3	150.7	42.0	2.7
Family: Polynoidae					

continued

Table 1 continued

Group and species	Oct.	Feb.	Apr.	Jun.	Aug.
Lepidonotus clava (Montagu, 1808)	0	0	0	1.3	0
Family: Syllidae					
Syllis hyalina (Grube, 1863)	6.3	38.7	45.3	11.7	22.7
Syllis schulzi (Hartmann-Schröder, 1960)	0	1	0	0	0
Syllis variegata (Grube, 1860)	40.3	31.3	11.7	6.3	9.7
Trypanosyllis zebra (Grube, 1860)	0	1	1.0	0	2.0
Family: Sabellidae					
Amphiglena mediterranea (Leydig, 1851)	0	2.0	1.0	0	1.0
Family: Serpulidae					
Hydroides dianthus (Verrill, 1873)	0	0	2.3	0.7	0
Hydroides elegans (Haswell, 1883) *	0	0	8.7	2.3	78.3
Serpula concharum (Langerhans, 1880)	0	1	5.7	3.7	0
Family: Spionidae					
Dipolydora coeca (Örsted, 1843)	0	1	0	0.7	2.3
Family: Cirratulida					
Caulleriella bioculata (Keferstein, 1862)	0	0	0	0.7	2.3
Family: Terebellidae					
Axionice medusa (Savigny in Lamarck, 1818) *	0	4.3	2.3	2.7	5.3
Order: Scolecida					
Family: Opheliidae					
Polyophthalmus pictus (Dujardin, 1839)	0	0	0	0	0.3
Family: Lumbrineridae					
Lumbrineris coccinea (Renier, 1804)	0	0	0	0	4.3
Phylum: Porifera					
Porifera sp.	+	0	+	0	+
Phylum: Cnidaria					
Hydrozoan polyps	0	0	0	2.3	0
Phylum: Bryozoa					
Family: Bugulidae					
Bugula sp.	+	0	+	+	0
Phylum: Sipuncula					
Class: Sipunculidae					
Sipunculidea sp.	0	0	1.0	0.7	2.0
Phylum: Mollusca					
Class: Bivalvia					
Order: Mytilida					
Family: Mytilidae					
Brachidontes pharaonis (P. Fischer, 1870) *	42	0	0	0.5	1.3
Venerupis corrugata (Gmelin, 1791)	0	0	0	0	0.3
Order: Gastropoda					
Family: Fissurellidae					
Fissurella sp.	0	1.0	0	0	0
Phylum: Echinodermata					
Order: Ophiuroida					
Family: Ophiuridae					
Ophiura sp.	0	54.7	9.7	0	2.0
Phylum: Chordata					
Class: Ascidiacea					
Ascidiacea sp.	11.7	1.0	6.3	0	1.0
Total count	3041.3	1279.3	1591.4	1255.3	2582.3

Footnote: *non-indigenous

patterns of seasonal abundance, whereas the crustaceans showed two peaks in autumn and late summer (Fig. 3), while polychaetes had a peak during spring (Fig. 4).

Only 9.3% of the associated taxa were responsible for 88.9% of total abundance, mainly due to the dominance of the crustacean amphipods *E. pectenicrus* (75.4%), *Jassa marmorata* (6.2%), *Apohyale perieri* (3.7%), and the polychaete *Pseudonereis anomala* (3.5%). Other species represented low percentages of the total fauna, such as the crustaceans *Tanais dulongii* (1.5%), *Cirolana bovina* (1.3%) and *Sphaeroma serratum* (1.1%), and the polychaetes *Syllis hyalina* (1.3%) and *S. variegata* (1.0%). All other species were mostly found either occasionally or in low numbers (Table 1). The contribution of crustaceans and polychaetes (relative abundance) to the total count of the associated fauna experienced seasonal variation. As shown in Table 2, the crustaceans formed 92.8-94.8% during summer and autumn, against 80.2-84% in winter and spring, when polychaetes attained their highest percentages (15.4% and 14.9%, resp.). On the other hand, the number of polychaete species (14 and 15) was higher than the crustaceans (8 and 11) during winter and summer, respectively, but in autumn 3 polychaete species occurred against 9 species for crustaceans.

The major associated species demonstrated variable seasonal contribution to the total count. For example, *E. pectenicrus* represented 58.3% and 60.8% of the total fauna in winter and spring, respectively (Figs S2 and S3), jumping to 86.1-90.1% during summer (Figs S4 and S5), while the second abundant crustacean, *J. marmorata*, showed the lowest percentage (1.2%) in autumn (Fig. S1) and the highest (18.3%) in spring (Fig. S3). In contrast, *A. perieri* displayed a flash appearance in autumn, constituting 11.8% of the total associated fauna (Fig. S1), while it occurred in very low counts or completely disappeared during the other seasons.

Pseudonereis anomala was the most abundant polychaete, particularly in winter and spring forming 7.3 and 9.5 %, respectively, of the associated fauna (Figs S2 and S3). This species displayed less contribution in autumn (1.9 %) and early summer (3.3 %) (Figs S1 and S4), while it disappeared in late summer, when *Hydroides elegans* became the dominant polychaete, constituting 3% of the total associated fauna (Fig. S5). In addition, *Syllis hyalina* showed relatively active contribution (3% and 2.8%, resp.) in the fauna of winter and spring (Figs S2 and S3). *Syllis variegata* displayed its maximum contribution (2.5%) in early summer (Fig. S4).

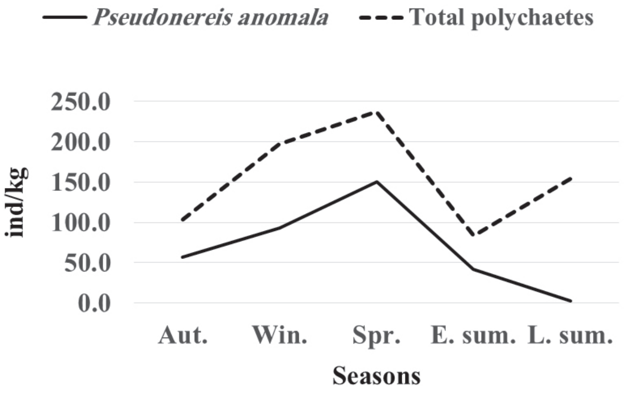

Fig. 4: Seasonal abundance of total polychaetes and *Pseudonereis anomala* associated with *Calyptotheca alexandriensis* in the Eastern Harbour of Alexandria (E. sum.: early summer; L. sum.: late summer).

Furthermore, some crustacean species showed less active contribution to the associated fauna, particularly during autumn and winter, like *T. dulongii* (2.5-2.7%), *C. bovina* (2.4-2.5%), and *S. serratum* (1.5-1.8%). Also, the mollusc *Brachidontes pharaonis* constituted 1.4% of the associated fauna in autumn against 4.3 % for the echinoderm *Ophiura* sp., in winter.

The MDS plot (Fig. 5) depicts the similarity amongst all replicate samples at a seasonal level. Samples from the same sampling site were grouped together. A clear seasonal pattern was derived from this analysis which indicated a cyclical trend of samples. Also, the relative distances among seasons were always significantly different for all stations, as shown by the ANOSIM test (Global R: 0.693, p <0.05).

The highest values of the harmonic Spearman coefficient as calculated between the abiotic variables and similarity matrices of associated fauna (BIOENV analysis) indicate correlations between the variables and the seasons. To a certain extent, the same combinations of environmental variables were correlated with the multivariate pattern of microbenthic community in the four seasons (Table 3). This analysis indicates that there are no significant differences either in the number of abiotic variables associated or in the *pw* values, derived from BIOENV analysis for each season.

The SIMPER analysis identified ten species as making a significant contribution to the associated community similarity pattern over all sampling efforts. These species, in most cases, accounted for more than 95% of the total abundance of the macrobenthic fauna. The species forming the major part of the communities were the amphipods *E. pectenicrus* and *J. marmorata* and the polychaete *P. anomala* (Table 4).

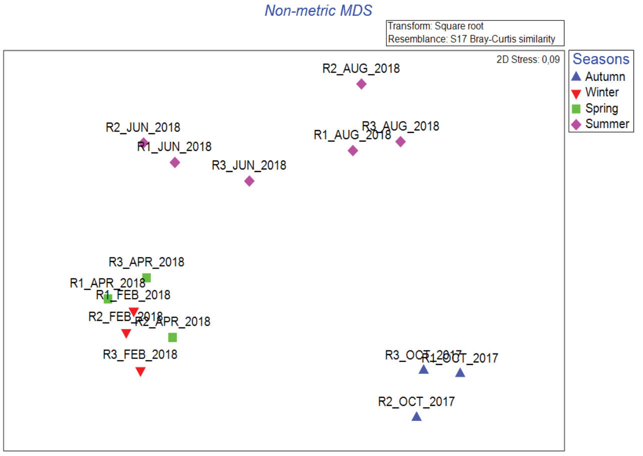

Fig. 5: MDS of species aggregation in the vicinity of *Calyptotheca alexandriensis* in the EH during 2017-2018.

Table 2. Relative contribution of the main groups of the fauna associated with colonies of the bryozoan *Calyptotheca alexandriensis* in the Eastern Harbour of Alexandria.

Season	% of total fauna count			% of species		
	Crustaceans	Polychaetes	Others	Crustaceans	Polychaetes	Others
Autumn	94.8	3.4	1.8	56.3	18.8	24.9
Winter	80.2	15.4	4.4	32.0	56	12
Spring	84.0	14.9	1.1	40.0	40.0	20
Early summer (June)	92.8	6.6	0.6	34.4	43.8	21.8
Late summer (August)	93.4	5.9	0.7	30	50	20
Total	**90.5**	**7.9**	**1.6**	**30.2**	**48.8**	**21**

Table 3. Environmental variables, best correlated with the distribution pattern of the associated community, during the four seasons. Crosses indicate linked variables with the multivariate community pattern in each sampling season.

	DIP	NO_2	NO_3	SiO_4	DO	Chl a	TempA	TempW	pH	Sal	*p*w
Autunm					+	+				+	0.721
Winter					+				+	+	0.709
Spring					+				+		0.692
Summer					+	+			+	+	0.684
Total					+				+	+	0.673

Footnote: DIP: dissolved inorganic phosphorous; NO_2: nitrite; NO_3: nitrate; SiO_4: silicate; DO: dissolved oxygen; Chl-a: chlorophyll-a; TempA: air temperature; TempW: water temperature; Sal: salinity.

Table 4. Contribution percentages of the most significant species.

Species	Summer	Autumn	Winter	Spring
Elasmopus pectenicrus	55.31	37.86	29.55	33.04
Jassa marmorata	9.72	-	13.37	18.9
Syllis hyalina	4.75	-	6.75	6.79
Pseudonereis anomala	4.31	-	10.52	13.26
Stenothoe eduardi	-	14.59	-	-
Tanais dulongii	-	6.57	-	-
Cirolana bovina	-	6.39	-	-
Balanus sp.	-	6.09	-	-
Ophiura sp.	-	-	7.19	-
Syllis variegata	-	-	6.19	-

Discussion

The faunal community (43 species) associated with *C. alexandriensis* in the EH of Alexandria appeared less diverse compared to those found with other bryozoan species and different in species composition (Table 5). This community was also more diverse than the benthic communities settled on artificial panels suspended at the same place in the EH (cf. Ramadan *et al.*, 2006) near the area of the present study (Table 6). Among the associated taxa, 9 species were non-indigenous, including 5 polychaetes, one mollusc, and 3 crustaceans (Table 1). This number was lower than those numbers recorded in marinas and harbours in several countries of the Mediterranean Sea, for example, Spain (10-11 species), France (2-17), Italy (5-20), Malta (13-14), Greece (12-27), Turkey (4-14), and Cyprus (17-18) (Ulman *et al.*, 2017).

Wood *et al.* (2012) reported sponges, cnidarians, bryozoans, molluscs, annelids, arthropods, echinoderms, and various macroalgae as associated taxa with different bryozoan species that were recorded from different world regions (Table 5). All the animal groups mentioned by Wood *et al.* (2012) were found with the *C. alexandriensis* colonies during the present study and within the benthic communities in the EH (Ramadan *et al.*, 2006). Among the representatives of these groups, seven species were previously recorded by Ramadan *et al.* (2006) and still existing in the EH, namely, the tanaid *T. dulongii*, the amphipods *E. pectenicrus* and *J. marmorata*, the isopods *S. serratum*, *C. bovina,* and *D. bidentata*, and the polychaete *H. elegans*. Also, most of the crustaceans and polychaetes associated with *C. alexandriensis* were known from the benthic communities of the Alexandria coast, some of them in high numbers (Soliman, 1997; Dorgham *et al.*, 2014). The long-term observation of the fouling fauna in the EH has revealed periodic shift in the dominance of the fouling

Table 5. Numbers of species of dominant taxa associated with different bryozoan species.

Habitat-building Bryozoan species	Associated fauna	Reference
Pentapora fascialis (Pallas, 1766), west coast of Italy	Mollusca (19 spp.)	Ferdeghini & Cocito, 1999
Cinctipora elegans (Hutton, 1873), southern New Zealand	Mollusca (20 spp.)	Willan, 1981
Schizoporella errata (Waters, 1878), south-eastern Brazil	Annelida (62 spp.)	Morgado & Tanaka, 2001
Schizoporella pungens (Canu & Bassler, 1928), northern Gulf of Mexico	Arthropoda (23 spp.)	Lindberg & Stanton, 1988
Celleporaria agglutinans (Hutton, 1873), New Zealand.	Bryozoa (92 spp.)	Bradstock & Gordon, 1983
Hippomenella vellicata (Hutton, 1873), south-eastern New Zealand	Bryozoa (80 spp.)	Junge, 1998
Pentapora fascialis (Pallas, 1766), Italy	Bryozoa (27 spp.)	Ferdeghini & Cocito, 1999
Cellaria salicornioides (Lamouroux, 1816), Adriatic Sea	Bryozoa (31 spp.)	McKinney & Jaklin, 2000
Flustra foliacea (Linnaeus, 1758), south-west Wales, United Kingdom	Bryozoa (25 spp.)	Stebbing, 1971
C. elegans, H. vellicata and C. agglutinans, Otago shelf, southern New Zealand	Non-bryozoans (>130 spp.)	Wood, 2005
Pentapora fascialis (Pallas, 1766), Ligurian Sea (north-western Italy)	Non-bryozoans (84 spp.)	Ferdeghini & Cocito (1999
Schizoporella errata (Waters, 1878), off Ubatuba, south-eastern Brazil	Non-bryozoans (115 spp.)	Morgado & Tanaka, 2001
Calyptotheca alexandriensis (AbdelSalam, Taylor & Dorgham, 2017), Eastern Harbour of Alexandria, Egypt	Total fauna (43 spp.)	Present study

Table 6. Historical modification of the bottom fouling community structure in the Eastern Harbour of Alexandria.

Species Number	Dominant Species	Reference
19	*Hydroides norvegica* Gunnerus, 1768, *Amphibalanus amphitrite* (Darwin, 1854) and *Bugula neritina* Linnaeus, 1758	Banoub, 1960
20	*H. norvegica*, *A. amphitrite* and *B. neritina*	Megally, 1970
23	*H. norvegica*, *Perforatus perforatus* (Bruguière, 1789) and *B. neritina*	Ghobashy, 1976
35	*Hydroides elegans*, *Ericthonius brasiliensis*, *Monocorophium sextonae* (Crawford, 1937) and *B. neritina*	El-Komi, 1991
29	*H. elegans*, *A. amphitrite*, *Polydora ciliata* and *B. neritina*	El-Komi, 1992
27	*H. elegans*, *M. sexton*, *Amphibalanus eburneus* (Gould, 1841) and *A. amphitrite*	El-Komi, 1998
24	*H. elegans*, *A. amphitrite*, *Apocorophium acutum* Chevreux, 1908 and *E. pectenicrus*	Ramadan *et al*., 2006
36	*E. pectenicrus, J. marmorata*, *Apohyale perieri* and *P. anomala*	Present study

groups, from polychaetes, cirripeds, and bryozoans during the period 1960–1976 to polychaetes, amphipods, and bryozoans during 1991, with the dominance of the polychaete *H. elegans* in all earlier records (Ramadan *et al.*, 2006). Our results indicate the dominance of two amphipod species (*E. pectenicrus* and *J. marmorata*) and of the polychaete *P. anomala* on the surface of *C. alexandriensis* colonies. Although *P. anomala* was abundant most of the year, it was replaced in late summer (August) with *H. elegans* constituting 51% of the polychaete count. The summer abundance of *H. elegans* in the EH could be explained by its rapid maturity (Paul, 1937) and short larval period (Hadfield *et al.*, 1994) enabling it to colonize newly submerged surfaces (Holm *et al.*, 2000), particularly at high temperature (25°C, Nedved & Hadfield, 2009).

The periodical alternation of benthic animal groups in the EH during the past several decades could be explained in accordance with the serious changes in the environmental characteristics of the EH due to the modification of the sewer system and the stoppage of sewage discharge. On the other hand, the numerical abundance of fauna associated with *C. alexandriensis* was mainly caused by four species (*E. pectenicrus*, *J. marmorata*, *A. perieri*, and *P. anomala*), and most of the other representatives are rare or found in low counts. The high diversity and low number of dominant species in the EH were also observed in another area by Hughes (1984) who stated that biogenic substrata are generally characterized by high species diversity of associated assemblages of many rare species and few dominant ones. However, the dominance pattern of the fauna associated with *C. alexandriensis* appeared more or less different from that recorded previously along the coast of Alexandria. Hamdy *et al.* (2018) recorded 6 dominant crustaceans on the Alexandria coast with the following abundance rank *T. dulongii*>*D. bidentata*>*S.serratum*>*A. perieri*> *J. marmorata*>*E. pectenicrus*. During the present study, *E. pectenicrus* was the absolute dominant crustacean and was accompanied in descending order by *J. marmorata*, *A. perieri*, *T. dulongii*, *C. bovina*, and *S. serratum*. Dorgham *et al.* (2014) recorded 10 dominant polychaetes along the Alexandria coast, forming 81.3% of their total count. The abundance of these species was ranked as follows: *Spirobranchus triqueter* (16.8%), *Syllis ergeni* (13.4%), *Naineris laevigata* (10.8%), *P. anomala* (10.4%), *Syllis pulvinata* (8.4%), *Syllis hyalina* (7.4%), *Capitella capitata* (5%), *Monticellina cfr. heterochaeta* (4.2%), *Salvatoria clavata* (2.5%), and *Platynereis dumerilii* (2.5%). Our results recorded three dominant polychaetes only on the *C. alexandriensis* colonies, namely, *P. anomala, S. hyalina*, and *S. variegata*, but with extremely lower counts than those found by Dorgham *et al.* (2014). The dominance differences between the fauna associated with *C. alexandriensis* in EH and along the coast of Alexandria could be apparently explained by the rapid change in the environmental conditions in the EH resulting from eutrophication condition, different human activities, and the short flushing time (2-3 days).

The dominance of polychaetes and crustaceans on the colonies of *C. alexandriensis* has also been observed in communities associated with other bryozoans. For example, a large number of polychaete species were found on the bryozoan *S. errata,* while high diverse crustaceans occurred with *Schizoporella pungens* (Table 5). Such differences may be attributed to differences in colony structure of the different bryozoan species: *C. alexandriensis* has an erect foliaceous colony, comprising an open honeycomb of anastomosing bifoliate fronds forming a spheroidal mass (Abdel-Salam *et al.*, 2017), and provides limited space for other animals when compared to the branched colonies of *S. errata*. Furthermore, the colonies of *C. alexandriensis* are exposed to the stress of salinity variation and water turbidity, which also affect the species richness of the associated fauna. The differences in structure of the colonies of these two bryozoan species were revealed in the species composition of their associated fauna. Morgado and Tanaka (2001) observed the dominance of the isopod *Excorallana quadricornis* and the decapods *Pachycheles maginanus* and *Hexapanopeus schmitti* on *S. errata,* while on *C. alexandriensis* decapods were mostly found in low counts, except for the locally relatively high count of *Alpheus lobidens* in spring. During the present study, decapods were represented by 4 species only against 23 species associated with the bryozoan *S. pungens* in Florida (Lindberg & Stanton, 1988), 24 species with *S. errata* in Brazil (Morgado & Tanaka, 2001), and 31 species of crabs with *S. unicornis* in the northeastern coast of São Paulo State, Brazil (Alves *et al.*, 2013). The differences in diversity of associated fauna may be also due to differences in local water currents affecting recruitment or higher abundance of predatory and territorial decapods (Duarte & Nalesso, 1996).

The seasonal differences between the crustaceans and polychaetes indicated by Bray-Curtis similarity index could be attributed mainly to the great difference in the seasonal abundance of some species, particularly the dominant species such as *E. pectenicrus*, *J. marmorata*, and *P. anomala*. These differences were also correlated to the variations in the environmental parameters.

Greater dissimilarities were observed in the multivariate associated microbenthic pattern between seasons. The tendency for a cyclic (progression-retrogression) community pattern was observed. The aforementioned trend must be examined with additional seasonal data in order to examine its stability. BIOENV showed that the number of abiotic variables and their resulting rho values correlated with the microbenthic multivariate pattern did not differ between the sampling sites. Therefore, this group of abiotic parameters significantly influenced the distribution patterns of species communities within the bryozoans.

Although the high phytoplankton production in the EH may enhance the growth of the fauna associated with *C. alexandriensis*, water movements and wave action may negatively affect this growth. Taylor (2000) admitted the importance of high phytoplankton biomass for bryozoans and the unfavourable effect of sedimentation and/or disturbance and stagnant conditions. Further, wave energy is likely to be destructive to bryozoan colonies, particularly those on soft substrata liable to resuspension (Cocito, 2004).

The present study revealed the new bryozoan, *C. alexandriensis*, as important benthic bioconstructor, providing suitable substrate for numerous taxa in the EH of Alexandria. The associated fauna is comprised of nine different taxonomic groups, but crustaceans and polychaetes were the dominant by number of species and numerical abundance. Polychaetes were more diverse than crustaceans, reflecting the preference of C. *alexandriensis* colonies as refuge. However, the crustaceans were responsible for 90.5% of the count of total associated fauna, mainly due to *E. pectenicrus*, and to a less extent of *J. marmorata*, *H. perieri*, *T. dulongii*, *C. bovina*, and *S. serratum*. Nine species were non-indigenous, including one mollusc (*B. pharaonis*), three crustaceans (*E. pectenicrus, A. lobidens*, and *C. hellerii*), and 5 polychaetes, namely, *P. anomala, H. elegans*, *E. complanata*, *L. canariensis*, and *A. medusa.* The latter polychaete was considered a questionable species (Zenetos *et al.*, 2011). Both *E. pectenicrus* and *P. anomala* are considered established species, as they could build a healthy population in the EH. Spring and summer seem to be more suitable for higher diversity of the associated fauna than autumn and winter; meanwhile, the numerical abundance was the highest in autumn and the lowest in winter, spring, and early summer.

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