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The Impact of Some Environmental Factors on the Distribution of the Benthic Ostracod Species from of Safaga Island, Red Sea, Egypt

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Abstract

The benthic ostracods of Red Sea of Egypt have received little attention in ecological studies. Temperature, depth, salinity, dissolved oxygen, pH, conductivity, and other environmental variables all have an impact on benthic ostracods. This study aimed to determine the influence of environmental parameters on the distribution of benthic ostracods by determining the similarity and dissimilarity between the eight collection sites, investigating the regional distribution form by accomplished Multidimensional Scaling (MDS), and recognizing the percentage of the influence of each species on the resemblances and variances within the clusters formed by SIMPER analysis, determining the relationships between depth and other factors by Spearman's rank correlation coefficient. A total of 43 ostracod species had been identified. According to the frequency index, a single species was rare, six were common and the remaining species (36) were dominant. Seven ostracods species were found across all sites and *Cytherelloidea* sp. was found in two. The abundance and richness of ostracod species were correlated positively with water temperature, dissolved oxygen, organic matter, salinity, and calcium carbonate. The cold water is preferred by the ostracods *Cylindroleberis vix* and *Prionotoleberis lux* and the warm water is favored by podocopid ostracods. The findings of this study will aid in the identification of ostracod species, as well as understanding the characteristics and ecological variables in this zone of the Red Sea in Egypt. The current investigation is an attempt to shed the light on the features of ostracods that live on the east side of Safaga Island.

Keywords

Marine Ostracods, Ecological Parameters, Benthic Ostracods, Red Sea

1. Introduction

The Ostracoda is a class of Crustacea characterized by a bivalved carapace, which encloses the body and appendages. Ostracods occur in almost all types of water bodies, and they are one of the most abundant groups of benthic microfauna. In addition, they distribute almost everywhere from shallow marine to deep-sea environments, and they are useful as indicators of the environmental parameters variation [1].

Generally, the controlling factors on marine ostracods are water temperature, depth, salinity, dissolved oxygen, pH, alkalinity, food supply and sediment organic matter content [2]. To testify this, Mesquita-Joanes *et al.* [3] maintained that temperature is the most important factor affecting ostracod growth and survival. Furthermore, Ruiz *et al.* [4] stated that salinity was the most important factor in species distribution. Also, Ruiz *et al.* [4] stated that ostracods may be affected by pH and electrical conductivity.

Though ostracod species are numerous and abundant in the Egyptian Red Sea region, benthic ostracods have received little attention in ecological studies. What we have are only some studies on the recent benthic marine ostracods of the Red Sea, such as [5] which dealt only with Cypridinidae, [6] characterized the ostracod community of Al Gardaqa, and [7] investigated the ostracod assemblages of the Abu Dhabi lagoon. In addition, [8] and [9] investigated ostracods from the Gulf of Aqaba, [10] and [11] gave information on foraminifers and ostracods from the Jordanian Gulf of Aqaba. Also, [12] gathered data on benthic ostracods from El Hameira (Gulf of Aqaba) and [13] collected data on ostracods from Safaga Bay.

The goals of this study were to identify and determine the ostracod assemblages that live between 0.5 m to 30 m depths on the east side of Safaga Island, to determine the ecological parameters of the environment in which these species live and to figure out the impact of these ecological factors on the distribution and abundance of ostracod species according to the seasons.

2. Materials and Methods

In the current study, 32 samples are collected by using the nylon net (150 μm mesh size) and Van Veen grab from eight stations of the east side of Safaga Island (**Figure 1** and **Table 1**). The period of the collection extends through four seasons between 2018 and 2019 (June 2018, September 2018, January 2019, and March 2019). The nylon net was used in collecting of samples at depths from 0.5 - 1 m while, samples at depths from 5 to 30 m were collected by the Van Veen grab. At each one of 8 collection sites, about 500 ml of sediment samples were collected for studying species of ostracods. The sediment samples containing ostracod species were fixed in 4% formaldehyde solution.

The ostracod species studied in this work were not listed in the IUCN Red List of Threatened Species (http://www.iucnredlist.org/) [14]. No permits were required for the labeled study, which conformed to all applicable guidelines.

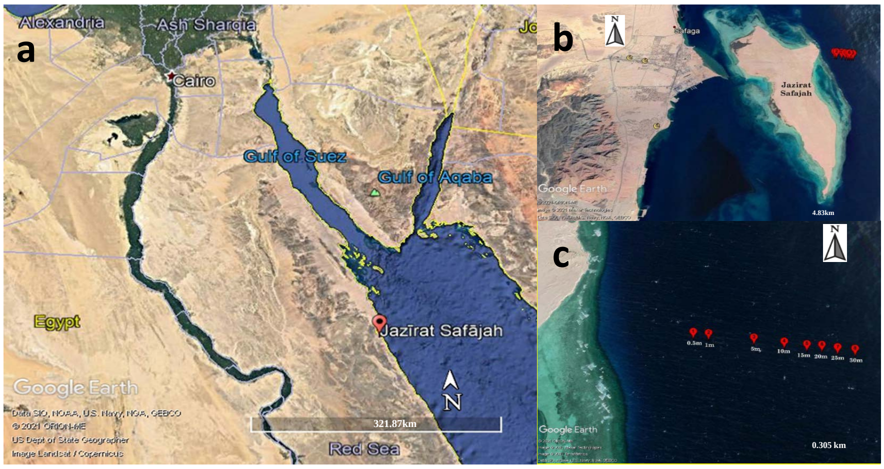

Figure 1. (a) Map showing location of Gazirat safaga. (b) Map showing the eight collecting sites. (c) Map showing enlargement of the eight collecting sites at different depths (from google earth).

Table 1. Depths and coordinates of the stations in the east side of Safaga Island.

Depth (m)	Coordinates
Site 1: 0.5 m	26˚45'34.93"N - 34˚0'3.42"E
Site 2: 1 m	26˚45'35.17"N - 34˚0'5.92"E
Site 3: 5 m	26˚45'34.85"N - 34˚0'12.43"E
Site 4: 10 m	26˚45'34.65"N - 34˚0'17.83"E
Site 5: 15 m	26˚45'34.3"N - 34˚0'21.16"E
Site 6: 20 m	26˚45'33.70"N - 34˚0'23.57"E
Site 7: 25 m	26˚45'32.94"N - 34˚0'25.70"E
Site 8: 30 m	26˚45'32.1"N - 34˚0'28.51"E

At each collection site, some ecological factors such as pH, dissolved oxygen (DO), water temperature, electrical conductivity and salinity were measured seasonally using an environmental Multi Probe System. Also, total dissolved solids (TDS) were calculated by multiplying the electrical conductivity value by 0.65. Additionally, organic matter, and calcium carbonate percentage were determined.

Ostracod species were picked in the laboratory using a tiny pipette from a petri dish containing some of the collected samples under a binocular microscope. Then ostracod species were counted, preserved in 70% alcohol and examined in detail under a stereomicroscope.

For scanning electron microscope studies, the collected ostracod species were fixed in a mixture of one volume of 1% of osmium tetraoxide and three volumes of 4% glutraldehyde. Then they were dehydrated in series of ethanol and sputter-coated with gold, and viewed under a JSM 5400 LV SEM, at an accelerating voltage of 15 kV at Assiut University.

The identification of ostracod species was conducted by using a variety of references such as: Bonaduce & Pugliese [8], Bonaduce *et al.* [9], Bonaduce *et al.* [6] [15] [16] [17] [18] and the help of Australian Museum. In the current study, the frequency of the ostracod species was calculated by using [19] frequency index. The results were evaluated as dominant (F ≥ 50%), common (50% > F ≥ 25%) and rare (F < 25%). To determine the similarity between the eight collection sites, Bray-Curtis Similarity Index was done. The Bray-Curtis dissimilarity was used to measure the variances in species populations between two different sites and can be calculated with the following formula: $BC_{ij} = 1 - \left(2C_{ij}\right) / \left(S_i + S_i\right)$. Multidimensional Scaling (MDS) was accomplished to investigate the regional distribution form [20]. SIMPER analyses were done to recognize the percentage of the influence of each species on the resemblances and variances within the clusters formed after mass analysis. Spearman's rank correlation coefficient was done to determine the relationships between depth and other factors.

3. Results

3.1. Ecological Factors

Table 2 and **Figures 2(a)-(h)** summarized the values of the measured ecological parameters in Sea water of the collecting sites as temperature (˚C), pH, salinity (‰), dissolved oxygen (mg/L), conductivity (ms/cm), $CaCO_3$ (%), TDS (g/l) and organic matter (%). The highest water temperature (35˚C) was measured at site1 in summer 2018, and the lowest water temperature (9˚C) was measured at site 8 in winter 2019 (**Figure 2(a)**). 504 individuals of ostracods belonging to 36 species were recorded on site 1 in summer (35˚C) and 31 individuals of ostracods representing eight species were recorded on site 8 (9˚C) in winter. 8.5 was the highest value of pH recorded in autumn and spring at sites 5 and 6, respectively. Besides, the lowest value of pH was 7.3 in spring at site 2.

The values of salinity varied from 38.2‰ to 42.2‰, where the lowest value was recorded in spring 2018 at site 6 and the highest value was noted in winter and spring at site 4 and site 8, respectively. Dissolved oxygen fluctuated between 4.11 to 9.6 mg/L and the conductivity values ranged from 60.1 to 64.6 ms/cm. As well as, total calcium carbonate ranged from 50% to 89%. Also, TDS ranged between 33.4 to 39.8 g/l and organic matter varied from 8.9% to 24.6%.

3.2. Ostracod Species and Seasonal Distributions

The collecting ostracods (39 species of Podocopida and four species of Myodocopida) identified in eight collecting sites on the east side of Safaga Island, as well as their Frequency Index values, were shown in Appendix, **Table 3**, and **Figures 3-6**. The frequency index (Fs) of the identified ostracod species (**Figures 3-6**) was calculated, yielding the following results; the ostracod species *Cytherelloidea* sp. gathered as rare and the sixteen species: *Paranesidea* sp., *Neonesidea* aff. *Michaelseni*, *Aglaiocypris triebeli*, *Hiltermannicythere* sp., *Leptocythere rara*, *Rutiderma* sp., *Loxoconcha* sp., *Loxoconcha gisellae*, *Loxocorniculum*

Table 2. Values of ecological parameters in the eight sampling stations during the four seasons.

Sites	Seasons	T (°C)	pH	Salinity (‰)	Dissolved Oxygen (mg/L)	Conductivity (ms/cm)	$CaCO_3$ (%)	TDS (g/l)	Organic matter (%)	Ind. No.	Richness
0.5 m Site 1	Summer	35	7.8	39.7	9.60	60.4	62	35.6	12.7	504	36
	Autumn	18	8	40.2	6.68	63.5	55	37.9	22.7	272	34
	Winter	14	8.2	41	7.47	63.9	50	39.4	16.6	171	35
	Spring	23	7.4	41.3	6.68	62.6	71	36.9	19.5	408	35
1 m Site 2	Summer	33.5	8.1	42.1	9.56	63.9	50	37.4	24.6	376	33
	Autumn	19	8	40.2	9.26	63.4	66	39.5	16.7	222	33
	Winter	12.8	7.6	39.4	9.15	60.8	54	33.9	9.7	256	33
	Spring	22.5	7.3	39	7.39	60.1	78	35.8	12.8	245	33
5 m Site 3	Summer	32	8	38.9	9.26	64.2	73	36.2	10.5	327	33
	Autumn	16	8.4	39.6	7.68	63.1	51	37.1	18.6	378	32
	Winter	12	7.4	41.8	7.31	60.6	89	37.9	11.7	138	32
	Spring	20	7.9	40.9	7.42	60.3	63	34.9	19.5	317	33
10 m Site 4	Summer	30.5	7.6	40.6	6.40	62.7	83	39.0	15.6	264	31
	Autumn	15	8.3	41	6.53	63.2	72	39.6	18.4	147	31
	Winter	10	7.9	42.2	6.25	61.4	60	33.9	14.9	185	30
	Spring	18	7.8	38.6	5.24	61.1	53	37.6	20.3	201	29
15 m Site 5	Summer	25.5	8.1	41.5	8.21	64.6	59	36.7	14.7	217	34
	Autumn	15	8.5	41.9	7.62	61.7	83	34.9	17.4	164	34
	Winter	11.5	7.5	39.4	5.40	61.3	59	38.4	19.3	90	34
	Spring	18	8	42	4.63	60.3	62	38.0	12.6	150	31
20 m Site 6	Summer	19	7.8	38.8	7.46	61.8	55	33.5	21.7	392	29
	Autumn	14	7.9	39.3	6.62	60.1	67	38.2	22.6	261	27
	Winter	13	8.2	40	4.61	63.2	82	35.7	12.2	71	28
	Spring	16	8.5	38.2	4.63	63.7	65	33.9	21.7	277	28
25 m Site 7	Summer	18.5	8.1	42	9.51	62.5	76	39.8	16.2	155	19
	Autumn	13	7.8	40.3	7.64	62.8	85	36.5	19.7	91	19
	Winter	11	8	41	5.34	60.1	52	38.7	20.4	101	14
	Spring	14	7.6	38.5	4.43	64.3	59	33.4	9.5	107	19
30 m Site 8	Summer	17	7.9	38.9	5.60	64.2	81	36.8	13.8	97	9
	Autumn	13	7.8	39.7	5.26	61.6	80	34.9	8.9	58	9
	Winter	9	8	41.5	4.81	63.1	74	37.2	23.6	31	8
	Spring	13	8.4	42.2	4.11	60.5	52	37.6	14.8	70	9

Table 3. Frequency index values (Fs) for collected species.

Identified ostracod species	0.5 m	1 m	5 m	10 m	15 m	20 m	25 m	30 m	Fs (%)
Aglaiocypris triebeli (Hartmann, 1964)		*	*				*		37.5
Callistocythere arcana Bonaduce *et al.*, 1976	*	*	*		*	*		*	75
Callistocythere fluctuans Puglies *et al.*, 1984	*	*	*	*		*			62.5
Carinocythereis sp. 1			*	*	*	*			50
Carinocythereis sp. 2	*	*	*	*	*	*			75
Caudites levis Hartmann, 1964	*	*	*	*	*	*	*	*	100

Continued

Cylindroleberis vix Korniker, 1992	*		*	*	*	*	*	*	87.5
Cyprideis littoralis Brady, 1868	*	*		*		*			50
Cyprideis torosa (Jones, 1850)	*	*	*		*				50
Cytherella cf. *punctata* Brady, 1868	*	*	*	*					50
Cytherelloidea sp.	*				*				25
Ghardaglaia triebeli Hartmann, 1964	*	*	*	*	*	*	*	*	100
Hemicytherura videns aegyptica Hartmann, 1964	*				*	*			37.5
Hiltermannicythere sp.	*		*		*	*			50
Hiltermannicythere rubrimaris (Hartmann, 1964)	*		*		*				37.5
Jonicythere sp.	*	*		*	*	*			62.5
Leptocythere arenicola Hartmann, 1964	*	*	*	*			*		62.5
Leptocythere rara (Mueller, 1894)		*	*		*	*			50
Loxoconcha sp.	*	*		*		*			50
Loxoconcha ghardaqensis Hartmann, 1964	*	*	*	*	*	*	*	*	100
Loxoconcha gisellae Bonaduce *et al.*, 1980	*		*	*	*				50
Loxoconcha ornatovalve Hartmann, 1964	*	*		*	*	*	*		75
Loxoconchella dorsobullata Hartmann, 1964	*	*				*			37.5
Loxocorniculum ghardaquensis (Hartmann, 1964)		*	*		*				37.5
Macrocypris minna (Baird, 1850)	*	*	*	*	*				62.5
Miocyprideis cf *spinolusa* (Brady, 1868)		*	*	*	*	*	*		75
Moosella striata Hartmann, 1964	*	*	*	*	*	*	*		87.5
Neonesidea aff. *michaelseni* Hartmann, 1982		*		*	*		*		50
Neonesidea schulzi (Hartmann, 1964)	*	*	*	*	*	*	*	*	100
Paradoxostoma altecaudatum Hartmann, 1964	*	*	*	*	*				62.5
Paradoxostoma arcuatum Hartmann, 1964	*	*	*		*	*			62.5
Paranesidea sp. Bate, 1970	*	*		*					37.5
Paranesidea fracticorallicola Maddocks, 1969	*	*	*	*	*	*	*	*	100
Prionotoleberis lux Korniker, 1992	*	*	*	*	*	*	*	*	100
Propontocypris sp.	*	*	*	*	*				62.5
Quadracythere borchersi (Hartmann, 1964)	*	*	*	*	*	*			75
Rutiderma sp.			*			*	*	*	50
Tanella gracilis Kingma, 1948	*	*	*	*	*	*	*	*	100
Triebelina sp.	*	*	*	*	*	*			75
Xestoleberis ghardaqe Hartmann, 1964	*		*	*	*		*		62.5
Xestoleberis rhomboidea (Hartmann, 1964)	*	*	*	*	*	*	*		87.5
Xestoleberis rotunda Hartmann, 1964	*	*	*	*	*	*	*		87.5
Zeugophilomedes grafi Hartmann, 1964	*	*		*	*	*	*	*	87.5

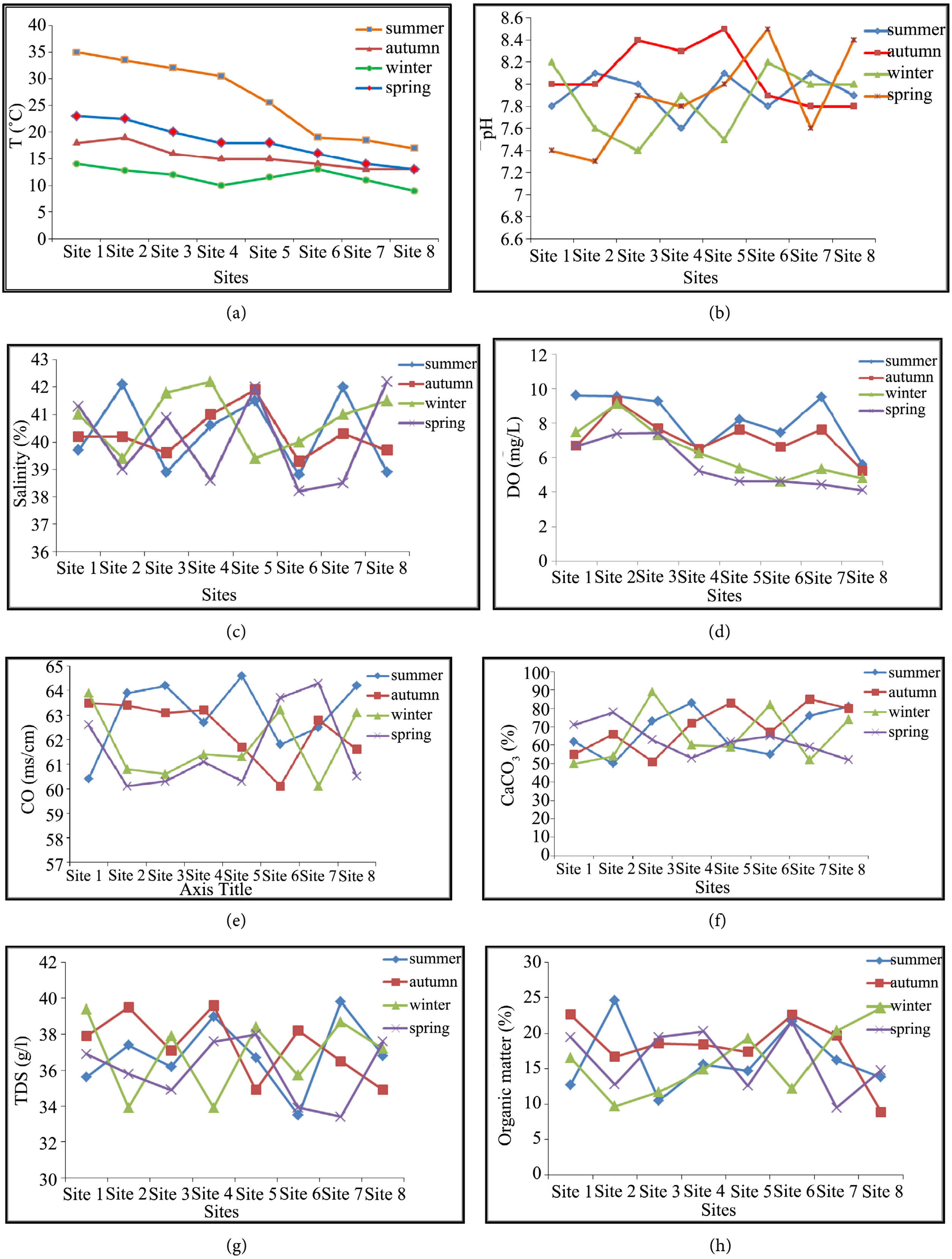

Figure 2. The seasonal differences of the studied ecological factors: (a) temperature, (b) pH, (c) salinity, (d) dissolved oxygen, (e) conductivity, (f) calcium carbonate, (g) TDS, (h) organic matter at the collecting sites.

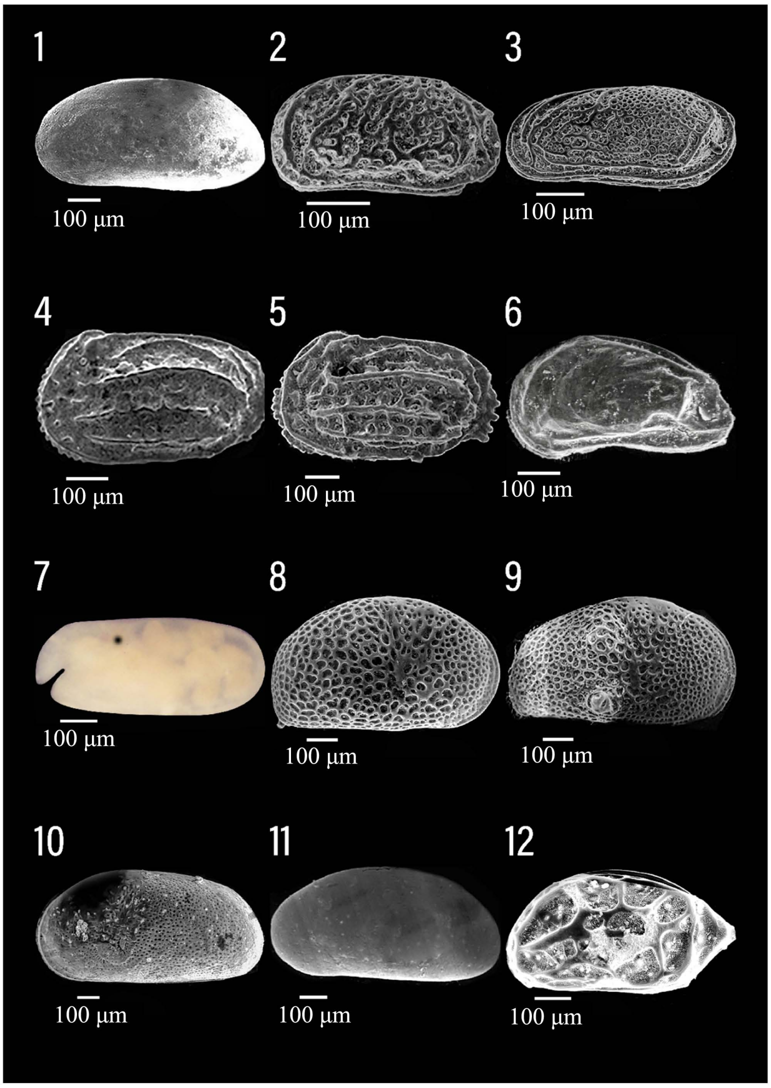

Figure 3. Scanning Electron Microscope showing images of the external view of: 1: *Aglaiocypris triebeli*; 2: *Callistocythere arcane*; 3: *Callistocythere fluctuans*; 4: *Carinocythereis* sp. 1; 5: *Carinocythereis* sp. 2; 6: *Caudites levis*; 8: *Cyprideis littoralis* (after [46]); 9: *Cyprideis torosa*; 10: *Cytherella* cf. *punctata*; 11; *Ghardaglaia triebeli*; 12: *Hemicytherura videns aegyptica* (after [46]) and 7: photograph of *Cylindroleberis vix*.

ghardaquensis, *Loxoconchella dorsobullata*, *Cytherella* cf. *punctate*, *Carinocythereis* sp. 1, *Hiltermannicythere rubrimaris*, *Hemicytherura videns aegyptica*, *Cyprideis littoralis* and *Cyprideis torosa* were grouped as common and the remaining species (26) were dominant.

3.3. Species Abundance

According to the seasonal collecting samples, 43 of ostracods were collected and identified (**Figures 3-6**). Furthermore, the highest number of ostracod species (richness) (36) was recorded in summer (**Figure 7**) at the first site and the lowest number of species (8) was observed in winter at site 8 (**Figure 7**). Then, the maximum number of ostracod individuals (504) was detected at site1 in the

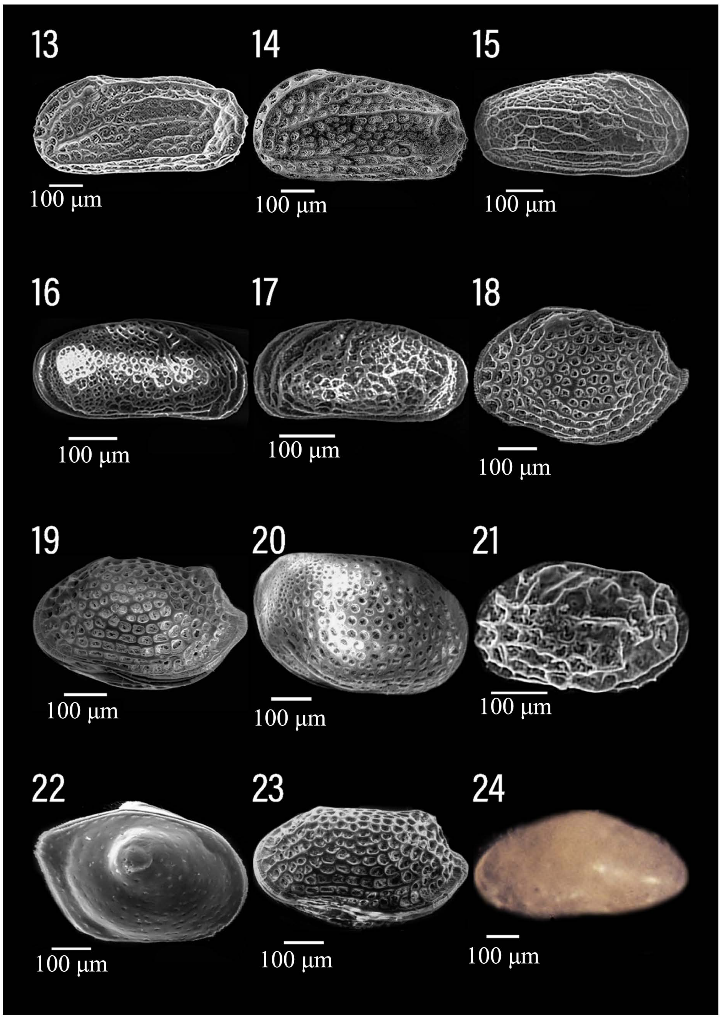

Figure 4. Scanning electron microscope showing images of the external view of: 13: *Hiltermannicythere rubrimaris*; 14: *Hiltermannicythere* sp.; 15: *Jonicythere* sp.; 16: *Leptocythere arinecola* (after [46]); 17: *Leptocythere rara*; 18: *Loxoconcha* sp.; 19: *Loxoconcha ghardaqensis*; 20: *Loxoconcha gisellae* (after [46]); 21: *Loxoconcha ornatovalve*; 22: *Loxoconchella dorsobullata*; 23: *Loxocorniculum ghardaquensis*; and 24: photograph of *Macrocypris minna*.

summer and the lowest number of individuals was noted at site 8 in winter (**Figure 7** and Appendix).

The distribution of ostracod species shows differently at each site. Seven ostracod species (*Paranesidea fracticorallicola*, *Neonesidea schulzi*, *Tanella gracilis*, *Caudites levis*, *Loxoconcha ghardaqensis*, *Prionotoleberis lux*, *Ghardaglaia triebeli*) were observed in every collecting site, so they have broader ranges of tolerances to diverse environmental factors. On the other hand, ostracod species *Cytherelloidea* sp. occurred in two collecting sites only and twelve species represented 44% of the total number of collecting ostracod species. A species of the genus *Rutiderma* Brady & Norman, 1896 (**Figure 5** image 36) is reported in this paper for the first time but it is not described and therefore it is left in open nomenclature.

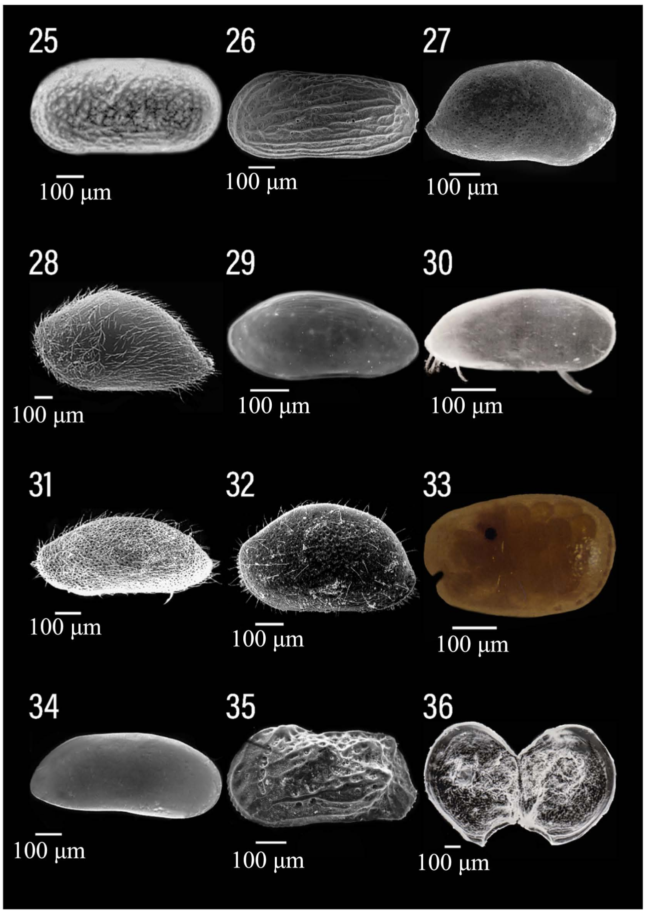

Figure 5. Scanning electron microscope showing images of the external view of: 25: *Miocyprideis* cf *spinolusa*; 26: *Moosella striata* (after [46]); 26: *Hiltermannicythere* sp.; 27: *Neonesidea* aff. *Michaelseni* (after [46]); 28: *Neonesidea schulzi*; 29: *Paradoxostoma altecaudatum* (after [46]); 30: *Paradoxostoma arcuatum*; 31: *Paranesidea* sp.; 32: *Paranesidea fracticorallicola*; 34: *Propontocypris* sp.; 35: *Quasdracythere borchersi* (after [46]); 36: *Rutiderma* sp. and 33: photograph of *Prionotoleberis lux*.

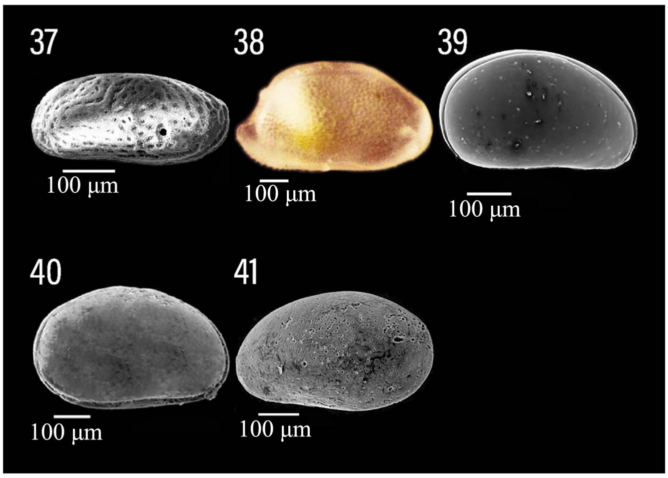

Figure 6. Scanning electron microscope showing images of the external view of: 37: *Tanella gracilis* (after [46]); 39: *Xestoleberis ghardaqe*; 40: *Xestoleberis rhomboidea*; 41: *Xestoleberis rotunda* (after [46]) and 38: photograph of *Triebelina* sp.

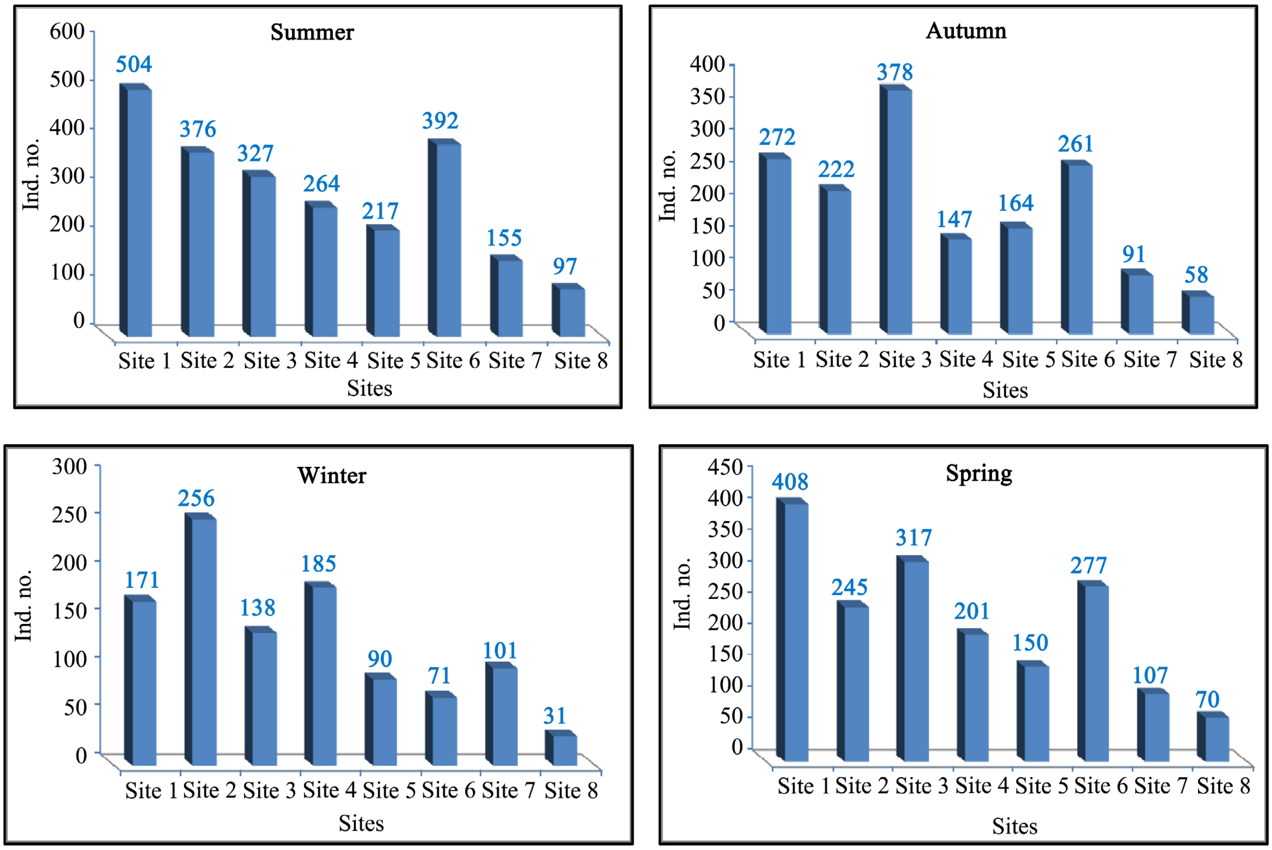

Figure 7. Seasonal fluctuations in the individual numbers of ostracod species at the sampling sites during the period of collection.

According to Appendix and Table 4, site 1 had the highest number of ostracod individuals (1355) and site 8 had the lowest number (256). Furthermore, site 1 had the highest number of ostracod species (36) and site 8 had the lowest number (11). Also, *Prionotoleberis lux* was the dominant species in summer, *Cylindroleberis vix* in autumn, *Caudites levis* in winter and *Cylindroleberis vix* in spring according to the dominancy index values.

3.4. Bray-Curtis Similarity and Multidimentional Scaling (MDS) Ordination

The dendrogram of Bray-Curtis similarity and Multidimentional scaling (MDS) ordination of the collecting sites was formed of Bray–Curtis average clustering and the similarities between the stations were displayed in groups and shown in Figure 8 and Figure 9. The groups that exhibited the highest similarity and difference in each season were determined according to SIMPER analysis results. In summer, the similarity revealed three groups; the similarity within the first group was 42.3%, within the second group was 41% and was 59.5% within the third group. In autumn, the similarity displayed two groups; the similarity inside the first group was 42.1%, while that similarity was 34.2% within the second group. Furthermore, the similarity between the two groups was 38.5% and 40.3% of the first and second groups, respectively, during the winter season. In spring,

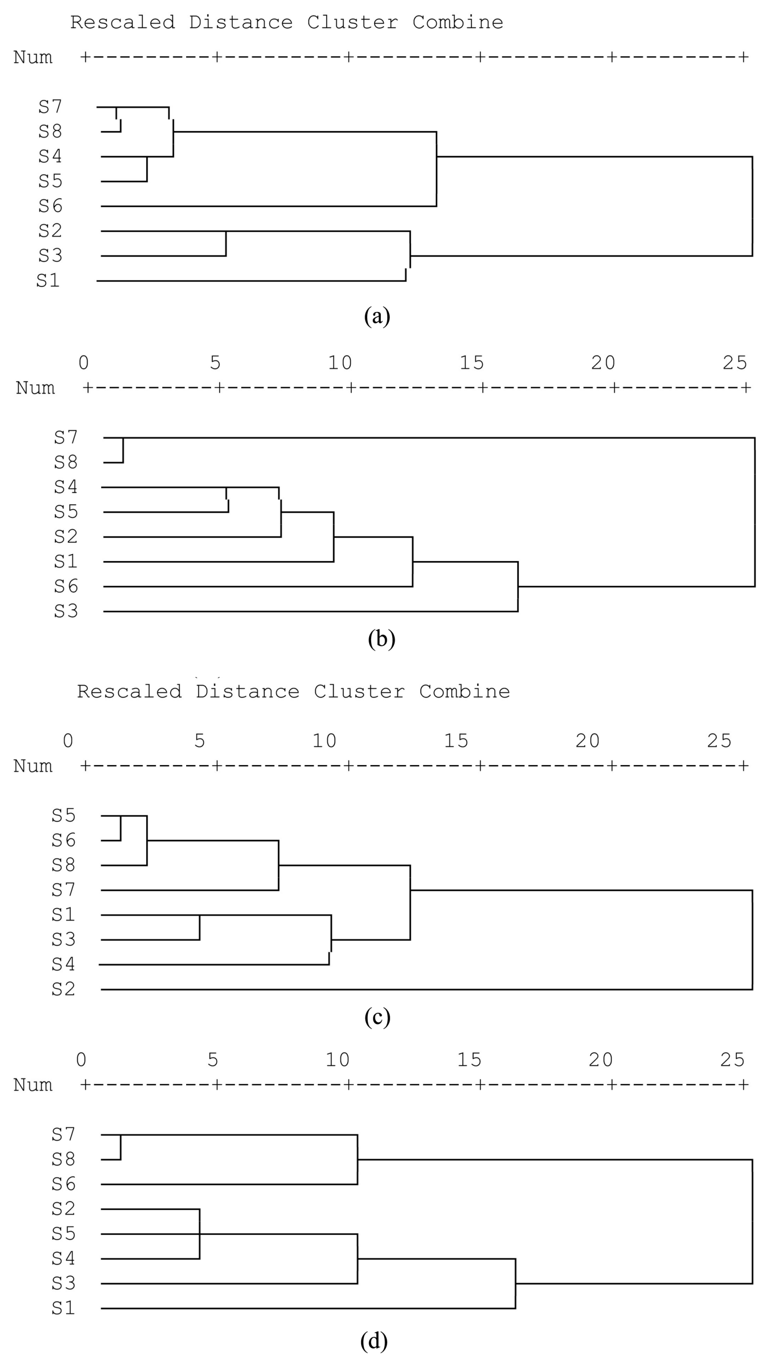

Figure 8. Bray-Curtis similarity dendrograms of individual numbers of ostracod species at the collecting sites. (a) Summer; (b) Autumn; (c) Winter; (d) Spring.

Table 4. The total seasonal number of ostracod individuals.

Season	Summer	Autumn	Winter	Spring
No. of ostracod individuals	2332	1593	1043	1765

the similarity revealed two groups; those were 44% and 36.7% in the first and second groups, respectively.

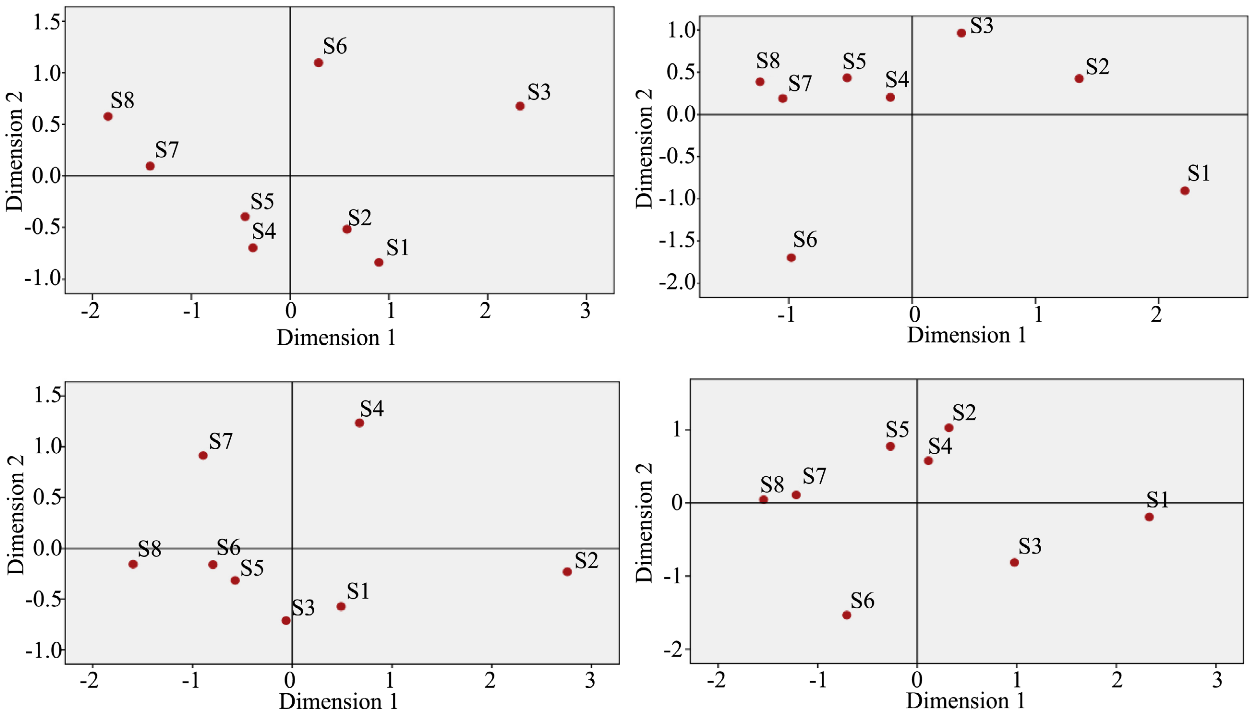

Figure 9. MDS ordination of the collecting sites produced with Bray–Curtis average clustering method.

The correlation among measured parameters such as water temperature, pH, salinity, dissolved oxygen, conductivity, total calcium carbonate, TDS, total organic matter, individual number, richness and depth were determined using Spearman's rank correlation coefficient method and listed in Table 5. The results of correlation analysis displayed that the individual number and richness of ostracods were positively correlated with water temperature, dissolved oxygen, organic matter, salinity and total calcium carbonate, and the individual number of ostracods was negatively correlated with the depth of sea water.

4. Discussion

The results of this study confirmed the presence of distinct difference in the abundance of ostracod species between the eight collecting sites. The shallow sites (site 1 and 2) were characterized by higher densities than those of the benthic sites, this is chiefly related to the location of sites in an area contains seagrass, sea beds and macro-algae, thus the availability of food for ostracods. [21] recorded that some ostracod species living in close proximity to sea grasses, algae, and mangrove trees, which are abundant along the Red Sea's coast. Moreover, [21] recorded that the ostracod species with higher percentages are associated with algae and seagrasses. The leaves promote the growth of macroalgae, which provide food and shelter for invertebrates, allowing them to reach significantly higher densities than in unvegetated benthic habitats [22]. According to Xie *et al.* [23] the benthic aquatic is not suitable for ostraod surviving because the decreasing of plants and reducing of water transparency.

Table 5. The matrix of spearman's rank correlation between ostracod assemblages and environmental factors in the sampling stations.

		T	pH	salinity	Dissolved Oxygen	Conductivity	$CaCO_3$	TDS	Organic matter	Individual No.	Richness	Depth
T	R		−0.106	−0.057	0.562**	0.196	−0.033	0.043	−0.037	0.717**	0.444*	−0.483**
	Sig.		NS	NS	S	NS	NS	NS	NS	S	S	S
pH	R			0.231	−0.059	0.319	−0.215	0.098	0.266	−0.086	−0.114	0.220
	Sig.			S	NS	S	S	NS	S	NS	NS	S
Salinity	R				0.104	−0.117	0.045	0.368*	0.104	0.292	0.215	−0.029
	Sig.				NS	NS	NS	S	NS	S	S	NS
Dissolved Oxygen	R					0.105	−0.021	0.089	−0.019	0.591**	0.507**	−0.590**
	Sig.					NS	NS	NS	NS	S	S	S
Conductivity	R						0.040	0.050	0.069	−0.014	−0.007	0.025
	Sig.						NS	NS	NS	NS	NS	NS
$CaCO_3$	R							0.015	0.294	0.312	0.284	0.236
	Sig.							NS	S	S	NS	S
TDS	R								0.267	−0.190	0.009	−0.100
	Sig.								S	NS	NS	NS
Organic Matter	R									0.204	0. 25	−0.009
	Sig.									S	S	NS
Individual No.	R										−0.642**	−0.669**
	Sig.										S	S
Richness	R									.		−0.870**
	Sig.											S

S: Correlation is significant. NS: Correlation is not significant. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Distribution and abundance of ostracod species and specimens are related to numerous diverse ecological factors (Batmaz *et al.*, [24]). The ecological parameters (temperature, dissolved oxygen, pH, salinity, $CaCO_3$ (%) and TDS) and the physical characteristics (depths, aquatic plants and predation) control the occurrence and abundance of ostracod species [25] [26].

According to the results of Spearman's rank correlation (**Table 5**), the individual number of ostracod species was correlated positively with temperature. Also, [27] noted that the species occurrence was positively related to both water temperature and electrical conductivity. In addition to this, Mesquita-Joanes *et al.* [3] discovered a high positive association between water temperature and ostracod population expansion, suggesting that temperature is important for species survival. Correspondingly, [28] and [22] noted that no direct relationship occurs between the distribution of ostracod species and temperature. [29] recorded that, water temperature and salinity are the major controlling factors governing ostracod distribution in estuarine environments. Moreover, a positive correlation was observed between individual numbers and richness and salinity, according to the correlation of Spearman's rank ($P < 0.01$) (**Table 3**). [25] [26] suggested that salinity is an active factor in the diversity and the abundance of ostracod species. In the same way, [30] approved that salinity has a significant effect on the diversity of ostracod species.

In the current study, dissolved oxygen ranged from 4.11 to 9.6 mg/L and it correlated positively with individual and species numbers. According to Ahmed *et al.* [31] the higher values of dissolved oxygen during some months are owed to increase the activity of the photosynthesis process, while lower values might be because of using the organic substances and breathing of organisms. Moreover, [32] noted that dissolved oxygen is not an important factor within an aquatic ecosystem and it is the smallest effective analyst for the ostracod species, respectively. On the other hand, Külköylüoglu *et al.* [33] [34] noted a positive correlation between individual numbers of the species and dissolved oxygen. The pH of water of the current study does not fluctuate greatly at the different depths during the four seasons. Similarly, data noted by Sridhar *et al.* [35].

From this study, it is concluded that the relationship between abundance and richness of ostracod species were positive with total organic matter and total calcium carbonate. A similar observation was noted by [36]. [37] noted that the greater portion of the calcium carbonate content was made by the carbonate shells of some organisms like molluscs, foraminifera and algae.

The Bray-Curtis Similarity Index and MDS of the current result revealed that, the highest similarity in summer (59.5%) in the third group at sites 2 and 3. Furthermore, the highest similarity in autumn (42.1%) inside the first group was noted at sites 7 and 8. In other words, the highest similarity in winter (40.3%) was determined in the second group at stations 1 and 3. As well, the highest similarity in spring (44%) in the first group was recorded at sites 7 and 8. However, Bray-Curtis similarity index of some ostracod spcies from the Sea of Marmara showed five clustering groups and the level of similarity is very associated with habitat type and depth (Paçal *et al.*, [38]).

The present collected ostracods categorized as follows: *Cytherelloidea* sp. was rare, sixteen species were common and the remaining species (26) were dominant. In the Adriatic Sea, *Loxoconcha agilis* was found to be the dominant species between 20 and 60 metres deep [28]. [21] recorded four rare species (*Leptocythere arenicola*, *Cytherelloidea* sp., *Paranesidea* n. sp., and *Cytherois gracilis*) in the intertidal zone of the mangrove ecosystem of the Red Sea Coast.

During four seasons, 32 samples were collected from 8 sites, where the individual numbers of ostracod species were biggest in summer and the lowest number were recorded in winter. Moreover, the richness of ostracods was close to each other in all seasons and all sites, except in the eighth site (30 m) where the richness was very low. The current study showed that the number of podocopid ostracods increase in low depths and decrease in high depths so, they favored the warm water. [39] discovered that the ostracods they collected were rare and only found in the warm waters of the E and NE shelves. Further, the individual number of *Cylindroleberis* vix and *Prionotoleberis* lux increases in deep water and decreases in shallow water, indicating that they prefer cold water. [19] discovered that *Cylindroleberis* vix at 15 to 20 m depth in the Mozambique Channel, Mayotte, and *Prionotoleberis* lux at 300 to 350 m depth near Mayotte, Indian Ocean.

The temperature is well known as the most important factor in increasing reproduction, and breeding periods influence the seasonal dominance of species. Orth *et al.* [40] noted that the low water temperatures from 15˚C to 20˚C resulted in the longest survival times, but high water temperatures between 20˚C to 24˚C provided the highest rates of moulting and shortest intermoult times. Also, in several crustacean species, higher temperatures determine an increase in the molt increment during the juvenile phase, while during the mature growth phase the reverse is true [40] [41]. [42] found that in small animals, the link between temperature and intermolt shortening is strong, but bigger animals are less responsive to temperature changes.

The data gained from the current study recommend that ostracod species have different tolerance values to many factors in variety of depths except *Cytherelloidea* sp. (Külköylüoglu *et al.*, [33]; Külköylüoglu *et al.*, [44]; Yavuzatmaca *et al.*, [45]) support this datum.

5. Conclusions

In this study, 6733 ostracod individuals belonging to 43 species were collected seasonally from the east side of Safaga Island. The effects of some environmental factors on the collected ostracod species were determined in the eight collecting sites (see **Table 2**). The current results show that ostracod species have been affected by temperature, salinity, conductivity, pH, dissolved oxygen, TDS, and organic matter and $CaCO_3$ at eight sampling stations. The highest number of ostracod individuals and richnesss were observed in summer, while the lower ones were recorded in winter. Furthermore, the statistical analyses were used to assess the influence of ecological factors on the present ostracod species at the various collecting sites.

The study of benthic ostracod environment relationships allows us to better understand the environmental characteristics, distribution and identification of the ostracod species found on the east side of Safaga Island at depths fluctuating from 0.5 to 30 m, providing variable information about biotic and abiotic ostracods patterns.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix

List of number of ostracod species collected during four seasons and corresponding abundances in the eight samples.

Species	Season	0.5 m	1 m	5 m	10 m	15 m	20m	25 m	30 m	Individual No.
Aglaiocypris triebeli (Hartmann, 1964)	summer	0	9	11	0	0	0	4	0	**24**
	autumn	0	3	14	0	0	0	3	0	**20**
	winter	0	11	2	0	0	0	4	0	**17**
	spring	0	7	7	0	0	0	5	0	**19**
Callistocythere arcana Bonaduce *et al.*, 1976	summer	17	9	7	0	6	17	0	0	**56**
	autumn	10	8	14	0	1	12	0	0	**45**
	winter	6	12	5	0	3	2	0	0	**28**
	spring	10	5	12	0	3	8	0	0	**38**
Callistocythere fluctuans Pugliese *et al.*, 1984	summer	10	9	10	7	0	2	0	0	**38**
	autumn	4	9	13	4	0	8	0	0	**38**
	winter	6	8	4	3	0	3	0	0	**24**
	spring	14	2	6	7	0	4	0	0	**33**
Carinocythereis sp. 1	summer	0	0	6	9	3	19	0	0	**37**
	autumn	0	0	2	5	6	9	0	0	**22**
	winter	0	0	3	3	1	1	0	0	**8**
	spring	0	0	3	0	2	5	0	0	**10**
Carinocythereis sp. 2	summer	14	5	13	4	6	7	0	0	**49**
	autumn	7	11	8	2	3	8	0	0	**39**
	winter	6	4	2	0	2	0	0	0	**14**
	spring	16	7	6	4	3	5	0	0	**41**
Caudites levis Hartmann, 1964	summer	21	10	11	7	6	4	4	0	**63**
	autumn	6	5	9	6	8	4	5	1	**44**
	winter	11	13	9	3	4	2	9	3	**54**
	spring	9	8	21	3	6	11	2	1	**61**
Cylindroleberis vix Korniker, 1992	summer	7	0	14	23	19	43	33	26	**165**
	autumn	5	0	9	2	9	15	33	40	**113**
	winter	4	0	6	7	4	4	7	13	**45**
	spring	6	0	13	7	2	31	20	28	**107**
Cyprideis littoralis Brady, 1868	summer	7	16	0	2	0	4	0	0	**29**
	autumn	7	8	0	6	0	6	0	0	**27**
	winter	3	5	0	3	0	3	0	0	**14**
	spring	0	12	0	5	0	2	0	0	**19**

Continued

Cyprideis torosa (Jones, 1850)	summer	9	10	15	0	7	0	0	0	**41**
	autumn	11	4	5	0	2	0	0	0	**22**
	winter	2	7	4	0	3	0	0	0	**16**
	spring	7	5	12	0	3	0	0	0	**27**
Cytherella cf. *punctata* Brady, 1868	summer	5	0	6	9	0	0	0	0	**20**
	autumn	7	12	5	6	0	0	0	0	**30**
	winter	0	3	2	2	0	0	0	0	**7**
	spring	2	4	9	8	0	0	0	0	**23**
Cytherelloidea sp.	summer	19	0	0	0	4	0	0	0	**23**
	autumn	14	0	0	0	8	0	0	0	**22**
	winter	2	0	0	0	2	0	0	0	**4**
	spring	11	0	0	0	0	0	0	0	**11**
Ghardaglaia triebeli Hartmann, 1964	summer	16	8	10	6	7	7	3	2	**59**
	autumn	13	7	12	1	4	7	2	0	**46**
	winter	3	10	3	8	4	3	0	1	**32**
	spring	17	7	11	6	6	5	2	0	**54**
Hemicytherura videns aegyptica Hartmann, 1964	summer	3	0	0	0	6	3	0	0	**12**
	autumn	0	0	0	0	5	7	0	0	**12**
	winter	5	0	0	0	4	2	0	0	**11**
	spring	5	0	0	0	3	6	0	0	**14**
Hiltermannicythere sp.	summer	23	0	6	0	6	4	0	0	**39**
	autumn	3	0	12	0	5	9	0	0	**29**
	winter	7	0	5	0	5	4	0	0	**21**
	spring	18	0	10	0	9	6	0	0	**43**
Hiltermannicythere rubrimaris (Hartmann, 1964)	summer	6	0	11	0	6	0	0	0	**23**
	autumn	10	0	0	0	9	0	0	0	**19**
	winter	7	0	4	0	2	0	0	0	**13**
	spring	12	0	7	0	2	0	0	0	**21**
Jonicythere sp.	summer	2	3	0	7	3	26	0	0	**41**
	autumn	0	7	0	5	5	0	0	0	**17**
	winter	5	11	0	4	2	3	0	0	**25**
	spring	13	13	0	4	8	3	0	0	**41**
Leptocythere arenicola Hartmann, 1964	summer	7	17	13	7	0	0	3	0	**47**
	autumn	8	4	16	3	0	0	2	0	**33**
	winter	4	6	3	4	0	0	6	0	**23**
	spring	5	11	4	7	0	0	4	0	**31**

Continued

Leptocythere rara (Mueller, 1894)	summer	0	16	15	0	2	27	0	0	**60**
	autumn	0	7	15	0	3	12	0	0	**37**
	winter	0	3	6	0	2	3	0	0	**14**
	spring	0	5	5	0	7	15	0	0	**32**
Loxoconcha sp.	summer	23	15	0	8	0	12	0	0	**58**
	autumn	12	0	0	2	0	11	0	0	**25**
	winter	3	3	0	4	0	1	0	0	**11**
	spring	4	7	0	6	0	0	0	0	**17**
Loxoconcha ghardaqensis Hartmann, 1964	summer	20	9	8	10	7	17	10	5	**86**
	autumn	10	8	19	4	6	19	4	3	**73**
	winter	2	6	5	10	5	4	9	3	**44**
	spring	21	8	18	18	4	18	5	8	**100**
Loxoconcha gisellae Bonaduce *et al.*, 1980	summer	10	0	8	9	2	0	0	0	**29**
	autumn	9	0	8	4	11	0	0	0	**32**
	winter	4	0	4	3	3	0	0	0	**14**
	spring	6	0	2	7	2	0	0	0	**17**
Loxoconcha ornatovalvae Hartmann, 1964	summer	7	20	0	8	5	11	4	0	**55**
	autumn	9	4	0	2	5	0	2	0	**22**
	winter	5	11	0	13	2	3	7	0	**41**
	spring	19	4	0	9	0	17	2	0	**51**
Loxoconchella dorsobullata Hartmann, 1964	summer	22	8	0	0	0	8	0	0	**38**
	autumn	8	5	0	0	0	6	0	0	**19**
	winter	3	5	0	0	0	2	0	0	**10**
	spring	12	11	0	0	0	10	0	0	**33**
Loxocorniculum ghardaquensis (Hartmann, 1964)	summer	0	12	14	0	4	0	0	0	**30**
	autumn	0	6	6	0	6	0	0	0	**18**
	winter	0	6	5	0	3	0	0	0	**14**
	spring	0	12	17	0	9	0	0	0	**38**
Macrocypris minna (Baird, 1850)	summer	20	17	8	9	4	0	0	0	**58**
	autumn	8	6	16	3	2	0	0	0	**35**
	winter	5	16	8	8	1	0	0	0	**38**
	spring	3	11	5	5	7	0	0	0	**31**
Miocyprideis cf. *spinolusa* (Brady, 1868)	summer	0	7	4	3	6	5	1	0	**26**
	autumn	0	3	4	2	3	9	3	0	**24**
	winter	0	2	5	3	4	1	0	0	**15**
	spring	0	0	6	0	0	6	9	0	**21**

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Moosella striata Hartmann, 1964	summer	19	18	8	8	8	13	4	0	**78**
	autumn	8	10	14	6	5	11	1	0	**55**
	winter	4	14	3	5	2	3	0	0	**31**
	spring	11	8	18	8	1	10	3	0	**59**
Neonesidea schulzi (Hartmann, 1964)	summer	24	14	6	6	6	18	7	2	**83**
	autumn	7	6	20	7	4	9	6	1	**60**
	winter	10	7	5	9	4	2	7	0	**44**
	spring	15	9	18	7	7	16	4	2	**78**
Neonesidea aff. *michaelseni* Hartmann, 1982	summer	0	16	0	11	4	0	9	0	**40**
	autumn	0	12	0	3	4	0	4	0	**23**
	winter	0	10	0	7	2	0	9	0	**28**
	spring	0	4	0	4	7	0	6	0	**21**
Paradoxostoma altecaudatum Hartmann, 1964	summer	22	10	10	8	5	0	0	0	**55**
	autumn	9	5	17	6	4	0	0	0	**41**
	winter	7	7	4	9	2	0	0	0	**29**
	spring	16	11	11	11	3	0	0	0	**52**
Paradoxostoma arcuatum Hartmann, 1964	summer	18	12	14	0	3	7	0	0	**54**
	autumn	7	4	8	0	5	12	0	0	**36**
	winter	2	12	6	0	3	1	0	0	**24**
	spring	14	10	14	0	2	4	0	0	**44**
Paranesidea sp.	summer	25	13	0	10	0	0	0	0	**48**
	autumn	5	5	0	10	0	0	0	0	**20**
	winter	5	10	0	6	0	0	0	0	**21**
	spring	16	2	0	8	0	0	0	0	**26**
Paranesidea fracticorallicola Maddocks, 1969	summer	9	10	10	9	2	19	3	2	**64**
	autumn	4	5	17	8	5	10	2	3	**54**
	winter	6	7	5	9	1	3	3	1	**35**
	spring	20	5	4	10	9	7	6	4	**65**
Prionotoleberis lux Korniker, 1992	summer	2	9	15	22	34	43	31	21	**177**
	autumn	6	7	10	3	3	9	4	2	**44**
	winter	3	4	1	9	2	2	9	3	**33**
	spring	3	9	5	6	3	21	17	16	**80**
Propontocypris sp.	summer	3	7	15	3	8	0	0	0	**36**
	autumn	6	5	8	6	3	0	0	0	**28**
	winter	2	6	4	3	1	0	0	0	**16**
	spring	9	11	10	9	5	0	0	0	**44**

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Quadracythere borchersi (Hartmann, 1964)	summer	15	12	6	9	3	2	0	0	**47**
	autumn	16	7	21	4	2	7	0	0	**57**
	winter	3	5	2	11	4	2	0	0	**27**
	spring	17	7	8	3	2	6	0	0	**43**
Rutiderma sp.	summer	0	0	9	0	0	25	6	19	**59**
	autumn	0	0	6	0	0	15	1	2	**24**
	winter	0	0	3	0	0	4	6	4	**17**
	spring	0	0	8	0	0	23	4	6	**41**
Tanella gracilis Kingma, 1948	summer	19	13	8	9	4	12	7	4	**76**
	autumn	8	6	17	2	3	10	6	3	**55**
	winter	7	2	8	8	3	2	9	0	**39**
	spring	12	4	9	6	5	16	9	2	**63**
Triebelina sp.	summer	4	11	7	7	8	3	0	0	**40**
	autumn	6	9	18	2	6	9	0	0	**50**
	winter	6	13	5	10	3	2	0	0	**39**
	spring	10	7	9	2	5	6	0	0	**39**
Xestoleberis ghardaqe Hartmann, 1964	summer	8	0	11	6	3	0	5	0	**33**
	autumn	11	0	8	4	6	0	3	0	**32**
	winter	4	0	3	3	2	0	0	0	**12**
	spring	16	0	14	5	6	0	2	0	**43**
Xestoleberis rhomboidea (Hartmann, 1964)	summer	29	12	9	10	9	7	8	0	**84**
	autumn	4	4	6	9	4	7	4	0	**38**
	winter	11	7	0	5	1	2	8	0	**34**
	spring	19	2	9	8	4	4	4	0	**50**
Xestoleberis rotunda Hartmann, 1964	summer	31	11	9	7	6	9	4	0	**77**
	autumn	13	16	21	9	4	7	1	0	**71**
	winter	6	10	4	5	3	3	0	0	**31**
	spring	17	`0	6	11	3	7	1	0	**45**
Zeugophilomedes grafi Hartmann, 1964	summer	8	8	0	11	5	18	9	16	**75**
	autumn	1	4	0	11	5	13	5	3	**42**
	winter	2	0	0	8	1	4	8	3	**26**
	spring	3	7	0	7	7	5	2	3	**34**
Individual number		**1355**	**1089**	**1160**	**797**	**616**	**1001**	**454**	**256**	**6728**

Abbreviations

Do: Dissolved oxygen; CO: Conductivity; T: Temperature; Ind. No: Individual numbers.