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Reef-building *Ficopomatus enigmaticus* and associated Polychaetes on artificial concrete blocks along Mediterranean seaside, Egypt

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ABSTRACT

This work aimed to study the seasonal and spatial variations in the structure and abundance of the Polychaetes populations associated with the reef-building *Ficopomatus enigmaticus* on artificial concrete blocks (ACBs) which were constructed along the Mediterranean seaside to solve the crucial impacts of climate changes and sea level-rise. The specimens were seasonally collected from the ACBs during the period extending from spring 2016 to winter 2017. During this study, two Polychaetes species were associated with *Ficopomatus enigmaticus* viz *Alitta succinea and Perinereis cultrifera*. *Ficopomatus enigmaticus* was the eudominant species recording a percentage of 72.5 of all the collected Polychaetes, while *Alitta succinea* was subrecedent forming 1.0 %. Additionally, *Perinereis cultrifera* dominated by 26.4%. Six October sites showed the highest average density of the studied species all the year round. Alternatively, the lowest average densities were detected in different sites and seasons as follows: in NIOF in spring and autumn; in Baltim in summer and in Beer Masoud in winter.

INTRODUCTION

The artificial concrete blocks are one of the means that protect the beaches from corrosion operations resulting from several things, such as the impact of urban activities in the beach area, climate change and other factors **(El-Sharnouby & Soliman, 2010)**. Among phylum Annelida, class Polychaeta plays an important role in the marine food chain, especially the Demersal fish **(Venkataraman& Raghunathan, 2015)**.

They form an important group of benthic organisms, their abundance and distribution are impacted by sediment texture and the algal cover **(Mikac & Musco, 2010**; **Musco, 2012)**, as well as by physical factors (**Giangrande, 1990)**. At the same time, Polychaetes play an important role in the ecosystem function and the dynamics and

diversity of benthic populations **(Giangrande *et al.* 2004, 2005**; **Papageorgiou *et al.*, 2006)**.

At Alexandria shores, Polychaetes showed changes in species diversity, dominancy and abundance. Some species were not detected,, while some others were listed for the first time **(Hamdy & Ibrahim, 2019)**. They were used in biomonitoring studies and were considered as biological indicators for water quality **(Musco *et al.*, 2009, 2011**; **Mikac *et al.*, 2011)**. Serpulid Polychaetes are commonly named fan-worms; they are widespread in marine environments, occurring in a wide depth range **(Ten Hove & Van den Hurk, 1993)**.

They attract more attention owing to their ability to foul human-made structures **(Kupriyanova *et al.*, 2006)**. *Ficopomatus enigmaticus* belong to Serpulidae (Sabellida-Polychaeta). It is commonly found in shallow waters where it has the opportunity to form reefs. However, it was found in deep waters **(Sluys *et al.*, 2005)**.

F. enigmaticus can tolerate polluted waters since it appeared abundant in the highly contaminated lagoon **(Diawara *et al.*, 2008; Tlig-Zouari & Maamouri-Mokhtar, 2008)**. Moreover, it lives in waters with high levels of domestic and industrial discharges **(Bustamante *et al.*, 2007; Shaban *et al*., 2020)**.

The present work aimed to study the temporal and spatial variations in the structure and abundance of the Polychaetes populations associated with reef-building *Ficopomatus enigmaticus* on ACBs along the Mediterranean seaside.

MATERIALS AND METHODS

1- Study Areas

During this work**,** the Polychaetes community was studied at five ecologically different sites (Fig. 1); namely, Baltim, Beer Masoud, Sidi Bisher, NIOF and the Sixth of October. The artificial concrete blocks (ACBs) were constructed along the Egyptian coast of the Mediterranean Sea, where five sites were selected. Sites under study were : Baltim at Latitude (Lat.) 31°35'24.48" N and Longitude (Long.) 31° 9'9.41"E. Its Breakwaters are parallel to the beach**;** Bir Masoud at Lat. 31° 16' 38.84" N and Long. 30° 0' 8.54" E; it has a natural rocky beach; Sidi Bisher at Lat. 31° 16' 38.84" N and Long. 30° 0' 8.54" E; its breakwaters are attached to the beach; the National Institute of Oceanography and Fisheries (NIOF) at Lat. 31° 12' 49" N and Long. 29° 53' 7" E; its breakwaters are attached to the beach, and the fifth site was the Sixth of October at Lat**.** 31° 05' 39.5" N and Long. 29° 43' 27.5" E.

Fig. 1. Study sites at the Mediterranean Sea, Egypt, during this work

2- Specimen collection

Specimens were seasonally collected from the ACBs at the chosen study sites during the period from spring 2016 to winter 2017. From the surface of ACBs, organisms were caught by hand using a sharp knife, then stored immediately in polyethylene jars filled with 10% seawater formalin solution for later examination provided with labels of dates and sites of collection, then transported to the laboratory for sorting and identification.

The identification of Polychaetes was carried out according to the descriptions recorded in previous studies **(Day, 1967; Ben-Eliahu, 1972, 1975a, b, 1976a, b, c, 1977a, b; Fauchald, 1977; Amoureux *et al.*, 1978; Appy *et al.*, 1980; Çinar *et al.*, 2003)**.

3- Population density

During each visit, at least 3 quadrates (25 x 25 cm) were laid at each site covering all different habitats of the study area. The number of each encountered animal was recorded according to the quadrate dimensions and expressed as the number of individuals per unit area. To express the population density at each site, the average of 3 x 3 quadrates (Ave.) were taken, while the standard deviation of the final mean of the number of objects present was calculated using Microsoft Excel. It was used to find the standard deviation of individuals and the total as a whole to find out the extent of dispersion in the sample relative to the mean.

4- Relative abundance (Ra)

It was calculated using the formula determined in the study of**Omori and Ikeda (1984)** as follows:

RA = N X 100 / Ns

- Where; "N" is the number of organisms of each taxon in the sample;
- "Ns" is the total number of organisms in the sample.

5- The dominancy of species

It was determined following the guidelines of **Engelmann (1978)** as follows:-

1- Eudominant (RA > 40%).
2- Dominant (RA ranged between 12.5 – 39.9 %).
3- Subdominant (RA ranged between 4 – 12.4 %).
4- Recedent (RA ranged between 1.3 – 3.9 %).
5- Subrecdent (RA ranged between < 1.3 %).

6- Similarity Matrix

Percentage of similarity between different sites was calculated by the following equation:

Kaczynski coefficient = 1/2 [(S/(S+U)) + (S/(S+V))] * 100

Where:

S: Number of species common in both sites (A and B).
U: Number of species found in A and absent in B.
V: Number of species found in B and absent in A

RESULTS

I- Polychaetes populations and dominancy

This study recorded three Polychaetes species that are included in two orders viz: Phyllodocida which is represented as a single-family called Nereididae with two species (*Alitta succinea and Perinereis cultrifera).* The second order is Sabellida, with one family called Serpulidae which includes *Ficopomatus enigmaticus*.

During the study period, the annual average density of the recorded species was 766.1 ind./ m^2. *Ficopomatus enigmaticus* was the eudominant species with dominance percentage of 72.5 with respect to all collected Polychaetes. It recorded the highest average annual density (556±87 ind./ m^2), while *Alitta succinea w*as the subrecedent one that formed 1.1 % of all collected Polychaetes. It recorded the lowest average annual density with values of 8.1±3ind/m^2 (Fig. 2 & 3). At the same time, *Perinereis cultrifera* dominated by 26.4% with an average annual density of 202±47ind/m^2.

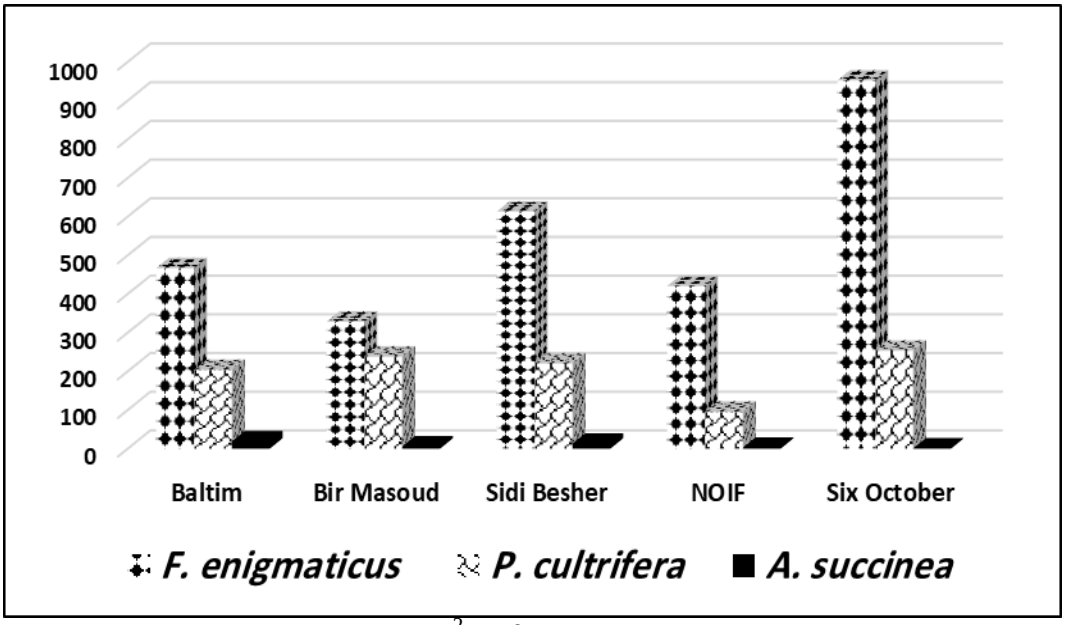

Fig. 2.the average density (ind./m^2) of the collected species during this study.

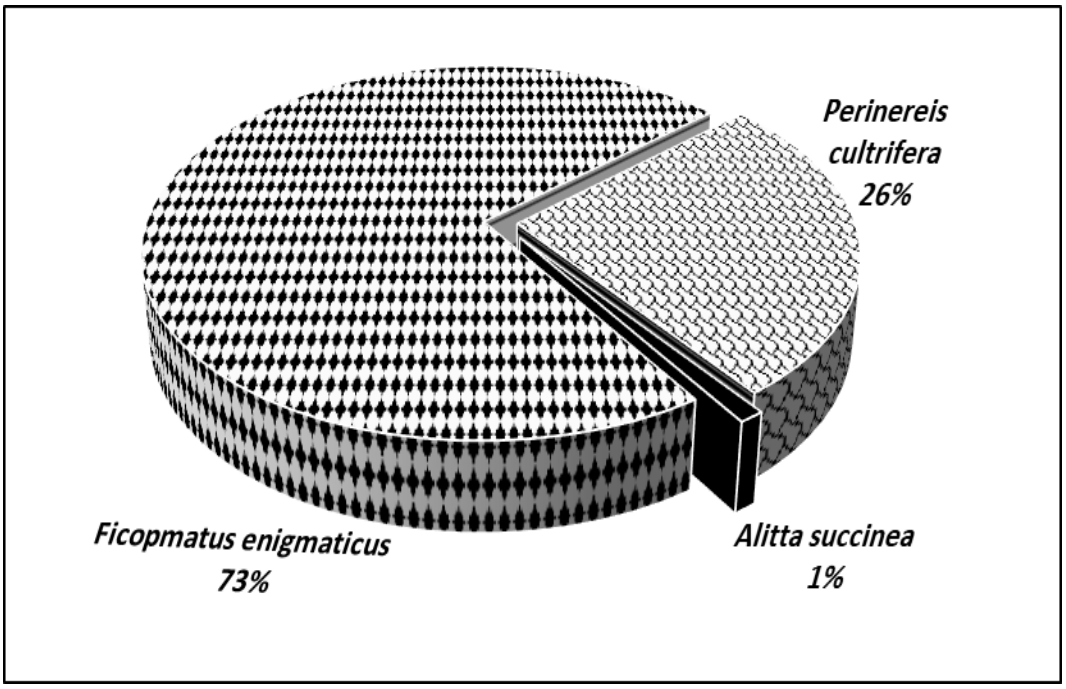

Fig. 3. Percentage of Polychaetes species during this work

2- Spatial distribution and frequency

The data presented in Table (1) shows three studied species collected from all selected sites during this work. The sixth of October site was the highest in the average density and relative abundance, comprising 31.5% of the collected species, followed by Sidi Besher site (22.1%), Baltim site (18%), Beer Masoud (14.9%), and NOIF which recorded a percentage of 13.5.

Table 1. Spatial relative abundance and average density (ind./m^2) of the studied species during this work

Site	Average ± SD.	Relative abundance
Baltim	688.75±98	18.0
Beer Masoud	572.6±87	14.9
Sidi Besher	846.25±223	22.1
NOIF	517.75±199	13.5
Six October	1205.5±276	31.5

3- Temporal distribution

The temporal frequency of Polychaete species in this study showed that all species occurred in all seasons. During the study period, spring had the highest annual average density (883.8±234ind./m^2) represented by 28.82% of all collected species. The second annual average occurred in winter (832, 2±276 ind./m^2, 27.14%) while the 3rd happened in autumn (803.6±245ind./ m^2, 26.21%) and the lowest was determined in summer (547.0±165 ind./m^2), recording a percentage of 17.84 (Table 2). During spring**,** *Ficopomatus enigmaticus* was eudominant by 79.2% of all collected polychaetes, while *Perinereis cultrifera* exhibited dominancy by 20.7 %. On the other hand, *Alitta succinea* was subrecedent (0. 1%). In summer, *Ficopomatus enigmaticus* showed eudominancy by 70.4 %, while *Perinereis cultrifera* listed dominancy by 27.2%, and *Alitta succinea* was recedent by 2.3%. During autumn, *Ficopomatus enigmaticus* cleared eudominancy by 61.7%, while *Perinereis cultrifera* showed dominancy of 36.1%, whereas *Alitta succinea* was recedent by 2.2%. In winter, *Ficopomatus enigmaticus* revealed eudominancy by 77.3%, while *Perinereis cultrifera* showed dominancy of 22.6. %, and simultaneously *Alitta succinea* was subrecedent by 0.1% (Fig. 4).

Table 2. Seasonal Polychaetes abundance during this study

Species Season	Spring	Summer	Autumn	Winter	Average ±SD
F.enigmaticus	700.0	385.2	495.8	643.0	556.0 ±68.3
P. cultrifera	183.0	149.0	290.4	188.0	202.6±41.5
A. succinea	0.9	12.8	17.4	1.2	8.1±2.0
Average±SD	883.8±234	547.0±165	803.6±245	832.2±276	766.1±178
%	28.82	17.84	26.21	27.14	100%

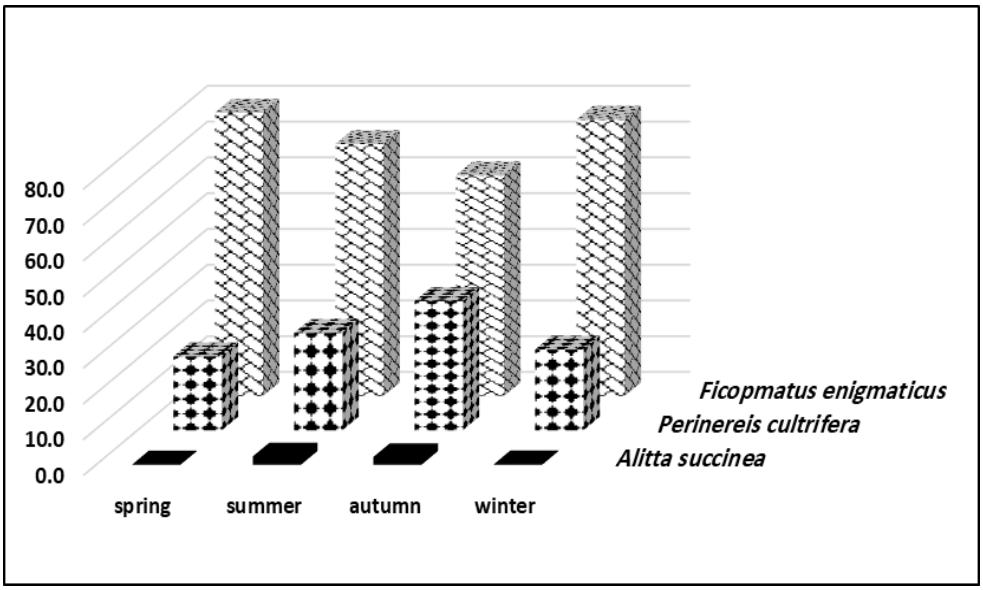

Fig. 4. The percentage of seasonal variation of the collected species during this work

4- Similarity of Polychaetes species during the study

The result of cluster analysis based on seasonal Polycheata composition (ACBs) is presented in Fig. (5). The presented data shows that during this work, the highest similarity (89%) was recorded between two sites; Baltim and Sidi Bisher, whereas the lowest was 81.3 % between Baltim and the sixth of October.

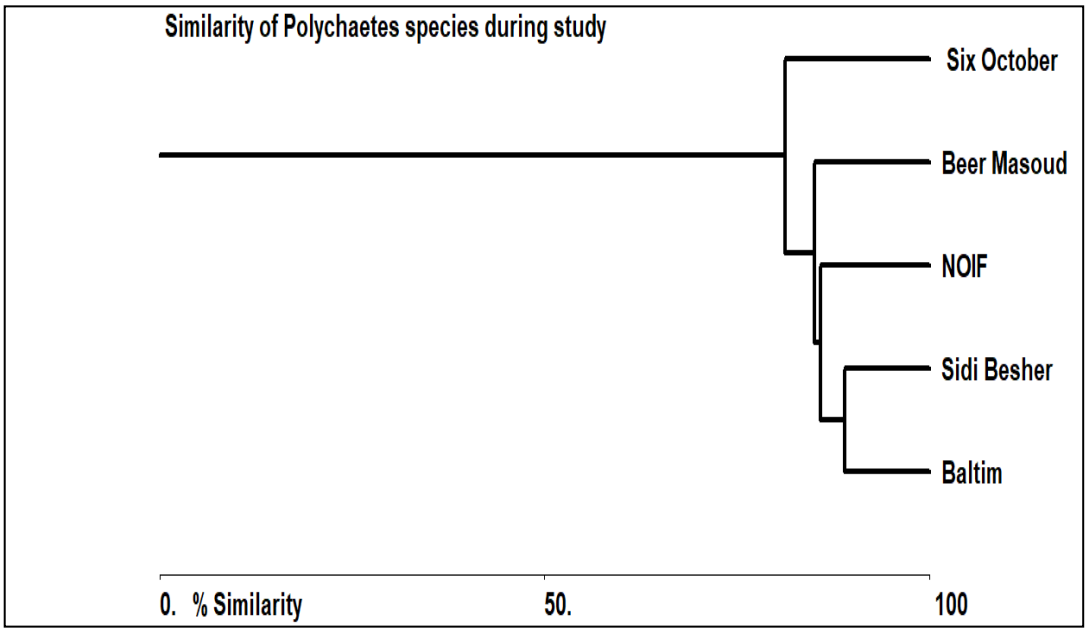

Fig. 5. Dendrogram representing the similarity among 5 sites surveyed considering Polychaeta species during the study

DISCUSSION

During the present study, the artificial slope of the ACBs increased the areas, the fauna and flora on the flat substrate areas. This finding agrees with several ecological studies assessing that the increased area would usually reflect the increased topographical relief and habitat diversity.

In the Mediterranean Sea, the special effect of algal morphology was proved to help in the structure of the associated fauna such as polychaetes **(Casoli *et al.*, 2019)**.

The recorded data showed that the 3 studied species were collected from all selected sites during this work. The annual fluctuation of macrobenthic diversity during 2006/2007 showed that, the annual percentage of Annelida was 16.6 of the total species **(Khalil *et al.*, 2013)**, compared to 7.9% recorded in the current studyfor Annelida collected from ACBs. Additionally, the previous authors identified 22 Annelida during 2007**)** compared to a number of only 3 in this study recorded during 2016/2017. Furthermore, they added that the annual average occurrence of Annelida was 2779 Org/m^2 in spring, while in summer it was 1492 Org/m^2. On the other hand, the average of Annelida in the present study was 838.8 ind./ m^2 in spring, and in summer the average was 547 ind./ m^2.

The shallow hard bottom and intertidal soft-bottom of the Polychaetes assemblages along the coast of Alexandria,, in the south-eastern side of the Mediterranean Sea (Levantine Sea), were examined to detect the annual cycle of Polychaetes assemblages and analyze the spatial-temporal patterns of variation in assemblages and the relevant factors related to Polychaetes distribution **(Dorgham *et al.*, 2014; Zakaria *et al.*, 2016, 2018)**.

Temporal frequency showed that, all species were found in all seasons, with spring recording the highest annual average (884 ind./m^2) and a percentage of 28.82in relation to all collected Polychaetes species. The second annual average occurred in winter (832ind./m2, 27.14 %) while the third one happened in autumn (804 ind./m2, 26.21%). It was noticed that the lowest annual average was 547ind./m^2, and it was detected in summer, recording a percentage of 17.84. The variations in the Polychaetes abundance may be attributed to the modification of the sewer system of Alexandria City **(Hamdy & Ibrahim, 2019**) and the changes in the environmental factors.

It is worthy to mention that, 66 species of Polychaetes were identified with 45,175 individuals **(Çinar *et al.*, 2008)**, while the present study listed an average annual abundance for Polychaeta of 3 species with 766.1 ind./m^2. Spatial variation of Polychaetes along the coast of Alexandria was more significant than a temporal variation on shallow hard substrates, suggesting that spatial variation of hard bottom Polychaetes assemblages might depend on the scale of observation, being high at small spatial scales but lower at the scale of kilometers **(Musco, 2012)**.

The present result indicates that the total annual average of Polycheata was 766.1ind./m^2 and the maximum value recorded in Six October was 1205.5 ind./m^2. On the other hand, the minimum value recorded in NIOF was 517.75ind./m^2.It was reported that the numerical density of Polycheata individuals displayed wide variation on the spatial and temporal scales, fluctuating among the sampling sites between a minimum of 233±305 ind./m^2 and a maximum of 3901±2597 ind./m^2 **(Hamdy & Ibrahim 2019)**.

Ficopomatus enigmaticus is a Serpulid Polychaetes species (order Sabellida: family Serpulidae) that was collected during the present work; it is an obligatory calcareous tube builder (**Vinn *et al.*, 2008; Vinn & Mutvei, 2009**). Prior to the year 1987, the first name of *Ficopomatus enigmaticus* was *Mercierella enigmatica* then it was considered as *Ficopomatus enigmaticus* (**Hove & Kupriyanova, 2009**). The originality of the name was argued upon; however its Australasian origin is the most accepted (**Daisie, 2009)**. It is an invasive species that forms aggregates named reefs which generate spaces among the tubes that are available to other organisms. Although this species has no known symbionts, it is interesting to note that some Polychaetes species are usually associated with the *Ficopomatus* reefs worldwide. For example, the Polychaetes Spionidae, *Boccardiella ligerica*, frequently lives among the tubes of *Ficopomatus* **(Schwindt & Obenat, 2005; Sluys *et al.*, 2005**)., *Ficopomatus* tubes have a low wave resistance (**Bianchi & Morri, 200**1), then it survives in calm waters (**Schwindt *et al.*, 2004**).

F. enigmaticus is dispersed by hull fouling and ballast water. Additionally, it can be dispersed in association with mollusks organisms used for aquaculture purposes (**Clearinghouse, 2008**).

During this work, the Polychaetes species *Perinereis cultrifera* and *Alitta succinea* were associated with the *Ficopomatus* reefs. *Perinereis cultrifera* Grube (1840) was listed by **Hamdy and Ibrahim (2019)** as Persistent Polychaetes species on the Alexandria coast since 1937. While, they reported the absence of Persistent Polychaetes species *Alitta succinea* (**Leuckart, 1847**) on the Alexandria coast.

The annual average of the recorded species during this work was 766.1±178 ind./m^2. *Ficopomatus enigmaticus* was the eudominant species that formed 72.5 % of all collected Polychaetes. It has the highest annual average being 556.0 ind./ m^2, while *Alitta succinea* was the subrecedent one which formed 1.1 %. It recorded the lowest annual average of 8.1 ind./m^2. At the same time, *Perinereis cultrifera* dominated by 26.4 % with an annual average of 202.6 ind./m^2. Remarkably, Kurt recorded the dominance of the latter species with 50% and identified it as the Most abundant Polychaetes in 2017 with a maximum value of 153 ind./ m^2 (**Kurt & Kuş, 2019**).

During spring, *Ficopomatus enigmaticus* appeared eudominant by 79.2% of all collected polychaetes, while *Perinereis cultrifera* exhibited dominancy of 20.7%. On the other hand, *Alitta succinea* was subrecedent (0.1%). In summer, *Ficopomatus enigmaticus* showed eudominancy with 70.4%, whereas *Perinereis cultrifera* were

dominant with 27.2%. Moreover, it was noticed that *Alitta succinea* was recedent by 2.3%. During autumn, *Ficopomatus enigmaticus* prevailed in eudominancy by 61.7%, while *Perinereis cultrifera* showed dominancy of 36.1%. At the same time, *Alitta succinea* was recedent by 2.2%. In winter, *Ficopomatus enigmaticus* revealed eudominancy by 77.3%, while *Perinereis cultrifera* showed dominancy by 22.6. %, at the same time *Alitta succinea* was subrecedent by 0.1%. Kurt assessed that *Alitta succinea* had a maximum value of 46 ind./ m^2 in 2017 and the minimum value was 8 ind./m^2 in 2015 (**Kurt & Kuş, 2019**).

The present study showed that *Perinereis cultrifera* showed about 26.4 % of the total Polychaetes among different investigated sites, with the highest average detected in autumn 290.4 ind/m^2 and the lowest in summer 149.0 ind./m^2. Nevertheless, Cinar listed that he found 3 species in hard substrates and 15 species on rocky shore (**Cinar, 2005)**.

Meghlaoui collected Perinereis cultrifera from four sites with 389 individuals present at El-Kala, 317 at Annaba, and 307 at Skikda throughout the year 2011, while in 2012 155 individuals were detected at Collo, 287 individuals at Skikda, 407 individuals at El Kala, and 506 individuals at Annaba (**Meghlaoui *et al.,* 2015)**. In comparison, the current study show that *Perinereis cultrifera* was recorded with an average annual occurrence of 202.6±41.5 ind./m^2.

Checking the similarity between sites, similarity among all sites was determined, the highest of which was that between Baltim and Sidi Bisher with a percentage of 89%. This may be attributed to the fact that those sites are considered to be highly touristic and abundant with human activities especially during summer. Human activities are one of the causes of the changes affecting marine biodiversity and species composition **(Mona *et al.,* 2019; Darweesh *et al*., 2021)**. On the other hand, the lowest similarity was detected between Baltim and the 6^{th} of October, and also 6th October was present in cluster alone away from all other sites. Thismay be due to the fact that the all investigated sites are adjacent to the coast except for the Sixth of October which is inside the water, away from the coast and parallel to the beach.

Due to the high levels of adaptation to a wide variety of environmental conditions, Polychaetes play key roles in ecosystem functioning and they have been used successfully as surrogates for the estimation of diversity and dynamics of benthic communities. The analysis of Polychaetes assemblage structure has been proved to be an efficient tool for assessing environmental health, and it is commonly used as a biological criterion for water quality and also in biomonitoring studies (**Mikac *et al.,* 2011)**.

CONCLUSION

As a result of climate change and sea-level rise reef-building, *Ficopomatus enigmaticus* and associated Polychaetes on artificial concrete blocks (ACBs) in the form of the hard substrate provided suitable habitat for three Polychaetes species with annual

average density of 766.1 ind./m^2, included in two orders viz, Phyllodocida which is represented by a single-family named Nereididae that had two species (*Alitta succinea* with average density 8.1±3ind/m^2 1.1 % and *Perinereis cultrifera* with average density 202±47ind/m^2 26.4%.The second order is Sabellida, which had one family called Serpulidae and includes *Ficopomatus enigmaticus* with an average density of 556±87 ind./m^2 72.5 %. These species occurred at all sites and seasons studied.

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