Egyptian Journal of Geology, v. 64, 2020, p. 433-454

TAXONOMY, DISTRIBUTION, AND ENVIRONMENTAL IMPLICATIONS OF BENTHIC MARINE OSTRACODS, ALONG THE RED SEA COAST OF EGYPT

El-Kahawy, R.[1], El-Shafeiy, M.[1], Helal, S. A.[2], Aboul-Ela, N.[1]

1- Geology department, Faculty of Science, Cairo University, Egypt

2- Geology department, Faculty of Science, Fayoum University, Egypt

ABSTRACT

Bottom sediment samples were collected from two sites located at the Red Sea coast of Egypt namely, Ras Gharib and Quseir. The samples were treated for their ostracods content. Identification, taxonomy, distribution, ecology, zoogeographical, and environmental aspects were carried out on the assemblage of the Ostracoda. Twenty-three ostracod species belonging to 20 genera, and 12 families were identified. The percentages of the most common ostracods are *Quadracythere* (19.35% and 17.83%), *Xestolebris* (10.42% and 7.4%), *Loxocorniculum* (17.37% and 14.42%), *Ghardaglaia* (4.22% and 17.91%), and *Moosella* (10.17% and 9.45%) for Ras Gharib and Quseir sites, respectively. Most of the observed fauna are Indo-Pacific.

From the environmental geochemical point of view, the Quseir area is characterized by sediments that are more enriched in some heavy metals, compared to the average shallow marine sediment contents. Ras Gharib site has, relatively, less heavy metal contents with coarser-grained sediments. Based on the Canonical Correspondences Analysis (CCA), pollution-tolerant species were observed in the contaminated stations such as *Ghardaglaia triebeli*, *Alocopocythere reticulata*, *Moosella striata*, and *Hiltermannicythere rubrimaris*, which can act as survivors. On the other hand, pollution-sensitive taxa such as *Jugosocythereis borchersi*, *Loxocorniculum ghardaqensis*, and *Xestolebris ghardaqae*, are characterizing the Ras Gharib area. Careful consideration should be maintained before long to conserve the Red Sea eco- and geo-systems.

Keywords: Ostracoda; Taxonomy; Nearshore Metal Contamination; Red Sea; Egypt

INTRODUCTION

Ostracods are a well-documented group within the crustaceans, due to its wealth of characteristic features, strong calcification, and tiny a carapace that fossilizes easily. The latter is characterized by the presence of a bivalve shell, hinged along the dorsal margin. Ostracods are known to inhabit a wide variety of aquatic environments (marine, brackish, and freshwaters). Their ecological attributes are very useful for recent and past environmental reconstructions (e.g., El Hmaidi et al., 2010; Nachite et al., 2010).

Along the Red Sea coast of Egypt, the marine eco- and geo- systems are dynamic, which have variable bottom sediment types, different habitats, and localized deposition and transportation processes (e.g., Mansour et al., 2000). These systems are affected by several anthropogenic activities such as phosphorite mining, oil exploration, fishing, urbanization, tourism, sewage, waste disposal, and shipping. Despite this, the study of modern ostracods has been relatively neglected along the Egyptian Red Sea coast (Helal and Abd El-Wahab, 2012). Instead, some taxonomic studies on recent ostracods (e.g. Hartmann, 1964; Helal and Abd El-Wahab, 2012; Mohammed et al., 2012) were conducted on the Red Sea area, relating species to their environment. According to Yasuhara et al. (2003), ostracods are a sensitive group to anthropogenic influences. As the bottom sediments can reflect the past and present environmental conditions of a water body, the objectives of the present work are the detailed investigations of the taxonomy, ecology, zoogeography, and heavy metal bio-monitoring of the Ostracoda assemblages collected from Ras Gharib and Quseir sites along the Red Sea Coast of Egypt. The present study seeks to improve the conservation and management of the Red Sea eco- and geo- systems in the future.

STUDY AREA

The study area encompasses two main sites along the Red Sea coast (Fig. 1). The Ras Gharib harbor (Lat. 28° 21' 27.79"–28° 20' 36.32"N and Long. 33° 7' 4.65"-33° 6' 37.80E), which suffers from hydrocarbon exploration activities in addition to clastic terrigenous influx from the surrounding volcanics and granitoids that resulted usually due to the flash flooding. Its bottom sediment facies are mainly sandy with a high percentage of $CaCO_3$ content. The Quseir harbor (Lat. 26° 6' 19.07"-26° 6' 7.47"N and Long. 34° 17' 25.05"-34° 16' 59.76" E) is suffering from several phosphorite mining activities, also alluvial fan deposits transporting sediments from the surrounding Precambrian complexes seaward, and enormous fuel wastes due to shipping activities. The Quseir site includes two Jetties: one is for tourist boats and another is for fishing boats. The bottom sediment facies are mainly muddy sand. In general, the biogenic constituents of the sediments are produced mainly in reefs, carried along the shore and deposited in the shelter of a large reef-spur (e.g., Reiss and Hottinger, 1984).

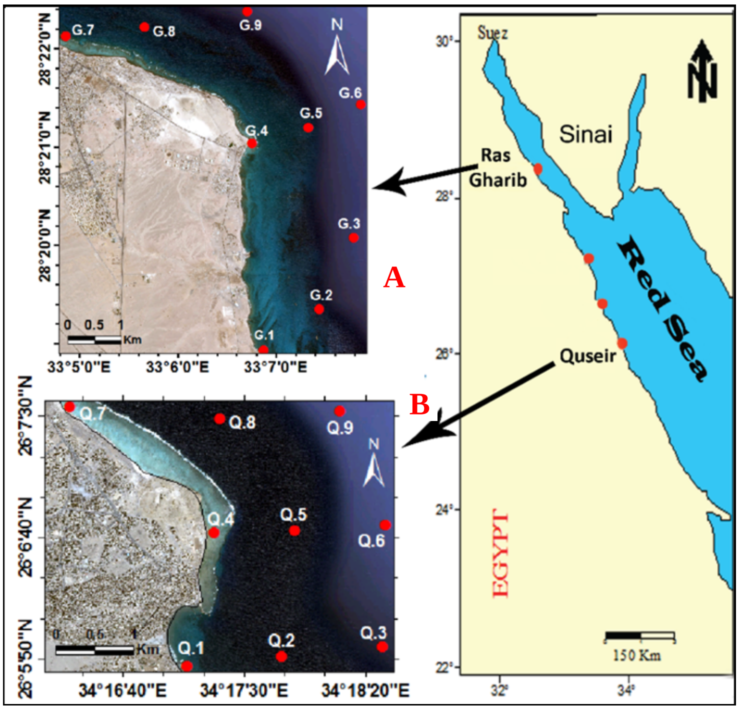

Fig. 1: A Regional map for the Red Sea coast of Egypt, and Satellite images from the Google Earth show samples location at the study areas, A- Ras Gharib site, B- Quseir site

MATERIAL AND METHODS

Sampling and Ostracods analysis

Surface marine sediment samples were collected in summer 2014 from Ras Gharib and Quseir sites. The water depth of the sampled sites ranges from a few centimeters to 7 m (Table 1 and Fig. 1). Samples were collected either by grab sampler (in deep water) or using hand sampling (around the beach), with different distances from and along the shoreline. The obtained samples are investigated for their ostracods content. The sediments were treated using normal washing techniques for the extraction of ostracods. 100 grams of the washed residue are inspected, and the obtained taxa were investigated and scanned using the Electron Microscope in the central laboratories of the Egyptian Mineral Resources Authority using the machine JSM 6063LA. The picking of ostracods was done on >125 µm fractions. Most of the picked specimens were disconnected valves and the carapaces were few. The ostracod assemblages were identified according to Moore (1961) and Hartmann (1964). The investigated species were counted, and the results are shown in Tables 2 and 3.

Salinity and pH of the seawater were measured for each sampling station using a Hydrolab Surveyor-4. Water depth was measured either by an echo-sounder instrument in deep stations, or by a water depth meter in shallow stations (<1 m). The water depth in the two sites ranged from 0.1 to 7 m.

Table 1: The measured ecological parameters in the two sites.

Station	Latitude (N)	Longitude (E)	Depth (m)	Salinity ‰	pH	Samples description
G1	28°20'36.32"	33° 6'37.80"	0.4	41.31	7.7	Coarse sand
G2	28°20'37.50"	33° 6'56.82	3	41.54	8.19	Silty sand
G3	28°20'38.09"	33° 7'9.71"	6	41.45	8.21	Silty sand
G4	28°20'54.28"	33° 6'39.41"	0.6	40.91	7.71	Biogenic sand
GS	28°20'56.16"	33° 6'54.23"	4	41.42	8.12	Silty sand
G6	28°20'57.11"	33° 7'7.57"	7	41.53	8.08	Silty sand
G7	28°21'21.44"	33° 6'33.79"	0.3	41.12	7.4	Gravely sand
G8	28°21'24.56"	33° 6'47.64"	3	41.61	8.33	Silty and
G9	28°21'27.79"	33° 7'4.65"	7	41.34	8.21	Silty sand
Q1	26° 6'7.47"	34°16'59.76"	0.1	40.39	7.41	Biogenic silty sand
Q2	26° 6'5.41"	34°17'4.17"		40.93	8.21	Muddy sand
Q3	26° 6'2.41"	34°17'11.37"	3	40.89	8.24	Muddy sand
Q4	26° 6'14.69"	34°17'11.94"	0.2	40.52	7.45	Biogenic muddy sand
QS	26° 6'10.74"	34°17'15.72"	1.5	40.96	8.13	Muddy sand
Q6	26° 6'8.11"	34°17'18.49"	4	40.93	7.86	Muddy sand
Q7	26° 6'22.30"	34°17'11.08"	0.2	40.62	7.62	Biogenic silty sand
Q8	26° 6'20.87"	34°17'18.58"	1.78	40.99	7.97	Muddy sand
Q9	26° 6'19.07"	34°17'25.05"	3	40.88	7.84	Muddy sand

Table 2: List of the identified Ostracoda species in the Ras Gharib site.

Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	Total	Species%
Hiltermaooicytbere rubrimaris	0		0	0	0	0	0	5	5	11	2.73
Caudites Iaevis	0	3	0		0	0	0	15	4	23	5.71
Ghardaglaia triebeli	0			0	0	0	0	6	9	17	4.22
Quadracythere borcbersi		5	6	0		5	6	32	22	78	19.35
Neonesidea scbulzi	0	2	0	0	2	3	0	4	2	13	3.23
Triebelina sertata	0		3	0	0	0	0	20	4	28	6.95
Paranesidean.sp	0	0		0	0	0	0	2		4	0.99
Mossella striata	0	0	0	0	0	0	0	27	14	41	10.17
Loxocuroiculum gbardaqeosis	0	13	6		4	0	0	29	17	70	17.37
Paraoesidea fracticorallicola	0		0	0	0	0	0	2		4	0.99
Cypridies torosa	0	0	0	0	0	0	0	7	0	7	1.74
Loxocoocba sp	0	0	0	0	0	0	0	2	2	4	0.99
Paradoxostomabreve	0	0	0	0	0	0	0	6	3	9	2.23
Xestolebris rbomboidea	0	4			2	0	0	11	4	23	5.71
Cytheroma dimorpba	0	0	0	0	0	0	3	5	2	10	2.48
Sclerochilus rectomarginatus	0	2	0	0	0	0	0	0	0	2	0.50
Xestolebris ghardaqae	0	4	2	0	0	3	0	7	3	19	4.71
Cytherelloidea sp	0	0	3	0	0	0	0	8	7	18	4.47
Paradoxostoma parabreve	0	0	0	0		2	0	0	0	3	0.74
Miocyprideis cf.spinolusa	0		0	0	0	0	0	0	0		0.25
Leptocytbere arenicola	0	0	3	0	0	0	0	12	3	18	4.47

Geochemical analysis of sediments

Chemical analysis was carried out on the sediment samples in Acme Labs, Bureau, Canada. Aliquots of 0.5 g of fine sediments (63 μm) were analyzed using Inductively Coupled Plasma-Emission Spectrometry

(ICP-ES). The samples were digested with a modified aqua regia solution (0.5 ml H_2O, 0.6 ml concentrated HNO_3, and 1.8 ml concentrated HCl) for 2 hours at 95ºC. Samples were cooled down, diluted to 10 ml with de-ionized water. The samples were then analyzed using a Perkin-Elmer OPTIMA 3000 Radial ICP for the element suite. For quality control (QC), replicates (~ 25% of the total number of samples) were analyzed under the same procedures. A series of geochemical reference standards (USGS, 1995) were used as controls to ensure the quality control and accuracy of the analysis. A standard matrix and a blank were running every 13 samples. The detection limits of the measured metals are; Cu (1 ppm), Zn (1 ppm), Mn (2 ppm), Cd (0.5 ppm), As (2 ppm), Pb (3 ppm), Cr (1 ppm), Ni (1 ppm). Mo (1 ppm), P (0.001 ppm), Fe (0.01 ppm), and Co (1 ppm).

Table 3: List of the identified Ostracoda species in the Quseir site.

Species	Q1	Q2	Q3	Q4	Q5	Q6	Q7	QS	Q9	Total	Species%
Hiltermannicytbere rubrimaris	33	53	31	16	18	27	34	27	19	258	2.39
Caudites Jaevis	14	18	14	11	21	18	9	15	21	141	1.31
Ghardaglaia triebeli	220	345	267	116	192	234	214	166	178	1932	17.91
Quadracythere borcbersi	256	286	203	177	189	201	271	187	154	1924	17.83
Neonesidea scbulzi	0	59	17	11	31	33	11	18	16	196	1.82
Triebelina sertata	0	0	0	3	9	9	7	6	9	43	0.40
Paranesidea n.sp	0	0	0	6	24	15	8	12	9	74	0.69
Mossella striata	134	179	129	31	45	123	157	121	101	1020	9.45
Loxocurniculum gbardaqensis	198	295	204	105	80	233	207	111	166	1599	14.82
Paranesidea fracticorallicola	21	44	11	7	12	27	21	23	17	183	1.70
Cypridies torosa	15	42	33	2	12	27	31	41	37	240	2.22
Loxoconcba sp	3	4	4	0		0	0	0	0	12	0.11
Paradoxostoma breve	0	9	6	0	9	14	0	8	6	52	0.48
Xestolebris rbomboidea	21	53	47	17	31	46	36	42	31	324	3.00
Cytheroma dimorpha	21	41	46	11	17	36	57	27	33	289	2.68
Sclerochilus rectomarginatus	45	76	54	7	16	74	61	53	49	435	4.03
Xestolebris gbardaqae	23	93	86	14	28	65	54	51	61	475	4.40
Cytherelloidea sp	21	41	34	4	8	31	21	21	19	200	1.85
Paradoxostoma parabreve	0	9	12	0	9	8	5	9	12	64	0.59
Miocyprideis cf.spinolusa	9	31	34	0	9	12	0	21	27	143	1.33
Leptocythere arenicola	7	11	9	3	7	9	13	9	6	74	0.69
Hemicytherura videns	0	2	0	0	5	0	0	0	4	11	0.10
Alocopocythere reticulata	144	193	136	46	73	143	151	112	102	1100	10.20

Statistical analysis

Canonical Correspondences Analysis (CCA) was conducted using PAST (Paleontological Statistical) software (version 3.20) to investigate the community's relation to abiotic parameters at the studied stations (e.g., Elshanawany, 2010). The arrows radiating from the center of the CCA chart indicate the direction of maximum variation. The arrows' length reveals the relative significance of each environmental variable. The angle between the environmental arrows is inversely proportional to the strength of their relationship. The environmental variables chosen are for the highest significant variations, whereas the neglected variables such as sand, pH, and temperature show less significant variations.

RESULTS AND DISCUSSION

Zoogeography

As the Red Sea is the northerly directed arm of the Indian Ocean, the ostracods show a clear Indo-Pacific affinity (e.g., Bonaduce et al., 1983) and many genera are in common such as *Alocopocythere*, *Bishopina*, and *Moosella*. Bate (1971) collected common species from the Red Sea and the Persian

Gulf from shallow marine sediments off Bagamoyo, Tanzania (East Africa). He noted ten species that are in common with the Red Sea as well as the Persian Gulf (Abu Dhabi lagoon). These species are *Xestoleberis rhomboidea* Hartmann, *X. rotunda* Hartmann, *X. multiporosa* Hartmann, *Neonesidea schulzi* (Hartmann), *Loxoconcha ornatovalvae* Hartmann, *Ghardaglaia triebeli* (Hartmann), *Hemicytherura videns aegyptiaca* Hartmann, *Paradoxostoma longum* Hartmann, *Cytheroma dimorpha* Hartmann and *Alocopocythere reticulate* (Hartmann). Most of these species were recorded in the present study samples, except *Loxoconcha ornatovalvae* Hartmann, *Paradoxostoma longum* Hartmann, *X. multiporosa* Hartmann, and *X. rotunda* Hartmann that were not observed.

Helal and Abd El-Wahab (2004) recoded 14 species out of 23 species present in both the Red Sea (Safaga Bay) and the Persian Gulf (Abu Dhabi lagoon), which are belonging to the Indo-Pacific realm affinity. They recorded also 3 species that are belonging to cosmopolitan, and 1 species, which is Mediterranean.

Distribution of Ostracods

The two sites (Ras Gharib and Quseir) are shallow sheltered environments that are dominated by phytal elements. The recorded ostracods are in the benthic, phytal, and shallow-water forms. The percentages of the most common ostracods are *Quadracythere* (19.35% and 17.83%), *Xestolebris* (10.42% and 7.4%), *Loxocorniculum* (17.37% and 14.42%), *Ghardaglaia* (4.22% and 17.91%), and *Moosella* (10.17% and 9.45%) for Ras Gharib and Quseir sites, respectively.

The present association is mainly of Indo-Pacific faunal elements with some endemic species. Very rare Mediterranean and cosmopolitan species were recorded. These taxa, mostly, were transported to the study area by birds. Ships, floating woods, derived algae, and other plants are other possible sources. The migration from the Red Sea to the Mediterranean is a common unidirectional migration via the Suez Canal (Lessepsian migration; Por, 2012). Anti-Lessepsian migration is rarely cited (Fouda and Abou-Zeid, 1990; Kandeel, 2002). More investigations are needed along the migration route (i.e. along with the northern parts of the Red Sea, the Gulf of Suez, and the Suez Canal) to decide whether the Mediterranean species were introduced to the study area via anti-Lessepsian migration or passive migration.

Systematic classification

The present study followed the classification given in the "Treatise on Invertebrate Paleontology, Part Q, Ostracoda" (Benson, 1961; Moore, 1961; Morkhoven, 1962; Hartmann and Puri, 1974) (Tables 2 & 3). The present taxonomic work leads to the identification of twenty-three species belonging to twenty-one genera and fourteen families. Occurrence, ecology, and Zoogeography are given for each individual species. Tables 2 and 3 show the taxonomic list, the total numbers of the studied species, percentage, and their occurrence.

Order: Podocopida Müller, 1894

Family: Bairdiidae Sars, 1888

Genus: *Paranesidea* Maddocks, 1969

***Paranesidea* n. sp. BCMMP, 1983**

(Pl. 1, Fig. 1)

1983 *Paranesidea* n. sp. **B**onaduce, **C**iliberto**, M**inichelli, **M**asoli& **P**ugliese, p.477, fig. 3: 10-13.

2012 Paranesidea sp **B**onaduce, **C**iliberto**, M**inichelli, **M**asoli& **P**ugliese; Helal & Abd El-Wahab, p. 66, pl.1, fig. 1.

Occurrence: The largest population of this species was observed in samples no. Q5, Q6, and Q8. It constitutes 0.7% of the total studied ostracods taxa.

Ecology: It is distributed in bottom sediments from sand to sandy silt at depths (0.2-6 m). The oceanographic parameters are as follows: salinity ranges from 40.52 to 41.61‰, and pH ranges from 7.4-8.33.

Zoogeography: Indian Ocean and Persian Gulf (Bonaduce et al., 1983).

***Paranesidea fracticorallicola* Maddocks, 1969 (Pl. 1, Figs. 2-4)**

1983 *Paranesidea fracticorallicola* Maddocks; Bonaduce et al, p.477, fig. 3, 7-9.

2010. *Paranesidea* cf. *P. fracticorallicola* Maddocks; Mostafawi et al, p. 248, pl. 1, fig. 7.

Occurrence: This species attains its highest occurrence in samples no. Q2 and Q6. It represents 1.67% of the total Ostracoda taxa.

Ecology: It is distributed in bottom sediments from sand to muddy sand at depths between the beach and 7 m. The oceanographic parameters are as follows: salinity ranges from 40.52 to 41.61‰, and pH range 7.4-8.33.

Zoogeography: Indo-Pacific, Persian Gulf, Red Sea (Maddocks, 1969, Bonaduce et al., 1983).

Genus: *Neonesidea* Maddocks, 1969

***Neonesidea schulzi* (Hartmann), 1964 (Pl. 1, Fig. 5)**

1964 *Triebelina schulzi* n.sp. Hartmann, p.44, pl.4, 5, figs.14-22.

1970 *Neonesidea schulzi* (Hartmann); Bate, P. 246, Pl. 1, Fig. 1i.

2004 *Neonesidea schulzi* (Hartmann); Helal & Abd El-Wahab, p.83, pl.1, fig. 2.

2012 *Neonesidea schulzi* (Hartmann); Mohammed and Keyser, p. 251, pl. 2, fig. 9.

Occurrence: This species attains its highest occurrence in samples no. Q2 and Q6. It represents 1.87% of the total Ostracoda taxa.

Ecology: This species occurs in the northern sandy silt sediments at depths (0.2-7 m). The average values of ecological conditions ranges are salinity (40.52-41.61‰), and pH (7.45-8.33). **Zoogeography**: Indian Ocean and Persian Gulf (Bate, 1970).

Genus: *Triebelina* Van den Bold, 1946

***Triebelina sertata* Triebel, 1975 (Pl.1, Fig. 6)**

1975 *Triebelina sertata* Triebel; Teeter, p. 422, Text-fig. 31.

2012 *Triebelina sertata* Triebel; Helal & Abd El-Wahab, p.64, pl.1, fig. g.

2012 *Triebelina sertata* Triebel;Mohammed et al. p. 151, pl. 1, fig. 17.

Occurrence: It gets its highest occurrence in samples no. G8, Q5, Q6, and Q9, respectively in ascending order. This species represents about 0.63% of the total Ostracoda taxa in the study area.

Ecology: This species distributed in silty sand bottom sediments and it is more dominated in the Ras Gharib than Quseir sites. The oceanographic parameters are as follows: salinity range 40.52- 41.61‰, and pH range 7.45-8.33.

Zoogeography: Cosmopolitan (Teeter, 1975; Malz and Lord, 1988).

Taxonomy, distribution, and environmental implications

Family: Trachyleberididae Sylvester-Bradley, 1948

Genus: *Quadracythere* Hornibrook, 1952

***Quadracythere borchersi* (Hartmann, 1964)**

(Pl. 1, Figs. 7-9)

1964 *Hemicythere borchersi* Hartmann; p. 119, pl. 56, figs. 318-221; pl.57, figs. 322- 323; pl.58, figs. 324-330.

1983 *Quadracythere borchersi* (Hartmann); Bonaduce et al, p. 478.

2012 *Quadracythere borchersi* (Hartmann); Helal & Abd El-Wahab, p. 63, pl. 1, fig. K.

Occurrence: This species exhibits a very wide distribution in the two sites. The samples that include high numbers of this species are Q1, Q2, and Q7. It constitutes 17.89% of the total Ostracoda in the studied area.

Ecology: It occurs in very shallow water at depth range (0.1-7 m) and dominant more in the muddy sand sediments. Ecological values: salinity ranges from 40.41 to 41.61‰, and pH varies between 7.45 and 8.33.

Zoogeography: Red Sea, Mozambique (Hartmann, 1964; Hartmann & Puri 1974; Bonaduce et al., 1983).

Genus: *Hiltermannicythere* Bassiouni, 1970

***Hiltermannicythere rubrimaris* (Hartmann, 1964). (Pl. 1, Fig. 10)**

1964 *Cythereis rubrimaris* Hartmann, p. 115, pl. 54, figs. 306-310; pl. 56, fig. 317.

1983 Hiltermannicythere rubrimaris (Hartmann); Bonaduce et al, p.481.

2011 *Hiltermannicythere rubrimaris* (Hartmann); Mohammed et al, pl. 11, fig. 172-173.

2012 *Hiltermannicythere rubrimaris* (Hartmann)*;* Helal & Abd El-Wahab p. 61, pl. 2, fig. m.

Occurrence: This species attains a very wide distribution in the Quseir site, whereas a limited distribution characterizing the Ras Gharib site. The samples that include high numbers of this species are Q2, Q7, and Q1. It constitutes 2.4% of the total Ostracoda in the studied area.

Ecology: It occurs in very shallow water depths and dominant more in the muddy sand. Ecological values: salinity ranges from 40.41 to 41.61‰, and pH varies between 7.45 and 8.33.

Zoogeography: Red Sea (Hartmann, 1964; Bonaduce et al., 1983; Helal and Abd El-Wahab, 2004)

Genus: *Moosella* Hartmann, 1964

***Moosella striata* Hartmann, 1964 (Pl. 1, Fig. 11)**

1964 *Moosella striata* Hartmann, pl. 46, figs. 270-273; pl. 50-51, figs. 289-297.

2010 *Moosella striata* Hartmann; Helal and Abd El-Wahab, P. 62, pl. 2, fig. N.

Occurrence: This species attains a very wide distribution in the Quseir site, while it was not observed in most of Ras Gharib samples (excluding G8 and G9). The samples that include high numbers of this species are Q2, Q7, and Q1. It constitutes 9.48% of the total Ostracoda in the studied area.

Ecology: It occurs in very shallow water depths and dominant more in the muddy sand. Ecological values: salinity ranges from 40.41 to 41.61 ‰, and pH varies between 7.45 and 8.33.

Zoogeography: Red Sea (Hartmann, 1964).

Family: Cytherellidae Sars, 1866

Genus: *Cytherelloidea* Alexander, 1929

***Cytherelloidea* sp. A Bate, 1971 (Pl. 1, Fig. 12)**

1971 C*ytherelloidea sp*. A Bate, P. 246, Pl. l, Fig. 1s.

Occurrence: This species was observed in both sites. It is found mostly in muddy sand facies at varied depth. It represents 1.88% of the total Ostracoda taxa.

Ecology: It is found in muddy sand facies. The ecological parameters are salinity (40.39– 41.61‰), and pH (7.45–8.33).

Zoogeography: The Red Sea and the Persian Gulf (Bate, 1971).

Family: Hemicytheridae Puri, 1953

Genus: *Caudites* Coryell & Fields, 1937

***Caudites levis* Hartmann, 1964 (Pl. 1, Fig. 13)**

1964 *Caudites levis* sp Hartmann, P. 117, Pl. 55, Fig. 311-316.

Occurrence: This species was recorded in all Quseir samples; however, it was observed in only four samples from Ras Gharib site. It represents 1.47% of the total ostracods' species.

Ecology: It is observed in the beach sediments and muddy silt bottom sediments. The highest population was recorded in samples no. Q2, Q5, Q6, Q9, and G8 in mostly muddy sand sediments. The ecological parameters are as follows: variable water depth, salinity 40.39-41.61 ‰, and pH 7.41-8.33.

Zoogeography: Red Sea (Hartmann, 1964).

Family: Campylocytheridae Puri, 1953

Genus: *Alocopocythere* Siddiqui, 1971

***Alocopocythere reticulata* (Hartmann), 1964 (Pl. 1, Fig. 14)**

1964 *Bradleya reticulata* sp Hartmann; p. 108, pl. 46, fig. 269; pl. 47-49, figs. 274-288.

1971 *Alocopocythere reticulata* (Hartmann); Bate, P. 246, Pl. 1, Fig. 2PP.

2012 *Alocopocythere reticulata* (Hartmann); Mohammed and Keyser, p. 274, pl. 12, fig. 194.

Occurrence: This species was not observed in the Ras Gharib site, but it is widely distributed in the Quseir site. Its dense population was recorded in samples no. Q2, Q1, Q6, Q7, and Q3. It constitutes 9.83% of the studied ostracods' species.

Ecology: The densest population of this species was recorded in sample no. Q2 in muddy sand sediment at water depths (0.1-4 m), with an average salinity of (40.79 ‰), and pH (~ 7.86).

Zoogeography: Red Sea, Indian Ocean, and Persian Gulf (Bate, 1971; Helal and Abd El-Wahab, 2012).

Family: Cytherideidae Sars, 1925

Genus: *Cyprideis* Jones, 1857

***Cyprideis torosa*, Jones, 1850 (Pl. 1, Fig. 15)**

2004 *Cyprideis torosa,* Jones; Helal & Abd El –Wahab, P. 60, pl. 2, fig. A-C.

2011 *Cyprideis torosa,* Jones; Mohammed & Keyser, pl. 3, figs. 33-36.

Occurrence: This cosmopolitan species was found in only one sample from the Ras Gharib site (G8), but it occurs in most of the Quseir samples. The samples no. Q2, Q8, and Q9 (42, 41, & 37 carapaces, respectively) show the highest ostracods content among all samples. It represents 2.21% of the total ostracods' species.

Ecology: This species was recorded in muddy sand facies at water depth ranges from 0.1 to 4 m. The oceanographic parameters are salinity with a range from 40.39 to 41.61‰, and pH that ranges from 7.84 to 8.33.

Zoogeography: Cosmopolitan (Guillaume et al., 1985).

Genus: *Miocyprideis* Kollmann, 1960

***Miocyprideis cf. spinulosa* (G. S. Brady), 1971 (Pl. 2, Fig. 1)**

1868 *Cytheridea spinulosa* n. sp. G. S. Brady, P. 182-183, Pl. 8, Fig. 1-6.

1880 *Cytheridea spinulosa* G. S. Brady, P. 112, Pl. 33, Fig. 6a-d.

1960 *Miocyprideis spinulosa* (Brady); Kollmann, P. 178, Pl. 18, Figs. 12-13, Pl. 19, Fig. 16.

1971 *Miocyprideis cf. spinulosa* (G. S. Brady); Gramann; P.124, Pl.15, Figs. 8-10.

Occurrence: This cosmopolitan species was found in only one sample from the Ras Gharib site (G2), but it was observed in most of the Quseir samples. The samples no. Q3, Q2, and Q9 (34, 31 & 27 carapaces, respectively) exhibit the highest ostracods content among all samples. It represents 1.29% of the total ostracod species.

Ecology: This species is recorded in muddy sand facies at depth ranges from 0.1 to 4 m. The oceanographic parameters: salinity ranges from 40.39 to 41.54‰, and pH ranges from 7.84 to 8.19.

Zoogeography: Cosmopolitan (Kollmann, 1960; Gramann, 1971).

Family: Cytheridea Baird, 1850

Genus: *Loxoconcha* Sars, 1866

***Loxoconcha sp*. Bate, 1970**

(Pl. 2, Fig. 2)

1970 *Loxoconcha* sp.A Bate; P. 246, Pl. 1, Fig. 1, l.

2004 *Loxoconcha* sp. A Bate; Helal & Abd El-Wahab, P. 12, pl. 1, fig. 11.

Occurrence: This species is of a rare distribution in the studied area. The highest population was recorded in samples no. Q1, Q3, and Q2 (4, 4, and 3 carapaces, respectively). It represents 0.14% of the total Ostracoda taxa.

Ecology: This species occurs commonly at depths ranges from 0.1 to 7 m in bottom facies varying from sandy silt to muddy sand. Oceanographic parameters: salinity between 40.39 and 41.61‰, and pH from 7.41 to 8.33.

Zoogeography: Indian Ocean and Persian Gulf (Bate, 1970).

Genus: *Loxocorniculum* Benson and Coleman, 1963

***Loxocorniculum ghardaquensis* (Hartmann), 1964 (Pl. 2, Fig. 3)**

1964 *Loxoconcha ghardaquensis* sp.Hartmann; p. 52, pl. 15, figs. 67-72; pl. 16, figs. 73-76; pl. 17, figs. 77-79; pl. 18, figs. 80-82.

1971 *Loxocorniculum ghardaquensis* (Hartmann); Bate, P. 254.

2012 *Loxocurniculum ghardaquensis*, **(**Hartmann); Helal & Abd El-Wahab. P.62, pl.2, fig. I.

Occurrence: High numbers of this widely distributed species were observed in the two sites. The highest population of this species was recorded in samples no. Q2, Q3, Q7, and Q6. It constitutes 14.91% of the studied ostracods' species.

Ecology: It occurs in very shallow water depths and increases in the very fine sand. Oceanographic parameters: salinity ranges from 40.41 to 41.61 ‰, and pH varies between 7.45 and 8.33.

Zoogeography: Red Sea (Hartmann, 1964).

Genus*: Sclerochilus*. Sars, 1866

***Sclerochilus rectomarginatus* Hartmann, 1964**

(Pl. 2, Fig. 4)

1964 *Sclerochilus rectomarginatus* n. sp. Hartmann, p. 93, pl. 41, figs. 242-243; pl. 42, figs. 224-250.

2012 *Sclerochilus rectomarginatus* Hartmann; Helal & Abd El-Wahab, p. 63, pl. 3, fig. I.

Occurrence: This species common in the Red Sea realm. Nonetheless, it was recorded in only one sample from the Ras Gharib site (G2) and the majority of Quseir samples. The highest populations were recorded in Q2, Q6, and Q7. It represents 3.9% of the total Ostracoda taxa

Ecology: It is found in muddy sand and silty sand facies. The ecological parameters are salinity (40.39-41.54‰), and pH (7.41-8.19).

Zoogeography: Red Sea (Hartmann, 1964).

Family: Cytheruridae G.W.Müller 1894. Genus: *Hemicytherura* Elofson, 1941.

***Hemicytherura videns* Hartmann 1964. (Pl. 3, Fig. 5)**

1964 *Hemicytherura videns aegyptica* Hartmann, p. 20, 50, pl. 13, figs. 61, 62

2012 *Hemicytherura aegyptica* Hartmann; Mohammed et al., pl. 4, fig. 44

Occurrence: This species exhibits a very rare distribution in the study area and is found only in Quseir samples. The highest contribution of this species was observed in samples no. Q5, Q9, and Q2, and its percentage is 0.1% out of the total ostracods in the study area.

Ecology: This species is recorded from muddy sand facies at depth range 0.1-3 m. The oceanographic parameters: salinity ranges from 40.88 to 40.96‰, and pH ranges from 7.84 to 8.21.

Zoogeography: Red Sea, Persian Gulf, and Indian Ocean (Hartmann, 1964; Bate, 1971).

Family: Leptocytheridae Hanai, 1957

Genus: *Leptocythere* Sars, 1925

***Leptocythere arenicola* (Hartmann, 1964)**

(Pl. 2, Fig. 6)

1964 *Leptocythere* (*Callistocythere) arenicola n.sp.* Hartmann, pl. 12, figs. 52-57, pl. 13, figs. 58-59.

1983 *Leptocythere arenicola* Hartmann; Bonaduce, Ciliberto, Minichelli, Masoli and Pugliese, p. 478.

2012 *Leptocythere arenicola* Hartmann; Helal & Abd El Wahab, p. 60, pl. 1, fig. I.

2012 *Leptocythere arenicola* Hartmann; Mohammed et al., p. 158, pl. 3, figs. 53, 54.

Occurrence: It was recorded in the two sites scarcely. The highest populations recorded are in Q2, G8, and Q7. This species represents 0.82% of the total Ostracoda taxa.

Ecology: It was observed in muddy sand and silty sand facies at a variant depth. The oceanographic parameters are salinity that ranges from 40.39 to 41.5361‰, and pH with range from 7.41 to 8.33.

Zoogeography: Red Sea (Hartmann, 1964; Bonaduce et al., 1983).

Family: Paracyprididae Sars, 1923

Genus: *Ghardaglaia* Hartmann, 1964

Ghardaglaia triebeli Hartmann, 1964 (Pl. 2, Fig. 7)

1964 *Ghardaglaia triebeli* n. sp. Hartmann, p. 41, pl. 6-9, figs. 23-40.

2012 *Ghardaglaia triebeli* n. sp. Hartmann; Helal and Abd El-Wahab, p.60, pl. 1, fig. f.

Occurrence: This species is widely distributed in the study area. The highest population was recorded in samples no. Q2, Q3, Q1, and Q6. It constitutes 17.41% of the studied ostracods' species.

Ecology: It was recorded at depths (0.1-7 m) in sand to mud bottom sediments. Oceanographic parameters: salinity ranges from 40.39 to 41.61 ‰, and pH values range 7.41-8.33.

Zoogeography: Indian Ocean and Persian Gulf (Bate, 1970).

Family: Cytheromatidae Elofson, 1939

Genus: *Cytheroma*. Mueller, 1894

Cytheroma dimorpha Hartmann, 1964 (Pl. 2, Fig. 8)

1964 *Cytheroma dimorpha* n. sp. Hartmann, p. 96, pl. 43, figs. 251- 255; pl. 44, figs. 226-259.

2012 *Cytheroma dimorpha* Hartmann; Helal & Abd El-Wahab, p. 63, pl. 3, fig. j.

Occurrence: This species was observed in the two sites. It was found mostly in the Quseir site in samples no. Q2, Q3, and Q7 at a variant depth. It represents 2.67% of the total Ostracoda taxa.

Ecology: This species was recorded in muddy sand and silty sand facies. The oceanographic parameters: salinity ranges from 40.39 to 41.61‰, and pH ranges from 7.45 to 8.33.

Zoogeography: Red Sea, Persian Gulf and Indian Ocean (Hartmann, 1964; Bate, 1971).

Family: Paradoxostomidae

Genus: *Paradoxostoma* Fischer, 1885

Paradoxostoma breve Mueller, 1894. (Pl. 2, Fig. 9)

1964 *Paradoxostoma breve* Mueller; Hartmann, p. 83, pl. 36, figs. 204-209.

2004 *Paradoxostoma breve* Mueller; Helal & Abd El-Wahab, p. 62, pl. 3, fig. D.

Occurrence: This species was observed in the two sites barely. It was found, mostly, in muddy sand facies at variant depth. It represents 0.55% of the total Ostracoda taxa.

Ecology: The ecological parameters are salinity (40.39-41.61‰), and pH (7.45–8.33).

Zoogeography: The Mediterranean Sea and the Red Sea (Hartmann, 1964; Bonaduce, 1983).

Paradoxostoma parabreve Hartmann, 1964. (Pl. 2, Fig. 10)

1964 *Paradoxostoma parabreve* n. sp. Hartmann, p. 84, pl. 38, figs. 222-225; pl. 39, figs. 231-233.

2012 *Paradoxostoma parabrev*e Hartmann; Helal & Abd El-Wahab, p. 62, pl. 3, fig. F.

Occurrence: This species is of very rare distribution in the study sites. The highest number of this species was observed in samples no. Q3, Q2, Q5, and Q8, and its percentage is 0.6% of the total Ostracoda in the study samples.

Ecology: This species is recorded in muddy sand facies at depths from 0.1 to 3 m. The oceanographic parameters: salinity ranges from 40.52 to 41.53‰, and pH ranges from 7.62 to 8.12.

Zoogeography: Red Sea (Hartmann, 1964).

Family: Xestoleberididae Sars, 1928

Genus: *Xestoleberis* G. O. Sars, 1866

***Xestoleberis ghardaqae.* Hartmann, 1964 (Pl. 2, Fig. 11)**

1964 *Xestoleberis ghardaqae* n. sp. Hartmann, p. 71, pl. 27, figs. 142-148; pl. 28, figs. 149-153.

2012 *Xestoleberis ghardaqae* Hartmann; Helal & Abd El-Wahab, p. 63, pl. 3, fig. m.

Occurrence: This is a widely distributed species, and its dense populations were recorded in samples no. Q2, Q3, and Q6 (93, 86, & 65 carapaces, respectively), which represents 4.41% of the total Ostracoda taxa.

Ecology: This species represents the most abundant species of genus *Xestoleberis*. It occurs commonly in fine sand to muddy sand facies at variant water depth. Oceanographic parameters are valued; salinity from 40.39 to 41.61‰, and pH from 7.45 to 8.33.

Zoogeography: Red Sea (Hartmann, 1964).

***Xestoleberis rhomboidea* Hartmann, 1964 (Pl. 2, Fig. 12)**

1964 *Xestoleberis rhomboidea* sp Hartmann, p. 75, pl. 32, 33, figs. 177-186.

1970 *Xestoleberis rhomboidea* Hartmann; Bate, p. 246, pl. 1, fig. 1, b; pl. 2, fig. 1, 2b.

Occurrence: This species can be considered as one of the most common species and was observed in most samples. The highest populations were found in samples no. Q2, Q6, Q3, and Q8 (53, 47, 46, & 42 carapaces, respectively). It constitutes 3.1% of the studied ostracods' species.

Ecology: This species occurs commonly in sandy gravel to mud bottom facies at variant water depth. The ecological parameters are salinity with range 40.39-41.61‰, and pH with range 7.45-8.33.

Zoogeography: Indian Ocean, Red Sea, and Persian Gulf (Hartmann, 1964; Bate, 1970).

Geochemistry of Sediments

The geochemical analysis data are shown in table (4). Elemental geochemical maps were constructed to exhibit their spatial distribution in each site (Figs. 2-5).

Ras Gharib Site

The Fe content reveals its lowest content around a shallow station G.4 (1500 ppm), whereas the highest content was measured around station G.7 (19900 ppm). The Fe content increases, to some extent, away from the coastline in two stations: G.5 and G.9 (Fig. 2). The indicated contributions are much lower than that of the average marine sediment (32000 ppm; Li, 2000). On the other hand, the P concentration is valued higher than the average marine sediment (600 ppm; Li, 2000) with a maximum content observed in station G.9 (1600 ppm) and a minimum in station G.4 (230 ppm), averaging 558 ppm. The B concentration shows low values in the total stations; however, the maximum concentration was found around station G.6 (47 ppm) and the minimum was found around station G.9 (22 ppm).

Table 4: Geochemical analysis data for the studied samples of each site.

Sample	P	Fe	Pb	Zn	Cu	Cd	Ni	Mn	As	B	Cr	Co
G.1	490	3700	3	7	186	0.6	1	75	2	43	7	1
G.2	510	3800	4	11	39	0.4	1	78	2	41	7	1
G.3	490	3700	3	7	1	0.3	1	75	2	43	7	1
G.4	230	1500	8	4	36	0.8	1	54	3	34	2	1
G.5	630	5800	15	15	81	0.4	2	89	2	44	8	1
G.6	340	2100	6	10	2	0.1	1	56	2	47	4	1
G.7	310	19900	4	15	21	0.7	3	101	3	31	18	2
G.8	420	2800	3	6	1	0.5	1	77	3	40	6	1
G.9	1600	8400	3	21	6	0.6	22	150	3	22	27	3
Q.1	2240	10300	14	49	17	1.9	25	150	7	21	28	4
Q.2	3710	12500	16	54	16	1.6	32	180	6	22	36	5
Q.3	790	5800	3	19	3	0.6	4	116	2	20	7	2
Q.4	53000	6400	29	59	14	2.9	10	317	15	244	30	1
Q.5	51000	5500	19	54	6	3.8	9	320	12	253	32	1
Q.6	4120	11300	12	40	11	0.6	28	168	6	26	34	4
Q.7	1410	7900	6	20	7	1.7	22	148	4	23	25	3
Q.8	1520	7900	3	20	5	0.9	22	149	4	25	25	3
Q.9	1600	8400	3	21	6	0.5	22	150	3	22	27	3
Minimum	230	1500	3	4	1	0.1	1	54	2	20	2	1
Maximum	53000	19900	29	59	186	3.8	32	320	15	253	36	5
Average	6911.7	7094.4	8.6	24.0	25.4	1.1	11.5	136.3	4.5	55.6	18.3	2.1
Mansour et al., 2000	116.7	6643.4	19.8	17.6	14	1	23.5	205.1	###	----	----	----
El-Sorogy et al., 2006	1104	527.75	3.13	5.32	0.65	0.5	1.88	91.7	----	----	----	----

In the study shallow sediment, Cu concentration is of a maximum contribution in station G.1 (186 ppm) and its minimum contribution was observed in station G.3 (3 ppm), averaging 41 ppm. Nonetheless, Cu has a content of 43 ppm in the average shallow marine sediment (Callender, 2005). This indicates that Cu has a higher contribution than normal shallow marine sediments. Mn is leaped in station G.9 (150 ppm) and declined toward station G.4 (54 ppm), which is much lower than the average marine sediment (2700 ppm) (e.g., Li, 2000). The Zn concentration in the study bottom sediments reaches its maximum in station G.9 (21 ppm), while the minimum concentration was found in G.4 (4 ppm; Fig. 3), which is much less than its content in average shallow marine sediments (111 ppm; Callender, 2005). The Pb concentration in the study sediments ranges from 3 ppm in most of Ras Gharib stations to 15 ppm in station G.5 that is lower than its content in the average shallow marine sediment (23 ppm; Callender, 2005). The Cd concentration increases in the shallow area around Ras Gharib harbor (0.8 ppm at G.4; Fig. 3) and decreases toward the deeper water to 0.1 ppm (G.6; Fig. 3), averaging 0.4 ppm. It is generally, higher than the Cd content in the average shallow marine sediment (0.2 ppm). The Ni concentration in the study bottom sediments reaches its maximum at station G.9 (22 ppm), while the whole remaining concentrations have 1-3 ppm (Fig. 2). These values are, generally, lower than the average shallow marine sediment composition (44 ppm). Mostly, the Cr increases in the north direction and is of a maximum concentration at station G.9 (27 ppm), whereas the minimum concentration was measured around station G.4 (2 ppm), which are negligible values compared to the average shallow marine sediment composition (79 ppm). The Co and As concentrations in the overall stations are of low values and consequently no significant influence could be revealed (Fig. 3).

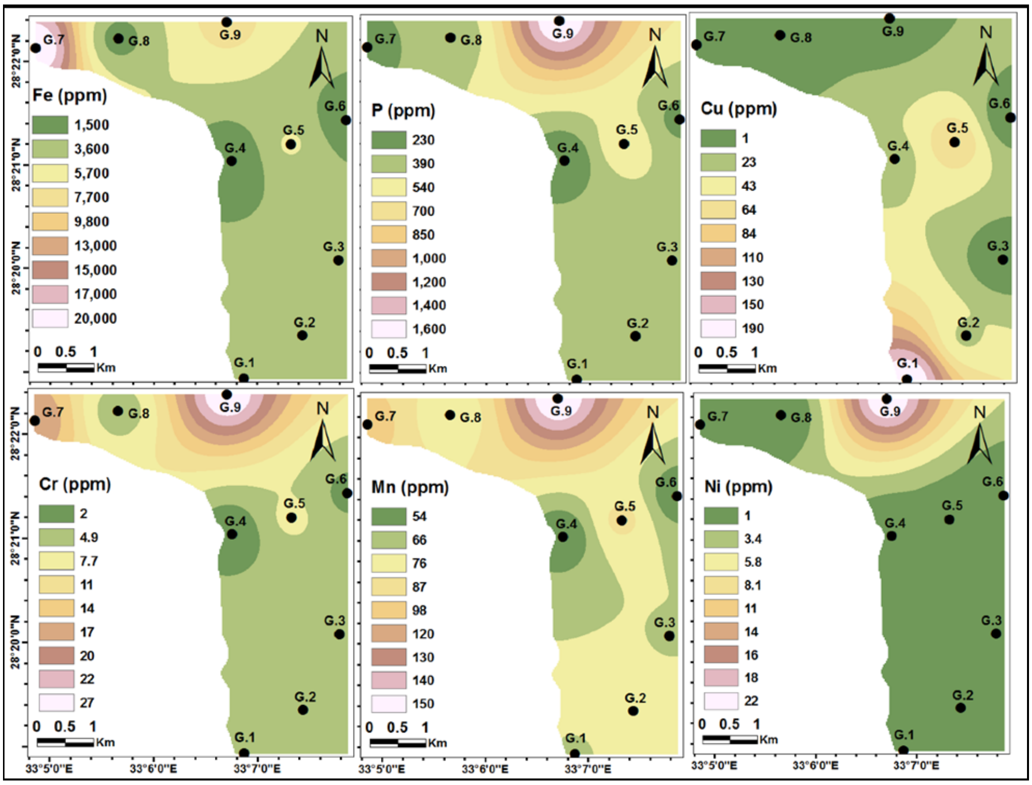

Fig. 2: Spatial distribution of elements Fe, P, Cu, Cr, Mn, and Ni in the Ras Gharib site.

Quseir Site

The Fe content in the study of marine sediment ranges from 5500 ppm in station Q.5 to 12500 ppm in station Q.2, averaging 8444.4 ppm (Fig. 5). Alike the Ras Gharib, these values are significantly lower than the average marine sediments. Nevertheless, the P concentration is valued as the highest in station Q.5 (53000 ppm), while the lowest concentration was recorded in station Q.3 (790 ppm), with an average of 13265.5 ppm. These contents are significant and of higher contribution compared to the average marine sediment value as well as higher than that of the Ras Gharib P contents, which is, most likely, linked to phosphorite mining activities.

The Mn concentration is generally lower than the Mn content in the average marine sediment with its highest value in station Q.5 (320 ppm), while the lowest concentration was found in station Q.3 (116 ppm), averaging 188.6 ppm. Zn concentration in the study sediment has generally lower contents than the average shallow marine sediment with a maximum content at station Q.4 (59 ppm) and a minimum at station Q.3 (6 ppm), averaging 37.3 ppm (Fig. 4). The highest measured value of Pb was recorded in station Q.4 (29 ppm), averaging 12 ppm. Its content is, partly, higher than the average shallow marine sediment (e.g., Callender, 2005; Fig. 4). Cu has a maximum observed content of 17 ppm in stations Q.1 and Q.2, whereas its lowest content (3 ppm) was observed in station Q.3. Unlike the Ras Gharib site, the Cu content is of lower contribution than the average shallow marine sediment. On the other hand, Cd has expressively higher contributions than the average shallow marine sediment (0.2 ppm) with a highest measured value of 3.8 ppm (Q.5) and a lowermost contribution of 0.5 ppm in stations Q.3, Q.6, and Q.9.

It is worth to mention that elements P, Fe, Pb, Zn, and Cu have significantly higher contents in the Quseir site than the Ras Gharib site (Figs. 2-5). Additionally, their contributions are noticeably higher than what was recorded by Mansour et al. (2000) as well as El-Sorogy et al (2006) in the same study area. This implies that the content of these elements in shallow marine sediment increases on a short-term scale. Cd is of a remarkable high contribution in the two studied sites, which is higher than that of the average shallow marine sediment and it could be of a hazardous effect. Furthermore, the Cu and Pb content of the study sites can be considered as a whistling alarm for potential toxicity in Ras Gharib and Quseir areas, respectively.

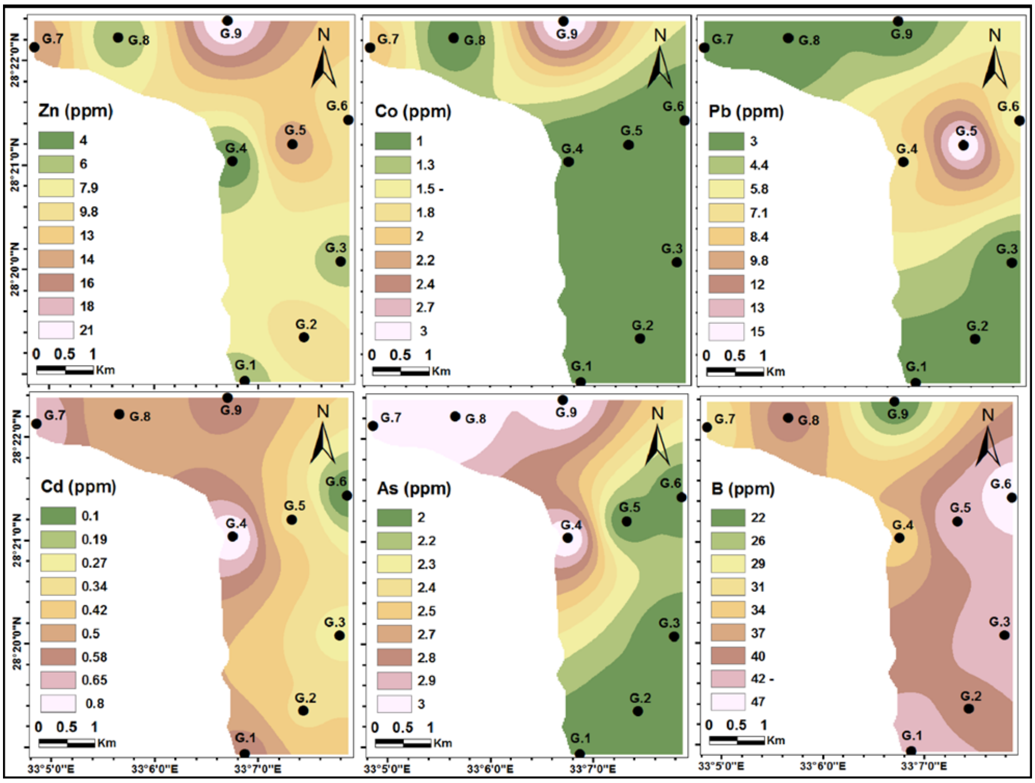

Fig. 3: Spatial distribution of elements Zn, Co, Pb, Cd, As, and B in the Ras Gharib site

Ostracods as pollution indicators

All the ostracods found in the present study were shallow marine mud dwellers, and all samples are composed of silty to muddy sand. To obtain information on the behavior of the ostracods toward the pollution in the coastal areas of the Red Sea, it is important to highlight the effect of the ecological parameters of ostracods distribution. This is to determine which of the ecological factors have the most impact on ostracods' distribution, especially around the polluted stations. Fig. 6 reveals the species and stations discrimination of Axis 1 based on their metal concentrations and other environmental factors. The first CCA axis explains 58.2% of the variation in the data set, whereas the second axis counts for 20.3%.

Axis 1 separates the stations based on pollution level into two groups. A number of ostracods species are located on the right (positive) side of Axis 1, being occupied by Ras Gharib stations, where depleted heavy metal concentrations, high Cu concentrations, and water depth are regarded as main controlling factors. These species include *J. borchersi*, *C. torosa*, *X. rhomboidea*, *X. ghardaqae,* and *L. ghardaqensis* (Fig. 6). The species positioned on the left (negative) side of Axis 1 are accompanied by high heavy metals concentrations. They include all Quseir stations and taxa; *Alocopocythere reticulata*, *Moosella striata, Ghardaglaia triebeli*, *Hiltermannicythere rubrimaris*, and to some extent *Cytheroma dimorpha* (Fig. 6). Consequently, *Ghardaglaia triebeli*, *Alocopocythere reticulata*, *Hiltermannicythere rubrimaris*, and *Moosella striata* can be considered as pollution bio-indicators due to their abundance even in stations that are enriched with heavy metals. On the other hand, *Xestolebris ghardaqae*, *Xestolebris rhomboidea*, *Cyprideis torosa*, *Jugosocythereis borchersi*, and *Cytheroma dimorpha* are pollution-sensitive species and their richness is declined noticeably at highly polluted stations (Fig. 6). The present study confirms the inference of own work using another bio-monitoring group of fauna (El-Kahawy et al., 2018), where the

Quseir site displayed a higher pollution load index than the Ras Gharib site. It is noteworthy that some localities along the Red Sea coast are starting to face hazardous heavy metal contamination, which is reasoned by the growing rate of external sources like industrial activities and other anthropogenic inputs discharging into it. Careful treatment of the afore-mentioned contamination sources should be considered in the near future to mitigate metals pollution hazard.

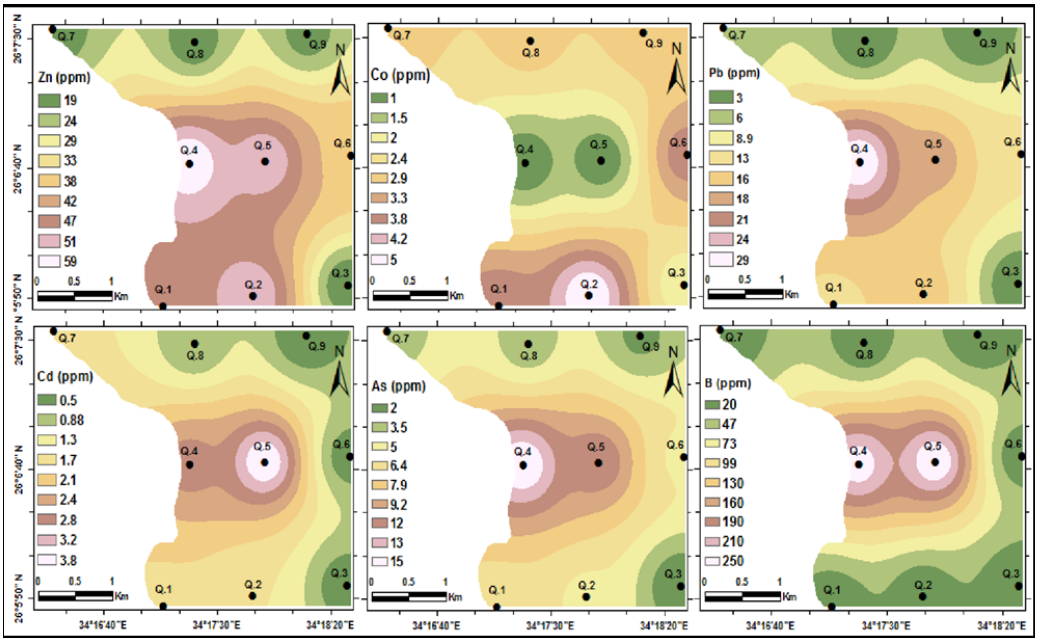

Fig. 4: Spatial distribution of elements Zn, Co, Pb, Cd, As, and B in the Quseir site.

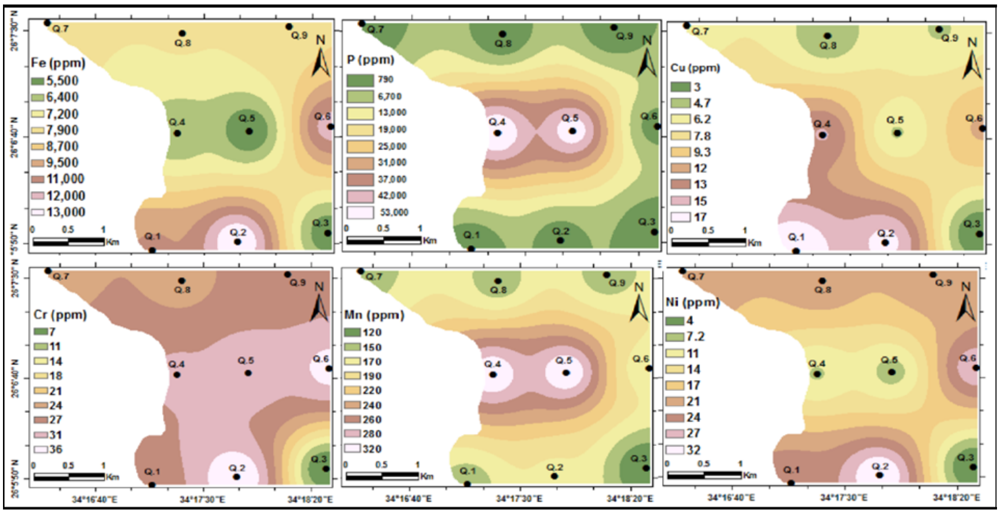

Fig. 5: Spatial distribution of elements Fe, P, Cu, Cr, Mn, and Ni in the Quseir site.

CONCLUSIONS

Eighteen sediment samples were collected from the Red Sea coast in two localities namely: Ras Gharib and Quseir sites. A systematic study of the Ostracoda took place in this study. A total of 12 families, 20 genera, and 23 species were identified. These species represented by benthic, phytal, and shallow-water forms. The percentages of the most common ostracods are *Quadracythere* (19.35% and 17.83%), *Xestolebris* (10.42% and 7.4%), *Loxocorniculum* (17.37% and 14.42%), *Ghardaglaia* (4.22% and 17.91%) and *Moosella* (10.17% and 9.45%) for Ras Gharib and Quseir sites, respectively. Zoogeographically, most of the identified fauna showed an Indo-Pacific affinity. Geochemically, the

Quseir area is characterized by sediments that are enriched in potentially hazardous metals and high silt content, compared to Ras Gharib. The Quseir encompasses the most contaminated stations. The Ras Gharib site is less contaminated, and the sediments are coarse-grained. We observed pollution-tolerant species such as *Ghardaglaia triebeli*, *Alocopocythere reticulata*, *Moosella striata*, and *Hiltermannicythere rubrimaris*, which are survivors in a contaminated system. Pollution-sensitive taxa such as *Jugosocythereis borchersi*, *Loxocorniculum ghardaqensis*, and *Xestolebris ghardaqae*, are characterizing Ras Gharib area. The species composition of the polluted areas can be considered as a good proxy for environmental assessment.

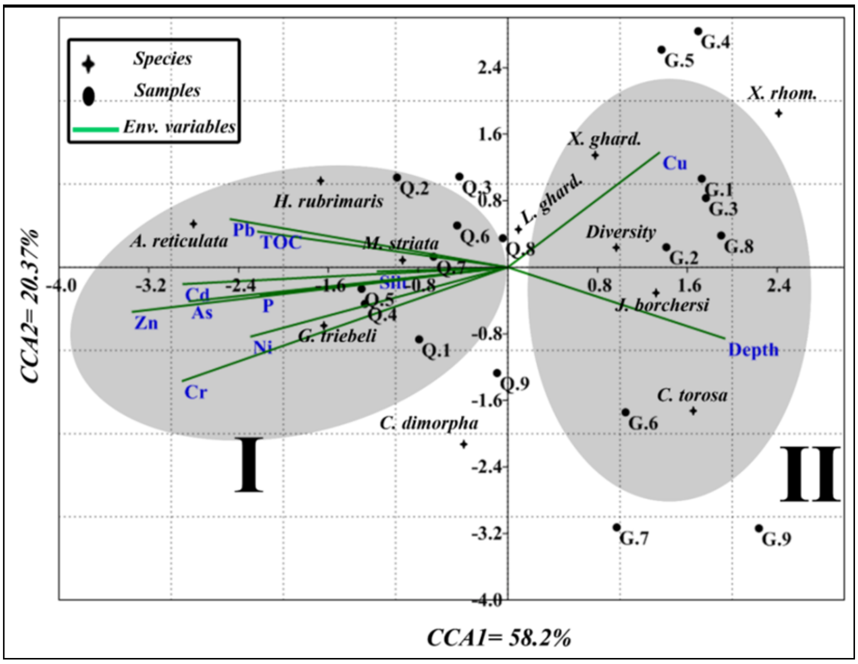

Fig. 6: Canonical correspondence analysis (CCA) tri-plot for the relative abundance of ostracods species in bottom sediment of each station, and the associated environmental variables.

ACKNOWLEDGEMENT

The authors wish to thank the National Oceanography and Fisheries institute, Hurghada branch and Prof. Dr. Mohamed Abd El Wahab for the help in sampling and ecological parameters. Also, the authors express their gratitude to the Cairo University for supporting us with the chemical analyses. We would like to thank Prof. Abdel Galil Hewaidy and Prof. Ahmed El-Kammar for revising and editing the manuscript.

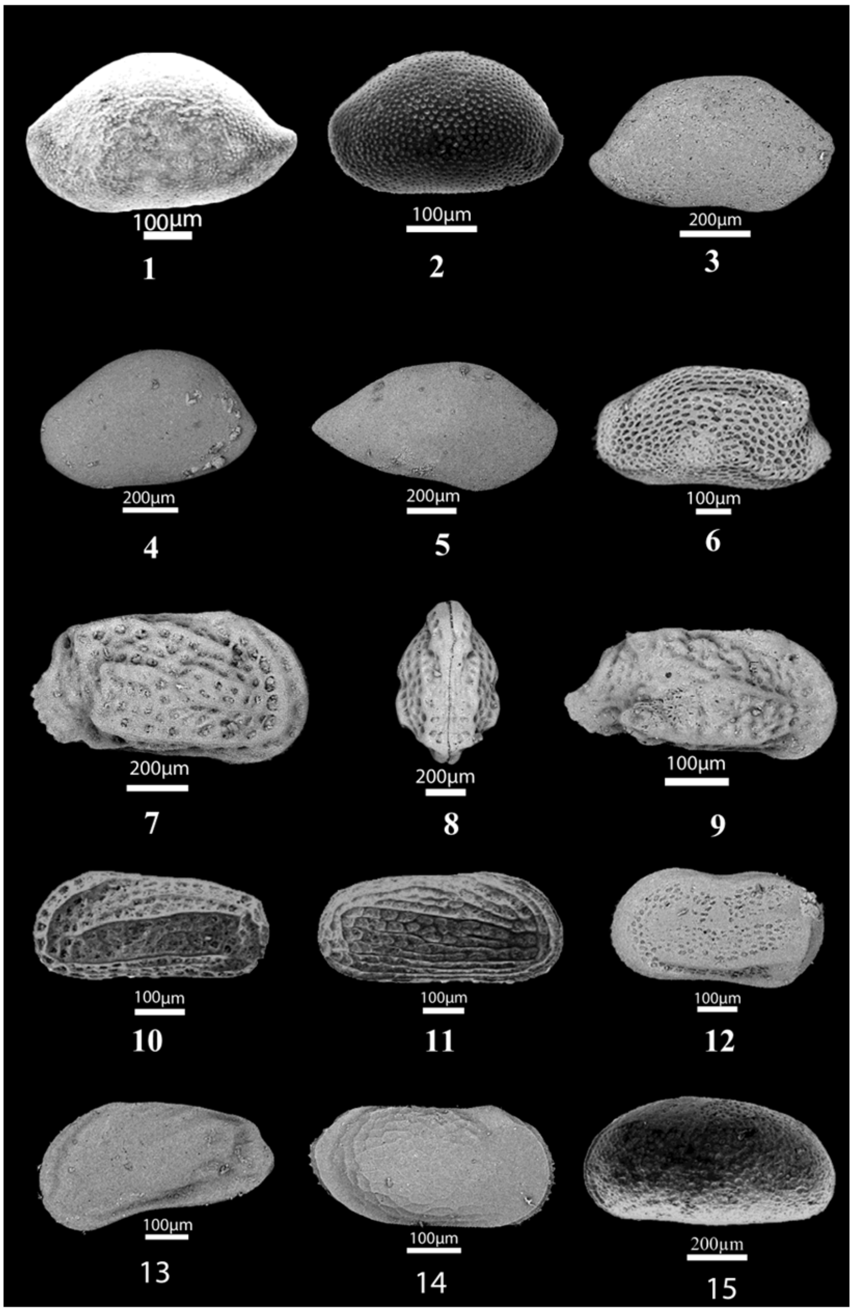

Plate 1:1 Paranesidea n.sp. BCMMP, 1983; LVC., 2-4: *Paranesidea fracticorallicola* Maddocks, 1969; 5, 7 LVC; 6 RVC., 5: *Neonesidea schulzi* (Hartmann, 1964); RVC.,6: *Triebelina sertata* Triebel, 1948; LVC., 7-9: *Quadracythere borchersi* (Hartmann, 1964); 1, 3 LVC; 2, DVC., 10: *Hiltermannicythere rubrimaris* (Hartmann, 1964); LVC., 11: *Moosella striata* Hartmann, 1964; RVC., 12: *Cytherelloidea* n. sp. BCMMP, 1983; LVC., 13: *Caudites levis* Hartmann, 1964; LVC, 14: *Alocopocythere reticulata* (Hartmann, 1964), RVC., 15: *Cyprideis torosa* (Jones, 1850); LVC.

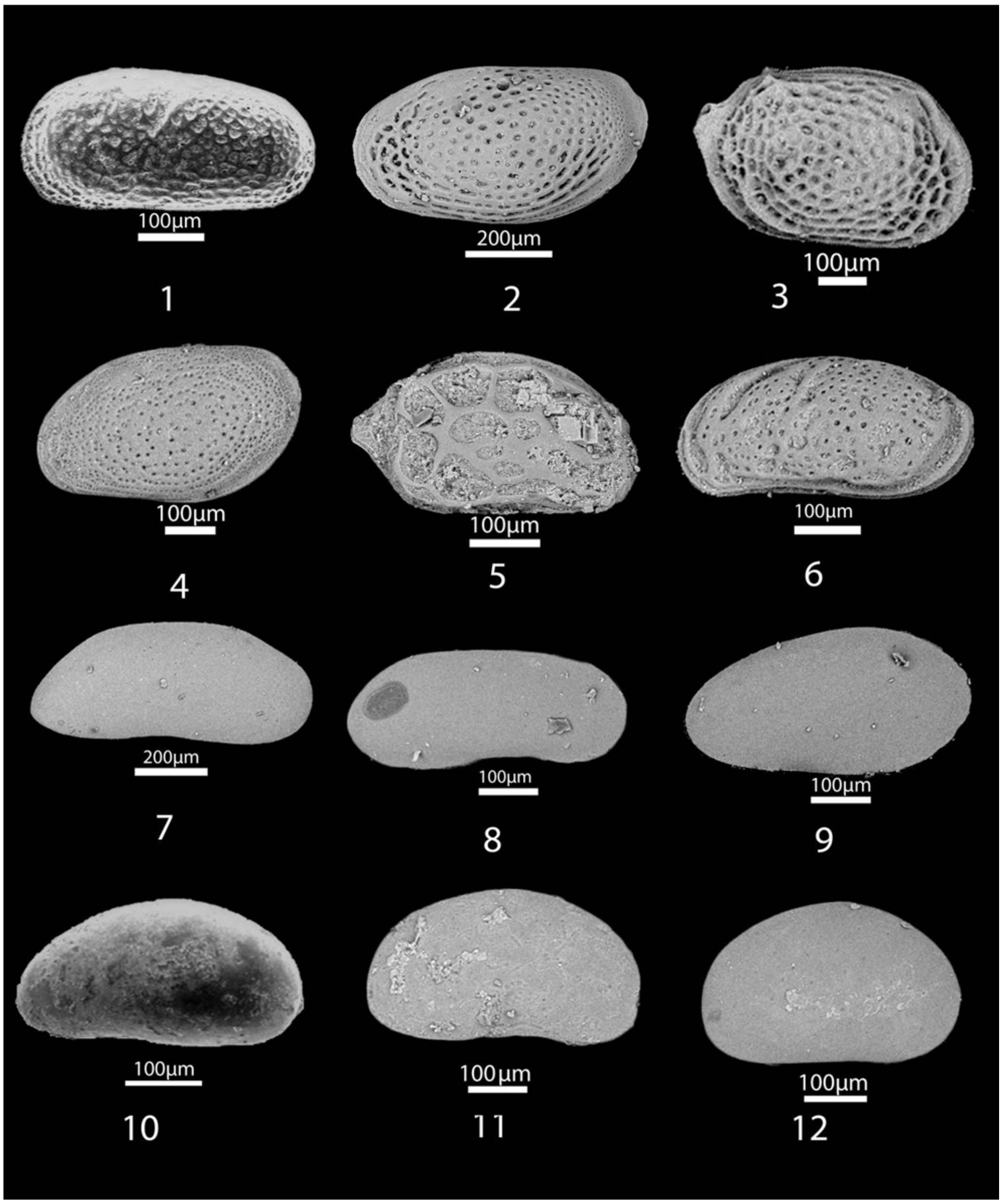

Plate 2: 1: *Miocyprideis cf spinolusa* (Brady, 1868); RVC., 2: *Loxoconcha* sp.A Bate, 1970; LVC., 3: *Loxocorniculum ghardaquensis* (Hartmann, 1964); RVC., 4: *Sclerochilus rectomarginatus* Hartmann, 1964; LVC., 5: *Hemicytherura videns* Hartmann 1964; RVC., 6: *Leptocythere arenicola* Hartmann, 1964; LVC., 7: *Ghardaglaia triebeli* Hartmann, 1964; RVC, 8: *Cytheroma dimorpha* Hartmann, 1964; LVC., 9: *Paradoxostoma breve* G. W. Mueller, 1894; RVC.,10: *Paradoxostoma parabreve* Hartmann,1964; RVC., 11: *Xestoleberis ghardaqae* Hartmann,1964 ; LVC., 12: *Xestoleberis rhomboidea* Hartmann,1964; LVC.

REFERENCES

Bate, R. H. (1971): The distribution of Recent Ostracoda in the Abu Dhabi Lagoon, Persian Gulf. - In: Oertli, H.J. (Ed): Paléoécolgie des Ostracodes. - Bull. Centre Rech. Pau. SNPA, 5, 239-256, 3 figs., 3 pls.; Pau.

Bate, R. H. (1971): Phosphatized ostracods from the Cretaceous of Brazil. Nature 230 (5293): 397-398.

Benson, R. H. (1961): Ecology of Ostracoda assemblages. Treatise on invertebrate paleontology, Part Q, Arthropoda 3 (56-63).

Bonaduce, G., Ciliberto, B., Minichelli, G., Masoli, M. and Pugliese, N. (1983): The Red Sea benthic ostracods and their geographical distribution. Proceedings of the 8th Int. Sym. on Ostracoda: Applications of Ostracoda: 472-491.

Brady, G. S. (1868): A monograph of the recent British Ostracoda. Trans. Linnean Soc. London. 353-495, Pls. 23-41.

Callender, E., (2005): Heavy Metals in the Environment-Historical Trends. In: Lollar, B. S. (Ed), Holland, H.D., Turekian, K.K. (Ex. Eds), Environmental Geochemistry. Treatise on Geochemistry, 9, 612 p., Elsevier, Amsterdam.

El Hmaidi, A., El Moumni, B. and Nachite, D. (2010): Distribution et caractéristiques des associations d'ostracodes au Pléistocène supérieur et Holocène au niveau de la marge orientale du détroit de Gibraltar (mer d'Alboran, Maroc). Revue de micropaléontologie, 53 (1), 17-28.

El-Kahawy, R., El-Shafeiy, M., Helal, S., Aboul-Ela, N. and Abd El-Wahab, M. (2018): Morphological Deformities of Benthic Foraminifera as a response to the Red Sea nearshore pollution, Egypt. Environmental Monitoring and Assessment 190:312, doi.org/10.1007/s10661-018-6695-2.

Elshanawany, R., (2010): Microfossil assemblages as proxies to reconstruct anthropogenic induced eutrophication of two marginal Eastern Mediterranean Basins. Ph. D. thesis, University of Bremen, Germany.

El-Sorogy, A. S., Abd El-Wahab, M., Nour, H. E., Ziko, A. and Shehata, W. (2006): Faunal assemblages and sediment chemistry of some lagoons along the Red Sea coast, Egypt. Egypt. J. Paleont., 6, 193-224.

Fouda, M., Abou-Zeid, M. (1990): Bivalves of the Suez Canal lakes. Proc. Zool. Soc. AR Egypt, 21, 231-240.

Gramann, F. (1971): Ostracoden aus Neogene und Quartar der Danakil- Senke (Nordost-Athiopien). Beih. Geol. Jp., 106, 109-142.

Guillaume, M., J. Peypouquet, J. and Tetart, J. (1985): Quaternaire et actuel. Atlas des Ostracodes de France. Mem. Elf-Aquitaine, 9, 337-377.

Hartmann, G. (1964): Zur kenntnis der ostracoden des Roten Meeres. Kieler Meeresforschungen, vol. 20, Sonderheft.

Hartmann, G. and Puri, H. S. (1974): Summary of neontological and paleontological classification of Ostracoda. Mitteilungen aus dem hamburgischen zoologischen Museum und Institut, vol. 70, 7-73.

Helal, S. A. and Abd El-Wahab, M. (2004): Recent Ostracodes from marine sediments of Safaga Bay, Red Sea, Egypt. Egypt. J. Paleont., 4, 75-93.

Helal, S. A. and El-Wahab, M. (2012): Distribution of podocopid ostracods in mangrove ecosystems along the Egyptian Red Sea coast. Crustaceana, 85(14), 1669-1696.

Kandeel, K. (2002): Ecological and biological studies on some bivalves in Lake Timsah and the Bitter Lakes, Ph. D. Thesis, Suez Canal Univ., Egypt.

Kollmann, K. (1960): Cytherideinae und Schulerideinae n. subfam. (Ostracoda) aus dem Neogen des östl. Oesterreich. Mitteilungen der Geologischen Gesellschaft in Wien, 51(1958), 89-195.

Li, Y.-H. (2000): A Compendium of Geochemistry: From Solar Nebula to the Human Brain. Princeton University Press, Princeton, 475 pp.

Malz, H., Lord, A. (1988): Recent ornate bairdiid Ostracoda: origin and distribution. In: Ikeya, A.T.N., Ishizaki, K. (Eds.), Evolutionary biology of Ostracoda, its fundamentals and applications: 63-74, Elsevier, Amsterdam.

Mansour, A. M., Nawar, A. H. and Mohamed, A. W. (2000): Geochemistry of coastal marine sediments and their contaminant metals, Red Sea, Egypt: A legacy for the future and a tracer to modern sediment dynamics. Sedim. of Egypt, 8, 231-242.

Mohammed, M., Keyser, D. (2012): Recent ostracods from the tidal flats of the coast of Aden City, Yemen. Marine biodiversity, 42(2), 247-280.

Mohammed, M., Al-Wosabi, M., Keyser, D. and Al-Kadasi, W. M. (2012): Distribution and taxonomy of shallow marine Ostracods from Northern Socotra Island (Indian Ocean)-Yemen. Revue de micropaléontologie, 55(4), 149-170.

Mohammed, M., Al-Wosabi, M.A., Keyser, D. and Al-Kadasi, W.M. (2012): Distribution and taxonomy of shallow marine Ostracods from Northern Socotra Island (Indian Ocean)-Yemen. Revue de micropaléontologie, 55(4), 149-170.

Moore, R. C. (1961): Treatise on invertebrate Paleontology, Part Q, Arthropoda, (Ostracoda). Geol. Soc. Am. Univ. Kansas Press 422.

Morkhoven, F. (1962): Post-palaeozoic Ostracoda: Their Morphology, Taxonomy and Economic Use, Volume 2F. P. C. M. Van Morkhoven Elsevier Publishing Company, 1-204.

Mostafawi, N. and Nabavi, S.M. (2010): Ostracods from the Strait of Hormuz and Gulf of Oman, Northern Arabian Sea. Revista española de micropaleontología, vol. 42(2), 243-265.

Müller, G.W. (1894): Die Ostracoden des Golfes von Neapel und der angrenzenden Meeres-abschnitte. Fauna und Flora, Herausgegeben von der Zoologischen zu Neapel, 21 (1-8), 1-404.

Nachite, D., Rodríguez-Lázaro,J., Martín-Rubio, M., Pascual, A. and Bekkali, R. (2010): Distribution and ecology of recent ostracods from the Tahadart estuary (NW Morocco). Revue de micropaléontologie, 53, 3-15.

Por, F. D. (1978): Lessepsian migration: the influx of Red Sea biota into the Mediterranean by way of the Suez Canal. Ecological Studies No. 23, Springer-Verlag, Berlin Heidelberg, 228 pp.

Puri, H. S. (1953): The ostracod genus Hemicythere and its allies. J. Washington Acad. Sci., 43, 169-179.

Reiss, Z., Hottinger, L. (1984): The Gulf of Aqaba: ecological micropaleontology, Springer Berlin. Ecological Studies No. 50, Springer-Verlag, Berlin Heidelberg, 354 pp.

Sars, G. O. (1866): Oversigt of Norges Marine Ostracoder. Forhandlinger I Videnscabs-Selskabet I Christiania, 1-130.

Sars, G. O. (1925): An Account of the Crustacea of Norway. Bergen, 9, 1- 277.

Siddiqui, Q.A. (1971): Early Tertiary Ostracoda of the family Trachyleberididae from West Pakistan, Bull. Brit. Mus. (Nat. Hist), 1-42.

Teeter, J. W. (1975): Distribution of Holocene marine Ostracoda from Belize. Belize shelf carbonate sediments, clastic sediments and ecology. American Association of Petroleum Geologists, Studies in Geology 2, 400-499.

USGS. (1995): Available from: http://minerals.cr.usgs.gov/geo_chem_stand/marine.html.

Yasuhara, M., Yamazaki, H., Irizuki, T. and Yoshikawa, S., (2003): Temporal changes of ostracod assemblages and anthropogenic pollution during the last 100 years, in sediment cores from Hiroshima bay, Japan. Holocene, 13, 527-536.

التصنيف والتوزيع والدلالة البيئية للاوستراكودا البحرية القاعيه، علي طول ساحل البحر الأحمر في مصر

رمضان القهاوى[١]، معتز الشافعي[١]، صبحي هلال[٢]، نبيل أبو العلا[١]

[١] قسم الجيولوجيا ، كليه العلوم ، جامعه القاهرة ، مصر

[٢] قسم الجيولوجيا ، كليه العلوم ، جامعه الفيوم ، مصر

الخلاصة

تم جمع ١٨ عينه من الرواسب القاعية الحديثة من موقعين يقعان علي ساحل البحر الأحمر فى مصر، هما رأس غارب والقصير. عولجت هذه العينات لمحتواها من حفريات الاوستراكودا. تم دراسة الجوانب المتعلقة بتعريف الحفريات وتصنيفها وتوزيعها والإيكولوجيا الخاصة بها والتوزيع الجغرافى لها وكذلك الاثر البيئى علي التجمعات الاوستراكودية. كما تم ايضا التعرف علي ثلاثه وعشرين نوعا من أنواع الاوستراكودا التي تنتمي إلى ٢٠ جنس و ١٢ عائلة. النسب المئوية من هذه الانواع الأكثر شيوعا هي:

Quadracythere (19.35% and 17.83%), *Xestolebris* (10.42% and 7.4%), *Loxocorniculum* (17.37% and 14.42%), *Ghardaglaia* (4.22% and 17.91%), and *Moosella* (10.17% and 9.45%)

في موقعي رأس غارب والقصير علي التوالي . وتمثل هذه الكائنات أكثر من ثلاثه أرباع مجموع التجمعات في الموقعين. ومعظم الكائنات التي لوحظت هي تنتمى الهند والمحيط الهادئ. كما تم تسجيل بعض اصناف تتبع البحر الأبيض المتوسط بجانب الكائنات الحيوانية الهندية المسجلة. ومن وجهه النظر الجيوكيمياء البيئية ، تتميز منطقه القصير برواسب أكثر ثراء في بعض الفلزات الثقيلة، مقارنه بمتوسط محتويات الرواسب البحرية الضحلة. يحتوي موقع رأس غارب، نسبيا، علي محتويات معدنيه اقل كثافة مع رواسب خشنه الحبيبات. واستنادا إلى تحليل المراسلات المخروطية (CCA) ، لوحظت الأنواع التي تتحمل التلوث في المحطات الملوثة مثل Ghardaglaia triebeli, Alocopocythere reticulata, Moosella striata, and Hiltermannicythere rubrimaris والتي يمكن ان تتحمل تركيزات عالية من بعض العناصر. ومن ناحية أخرى ، فان الأصناف الحساسة للتلوث ، مثل Jugosocythereis borchersi, Loxocorniculum ghardaqensis, and Xestolebris ghardaqae ، تميز منطقه رأس غارب. وينبغي أخذ كل ما سبق فى عين الاعتبار والحيطة قبل مرور وقت طويل للمحافظة علي النظم الايكولوجيه والجغرافية للبحر الأحمر.