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Distribution and diversity of benthic Foraminifera from the coastal lagoons along the Egyptian Red Sea

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Abstract

Along the Egyptian Red Sea coast sixty-nine samples have been collected from three coastal lagoons Abu-Shaar, Umm al-Huwaytāt and Marsa Shūni Lagoons during summer 2003 and winter 2004 seasons. Coastal lagoons along the Egyptian Red Sea coast are areas of hyper- saline waters protected by linear barrier reefs. Seagrasses and algae are widely distributed especially in Marsa Shūni Lagoon on the soft muddy and sandy carbonate sediments on the flanks of the reefs and channels between them. Recent benthic represent 82 species belonging to 36 genera are recognized in marine sediment samples collected from the coastal lagoons on the Egyptian Red Sea. The dead foraminifera have a very high diversity and there is a dominance of Miliolina, followed by Rotallina and only sparse Textulariina. The living assemblages closely resemble those of the dead. It is inferred that the environment is not favorable for foraminifera and that there is high postmortem change in the fauna. On other hand, the foraminifera assemblages are dominated by Milliolina taxa such as *Sorites marginalis and Peneroplis planatus*, the two most abundant species in the all studied coastal lagoons. Cluster analysis shows two clusters namely; summer and winter clusters according to the abundance of foraminiferal species at the studied lagoons. Number of species (S), Species diversity (H'N) & the evenness index (J') have been calculated in the studied localities according to relative abundance. It has its maximum at Abu-Shaar lagoon and minimum one at Marsa Shuni lagoon. The strong correlation between (H'N) and (J') has been recorded while the correlation between (H'N) and (S) is weak at the studied localities.

Keywords: Benthic foraminifera, Distribution, Diversity, Coastal lagoons, Red Sea, Egypt.

1. Introduction

Foraminifera are tiny single-cell organisms that construct shells. They inhabit a wide range of marine environment, from the intertidal zone to the deep sea in all regions and from tropical to the polar ecosystem. One group of these organisms considered to be most important for this integrated approach are foraminifera. Their tests provide the most abundant sediment particles (Piller, 1994), and they are present in all facies. This is optimal precondition for their use in ecological, facial and environmental interpretations.

Coastal lagoons along the Egyptian Red Sea (Figure 1) offer an excellent opportunity to study a warm shallow water fauna of hyper-saline environment. The recent foraminifera of the northern Red Sea and particularly of coastal lagoons have not been previously described and figured, although the foraminifera of other parts of the Red Sea have been studied by few authors during the last hundred and fifty years.

Few studies deal with the benthic foraminifera in the Red Sea .The Red Sea proper has been studied by Said (1949 & 1950a,b) and El-Deeb,(1978) where the authors surveyed large areas and provided an important informations. The Saudi Arabian coast, was carried out by Bahafzallah (1979), Bahafzallah & El-Askary (1981),Yusuf (1984), Montaggioni *et al*. (1986), Abou Ouf *et al*. (1988), Abou Ouf (1992) and Abou Ouf and El-Shater (1993). At the Red Sea shore of Yemen, El-Nakhal (1980) studied the recent foraminifera. Along the Egyptian coast, the shallow water foraminifera has been studied by Anan (1984) at Quseir - Marsa Alam, Obaidalla (1988) and Ouda and Obaidalla (1998) at Marsa Alam-Ras Banas, Azazi (1990) in the Gulf of Suez, Badawi (1997) in northern Red Sea, Haunold *et al*. (1997) at Safaga Bay and Aref and Madkour (1999 and 2000); Madkour (2000 and 2004), Mansour *et al*. (2005) and Madkour and Ali (2009) at different localities of the upper continental shelf of Red Sea .

The purpose of this study was to determine the abundance and distribution of the benthic foraminifera occurring in the hyper-saline environment in coastal lagoons along the Egyptian Red Sea. Both the dead and living assemblages were examined and the relationships between them were noted.

2. Material and methods

2.1. Geomorphology of the study areas

Abu Shaar Lagoon lies north Marine Biological Station about 5 km with maximum depth 8 m during the high tide level, its maximum length ca 1000 m (Table 1; Figure 1). This lagoon is often bordered by beach to the west, and fringing coral reefs to the east. Abu Shaar Lagoon has two water entrances, the first entrance is narrow and situated at the southern side, while the second one is relatively wide at the northern side. Its bottom floor is a mixture of sand, mud, and biogenic fragments. This lagoon is characterized by zonation of seagrass, algae, hydroids and coral patches. Diversity of invertebrate species is low.

Umm al-Huwaytāt Lagoon is situated 10km south Safaga city (Table 1; Figure 1). Generally, Safaga area is occupied by relatively low hill of sedimentary rocks surrounded by mountains of igneous and metamorphic rocks.Umm al - Huwaytāt Lagoon occupies about 1500 m^2 with gentle sloping. The lagoon boundaries are fringing reef to the east and beach to the west, (Figure 1). It has one inlet from the north and the maximum recorded depth is about 11 m. Sea bottom surveying by Scuba diving revealed the presence of several sandy substrata; sand with seagrass, muddy sand and biogenic sand with coral patches and coral reefs. Most sediment samples have brown color. This is due to phosphate shipment operations in Abu-Tartour Harbour near this lagoon.

Marsa Shūni Lagoon is located at 50 km north Marsa Alam City (Table 1; Figure 1). The area is an under construction touristic village owned by Mayfair Group for Touristic Investments. The lagoon is very shallow and it extends parallel to the shore with 1 km long and more than 500 m wide (Figure 1). Generally, a lot of fish larvae and juveniles were observed due the shallowness and warm water inside this lagoon. The main feature of this lagoon is the presence of a very big number of jelly fish. The area is highly sensitive, virgin, includes some integrated ecosystems (seagrass ecosystem and coral reef ecosystem) and no human impact observed but there is natural impact by Wadi El-Shūni contribution of sediments. Therefore, the site needs urgently a management action and some kind of protection.

Table 1. The measured hydrographic parameters of water mass in the studied lagoons.

Lagoon	Position		number Of sed. Samples	Season		Depth (m)	Temp. °C	Salinity ‰	DO mg\L	pH	TDS g/L	SPC ms/cm	Date
	Lat. ° / // N	Long. ° / // E											
Abu-Shaar	27 18 16	33 45 04	15	summer	Min.	0.5	28.0	42.1	5.2	8.8	40.0	60.9	2003
					Max.	9.3	29.4	43.4	8.5	8.9	41.1	64.4	
					avg.	3.2	28.7	43.1	6.8	8.9	40.8	63.8	
			11	winter	Min.	0.1	17.9	41.0	7.1	8.5	39.0	61.0	2004
					Max.	11.0	19.9	43.2	13.6	8.8	40.8	63.7	
					avg.	3.3	18.7	42.6	10.3	8.7	40.3	62.9	
Umm al-Huwaytat	26 38 55.6	33 57 44	13	summer	Min.	1.5	27.7	41.3	4.2	8.7	39.4	60.5	2003
					Max.	13.0	28.6	43.0	5.6	8.9	40.7	63.6	
					avg.	6.7	28.2	42.5	5.2	8.6	40.4	63.1	
			12	winter	Min.	1.5	17.8	41.6	7.3	8.3	40.5	63.4	2004
					Max.	10.7	21.7	44.5	12.8	8.5	41.9	65.6	
					avg.	5.5	19.5	43.7	9.9	8.4	41.4	61.6	
Marsa Shuni	25 26 27	34 41 37	9	summer	Min.	0.6	26.7	40.5	4.9	8.4	38.9	61.0	2003
					Max.	2.0	28.9	43.0	6.4	8.6	40.5	63.6	
					avg.	1.2	28.2	42.4	5.8	8.5	40.2	63.0	
			9	winter	Min.	0.6	19.6	41.6	8.6	8.3	38.7	60.9	2004
					Max.	2.0	22.4	42.6	14.7	8.8	40.4	63.1	
					avg.	1.2	22.3	42.6	11.0	8.4	40.4	63.1	

All parameters were measured during the collection samples at year 2004 by Hydrolab Instrument (Surveyor[4] 1997).
N= number of sediment samples, Temp.= temperature, DO= dissolved xygen, TDS= total dissolved salts, SPC= specific conductivity

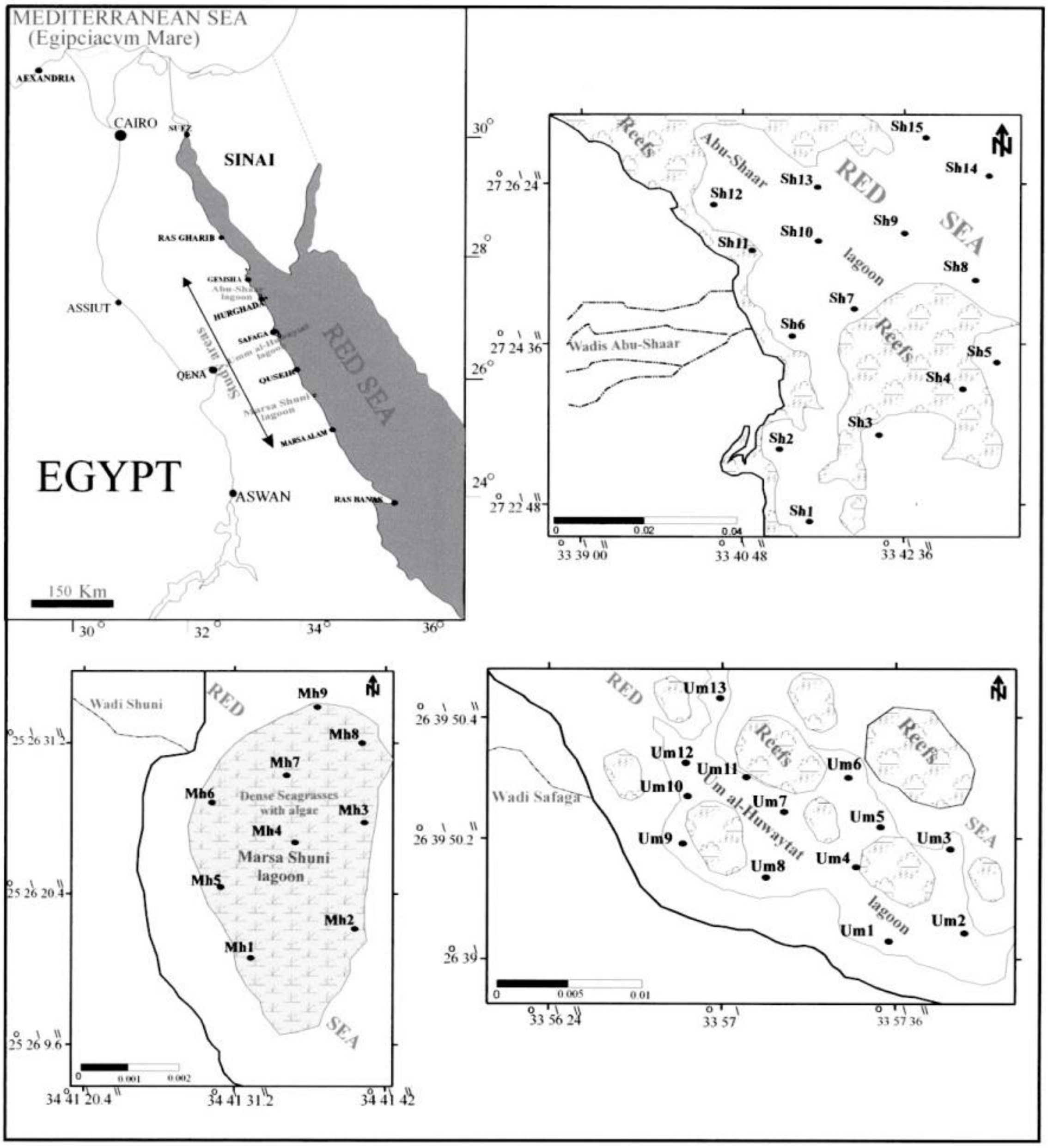

Figure 1. Study areas and sampling stations of benthic foraminifera along the Red Sea coast, Egypt.

2.2. Field work

In this study, using a small fishing boat sixty –nine sediments samples have been collected from extension of three selected coastal lagoons along the Egyptian Red Sea at Abu-Shaar, Umm al-Huwaytāt and Marsa Shūni Lagoons (Figure 1) using a small Van Grab sampler and some samples were taken by scuba diving. Some sediment samples were collected through the plan of the National Institute of Oceanography and Fisheries, Red Sea Branch. Samples were immediately stained on board in an alcohol/Rose-Bengal mixture for several days, washed over a 63 µm sieve and air-dried (Haunold *et al*., 1997).

Oceanographic parameters that control the coastal features of the Red Sea, such as salinity, temperature, pH and turbidity values were measured in a water sample overlying each sampling site. Water temperature (Temp), salinity (S), dissolved oxygen (DO), pH, total dissolved salts (TDS) and specific conductivity (Spec) were measured during summer 2003 and winter 2004 at the coastal lagoons by using the Hydrolab Instrument (Surveyor [(4)] 1997) as shown in (Table 1).

2.3. Laboratory methods

In the laboratory, all samples were washed again through a 63 µm sieve then oven-dried. Washed and dried samples were splitting by using a microsplitter to reduce the amount of sediment and the number of foraminifera. The faunal investigations were carried out on four fractions of sediments (1, ½, ¼ & 1/8mm) so as to pick a fraction for about 200 tests. Separate dead and living assemblage counts were made each of 200 – 250 individuals. Some errors may have occurred in the counting process. The foraminiferal species in each sample were identified based on the classification of foraminifera by Loeblich & Tappan (1988).

The cluster analysis was performed using SPSS Package (Statistical Package for Social Sciences).

2.4. Index of general diversity (Shannon –Wiener index)

In order to obtain overall information on the nature of the investigated foraminiferal population's species, indices are calculated. These are the diversity index and index of species which depend on the parameters expressing the frequency distribution of each species in a sample. Some of the diversity indices are based on a theoretical relationship between the number of species and individual in the samples. Other indices are determined by the number of species where, the species are found in a sample, the greater the diversity.

The species dominance is calculated by using the entropy concept according to Shannon and Wiener (1948) (in Buzas and Gibson, 1969). The diversity ($H^{\backslash}_N$) was calculated from the following formula:
Where:

$$H'_N = -\sum_{i=1}^{S} PiLogePi$$

Pi = *Ni/N* is the proportion of the total number of individuals (*N*) belonging to the I th species (*Ni*). The units of ($H^{\backslash}_N$) depend upon the base of the logarithm, which is largely a matter of choice. Base e is used for calculating the different diversity indices.
If all (S) species in a sample are equally common, each has a proportion of 1/S of the
total, thus, the measure:

$$H'_N = -\sum_{i=1}^{S} PiLogePi$$

Takes the value $H^{\backslash}max = -S(1/s\ Log_e\ 1/s) = Log_e\ S$. Thus, the measure of equally common species is simply the natural logarithm of the number of equally common species.
The evenness index (Pielou, 1966a,c) was also calculated in the present study from the Following formula:

$$J' = \frac{H'(observed)}{H'\max}$$

$J^{/}$ is the evenness index which compares the observed distribution of individuals among species, $H^{/}$ (observed) is the diversity calculated by Shannon and Wiener (1948) (in Buzas and Gibson, 1969), $H^{/}$ max = Log_e S, where S is the number of species.

3. Results and Discussion

3.1. Environmental parameters

The temperature of bottom water varied from 26.68°C at Marsa Shūni Lagoon and 29.44 °C at Abu-Shaar Lagoon in summer, to 17.77 °C at Umm al-Huwaytāt Lagoon and 22.36 °C at Marsa Shūni Lagoon in winter season (Table 1). Bottom and surface temperatures at nearly all stations in each locality were the same at the time of sampling. This indicates a good vertical mixing of the water. The water is hyper-saline due to the low rainfall and high evaporation. As seasonal variation was recorded with values of 40.53 ‰ at Marsa Shūni Lagoon to 43.4 ‰ at Abu-Shaar Lagoon in the summer, and 41 ‰ at Abu-Shaar Lagoon to 44.53 ‰ at Umm al-Huwaytāt Lagoon in the winter (Table 1). Approximately, no large changes in average salinities occur from summer to winter (Table 1). These values are higher than those of the adjacent Red Sea and reflect the limited water exchange between the coastal lagoon, the bays and the open sea. pH, DO (Dissolved Oxygen), TDS (total dissolved salts) and SPC (specific conductivity) of the study areas are measured. The results indicate that the sea water along the studied coastal lagoons is slightly alkaline and ranging between 8.25 in the south (Marsa Shūni Lagoon) to 8.93 in the north (Abu-Shaar Lagoon). The DO data indicates that the sea water in the shore areas, are ranging between 4.18 mg|L in the summer at Umm al-Huwaytāt Lagoon and 14.72 mg|L in the winter at Marsa Shūni Lagoon (Table 1).

3.2. Frequency and distribution of foraminiferal assemblages

The detailed taxonomy of the 77 species in summer 2003 and 82 species in winter 2004 belonging to 36 genera within 22 families and three suborders constituting the foraminifera fauna of the coastal lagoons along the Egyptian Red Sea is summarized in tables (2 & 3) and graphically represented in Figures (2, 3, 4 & 5). The benthic foraminifera found in the shore zone sediments of the coastal lagoons along the Egyptian Red Sea are represented by two suborders; Miliolina and Rotaliina while Textulariina is appeared rare. The comparison of the distribution of foraminifera throughout the studied localities shows that the highest average percentage of foraminifera is present at Abu-Shaar Lagoon (36.1 in summer; 38.5 in winter) and Marsa Shūni Lagoon (37.5% in summer; 34.4% in winter)) compared with Umm- al- Huwaytāt Lagoon (26.4% in summer; 27.08% in winter) (Tables 2 &3).

In general, the dead assemblage is the dominance in all the studied coastal lagoons compared with the live assemblages in summer and winter (Figure 2). Abu-

Shaar Lagoon recorded the highest values of the live assemblages compared to the other studied lagoons (Tables 2 & 3). This seems due to selective these small tests or to a relatively low production rate in comparison with the Miliolina. The other reason is probably due to anthropogenic activities and high contribution of terrestrial materials by wadis (Figure 1). Generally, the most dominant suborder is the Miliolina in all studied localities. This is probably related to the typical characteristics of subtropical carbonates that related to the Red Sea coast. Miliolina is very abu ndant but in general the high abundance is closed to the shore and this is especially well shown in the dead assemblage at the study coastal lagoons. Textulariina is one of the few groups which is more abundant away from the off-shore areas (Madkour, 2000). In general, the living assemblages show very low abundance near the shore and relatively higher values in the channels between the barrier reefs of the study areas.

From the distribution of benthic foraminifera in the studied localities, it is apparent that the porcelianeous foraminifera is the most abundant group and generally preponderant with an average 96.8 % in summer at Marsa Shūni Lagoon and 95.52% in winter of the total foraminiferal fauna at Abu-Shaar Lagoon. The distribution of porcelianeous group in Abu-Shaar Lagoon is near to the percentage of Marsa Shūni Lagoon. On the other hand, the hyaline foraminifera is the second group after porcelianeous group, Umm - al-Huwaytāt Lagoon recorded the high values compared with the other localities. Arenaceous foraminifera is rare and particularly common at Abu-Shaar Lagoon compared with Umm- al-Huwaytāt and Marsa Shūni Lagoons.

The Miliolina are mainly represented by members of the families, Soritidae (low value 31.54% in winter at Umm-al- Huwaytāt and high values recorded 64.26% in summer at Marsa Shūni Lagoon), Peneroplidae recorded high value (27.56 % in winter at Marsa Shūni Lagoon), Hauerinidae observed high values at Abu-Shaar Lagoon in summer and winter respectively (22.8 % and 15.88 %), Spiroloculinidae (constituting 7.3 % in summer at Umm- al-Huwaytāt Lagoon) and Alveolinidae (constituting 4.13 % in summer at Abu-Shaar Lagoon) of the total investigated fauna. The Rotaliina include a high diversity of families (11 families) but each family is generally found in a small percentage, with the exception of the above mentioned Elphidiidae which represents the most abundant at all studied coastal lagoons especially at Umm-al-Huwaytāt lagoon (9.3%) in winter of the total investigated fauna (Figure 5).

In addition, the Miliolina involves a high diversity of species (58 species), two species are generally found in high percentage *Sorites marginalis* (Lamarck) and *Peneroplis planatus* (Fichtel & Moll) at all studied coastal lagoons (Tables 2 & 3; Figure 5). These species live in association with segrasses, which are widely distributed throughout the coastal lagoons especially in Marsa Shūni Lagoon where *Sorites marginalis* constituting 64.26 % in summer and 59.45 % in winter of the total investigated fauna (Tables 2 & 3; Figure 5) but have been found living on sediment substrata too. Other species showing widespread occurrence in summer and winter at the study areas are *Peneroplis pertusus* (Forskal); *Hauerina diversa* Cushman; *Borelis schlumbergeri* (Reichel); *Qinqueloculina mosharrafi* Said; *Spiroloculina angulata* Cushman; and *Quinqueloculina neostraitulata* Thlmann. The rotaliid *Ammonia beccarii* (Linne′) representing high values followed by the textulariid *Textularia aegyptica* Said.

Cluster analysis

Statistical computations (cluster analysis) were performed with the program SPSS using a hierarchical cluster analysis (Ward's method). Cluster analysis shows two clusters summer and winter clusters according to the abundance of foraminiferal species at the studied lagoons (Figures 6 & 7).

Summer cluster was carried out based on 77 variables of foraminiferal species according to the number of foraminiferal tests at 37 sediment samples in the studied coastal lagoons (Figure 6). Five main clusters were obtained based on number of foraminiferal tests distribution. Cluster 1 represents 35.13% of the total samples and characterized by the abundance of *Sorites marginalis*, *Peneroplis planatus, Peneroplis pertusus*, *Pesudomassilina pacificensis* and *Elphidium crispum*. Cluster 2 represents 32.43% of the total samples and characterized by the abundance of *Sorites marginalis*, *Peneroplis planatus, Peneroplis pertusus*, *Spiroloculina angulata* and *Hauerina diversa*. All samples in clusters 1 & 2 fall at Abu-Shaar and Umm- al-Huwaytāt Lagoons except one sample (1Mh) belongs to Marsa El-Shuni Lagoon. Cluster 3 represents 13.51% of the total samples and characterized by abundance of *Sorites marginalis, Peneroplis planatus, Peneroplis pertusus*, *Quinqueloculina mosharrafi* and *Hauerina diversa*. All samples of cluster 3 fall at Umm- al-Huwaytāt and Marsa El-Shuni Lagoons except one sample (Sh1) in Abu-Shaar Lagoon. Clusters 4 & 5 represent by 19.02% of the total samples and all samples belong to Marsa El-Shuni Lagoon except one sample (Sh15) in cluster 5 belongs to Abu-Shaar Lagoon. The characterizing foraminiferal species for clusters 4 & 5 are *Sorites marginalis* and *Peneroplis planatus* compared to the other clusters. The occurrence of *Sorites* in both seagrass and coral-dominated areas suggests an epifaunal mode of life on both rigid and flexible substrates, without pronounced seagrass preference (Haunold *et al*., 1997). The impression of an extremely high abundance of this genus seems to a result from overestimation of these large tests by visual inspection. *Peneroplis* samples have been described from beach sands of the Red Sea coast (Anan, 1984). *Peneroplis* is reported as living on both seagrass and sediment substrates (Bahafzallah, 1979), and this genus is also very abundant in Persian Gulf. Similarly, most of the *Peneroplis* samples in the coastal lagoons originate from seagrass and sediment substrates.

Winter cluster was carried out on 82 variables of foraminiferal species according to the number of foraminiferal tests at 32 sediment samples in the studied coastal lagoons. Four clusters were distinguished (Figure 7). Cluster 1 was consisting of 14 samples (43.75% of the total samples) and characterized by the abundance of *Sorites marginalis*, *Peneroplis planatus, Peneroplis pertusus*, *Hauerina diversa*, *Spiroloculina angulata, Ammonia beccarii*, *Elphidium advenum* and *Elphidium crispum*. All samples of cluster 1 represent mixture from three lagoons but Umm- al-Huwaytāt Lagoon recorded high number of samples (8 samples). Cluster 2 represents 12.5% of the total samples and characterized by the abundance of *Spiroloculina angulata, Peneroplis planatus, Peneroplis pertusus*, *Sorites marginalis*, *Ammonia beccarii* and *Elphidim advenum.* All samples in cluster 2 fall at Umm- al-Huwaytāt Lagoon. This cluster represents the lowest cluster compared with the other clusters. Clusters 3 & 4 represented by 43.76% of the total samples and all samples belong to Abu-Sharr and Marsa El-Shuni Lagoons. The characterizing foraminiferal species for cluster 4 are *Sorites marginalis, Peneroplis planatus* and *Borelis schlumbergeri* and *Textularia aegyptica*. *Sorites marginalis* recorded the highest values (712.1±75.9) in cluster 4 compared with the other clusters.

Generally, the results of cluster analysis indicate that the bottom facies represent the essential factor in separating the sediments of the studied localities.

3.3. Diversity of the studied foraminiferal assemblages

The diversity indices calculated from the samples of the studied coastal lagoons are given in (Tables 2 & 3). In summer, species diversity was calculated according to relative abundance, H'_N ranged from 1.38 at Marsa Shūni Lagoon to 2.58 at Abu-Shaart Lagoon (Figure 8). Sometimes H'_N is decreased with depth and distance of the shore and there is a progressive increase offshore. Species evenness index (J′) recorded the highest value 0.28 was found at Abu-Shaar Lagoon and the lowest value 0.15 at Marsa Shūni Lagoon (Figure 8). In winter, species diversity (H'_N) varied between 1.54 at Marsa Shūni lagoon and 2.46 at Umm - al-Huwaytāt Lagoon (Figure 8). In the same manner, the highest value of evenness index (J′) was recorded at Umm- al-Huwaytāt Lagoon while the lowest value at Marsa Shūni Lagoon. Species diversity (H'_N) and evenness index (J′) in Marsa Shūni Lagoon recorded the lowest values compared with Abu-Shaar Lagoon and Umm-al-Huwaytāt. On the other hand, the correlations between H'_N and J′ and number of species (S) is weak ($r = -0.37$, $r = -0.45$) respectively, while the correlation between H'_N and J′ was very strong ($r = 0.9$) at the studied coastal lagoons (Figure 9). In addition, the evenness index (J′) is very low. This implies that all the samples at the study areas are from somehow restricted environment.

Table 2. Distribution and frequency of the recent benthic foraminifera at the coastal lagoons in summer season.

No. G.	No. Sp.	Species	Abu-Shaar Sum	Abu-Shaar %	Umm al-Huwaytat sum	Umm al-Huwaytat %	Marsa El-Shuni sum	Marsa El-Shuni %
1	1	*Hypramina laevigata* Wright, 1891	…	…	3	0.04	…	…
	2	*Textularia aegyptica* Said, 1949	227	2.41	78	1.13	…	…
	3	*Textularia agglutinans* d' Orbigny, 1839	10	0.11	7	0.1	…	…
	4	*Textularia conica* d' Orbigny, 1839	3	0.03	…	…	…	…
2	5	*Textularia floridana* Cushman, 1922	6	0.06	…	…	…	…
	6	*Textularia foliacea* Heron-Allen & Earland, 1915	…	…	1	0.01	…	…
	7	*Textularia gramen* d' Orbigny, 1846	1	0.01	…	…	…	…
	8	*Textularia candeiana* d' Orbigny, 1839	…	…	1	0.01	…	…
	9	*Textularia magnifica* Lalicker & Bermudez, 1938	13	0.14	…	…	…	…
3	10	*Eggerella advena* (Cushman, 1922)	7	0.07	12	0.17	…	…
4	11	*Clavulina angularis* d' Orbigny, 1826	34	0.36	26	0.38	25	0.26
	12	*Clavulina tricarinata* d'Orbigny, 1826	4	0.04	1	0.01	…	…
5	13	*Vertebralina striata* d'Orbigny, 1826	21	0.22	12	0.17	1	0.01
	14	*Spiroloculina acescata* Cushman, 1932	…	…	4	0.06	…	…
	15	*Spiroloculina angulata* Cushman, 1917	117	1.24	427	6.2	75	0.77
	16	*Spiroloculina aperta* Cushman & Todd, 1944	2	0.02	…	…	…	…
6	17	*Spiroloculina rugosa* Cushman & Todd, 1944	1	0.01	…	…	…	…
	18	*Spiroloculina indica* Cushman & Todd, 1944	32	0.34	52	0.76	…	…
	19	*Spiroloculina communis* Cushman & Todd, 1944	…	…	18	0.26	…	…
	20	*Spiroloculina* sp.	20	0.21	2	0.03	2	0.02
	21	*Quinqueloculina agglutinans* d' Orbigny, 1839	152	1.61	19	0.28	42	0.43
	22	*Quinqueloculina angularis* d' Orbigny, 1826	7	0.07	2	0.03	2	0.02
	23	*Quinqueloculina bidentata* d' Orbigny, 1839	45	0.48	16	0.23	55	0.56
	24	*Quinqueloculina costata* d'Orbigny, 1826	1	0.01	1	0.01	…	…
	25	*Q. crassa d' Orbigny var. subcuneata* Cushman, 1921	4	0.04	…	…	…	…
	26	*Quinqueloculina laevigata* d'Orbigny, 1826	27	0.29	7	0.1	6	0.06
7	27	*Quinqueloculina lamarckiana* d' Orbigny, 1839	29	0.31	1	0.01	16	0.16
	28	*Quinqueloculina mosharrafi* Said, 1949	144	1.53	94	1.37	140	1.43
	29	*Quinqueloculina neostraitulata* Thalmann, 1950	362	3.85	134	1.95	42	0.43
	30	*Quinqueloculina partschii* d' Orbigny, 1846	11	0.12	2	0.03	…	…
	31	*Quinqueloculina pseudoreticulata* Parr, 1941	…	…	57	0.83	…	…
	32	*Quinqueloculina poeyana* d' Orbigny, 1839	17	0.18	16	0.23	5	0.05

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Table 2. continue

No. G.	No. Sp.	Species	Abu-Shaar Sum	Abu-Shaar %	Umm al-Huwaytat sum	Umm al-Huwaytat %	Marsa El-Shuni sum	Marsa El-Shuni %
	33	*Quinqueloculina quinquecarinata* Collins, 1958	4	0.04	…	…	…	…
	34	*Quinqueloculina seminulum* (Linne', 1758)	1	0.01	1	0.01	…	…
	35	*Quinqueloculina subpolygona* Parr, 1945	3	0.03	…	…	…	…
	36	*Quinqueloculina intricata* Terquem, 1878	…	…	2	0.03	…	…
	37	*Quinqueloculina sp.*	630	6.69	308	4.47	295	3.02
8	38	*Massilina secans* d'Orbigny, 1826	8	0.08	…	…	…	…
	39	*Massilina misrensis* Said, 1949	44	0.47	92	1.34	7	0.07
9	40	*Hauerina diversa* Cushman, 1946	178	1.89	198	2.88	104	1.06
10	41	*Flintina sidebottomi* (Martinotti, 1920)	…	…	1	0.01	1	0.01
11	42	*Milolinella circularis* (Bornemann, 1855)	1	0.01			…	…
	43	*Milolinella subrotnda* Montagu, 1803	…	…	6	0.09	…	…
12	44	*Pesudomassilina pacificensis* (Cushman, 1924)	344	3.65	42	0.61	42	0.43
	45	*Pesudomassilina australis* (Cushman) *var. reticulata (Heron-Allen & Earland, 1915)*	3	0.03	54	0.78	3	0.03
13	46	*Pyrgo laevis* Defrance, 1824	1	0.01	…	…	…	…
	47	*Pyrgo denticulata* (Brady, 1884)	1	0.01	2	0.03	…	…
	48	*Triloculina affinis* d'Orbigny, 1826	48	0.51	181	2.63	2	0.02
	49	*Triloculina asymmetrica* Said, 1949	76	0.81	1	0.01	…	…
14	50	*Triloculina irregularis* (d'Orbigny, 1826)	1	0.01	4	0.06	…	…
	51	*Triloculina quadrata* Collins, 1928	…	…	24	0.35	…	…
	52	*Triloculina tricarinata* d'Orbigny, 1826	…	…	3	0.04	…	…
14	53	*Trloculina trigonula* (Lamarck, 1804)	5	0.05	1	0.01	2	0.02
	54	*Triloculina* sp.	…	…	3	0.04	…	…
15	55	*Schlumbergerina alveoliniformis* Brady, 1884	3	0.03	…	…	1	0.01
16	56	*Articulina sagra* d'Orbigny, 1839	1	0.01	1	0.01	…	…
17	57	*Parrina bradyi* (Millett, 1898)	…	…	3	0.04	1	0.01
18	58	*Nodophthalmidium antillarum* (Cushman, 1922)	…	…	3	0.04	…	…
19	59	*Borelis schlumbergeri* (Reichel, 1937)	389	4.13	87	1.26	…	…
	60	*Peneroplis planatus* (Fichtel & Moll, 1798)	1081	11.48	914	13.28	1575	16.11
20	61	*Peneroplis pertusus* (Forskal, 1775)	679	7.21	393	5.71	581	5.94
	62	*Peneroplis cylindriceus* Lamarck, 1804	168	1.78	35	0.51	136	1.39
21	63	*Spirolina acicularis* (Batsch, 1791)	…	…	8	0.12	…	…
	64	*Spirolina arietina* (Batsch, 1791)	166	1.76	23	0.33	48	0.49
22	65	*Sorites marginalis* (Lamarck, 1816)	3664	38.92	2896	42.07	6283	64.26
23	66	*Eponides repandus* (Fichtel & Moll, 1798)	1	0.01	1	0.01	…	…
24	67	*Planulina cf. wuellerstorfi* (Schwager, 1866)	…	…	…	…	8	0.08
25	68	*Planorbulina mediterranensis* d'Orbigny, 1826	4	0.04	6	0.09	6	0.06
26	69	*Cymbaloporella tabelleformis* (Brady, 1884)	…	…	3	0.04	1	0.01
27	70	*Cymbaloporetta bradyi* (Cushman, 1915)	…	…	16	0.23	2	0.02
28	71	*Cibicides equipunctatus* Hofker, 1808	16	0.17	21	0.31	…	…
29	72	*Amphistigina lessonii* d'Orbigny, 1826	2	0.02	3	0.04	2	0.02
30	73	*Ammonia beccarii* (Linne', 1758)	174	1.85	173	2.51	146	1.49
31	74	*Calcarina calcar* d'Orbigny, 1826	26	0.28	48	0.7	22	0.22
32	75	*Eliphidum crispum* (Linne' 1758)	304	3.23	124	1.8	68	0.7
	76	*Eliphidum advenum* (Cushman, 1922)	90	0.96	207	3.01	31	0.32
33	77	*Operculina cumingii* Carpenter, 1860	…	…	3	0.04	…	…
Total number of species			9413		6884		9778	
Shannon and Winner Species diversity (H'N)			2.58		2.14		1.38	
Evenness index (J')			0.28		0.24		0.15	
Live %			21.29		7.32		6.01	
Dead %			78.71		92.66		93.99	
Total Foraminiferal number per gram sediments			7816		2143		4079	

Table 3. Distribution and frequency of the recent benthic foraminifera at the coastal lagoons in winter season.

No.	No.		Abu-Shaar		Umm al-Huwaytat		Marsa El-Shuni	
G.	Sp.	Species	sum	%	sum	%	sum	%
1	1	*Hypramina laevigata* Wright, 1891	…	…	1	0.016	…	…
	2	*Textularia aegyptica* Said, 1949	93	1.029	46	0.724	24	0.297
	3	*Textularia agglutinans* d'Orbigny, 1839	11	0.122	…	…	…	…
	4	*Textularia conica* d'Orbigny, 1839	8	0.089	…	…	…	…
2	5	*Textularia floridana* Cushman, 1922	5	0.055	…	…	…	…
	6	*Textularia foliacea* Heron-Allen & Earland, 1915	2	0.022	…	…	…	…
	7	*Textularia candeiana* d'Orbigny, 1839	2	0.022	…	…	…	…
	8	*Textularia magnifica* Lalicker & Bermudez, 1938	10	0.111	…	…	…	…
3	9	*Eggerella advena* (Cushman, 1922)	10	0.111	…	…	…	…
	10	*Clavulina angularis* d'Orbigny, 1826	29	0.321	17	0.268	34	0.421
4	11	*Clavulina parisiensis* d'Orbigny, 1826	2	0.022	…	…	1	0.012
	12	*Clavulina tricarinata* d'Orbigny, 1826	4	0.044	…	…	…	…
5	13	*Vertebralina striata* d'Orbigny, 1826	9	0.1	7	0.11	3	0.037
	14	*Spiroloculina acescata* Cushman, 1932	15	0.166	…	…	…	…
	15	*Spiroloculina angulata* Cushman, 1917	17	0.188	604	9.507	41	0.508
	16	*Spiroloculina aperta* Cushman & Todd, 1944	8	0.089	2	0.031	…	…
6	17	*Spiroloculina indica* Cushman & Todd, 1944	34	0.376	8	0.126	2	0.025
	18	*Spiroloculina communis* Cushman & Todd, 1944	22	0.243	74	1.165	…	…
	19	*Spiroloculina corrugata* Cushman & Todd, 1944	9	0.1	…	…	…	…
	20	*Spiroloculina faveolata* Egger, 1893	14	0.155	…	…	…	…
	21	*Spiroloculina* sp.	21	0.232	1	0.016	…	…
	22	*Quinqueloculina agglutinans* d'Orbigny, 1839	91	1.007	20	0.315	43	0.533
	23	*Quinqueloculina angularis* d'Orbigny, 1826	2	0.022	…	…	2	0.025
	24	*Quinqueloculina bidentata* d'Orbigny, 1839	17	0.188	1	0.016	40	0.496
	25	*Quinqueloculina costata* d'Orbigny, 1826	9	0.1	…	…	…	…
	26	*Q. crassa d'Orbigny var. subcuneata* Cushman, 1921	13	0.144	…	…	…	…
	27	*Quinqueloculina cf. ferussacii* d'Orbigny, 1826	1	0.011	…	…	…	…
	28	*Quinqueloculina laevigata* d'Orbigny, 1826	17	0.188	6	0.094	12	0.149
7	29	*Quinqueloculina lamarckiana* d'Orbigny, 1839	3	0.033	1	0.016	18	0.223
	30	*Quinqueloculina mosharrafi* Said, 1949	53	0.587	117	1.842	88	1.091
	31	*Quinqueloculina neostraitulata* Thalmann, 1950	132	1.461	139	2.188	17	0.211
	32	*Quinqueloculina partschii* d'Orbigny, 1846	3	0.033	…	…	…	…
	33	*Quinqueloculina pseudoreticulata* Parr, 1941	1	0.011	30	0.472	…	…
	34	*Quinqueloculina poeyana* d'Orbigny, 1839	35	0.387	19	0.299	5	0.062
	35	*Quinqueloculina seminulum* (Linne', 1758)	35	0.387	…	…	8	0.099
	36	*Quinqueloculina subpolygona* Parr, 1945	7	0.077	…	…	…	…
	37	*Quinqueloculina intricata* Terquem, 1878	…	…	6	0.094	…	…
	38	*Quinqueloculina oblonga* (Montagu, 1803)	…	…	…	…	2	0.025
	39	*Quinqueloculina* sp.	454	5.025	45	0.708	232	2.876
	40	*Massilina secans* d'Orbigny, 1826	3	0.033	…	…	…	…
8	41	*Massilina spinata* Cushman & Ponton, 1932	1	0.011	…	…	…	…
	42	*Massilina misrensis* Said, 1949	16	0.177	112	1.763	3	0.037
9	43	*Hauerina diversa* Cushman, 1946	218	2.413	272	4.281	108	1.339
10	44	*Flintina sidebottomi* (Martinotti, 1920)	1	0.011	1	0.016	…	…
11	45	*Milolinella circularis* (Bornemann, 1855)	2	0.022	…	…	…	…
	46	*Milolinella subrotnda* Montagu, 1803	3	0.033	3	0.047	…	…
	47	*Pesudomassilina australis* (Cushman)						
12		*var. reticulata* (Heron-Allen & Earland, 1915)	…	…	55	0.866	1	0.012
	48	*Pesudomassilina pacificensis* (Cushman, 1924)	187	2.07	30	0.472	35	0.434
13	49	*Pyrgo laevis* Defrance, 1824	2	0.022	…	…	…	…
	50	*Pyrgo denticulata* (Brady, 1884)	12	0.133	2	0.031	…	…
	51	*Triloculina affinis* d'Orbigny, 1826	22	0.243	235	3.699	…	…
	52	*Triloculina asymmetrica* Said, 1949	88	0.974	1	0.016	…	…
	53	*Triloculina irregularis* (d'Orbigny, 1826)	2	0.022	…	…	…	…
14	54	*Triloculina quadrata* Collins, 1928	1	0.011	…	…	2	0.025
	55	*Triloculina tricarinata* d'Orbigny, 1826	…	…	1	0.016	…	…
	56	*Trloculina trigonula* (Lamarck, 1804)	1	0.011	…	…	…	…
15	57	*Schlumbergerina alveoliniformis* Brady, 1884	1	0.011	…	…	…	…
16	58	*Articulina pacifica* Cushman, 1944	…	…	2	0.031	…	…
	59	*Articulina sagra* d'Orbigny, 1839	1	0.011	1	0.016	…	…
17	60	*Parrina bradyi* (Millett, 1898)	2	0.022	…	…	…	…
18	61	*Nodophthalmidium antillarum* (Cushman, 1922)	1	0.011	7	0.11	…	…
19	62	*Borelis schlumbergeri* (Reichel, 1937)	317	3.509	122	1.92	1	0.012
	63	*Peneroplis planatus* (Fichtel & Moll, 1798)	863	9.552	1030	16.213	1325	16.423
20	64	*Peneroplis pertusus* (Forskal, 1775)	496	5.49	330	5.194	685	8.49
	65	*Peneroplis cylindriceus* Lamarck, 1804	124	1.372	16	0.252	158	1.958
21	66	*Coscinospira hemprichi* Ehrenberg, 1839	3	0.033	…	…	…	…

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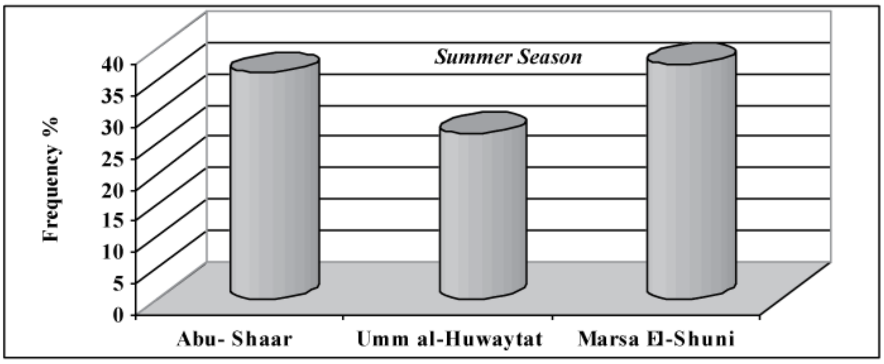
Table 3. continue

No. G.	No. Sp.	Species	Abu-Shaar sum	Abu-Shaar %	Umm al-Huwaytat sum	Umm al-Huwaytat %	Marsa El-Shuni sum	Marsa El-Shuni %
22	67	*Spirolina acicularis* (Batsch, 1791)	…	…	17	0.268	…	…
	68	*Spirolina arietina* (Batsch, 1791)	112	1.24	15	0.236	56	0.694
23	69	*Sorites marginalis* (Lamarck, 1816)	5058	55.982	2004	31.544	4796	59.445
24	70	*Amphisorus hemprichii* Ehrenberg, 1839	73	0.808	…	…	…	…
25	71	*Rosalina globularis* d'Orbigny, 1826	…	…	…	…	1	0.012
26	72	*Planorbulina mediterranensis* d'Orbigny, 1826	…	…	…	…	14	0.174
27	73	*Cymbaloporella tabelleformis* (Brady, 1884)	…	…	15	0.236	…	…
28	74	*Cymbaloporetta bradyi* (Cushman, 1915)	2	0.022	7	0.11	2	0.025
29	75	*Cibicides equipunctatus* Hofker, 1808	11	0.122	7	0.11	1	0.012
30	76	*Amphistigina lessonii* d'Orbigny, 1826	…	…	7	0.11	2	0.025
31	77	*Ammonia beccarii* (Linne', 1758)	76	0.841	284	4.47	117	1.45
32	78	*Calcarina calcar* d'Orbigny, 1826	44	0.487	40	0.63	49	0.607
	79	*Eliphidum crispum* (Linne' 1758)	73	0.808	252	3.967	106	1.314
33	80	*Eliphidum advenum* (Cushman, 1922)	19	0.21	339	5.336	34	0.421
	81	*Eliphidum jenseni* (Cushman, 1933)	2	0.022	…	…	…	…
34	82	*Operculina cumingii* Carpenter, 1860	…	…	2	0.031	…	…
Total number of species			9035		6353		8068	
Shannon and Winner Species diversity (H'N)			1.98		2.46		1.54	
Evenness index (J')			0.22		0.28		0.17	
Live %			18.46		4.66		11.51	
Dead %			81.54		95.27		88.49	
Total Foraminiferal number per gram sediments			12752		1962		3456	



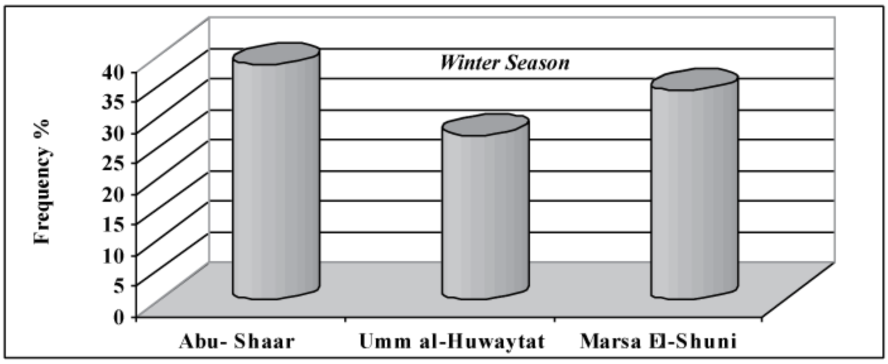


Figure 2. Frequency distribution of foraminiferal taxa throught the studied coastal lagoons.

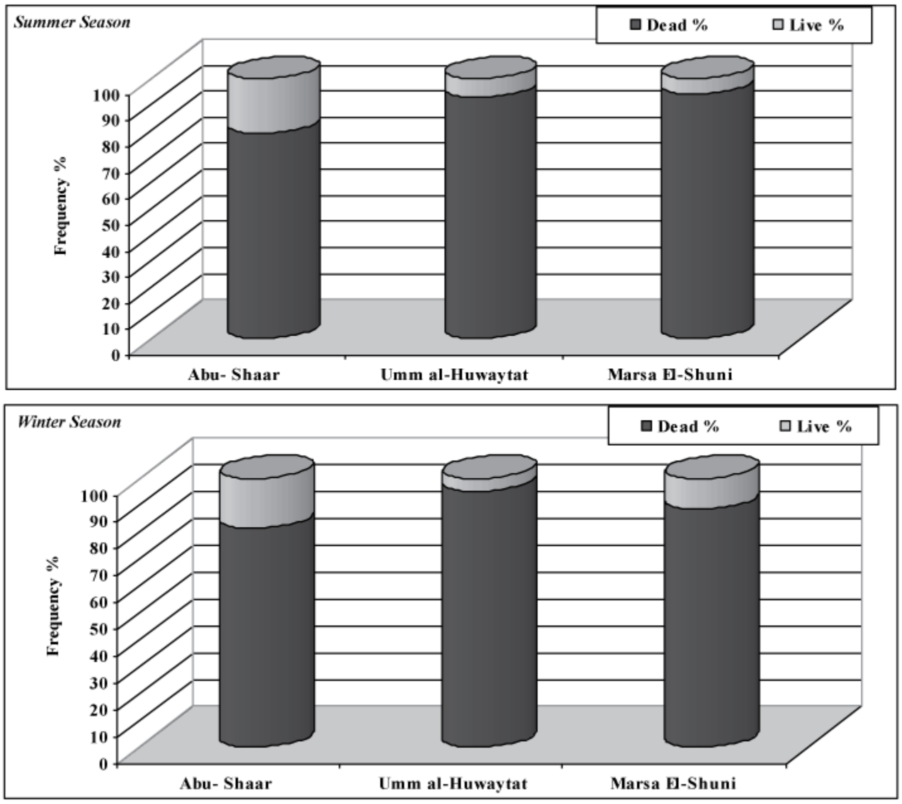


Figure 3. Frequency distribution of dead and alive foraminiferal taxa at the studied coastal lagoons.

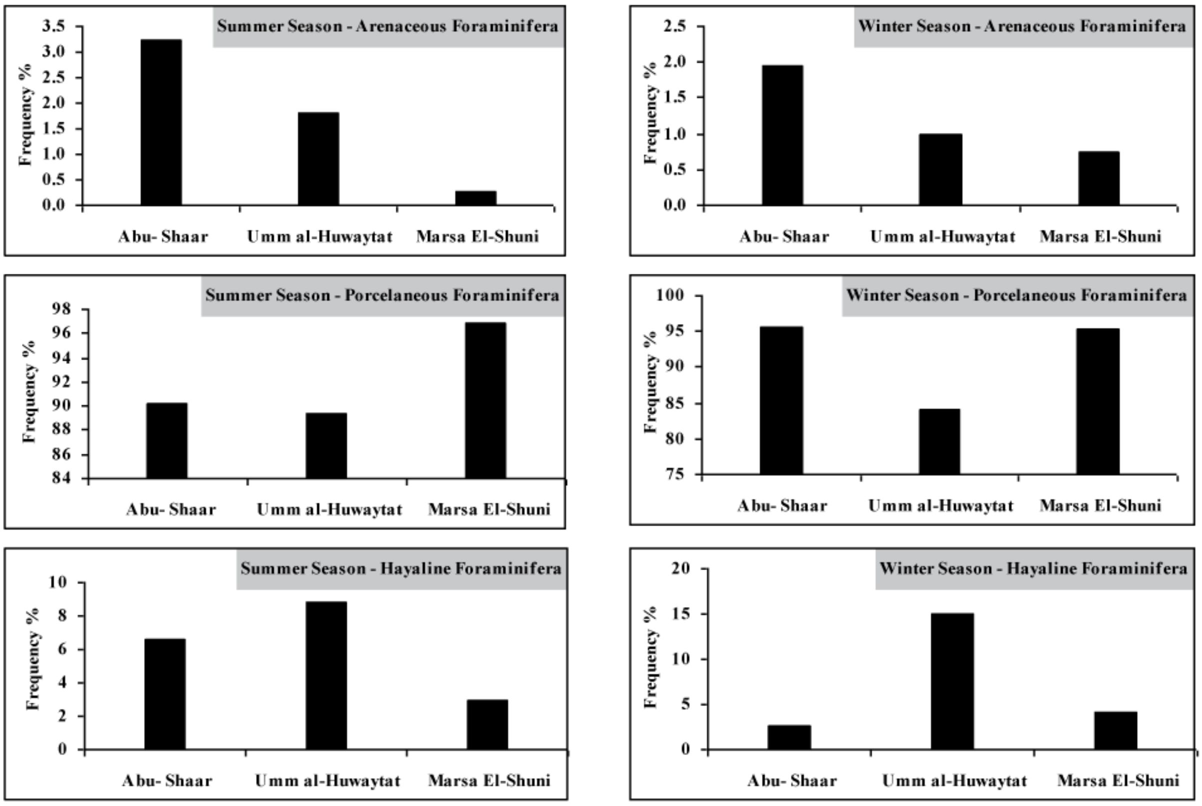


Figure 4. Frequency distribution of foraminiferal groups in summer and winter seasons at the studied coastal lagoons.

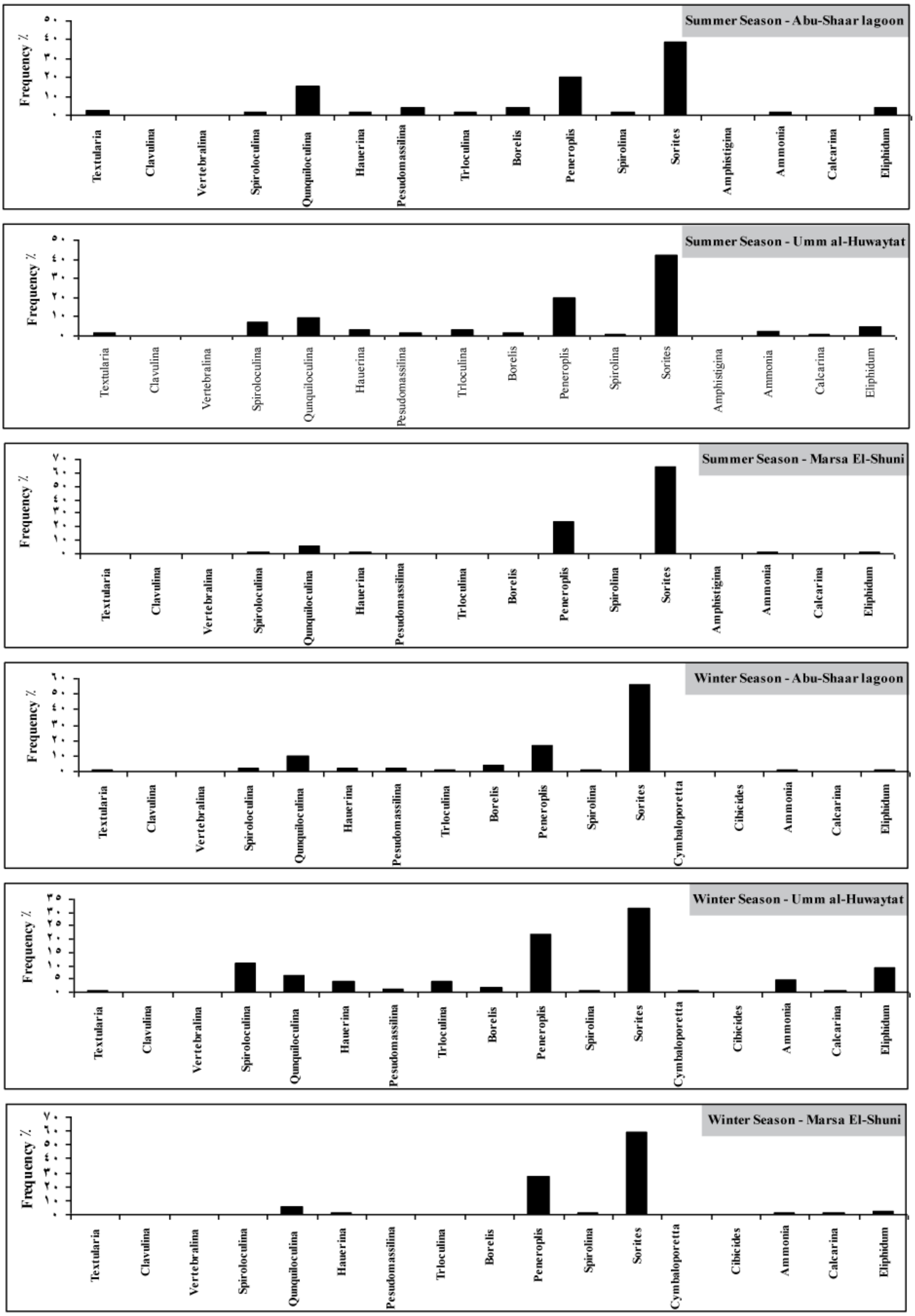


Figure ٥. Frequency distribution of foraminiferal genera of summer and winter seasons at the studied coastal lagoons.

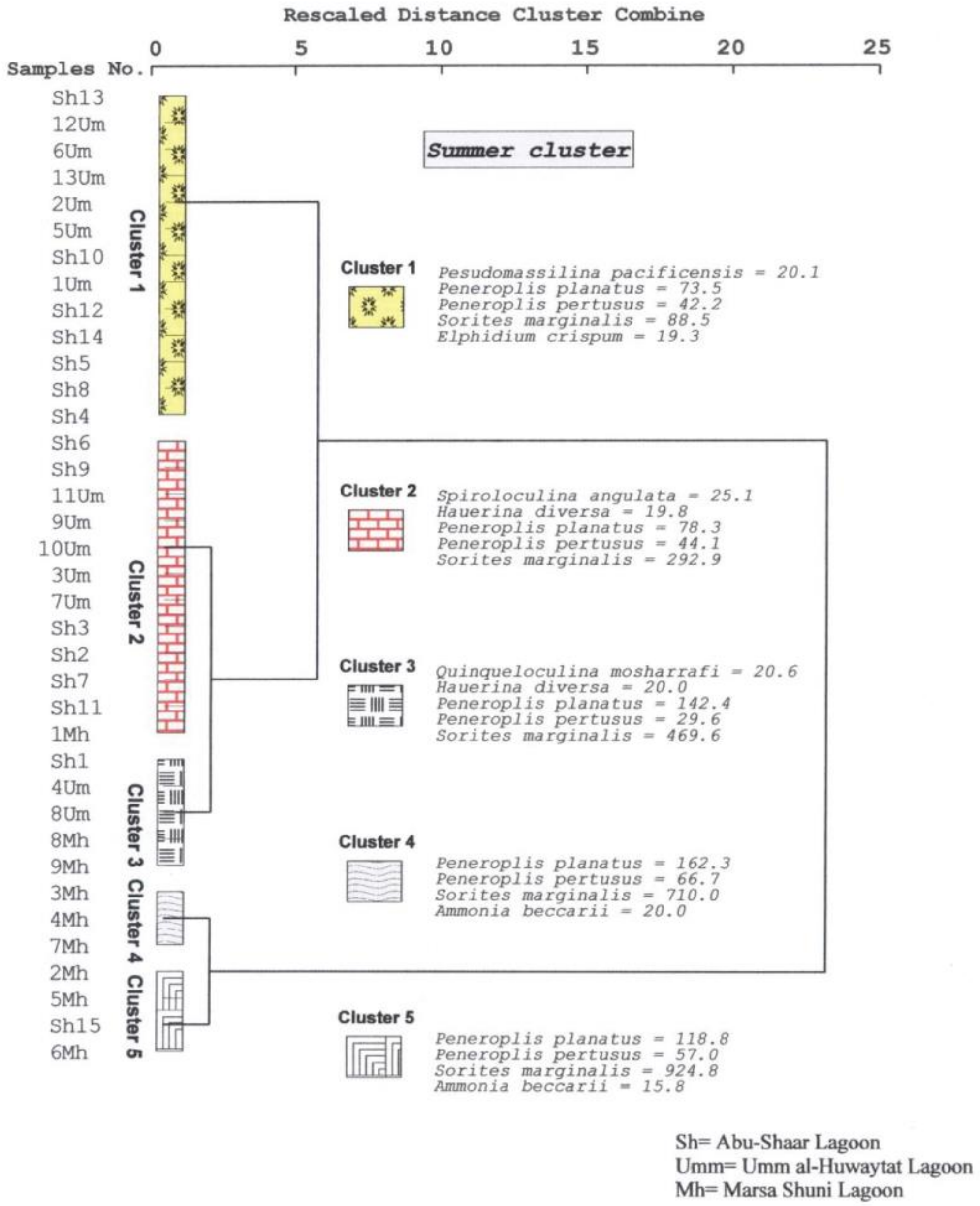


Figure ٦. Dendrogram from cluster analysis (Ward's method) exhibiting ٥ clusters each corresponding to a benthic foraminiferal species from the study coastal lagoons in summer season.

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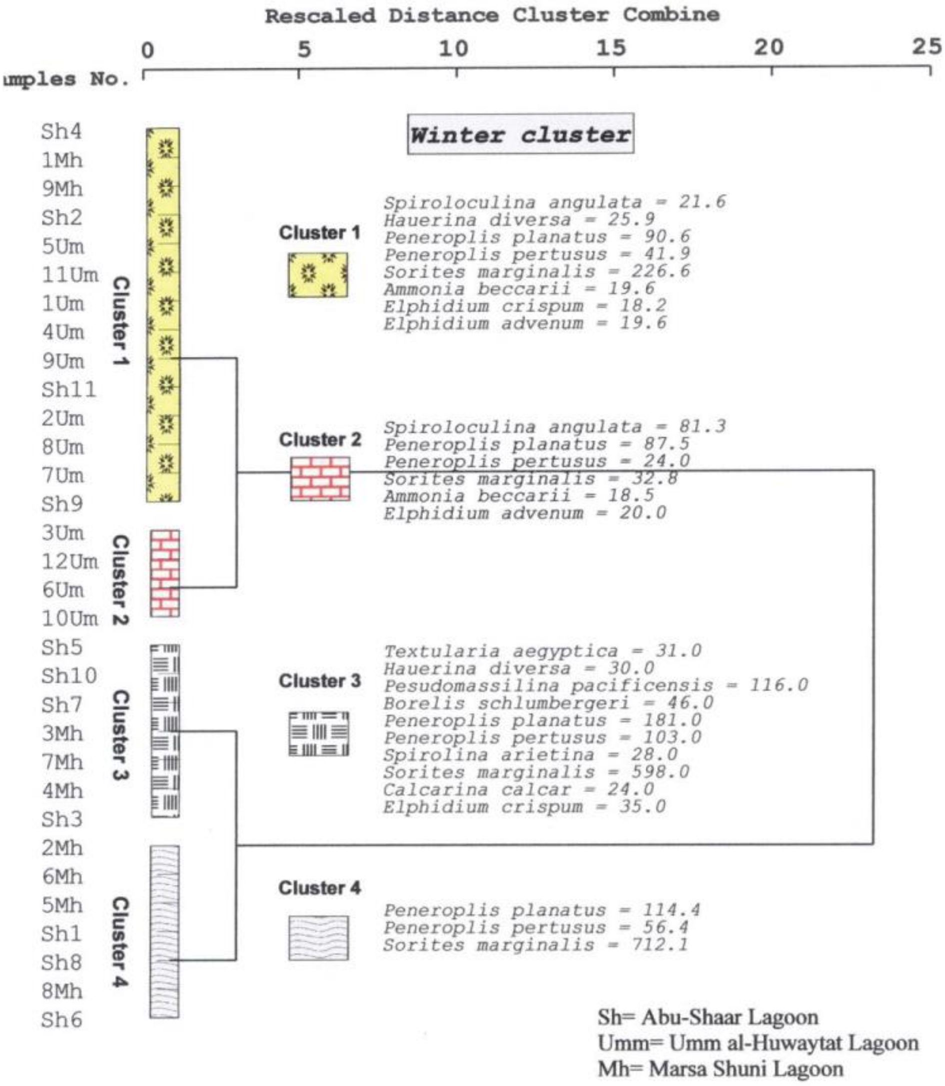

Figure 7. Dendrogram from cluster analysis (Ward's method) exhibiting 4 clusters each corresponding to a benthic foraminiferal species from the study coastal lagoons in winter season.

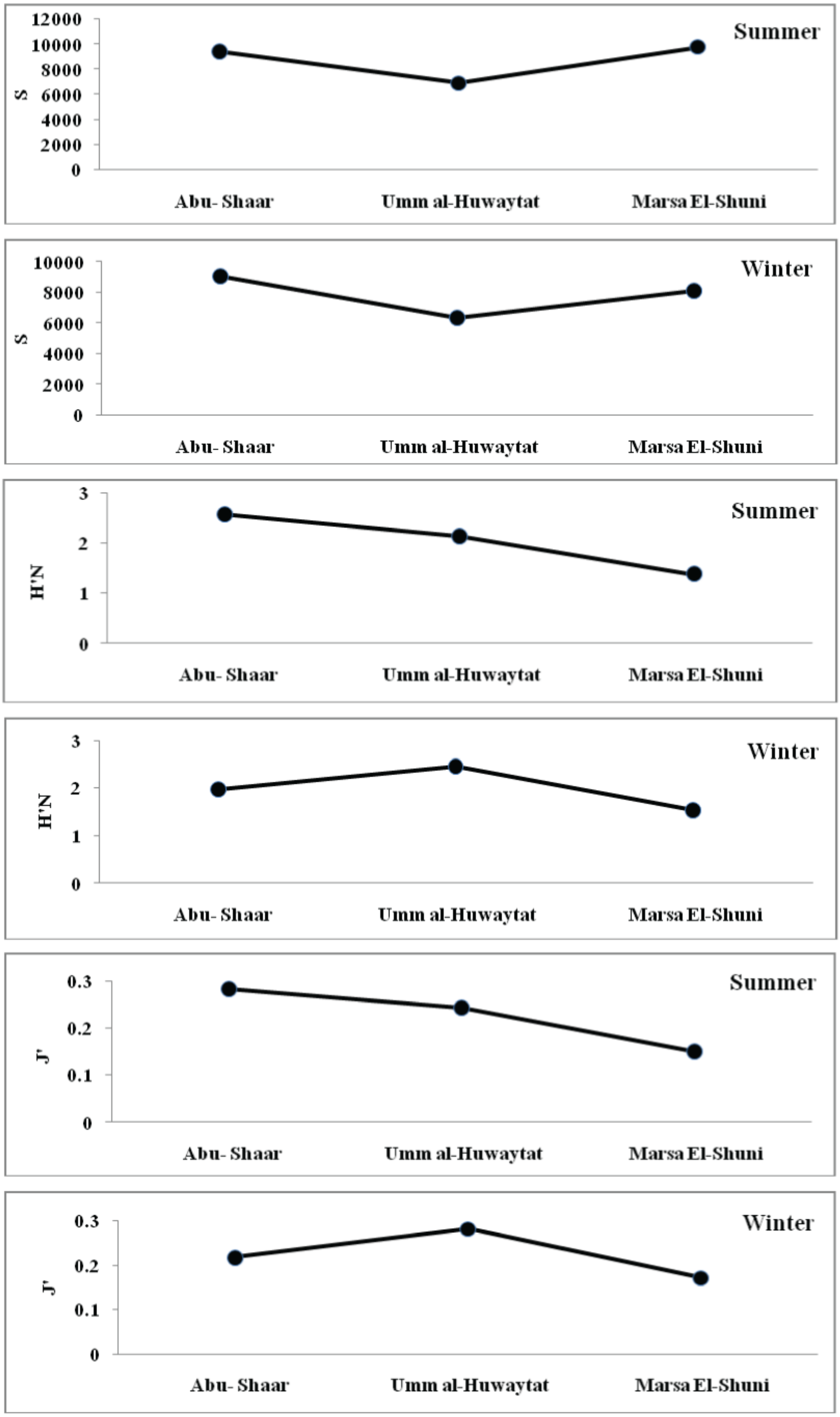

Figure ٨. Shannon species diversity according to relative abundance (H'_N), evenness index (J') and number of species (S) in summer and winter seasons at the studied coastal lagoons.

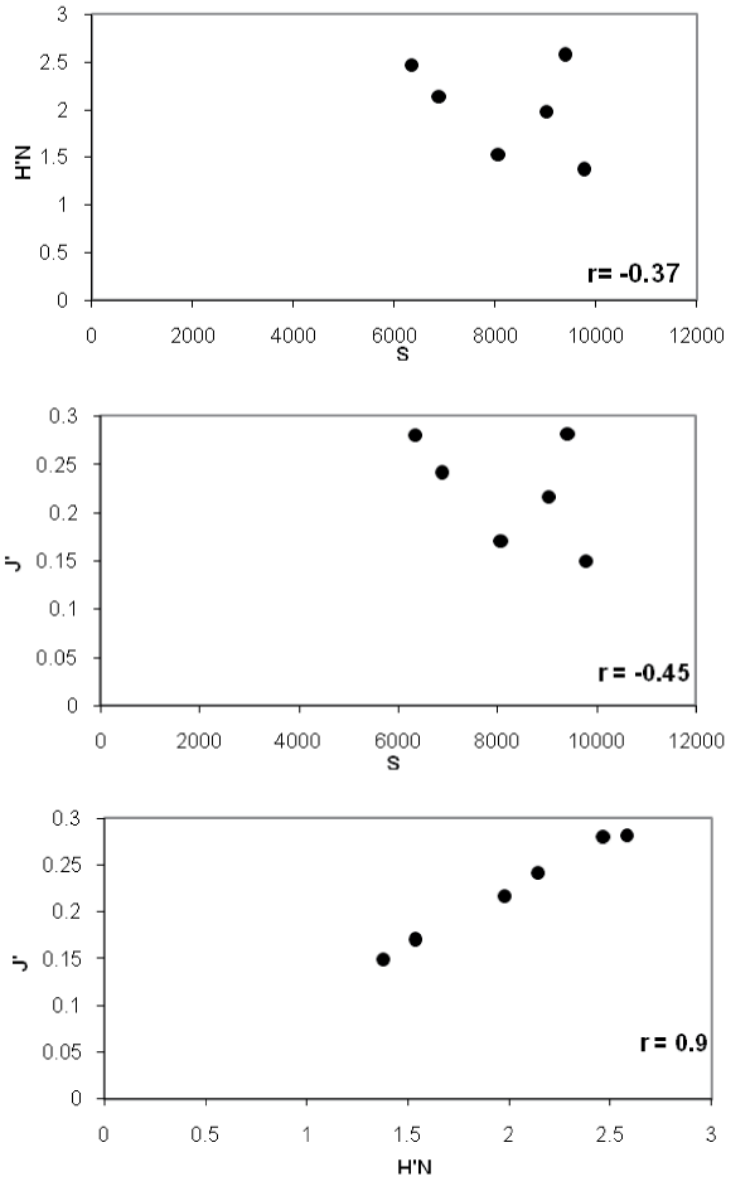

Figure ٩. Correlations coefficients between number of species (S), species diversity (H'_N) and evenness index (J') at the studied samples of coastal lagoons.

4. Conclusions

Sixty-nine samples have been collected in summer 2003 & winter 2004 and studied from three coastal lagoons along the Egyptian Red Sea coast. These localities, namely: Abu-Shaar Lagoon, Umm al-Huwaytāt Lagoon and Marsa Shuni Lagoon. The most important conclusions of this investigation can be summarized as follows:

1. The area sampled in this study is moderately hypersaline, has a small temperature variation and varied from sediment floored to seagrass covered. Moreover, the occurrence of recent foraminifera in such areas depends on numerous physical factors including lithology of sediments, salinity, water temperature, dissolved oxygen and organic concentrations, as well as bathymetry.

2. The foraminiferal fauna of the studied localities include 77 species in summer and 82 species in winter belonging to 36 genera and 22 families. The benthic foraminifera are distinguished by one suborder; Miliolina while Rotaliina and Textulariina are rare. The highest percentage of foraminfera is present at Abu-Shaar and Marsa Shuni Lagoons in summer and winter seasons comparable with that of Umm al-Huwaytāt Lagoon. The porcelianeous foraminifera of the total foraminifera are the most abundant in the different environments and are generally preponderant in summer and winter at all studied localities.

3. The dominant species of the suborder Miliolina include *Sorites marginalis* and *Peneroplis planatus* while the suborder Rotaliina is dominated by *Ammonia beccariia* and *Elphidium crispum*. *Sorites marginalis* representing large sized species have been recorded within narrow geographical limits during the investigations of this study. Individuals belonging to *Sorites marginalis* live particularly in seagrass beds where they expel their tests particularly at Marsa Shuni Lagoon where the density of seagrass is very high represents green rug covering. The relationship between the abundance and distribution of the benthic foraminifera in the different size fractions proved that *Sorites* are concentrated in the coarser fraction while *Elphidium* and *Ammonia* are abundant in the finer fraction. Moreover, an increasing proportion of *Sorites* and *Penreroplis* is a reflection of warmer climatic conditions.

4. The dead assemblages of foraminifera do not show a great deal of variation because of the broadly uniform environment. The living assemblages, although not identical with any of the seasonal dead assemblages, nevertheless recorded very faithfully the general distribution of the dead species. Generally, the abundance of the dead assemblages is much more than of any of the living assemblages.

5. Species diversity has been calculated in the studied localities using two different indices of diversity. Shannon species diversity (H'_N) has been calculated according to relative abundance. It has its maximum at Abu-Shaar Lagoon and minimum one at Marsa Shuni lagoon. The strong correlation between (H'_N) and (J') has been recorded while the correlation between (H'_N) and (S) is weak at the studied localities. Both the number of species (S) and the evenness index (J') are sensitive indicators of species diversity (H'_N) at the areas under study.

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References

Abou Ouf, A.: 1992, Benthic foraminifera in carbonate facies of a coastal sabkha, Red Sea, Saudi Arabia. *Marine Geology,* 104: 187-191.

Abou Ouf, M. and El-Shater, A.: 1993, Black benthic foraminifera in carbonate facies of a coastal sabkha, Saudi Arabia, Red Sea coast. *J. K. A. U. Marine Science,* 4: 133-141.

Abou Ouf, M.; Durgaprasada Rao, N.V. and Taj, R.: 1988, Benthic foraminifera from littoral sediments of Al Lith- Al Qunfidhah coast, South eastern Red Sea. *Indian Journal of Marine Science*.17: 217-221.

Anan, H. S.: 1984, Littoral recent foraminifera from the Quseir-Marsa Alam stretch of the Red Sea coast, Egypt. *Rev. De. Paléobiol.,* 8 / 2 : 26- 284.

Aref, M. and Madkour, H.A.: 1999, Assemblages distribution and species diversity of benthic foraminifera in the upper continental shelf along the Red Sea, Egypt. The First International Conference on the Geology of Africa, Assiut, Egypt. pp: 27- 54.

Aref, M. and Madkour, H.A.: 2000, Recent benthic foraminifera of the Egyptian Red Sea coast, their taxonomy, ecology and cooperative studies with that of the Eastern Mediterranean Sea. *Egyptian Journal of Geo*logy, 44(1): 257-286.

Azazi, G.: 1990, Recent sea floor benthic foraminiferal analysis from the Gulf of Suez, Egypt. Studies in Benthic Foraminifera, BENTHOS'90, Sendai: 135 - 149.

Badawi, A. F. M.: 1997, Planktic foraminifera as paleoecological indicators in the northern Red Sea. M. Sc. Thesis, Alexandria Univeristy, 81p.

Bahafzallah, A.A.K.: 1979, Distribution, Ecology and systematics of Recent benthic foraminifera from Jeddah Bay, Red Sea. Ph.D. Thesis, Univeristy of Bristol, London, 219 p.

Bahafzallah, A.A.K. and El-Askkary, M.A.: 1981, Sedimentological and Micropaleontological investigations of the beach sands around Jeddah, Saudi Arabia. *Bulletin of Faculty of Earth Science, K.A.U.,* 4: 25-42.

Buzas, M.A., and T.G. Gibson.: 1969, Species diversity: Benthic foraminifera in Western North Atlantic. *Science*, 163: 72-75.

El-Deeb, W. Z. M.: 1978, Ecological studies on foraminifera in Recent marine sediments of the Northern Red Sea .M.Sc. Thesis, Ain Shams Univeristy, Egypt, 304 p.

El-Nakhal, A. H.: 1980, Recent foraminifera from the sea shores of Yemen Arab Republic, pl. (1). The genus *Quinqueloculina*. *Journal of Science Collection, Riyadh Univeristy,* 2: 147-170.

Haunold, T. G.; Baol, C. and Piller, W. E.: 1997, Benthic foraminiferal association in the Northern Bay of Safaga, Red Sea, Egypt. *Marine Micorpaleontology* 29 : 85-210. Wien. Austria.

Loeblich, A. R. and Tappan, Jr.: 1988, Foraminiferal genera and their classification. Department of Earth and Space Science, Center for the Study of Evolution and the Origin of life, Uni. of California, Los Angeles, U.S.A., 790 p.

Madkour, H. A.: 2000, Studies on the benthic foraminifera in the recent marine sediments of the upper continental shelf of Red Sea, Egypt. M.Sc. Thesis, South Valley Univ eristy, Qena, 276 p.

Madkour, H. A.: 2004, Geochemical and environmental studies of recent marine sediments and some invertebrates of the Red Sea, Egypt. Ph.D. Thesis, South Valley Univ eristy, Qena, 319 p.

Madkour, H. A., and Ali, M. Y. : 2009, Heavy metals in the benthic foraminifera from the coastal lagoons, Red Sea, Egypt: Indicators of anthropogenic impact on environment (case study). *Environmental Geology,* 58: 543–553.

Mansour, A. M., Nawar, A. H., and Madkour, H. A.: 2005, Metals concentration of recent invertebrates along the Red Sea Coast of Egypt: A Tool for monitoring environmental hazards. *Sedimentology of Egypt,* 13:171-185.

Montaggioni, L. F., Behairy, A. K. A., El Sayed, M. K. and Yusuf, N.: 1986, The modern reef complex, Jaddah area, Red Sea: a facies model for carbonate sedimentation on embryonic passive margins, *Coral Reefs*, 5: 127-150.

Piller, W. E.: 1994, The Northern Bay of Safaga (Red Sea, Egypt):an actuopalaeontoligical approach, IV. Thin section analysis. *Beitr. Paläontol*ogy,18:1-73.

Pielou, E. C.: 1966a, The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology,* 13: 131-144.

Pielou, E. C.: 1966c, Species diversity and patterns-diversity in the study of ecological succession. *Journal of Theoretical Biology*, 10: 370-383.

Obaidalla, N.: 1988, Recent invertebrates along the Red Sea Coastal Plain between Marsa Alam and Ras Banas. M.Sc. Thesis, Assiut university, 239 p.

Ouda, Kh. and Obaidalla, N.: 1998, Ecology and distribution of recent subtidal foraminifera along the Rgyptian Red Sea shore, between Mersa Alam and Ras Banas. *Revista Espanola De Micropaleontologia*, 303): 11-34.

Said, R.: 1949, Foraminifera of the Northern Red Sea. Special Publications Cushman Laboratory for Foraminiferal Research, 26: 1-44.

Said, R.: 1950a, Additional foraminifera from the northern Red Sea. Cushman Found. Foram. Res. Contr. I; 5-9.

Said. R.: 1950b, The distribution of foraminifera in the Northern Red Sea. Contrib. Cushman Found. *Journal of Foraminiferal Research*, 1: 9-29.

Shannon, C. E. and Wiener, W.: 1948, The mathematical theory of communication. Urbana, Illinois Univ., Press.

Yusuf, N.: 1984, Distribution of Benthic foraminifera in the sediments of Eastern Red Sea between Jeddah and Yanbu Proc. Symp. Coral Reef Environmental Red Sea, Jeddah: 216-232.