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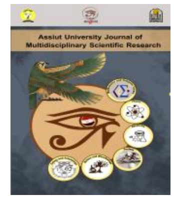

# Effect of Environmental Variations on Macro-benthos Occurrence and Abundance of the Red Sea Coast of Egyp

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## ABSTRACT

Benthic communities vary according to changes in the environmental factors in addition to human impacts. The present study aimed to investigate the changes of macro-benthos community in three sites at the Red Sea Coast of Egypt during summer (2019) and winter (2020). Benthic communities were studied at five sampling groups (Hs: El-Hamrawen summer, Ms: Sedy Malek summer, Hw: El-Hamrawen winter, Mw: Sedy Malek winter, Pw: Porto Ghalb winter). The results indicated that dissolved oxygen is the most important factor in macro-benthos composition, followed by carbonate content, salinity, water temperature, and conductivity. The structure of macro-benthos community spatially and seasonally differs according to changes of environmental factors. Related to changes of environmental variations benthos recorded the highest abundance and diversity for (Pw) community and the lowest one for (Hs). Seasonal changes in temperature may be the main factors influence other environmental factors which affect benthos community. This led to conclude that global warming could have significant consequences for vital coastal fauna.

## INTRODUCTION

Macro-benthic invertebrates provide essential ecosystem services; firstly, they accelerate detritus decomposition where dead organic matter is one of the main sources of energy for benthic species in shallow-water habitats. Secondly, benthic species supply food for both aquatic and terrestrial vertebrate consumers (e.g. fishes and birds). Thirdly, they release bound nutrients into solution and transfer them to the overlying open water by their feeding activities, excretion. Also, burrowing into sediments leading to increased growth of benthic microbes, algae, and rooted macrophytes which in turn consumed by herbivorous and omnivorous benthic invertebrates. Finally, predator benthic invertebrates can control the number and size of their prey [1, 2].

As macro-benthos play an important role in aquatic ecosystems, they are widely used as indicators to assess environmental stressors in marine ecosystems [3]. The connection between macro-benthos and environmental aspects has been an important issue in an aquatic ecological study [4]. Studying the relationship between macro-benthic organisms and environmental parameters is of good significance not only to keep up the equilibrium of the aquatic system but additionally to supply an essential scientific basis for the protection of the macro-benthos community [5].

Climatic changes might influence benthic communities with a large number of direct and indirect impacts and can have repercussions on other ecosystem component [6]. Seasonal changes in physicochemical characteristics exhibit a very dedicated impact on the occurrence and abundance of both aquatic flora and fauna [7]. The distribution outlines of the macro-benthos are determined by the temperature regime and its relations with other environmental factors including biotic and abiotic factors [8]. Macro-benthos might be affected positively or negatively by environmental factors of the environment depending on their sources [9].

The Red Sea facing rapid increase in human activity levels because of the marine recreational and industrial activities such as phosphate shipping and different fishing activities [10]. The Red Sea Coast of Egypt gets a variety of stresses due to overexploitation and human related activities. The main environmental problems and threats to the Red Sea ecosystems include recreation and tourism activities, urban agglomeration, oil pollution, marine shipping, solid waste disposal. Some of these pollutants may directly or indirectly be captured by bottom sediments [11]. Temperature [12], salinity [13], and nutrient availability [14] are all-natural latitudinal gradients in the Red Sea with substantial spatial variability [15].

The correlation between macro-benthos and environmental factors has been a serious subject in aquatic ecological research. Dong *et al*. [2] demonstrated that coastal ecosystems are exposed to disturbances caused by natural environmental changes and/or human activities. Therefore, the present research aimed to study the impact of seasonal changes of some environmental factors and anthropogenic effects on macro-benthic communities of the Red Sea Coast of Egypt as one of biomonitoring organisms in coastal ecosystems. The results help in understanding how the macro-benthic communities respond to changes of environmental factors.

## MATERIALS AND METHODS

### Studied sites and animal recording

This investigation was conducted at three locations along the Red Sea Coast (Fig. 1): El-Hamrawen, Sedy Malek, and Porto Ghalb. El-Hamrawen site (26°15'04.7"N 34°12'11.6"E) is located at, about 120 km south of Hurghada, and contains the largest and oldest phosphate harbor on the Egyptian Red Sea Coast. During shipping operations, transferring materials are exposed to strong winds on most days, causing phosphate particles to spread and fall into the sea [39]. Sedy Malek site is located about 50 km south of Al-Quseir, at (25°43'40.2"N 34°32'47.5"E). In front of this site, people come to visit Sheikh Malek's shrine, hence it's a religious tourist destination. This location receives a lot of rain, sometimes heavy rains. The third Porto Ghalb site is located at (25°32'44.9"N 34°38'26.1"E). It is one of the most remarkable and significant destinations for environmental diving since it considers a healthy and pollution-free environment.

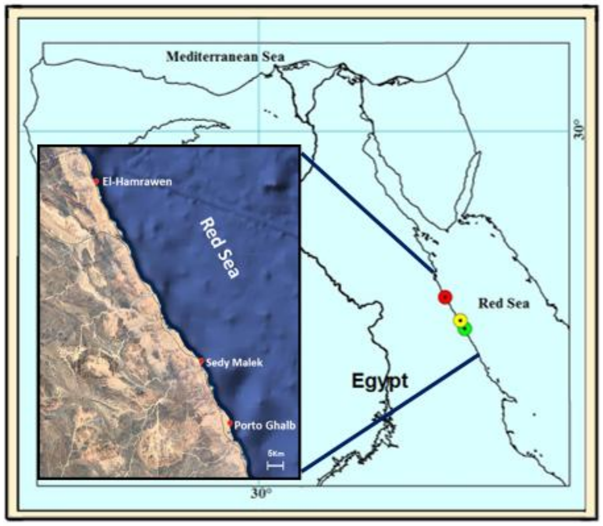


**Figure 1.** Map showing the location of the three studied sites on the Red Sea Coast of Egypt.

Macro-benthic fauna were observed and recorded by snorkeling and scuba diving in the depth reach to 5m at the investigated sites. The benthic fauna were estimated using a line transect (50 m) method. Two lines transect were extended in littoral zone, for each one macro-benthos were recorded within (5m×5m) quadrate on either side of the line transect every 10 m alternatively. During summer season (July 2019), benthos were recorded for El-Hamrawen and Sedy Malek only, while during winter (January 2020) they recorded for the three investigated sites. Hs, Ms, Hw, Mw, and Pw refer to samples collected from El-Hamrawen during the summer, Sedy Malek during the summer, El-Hamrawen during the winter, Sedy Malek during the winter, and Porto Ghalb during the winter, respectively.

## Environmental variables

Water- checker Hydrolab was used in the field to evaluate environmental factors such as air temperature (°C), water temperature (°C), water hydrogen ion concentration (pH), salinity (ppt), dissolved oxygen (mg/L), and conductivity (ms/cm). From the investigated sites, three surface sediment samples (about 1kg/sample) were obtained. After removing any existing Biota (fauna and flora), the sediments were dried away from direct sunlight and thoroughly mixed. In the laboratory, sediment grain size analyses, total organic matter and carbonate contents were estimated according to Folk [16], Brenner and Binford [17] and Basaham, and El-Sayed [18] respectively.

**Statistical analysis:**

The current data was tested using the SPSS software package (version 20) (SYSTAT statistical tool), and the tables and figures were created using Microsoft Excel 2010. A one-way ANOVA was used to look for significant differences between sample groups in environmental variables and biochemical markers. To discover different deviations between means, the Duncan test was performed.

## RESULTS

**1. Environmental variables:**

The environmental variables of the studied sampling groups showed considerable variations (Fig. 2). Statistical analysis showed clear differences among studied groups for all investigated variables except in case of total organic matter (TOC) (Fig. 2B), sediment pH (SedpH) (Fig. 2B) and coarse sediment group percentage (CSG) (Fig.2c). Regarding seasonal fluctuation of these variables, all studied variables recorded high values during summer samples (Hs, Ms) except dissolved oxygen (DO) which recorded high values during winter samples (Hw, Mw, Pw) (Fig.2B). The highest values (32.5±0.17 ºC, 42.04±0.03 ppt, 69.22±0.52 ms/cm, and 78.04±6.46 %) of air temperatures, salinity, conductivity, and carbonate content, respectively, were recorded during summer at Sedy Malek (Ms) (Figs. 2 A and C). Water pH was in the alkaline range, with the highest pH value (8.32±0.25) at the El-Hamrawen sample during summer (Hs). During winter, the highest dissolved oxygen content (8.27±0.91 mg/L) was found at Porto Ghalb samples (Pw). The medium sediments group (MSG) recorded the highest average percentage (59.43±17.87%, 57.69±3.27%, and 65.89±15.1%) at Hs, Ms, and Pw (Fig.2D) respectively. In contrast, Hw and Mw recorded the highest average percentage (38.74±17.86% and 42.16±4.69%, respectively) for the fine sediments group (FSG) (Fig.2D).

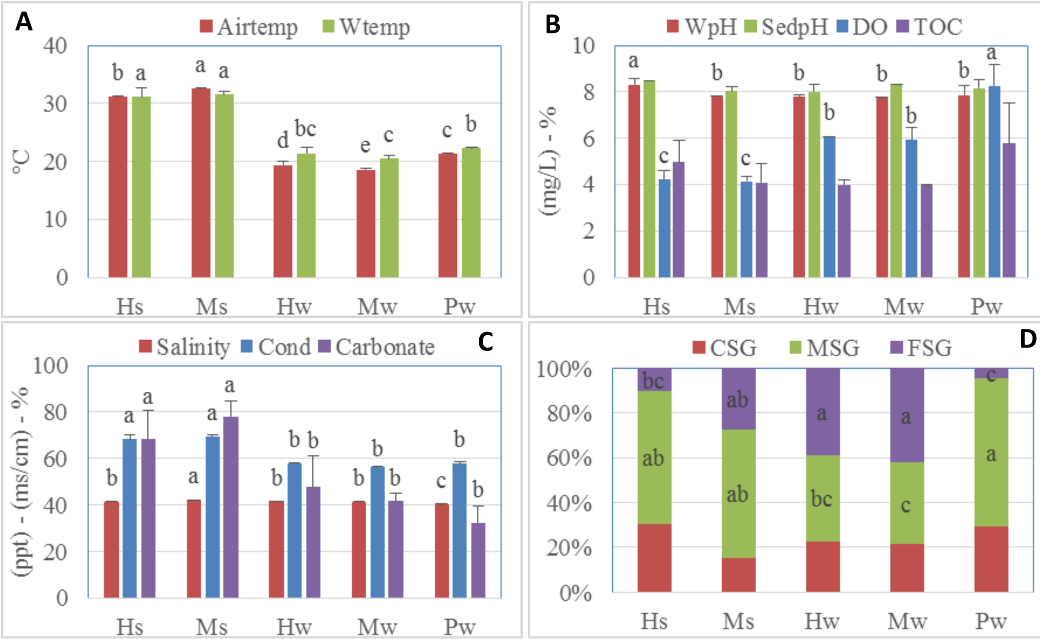


**Figure 2.** Mean ± standard deviation (Std.D) of investigated environmental variables; **A**: **Airtemp**, **Wtemp**: air and water temperature (ºC), **B**: **WpH**: water pH, **SedpH**: sediment pH, **DO**: dissolved oxygen (mg/L), **TOC**: total organic matter content (%), **C**: **Salinity** (ppt), **Cond**: conductivity (ms/cm), **Carbonate**: carbonate content (%), **D**: **CSG**: coarse sediment group (%), **MSG**: medium sediment group (%) and **FSG**: fine sediment group (%) for sample groups and statistical results (The similar characters for each variable show no significant difference).

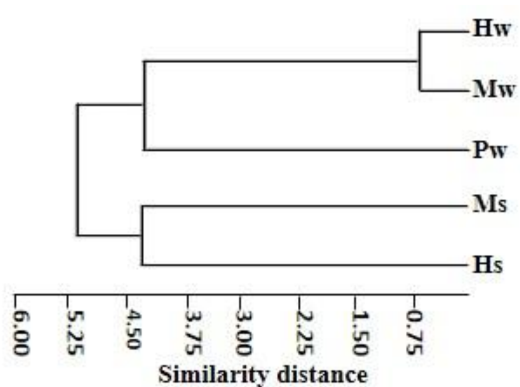


**Figure 3**. The dendrogram shows the similarity distance between sample groups based on recorded environmental variables.

After standardizing the collected data, cluster analysis was used to assess the distance between sampling groups based on differences in the studied environmental factors. The sampling groups were categorized into two subgroups approximately near to at similarity 4.5, one for summer samples and the other for winter samples, according to dendrogram analysis (Fig. 3). Winter samples from El-Hamrawen and Sedy Malek were the most similar (Hw and Mw).

**2. Abundance of the macro-benthos:**

Overall, 3353 macro-benthos were recorded in the studied samples, pertaining to 36 species. They were divided to 9 benthic groups; Chlorophyta (green algae), Phaeophyceae (brown algae), Demospongiae (sponge), Hydrozoa, Octocorallia (soft coral), Hexacorallia (hard coral), Annelida, Mollusca and Echinodermata. The benthic communities were represented by 17, 20, 20, 29, and 23 species of macro-benthos at Hs, Ms, Hw, Mw and Pw, respectively. The contribution of the various macro-benthos to total abundance demonstrated that, *Tridacna squamosa* (Hymenopterans) was almost entirely a dominated species, which comprised 100% of the total macro-benthos followed by *Diadema setosum* (93%) and *Echinometra mathaei* (91%). The recorded benthos were divided into dominancy classes; eudominant (18 species), dominant (12 species), and subdominant (6 species) (Table 1).

Table (1) demonstrates the contribution of the various macro-benthos species to the communities at each sample groups. At all studied sampling groups, the total macro-benthos's abundance was almost entirely dominated by *Pocillipora verrucosa* (hard coral), represented 12.31%, 10.07%, 10.19%, 12.76% and 17.91% at Hs, Ms, Hw, Mw and Pw, sample groups respectively. The density of macro-benthos groups showed variations between the study samples. These variations were statistically significant in case of Chlorophyta (F= 7.693, $p <$ 0.001), Demospongiae (F= 4.151, p= 0.007), Hydrozoa (F= 7٤.٦٤١ , 0.004), Demospongiae Hexacorallia (F= 7.705, p= <0.001) and Mollusca (F= 4.597, 0.004) (Table 2). Chlorophyta recorded at Hs (0.9±0.74 Individuals/25m$^2$) and Mw (0.8±0.79 Individuals/25m$^2$) only while Demospongiae absent from Hw and recorded the highest density at Mw (1.2±0.79 Individuals/25m$^2$). Also, Mw has the highest densities of Hydrozoa (16.7±17.91 Individuals/25m$^2$) and Mollusca (22.2±14.88 Individuals/25m$^2$). Whereas Hexacorallia recorded the highest density at Pw (80.2±6.69 Individuals/25m$^2$) (Table 2).

**Table 1.** The total numbers (No.) and the relative abundance (%) of the recorded macro-benthos for different sample groups with percentages of frequency and dominance.

| Macrobenthos | Hs | | Ms | | Hw | | Mw | | Pw | | F% | Dominance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % | No. | % | | |
| Chlorophyta (Green algae) | | | | | | | | | | | | |
| *Halimeda tuna* | 9 | 2.26 | 0 | 0.00 | 0 | 0.00 | 8 | 0.73 | 0 | 0.00 | 29 | dominant |
| Phaeophyceae (Brown algae) | | | | | | | | | | | | |
| *Padina pavonica* | 20 | 5.03 | 9 | 1.56 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 33 | dominant |
| *Saragasum* sp | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 22 | 2.02 | 0 | 0.00 | 22 | dominant |
| *Turbinaria turbinata* | 8 | 2.01 | 36 | 6.25 | 30 | 4.63 | 26 | 2.39 | 17 | 2.65 | 82 | eudominant |
| Demospongiae | | | | | | | | | | | | |
| *Agelas schmidti* (orange sponge) | 4 | 1.01 | 2 | 0.35 | 0 | 0.00 | 6 | 0.55 | 0 | 0.00 | 22 | dominant |
| *Ircinia arbuscula* (Black sponge) | 6 | 1.51 | 4 | 0.69 | 0 | 0.00 | 6 | 0.55 | 2 | 0.31 | 31 | dominant |
| Hydrozoa | | | | | | | | | | | | |
| *Millepora dichotoma* | 21 | 5.28 | 20 | 3.47 | 20 | 3.09 | 66 | 6.06 | 34 | 5.30 | 60 | eudominant |
| *Millepora platyphyllia* | 1 | 0.25 | 31 | 5.38 | 0 | 0.00 | 101 | 9.27 | 21 | 3.27 | 36 | dominant |
| Octocorallia (Soft coral) | | | | | | | | | | | | |
| *Lobophytum pauciflorum* | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 9 | 0.83 | 0 | 0.00 | 11 | subdominant |
| *Dendronephthya hermprichi* | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 2 | 0.31 | 4 | subdominant |
| *Heteroxenia fuscescens* | 0 | 0.00 | 0 | 0.00 | 16 | 2.47 | 0 | 0.00 | 0 | 0.00 | 7 | subdominant |
| *Sinularia polydactyla* | 9 | 2.26 | 49 | 8.51 | 16 | 2.47 | 8 | 0.73 | 3 | 0.47 | 42 | eudominant |
| Hexacorallia (Hard coral) | | | | | | | | | | | | |
| *Acropora* sp. | 29 | 7.29 | 57 | 9.90 | 58 | 8.95 | 88 | 8.08 | 65 | 10.12 | 82 | eudominant |
| *Stylophora pistillata* | 5 | 1.26 | 26 | 4.51 | 23 | 3.55 | 74 | 6.80 | 67 | 10.44 | 76 | eudominant |
| *Pocillipora verrucosa* | 49 | 12.31 | 58 | 10.07 | 66 | 10.19 | 139 | 12.76 | 115 | 17.91 | 78 | eudominant |
| *Porites* sp. | 33 | 8.29 | 37 | 6.42 | 54 | 8.33 | 68 | 6.24 | 57 | 8.88 | 64 | eudominant |
| *Platygra daedalea* | 2 | 0.50 | 5 | 0.87 | 22 | 3.40 | 37 | 3.40 | 19 | 2.96 | 49 | eudominant |
| *Seriatopora hystrix* | 7 | 1.76 | 8 | 1.39 | 36 | 5.56 | 17 | 1.56 | 10 | 1.56 | 53 | eudominant |
| *Fungia fungites* | 2 | 0.50 | 2 | 0.35 | 0 | 0.00 | 5 | 0.46 | 35 | 5.45 | 27 | dominant |
| *Favites* sp. | 7 | 1.76 | 8 | 1.39 | 14 | 2.16 | 5 | 0.46 | 5 | 0.78 | 47 | eudominant |
| *Tubastraea micranthas* | 0 | 0.00 | 3 | 0.52 | 27 | 4.17 | 5 | 0.46 | 13 | 2.02 | 29 | dominant |
| *Glaxia fascicularis* | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 7 | 0.64 | 7 | 1.09 | 20 | dominant |
| *Echinopora* sp | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 5 | 0.46 | 8 | 1.25 | 13 | dominant |
| *Lobophyllia corymbosa* | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 9 | 0.83 | 0 | 0.00 | 11 | subdominant |
| Annelida | | | | | | | | | | | | |
| *Sabellastarte sanctifosephi* | 17 | 4.27 | 26 | 4.51 | 52 | 8.02 | 63 | 5.79 | 39 | 6.07 | 62 | eudominant |
| Mollusca | | | | | | | | | | | | |
| *Conus vexillum* | 0 | 0.00 | 11 | 1.91 | 38 | 5.86 | 38 | 3.49 | 11 | 1.71 | 71 | eudominant |
| *Tectus dentatus* | 0 | 0.00 | 5 | 0.87 | 0 | 0.00 | 6 | 0.55 | 1 | 0.16 | 20 | dominant |
| *Dendropoma muximum* | 28 | 7.04 | 50 | 8.68 | 46 | 7.10 | 50 | 4.59 | 21 | 3.27 | 71 | eudominant |
| *Tridacna squamosa* | 29 | 7.29 | 38 | 6.60 | 29 | 4.48 | 86 | 7.90 | 42 | 6.54 | 100 | eudominant |
| *Tridacna maxima* | 12 | 3.02 | 17 | 2.95 | 8 | 1.23 | 42 | 3.86 | 23 | 3.58 | 84 | eudominant |
| Echinodermata | | | | | | | | | | | | |
| *Ophiocoma scolopendrina* | 35 | 8.79 | 8 | 1.39 | 34 | 5.25 | 22 | 2.02 | 0 | 0.00 | 56 | eudominant |
| *Echinometra mathaei* | 32 | 8.04 | 24 | 4.17 | 20 | 3.09 | 16 | 1.47 | 4 | 0.62 | 91 | eudominant |
| *Diadema setosum* | 31 | 7.79 | 35 | 6.08 | 29 | 4.48 | 50 | 4.59 | 21 | 3.27 | 93 | eudominant |
| *Trypenastus gritila* | 0 | 0.00 | 0 | 0.00 | 2 | 0.31 | 0 | 0.00 | 0 | 0.00 | 4 | subdominant |
| *Heterocentrotus mamillatus* | 2 | 0.50 | 5 | 0.87 | 8 | 1.23 | 5 | 0.46 | 0 | 0.00 | 31 | dominant |
| *Holothuria atra* | 0 | 0.00 | 2 | 0.35 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 4 | subdominant |

The percentage composition of benthic groups at studied sampling groups revealed that Hexacorallia (hard coral) recorded the highest percentage of species composition in studied samples constituting 33.7%, 35.4%, 46.3%, 42.1% and 62.5% of the total benthos at Hs, Ms, Hw, Mw and Pw, respectivly. Hexacorallia follwed by Echinodermata at Hs (25.1%) while at Ms, Hw, Mw and Pw follwed by Mollusca represented by 21%, 18.7%, 20.4% and 15.3% of the total benthos, respectively (Fig. 4).

**Table 2.** The mean densities (Individuals/25m$^2$) ± standard deviation (Std.D) for benthic groups at different sample groups and statistical results (The similar characters show no significant difference).

| Benthic groups | Hs | | | Ms | | | Hw | | | Mw | | | Pw | | | F | P value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | ± | Std.D | Mean | ± | Std.D | Mean | ± | Std.D | Mean | ± | Std.D | Mean | ± | Std.D | | |
| Phaeophyceae | 2.80 | ± | 1.03 | 4.50 | ± | 4.33 | 3.00 | ± | 1.49 | 4.80 | ± | 1.55 | 3.4 | ± | 1.82 | 1.37 | 0.262 |
| Chlorophyta | 0.90 | ± | 0.74**a** | 0.00 | | | 0.00 | | | 0.80 | ± | 0.79**a** | 0.00 | | | 7.693 | <0.001 |
| Demospongiae | 1.00 | ± | 1.05**ab** | 0.60 | ± | 0.70**ab** | 0.00 | | | 1.20 | ± | 0.79**a** | 0.40 | ± | 0.55**ab** | 4.151 | 0.007 |
| Hydrozoa | 2.20 | ± | 2.25**b** | 5.10 | ± | 5.72**b** | 2.00 | ± | 2.21**b** | 16.70 | ± | 17.91**a** | 11.00 | ± | 3.24**ab** | 4.641 | 0.004 |
| Octocorallia | 0.90 | ± | 1.37 | 4.90 | ± | 5.76 | 3.20 | ± | 5.31 | 1.70 | ± | 1.89 | 1.00 | ± | 1.00 | 1.746 | 0.159 |
| Hexacorallia | 13.40 | ± | 13.18**c** | 20.40 | ± | 18.73**c** | 30.00 | ± | 20.83**bc** | 45.90 | ± | 40.78**b** | 80.20 | ± | 6.69**a** | 7.705 | <0.001 |
| Annelida | 1.70 | ± | 1.83 | 2.60 | ± | 3.03 | 5.20 | ± | 6.51 | 6.30 | ± | 7.47 | 7.80 | ± | 1.10 | 2.054 | 0.105 |
| Mollusca | 6.90 | ± | 2.85**c** | 12.10 | ± | 9.21**cb** | 12.10 | ± | 4.98**cb** | 22.20 | ± | 14.88**a** | 19.60 | ± | 1.14**ab** | 4.597 | 0.004 |
| Echinodermata | 10.00 | ± | 6.51 | 7.40 | ± | 2.46 | 9.30 | ± | 2.83 | 9.30 | ± | 2.83 | 5.00 | ± | 1.22 | 1.85 | 0.138 |

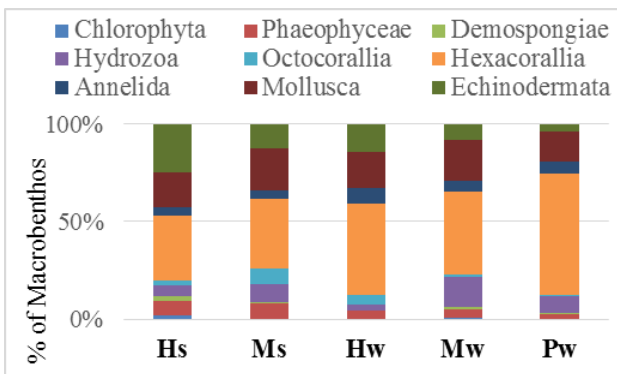


**Figure 4.** Percentage composition of benthic groups at studied sample groups.

The abundances of the recorded benthic were indicated different similarity distances between the different study sample groups. Pw and Mw were separated from the other samples. Hs and Ms were similar to each other followed by Hw (Fig. 5).

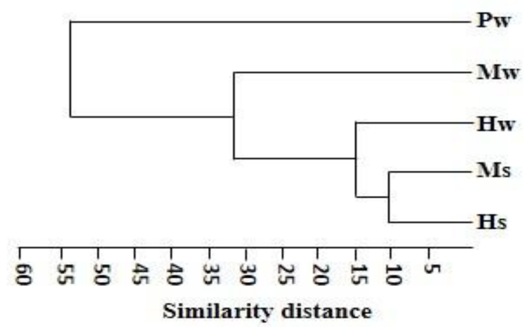


**Figure 5.** Dendrogram showing the similarity distance between the studied sample groups based on the abundances of the recorded benthic groups.

### 3. Biodiversity of macro-benthos:

The current study indicated that some differences in the macro-benthos species biodiversity among sampling groups (Fig. 6). Data analysis revealed significant differences among sampling groups in all studied diversity parameter (Figs. 6A-D) except Shan. Equitability (F=1.832, P=0.142) (Fig.6E). Pw sample recorded the highest values of total abundance, species numbers, Margalef species richness and Shannon diversity while Hs samples recorded the lowest values of these parameters (Figs. 6C and D).

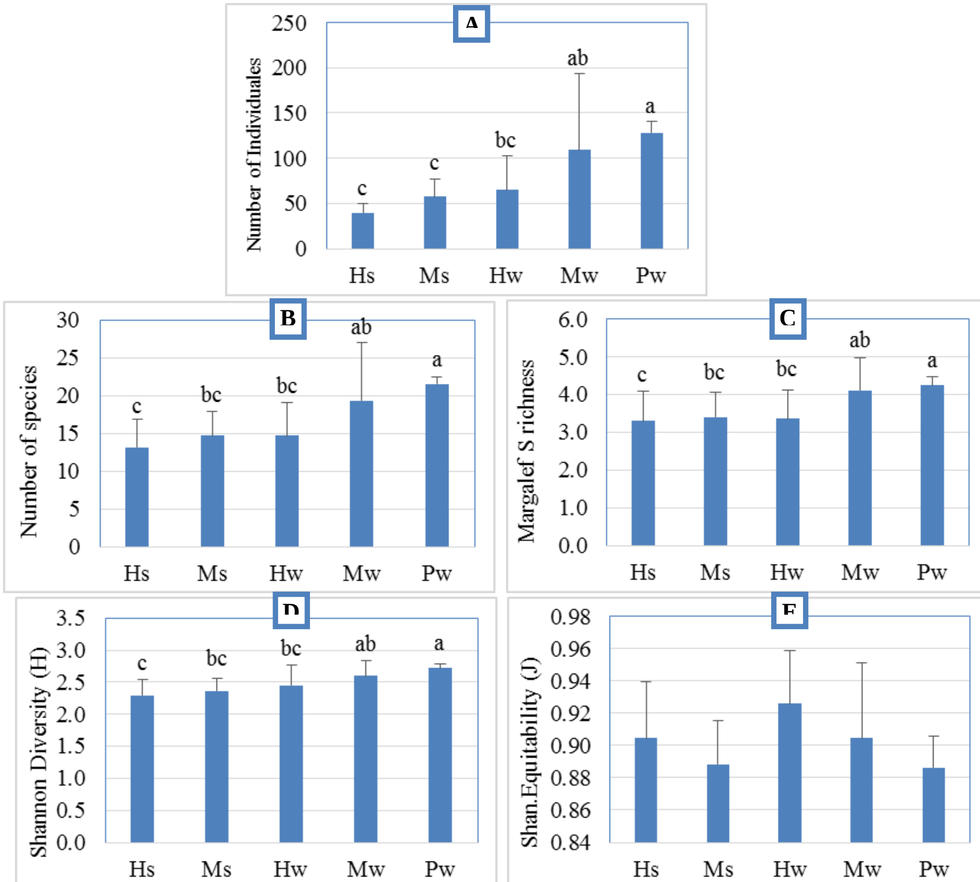


**Figure 6.** The mean values ± standard deviation (Std.D) of biodiversty pramters of the recorded macro-benthos at studied sample groups. A: Total abundance, B: Species numbers, C: Margalef species richness, D: Shannon diversity (H), and E: Shan. Equitability (J). (The similar characters show no significant difference).

According to these biodiversity parameters benthic community point to different similarity distances between studied sampling groups. At two similarity distance, the samples separated to three groups; first similar group includes Hs and Ms and the second includes Pw and Mw, while the third group Hw was separated from the other samples in single grouped near to the first one (Fig. 7).

## 4. Response of macro-benthos to the environment variables:

To study the effect of environmental variables on macro-benthos, canonical correspondence analysis (CCA) ordination was performed on the abundance of the collected macro-benthos groups and the corresponding studied environmental variables. Diagram of canonical correspondence analyses are shown in Fig. 8. The first two CCA axes together account for approximately 59.4% of the relations between macro-benthos and environmental data. The results of CCA reveal that macro-benthos composition is mostly related to dissolved oxygen followed by carbonate content, salinity, water temperature and conductivity, while the rest of the studied environmental variables has relatively small effects on benthic, especially sediment total organic matter content and water pH. Water dissolved oxygen showed a positive association with the abundance of Hexacorallia and negative with the abundance of Mollusca, Echinodermata, and Phaeophyceae. In contradicts, Salinity, conductivity, carbonate content and temprture negative correlate with Hexacorallia and positive with the abundance of Mollusca, Echinodermata, and Phaeophyceae (Fig. 8).

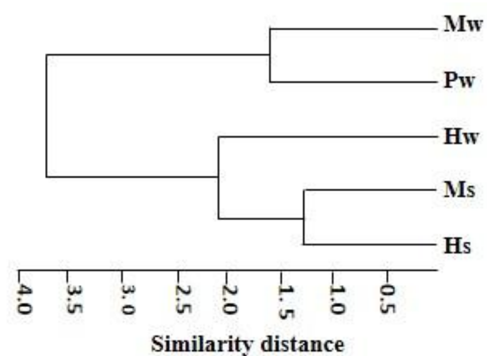


**Figure 7.** Dendrogram showing the similarity distance between the studied sample groups based on the investigated biodiversity parameters of the recorded macro-benthos.

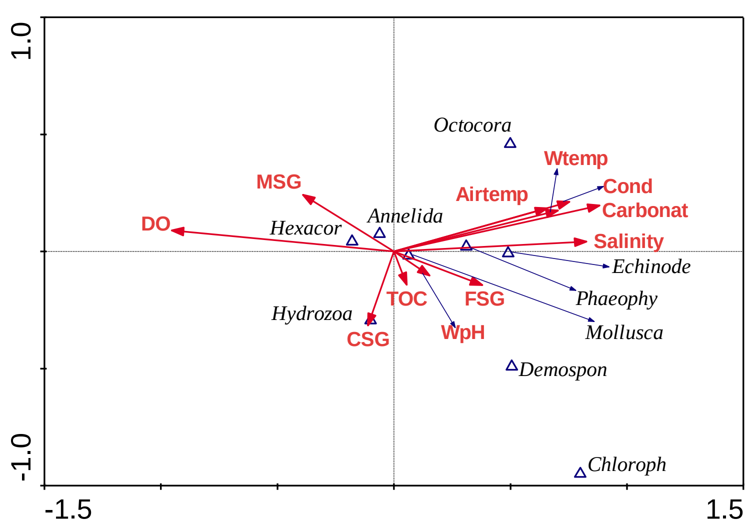


**Figure 8.** Biplot of the canonical correspondence analysis (CCA) results on environmental variables and benthic groups abundances in study sample groups. Benthic groups notation: Phaeophy= Phaeophyceae,

Chloroph= Chlorophyta, Demospon= Demospongiae Hydrozoa, Octocora= Octocorallia, Hexacor= Hexacorallia, Annelida, Mollusca and Echinode= Echinodermata. Environmental variables notation: Airtemp= air temperature, Wtemp: water temperature (ºC), WpH= water pH, DO= dissolved oxygen (mg/L), TOC= total organic matter content (%), Salinity (ppt), Cond= conductivity (ms/cm), Carbonat= carbonate content (%), CSG= coarse sediment group (%), MSG= medium sediment group (%) and FSG= fine sediment group (%).

## DISCUSSION

The significant differences of environmental factors among studied sampling groups led to classify them to two main groups: summer and winter samples. This may be related to the relatively wide range of air and water temperatures according to season in Egypt. The climate in Egypt is characterized by hot summer and moderate winter [19]. EEAA [20] reported that the overall climate of Egypt is dry, hot, and desert, with a slight winter season with rain over the coastal areas, and a hot dry summer season. The only differences between the seasons are variations in daytime temperatures and changes in usual winds. In the coastal regions, temperatures range between an average minimum of 14° C in winter and an average maximum of 30° C in summer.

The abundance and diversity of investigated macro-benthos showed variations among studied communities. The result revealed that Hexacorallia (hard coral) recorded the highest percentage of species composition in studied samples. *Pocillipora verrucosa* (Hard coral) was almost totally dominant for the total macro-benthos abundance. The population structure of this specie was reported in the Saudi Arabian Red Sea and studied over an 850-kilometers distance over a unique latitudinal environmental gradient by Robitzch *et al*. [21]. They illustrated that *P. verrucosa* has a high level of genetic heterozygozity, which could have an essential significance for the species capacity to adapt to changing environments. In comparison to other Scleractinia families (hard corals), the Pocilloporidae has the highest reproductive success in the Red Sea [22] although it is commonly considered as a coral family that is exposed to environmental changes [23].

The contribution of different macro-benthos to total abundance revealed that *Tridacna squamosa* was almost entirely a dominating species, accounting for 100% of all recorded macro-benthos in the present study. Rossbach *et al*. [24] stated that all three gigantic clam species were recorded for the Red Sea, *T. maxima*, *T. squamosa*, and *T.*

*squamosina*, during the fieldwork. While *T. maxima* and *T. squamosa* were found across the Saudi Arabian Red Sea coastline from the northern part of the Gulf of Aqaba to the southern Farasan banks. They are ecologically significant as physically contributing topographic relief (important as nurseries for fish) and calcium carbonate to the reef framework [25, 26].

In the present study, the second recorded macro-benthos species in terms of dominancy was *Diadema setosum* (93%). Diadema is a genus of tropical sea urchins that contains nine species and is ecologically important [27]. Sea urchins are Indo-Pacific origin; their native range extends from the mid Pacific to the East African [28] including the Red Sea. It is especially abundant in the northern part of the Gulf of Suez [29]. Vafidis *et al*. [30] studied *D. setosum* in the south Aegean Sea (eastern Mediterranean). They narrated that in many Dodecanese islands, the species; *D. setosum* exhibits small populations in the shallow rocky sublittoral zone (less than 10 m), with locally dense patches of mature individuals.

*Echinometra mathaei* was the third macro-benthos species in reference to dominancy (91%) in the current study. Mahdy *et al*. [31], concluded that along red sea, the Echinoderm community showed a variety of classes and species composition. They found that *E. mathaei* was the most frequently recorded Echinoidea in the Red Sea Coast of Egypt. Dumas *et al*. [32] concluded that Sea urchins, with their high population dynamics, high recruitment rate, and migratory, usually have systems in place to keep their population stable in extremely changeable environments. *E. mathaei* had a higher density in the summer than in the winter, but *T. squamosa* had a higher density in the winter than in the summer. This may indicate that the high density of the studied species could be related to the spawning period. According to Magalhães *et al*. [33] macrofauna community composition is well-suited to assessing the influence of environmental conditions at both seasonal and geographical scales.

The current study provides baseline data of the macro-benthos and characterizes a number of the environmental parameters that might influence the variability of macro-benthos. The results of the statistical analysis confirmed that macro-benthos composition is mostly related to dissolved oxygen, carbonate content, salinity, water temperature and conductivity. This correlation may interpret the highest values of total abundance, species numbers, Margalef species richness and Shannon diversity for (Pw) benthos community which characterized by the highest DO concentration. Dissolved oxygen acted differently from the rest of the environmental variables, and its increase was observed in winter season at (Hw, Mw, and Pw) sampling groups. Badran [34] concluded that the DO concentration depends on the temperature (air/water), the intensity of biological productivity and the concentration and composition of organic matter.

The negatively effect of water temperature, conductivity, salinity and carbonate content on the Hexacorallia (hard coral) which recorded the highest percentage of species composition in studied communities can explain the lowest abundance and diversity of benthos in (Hs) community which characterized by high values of these parameters. El Gammal *et al*. [35] reported that the high salinity in summer may be due to the high evaporation rate in the Red Sea. Barakat *et al*. [36] stated that the conductivity values reflect the level of total dissolved solids (TDS) in wastewater. Industrial effluent, changes in the water balance (limited inflow, increasing water consumption, or higher precipitation), or salt-water intrusion are all common causes of changes in TDS concentrations in natural waters [37]. Naidu and Niitsuma [38] stated that because evaporation in the Red Sea exceeds freshwater supply, the outflow of Red Sea water is warmer and more saline than the Arabian Sea.

On the other side, different human activities at the studied sites are also might be considered as reasons for the variations in studied benthos communities. There's a phosphate port at El-Hamrawen, which could be a supply of chemical pollution [39] whereas, Sedy Malek could be a holidaymaker site attraction frequented by folks to go to Sedy Malek's shrine. Also, this site is considered as associate outlet for rain and torrential rains, while Porto Ghalb is an associate integrated holidaymaker town that belongs to Marsa Alam Rivera, the Red Sea, and is found in a nature protected area.

## CONCLUSION

The structure of macro-benthos community spatially and seasonally differs according to changes of environmental factors. The most dominant group was the hard coral species (*Pocillipora verrucosa*) which was almost totally responsible for the total macro-benthos abundance in all samples. The contribution of different macro-benthos to total abundance revealed that *Tridacna squamosa*, *Diadema setosum*, and *Echinometra mathaei* were almost entirely a dominating species. Macro-benthos's composition is mostly related to dissolved oxygen followed by carbonate content, salinity, water temperature and conductivity. Seasonal changes in temperature may be the main factors that influence other environmental factors which affect benthos community.

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