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Living benthic foraminifera around the Umm al Maradim Island (Kuwait)

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Abstract

The present investigation focuses on the unique Island of Umm al Maradim that represents the largest and southernmost coral island in Kuwait. Thirty-seven stations around the Island were sampled for living benthic foraminiferal analyses. Relatively high values of diversity for both total and living assemblages, 101 and 96 species, respectively, have been documented. These figures are sensibly higher than those documented in most of the previous studies around Kuwait territorial waters. Porcelaneous test in terms of abundance dominates the foraminiferal assemblages followed by hyaline tests and only a minor part of the assemblages was represented by agglutinated foraminifera. The high dominance of porcelaneous tests might be explained by the peculiar physiographic setting and the presence of coral reef around the Island. Very low foraminiferal abundances were associated with shallower environments, like the subtidal zone around the island, whereas higher values were found at deeper and more distal stations. Planispiral morphotypes were found dominant at the more shallow-proximal stations, while milioline morphotypes dominated at intermediate depth and trochospiral morphotypes were more abundant at greater water depth. This paper contributes towards the documentation of benthic foraminiferal diversity around the islands in the Kuwait territorial water.

Keywords: Benthic foraminifera; cluster analysis; diversity; Kuwait; Umm al Maradim Island

1. Introduction

Foraminifera, single-celled organisms, inhabit a wide range of marine environments, from the intertidal zone to the deep sea. Recent benthic foraminifera and their ecology have been extensively studied in the Arabian Gulf (See Cherif *et al.*, 1997; Arslan *et al.*, 2016). On the other hand, few studies have been performed on recent benthic foraminifera from Kuwait coastal water. These marine environments include the Sulaibikhat Bay (Al-Zamel *et al*. 2009; Al-Enezi & Frontalini, 2015), the subtidal zones of the western part of the Shatt Al-Arab Delta (Al-Zamel & Cherif, 1998), tidal creeks in Khor AI-Mufateh and Khor Al-Mamlaha in the southeast of Kuwait (Al-Zamel *et al.*, 1996) and a carbonate ramp located offshore Kuwait (Parker & Gischler, 2015). Most of these studies have focused on the total assemblages and rarely on the distribution of living benthic foraminiferal assemblages. Furthermore, previous researches have been mainly conducted in the northern marine environments of Kuwait. In the context of recording the overall Kuwaiti benthic foraminiferal diversity and species' distribution, this study was conducted to document the benthic foraminiferal diversity and the assemblages' distribution around the poorly known Umm al Maradim Island (Kuwait).

2. Study area

Umm al Maradim Island covers an area of 65 ha and is located in the southeastern part of the Arabian Gulf in Kuwait territorial waters (28°40′21.40″ N 48°39′28.42″E) near the latitude of the Kuwait-Saudi Arabian border (Figure 1a). Unlike the other northern Kuwaiti islands, Umm al Maradim is surrounded by deep waters that enable ships to land directly at its shores. The surrounding rift is dominated by a massive stand of Porites corals and small colonies of branching Acropora and Stylophora (Al-Yamani *et al*., 2004). The beach of the island is dominated by carbonate grain shell and shell fragments, pelycepods, gastropods, echinoid spines, coralline algal, quartz and heavy minerals (Al-Ghadban *et al.*, 1994). The marine biota around the island has been scarcely studied.

3. Materials and Methods

3.1 Sampling

Thirty-seven sediment samples were collected using a box-corer along 8 transects around the Umm Al-Maradim Island (Figure 1b) on June 2000. Water depth at collection sites ranged between 1 and 35.1 m. The uppermost parts of sediment (2 cm) were stored in polyethylene jars. Physico-chemical parameters (salinity, pH, dissolved oxygen (DO), turbidity, conductivity and

temperature) were measured using a Hureba system.

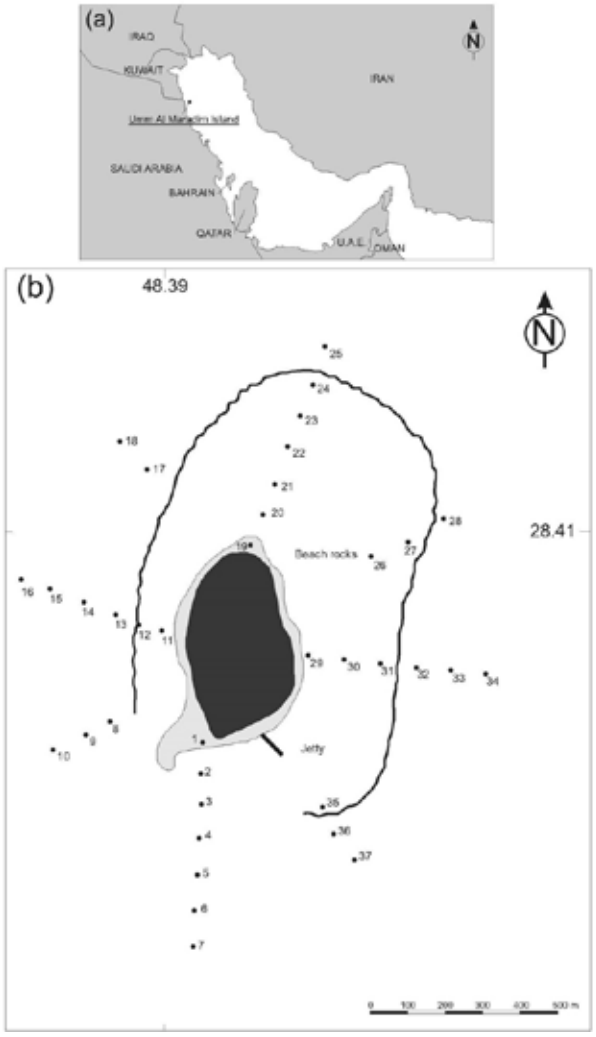

Fig. 1. (a) Location of Umm al Maradim Island. (b) Sampling station around the island

3.2 Grain-size analysis

The sediment analyses were performed following the Regional Organization for the Protection of the Marine Environment (ROPME) method (1999). The statistical size parameters were calculated following the procedure of Folk & Ward (1957).

3.3 Benthic foraminiferal analysis

Immediately after sampling, an aliquot of 20 cm3 was treated with a rose Bengal solution (2 g/L) h to distinguish between living and dead foraminifera. Quantitative analyses on benthic foraminifera were performed on the fraction >125 µm. A total of 300 specimens of living and 300 ones of dead assemblages were hand-picked for taxonomical analysis. In this study, the suprageneric classification of WoRMS (2016) was largely followed. Several foraminiferal parameters including species diversity (S), the Fisher α index, the Shannon-Weaver index or information function (H'), evenness (J); and equitability (E) were calculated using the Paleontological Statistics Software Package (PAST).

3.4 Statistical analysis

Stations containing at least 100 specimens in the living assemblages were retained for the statistical analyses. Only species with a relative abundance greater than 5% in at least one sample were included in the statistical treatment. The relative abundances of taxa were logarithmically normalized log(1+X) prior to statistical analysis. Q- and R-modes Cluster Analysis (CA) were carried out by adopting the Ward's linkage method and given in terms of the Euclidean distance using Statistica 7.0.

4. Results

4.1 Physico-chemical parameters and grain-size

Figure 2 shows the sample areas and depths. The salinity averaging 37.8 ranged from 37.5 to 38.1. The pH and DO showed only minor fluctuations among the sampling stations ranging from 8.08 to 8.14 and from 6.41 to 6.89 mg/l, respectively. Higher values of DO were documented around the western and southwestern parts of the island. The island is dominated by a sand-size fraction ranging from 56.3% to 99.3%. Gravel and mud represented only minor parts of sediments and accounted on average for 14.7% and 0.2%, respectively. Higher sand contents were normally found around the southeastern and northwestern parts of the island.

4.2 Benthic foraminiferal diversity and suprageneric classification

A total of 101 benthic foraminiferal species belonging to 48 genera were identified in the total assemblages (Table 1). Following WoRMS (2016), 5 orders of benthic foraminifera were found on Umm al Maradim Island. These include: Lituolida, Textulariida, Miliolida, Lagenida and Rotaliida (Table 1).

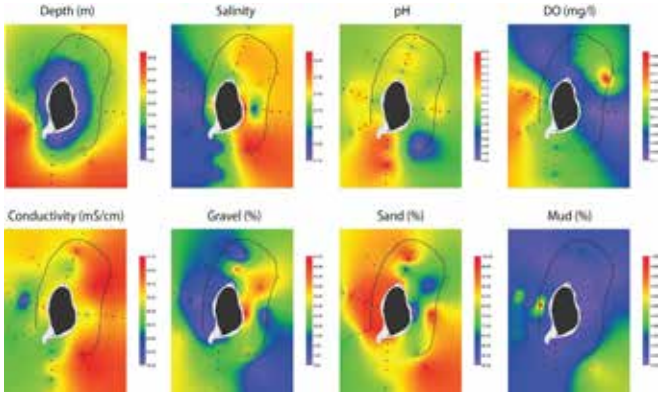

Fig. 2. Water depth, Physico chemical, Grain-size parameters' distribution

Table 1. Generic and suprageneric classification of benthic foraminiferal taxa recognized around Umm al Maradim Island

Order	Superfamily	Family	Genus	Species
Lituolida	Lituoloidea	Lituolidae	*Ammobaculites*	*Ammobaculites agglutinans*
Textulariida	Textularioidea	Textulariidae	*Sahulia*	*Sahulia barkeri*
			Textularia	*Textularia porrecta*
				Textularia cf. *occidentalis*
Miliolida	Nubecularioidea	Fischerinidae	*Vertebralina*	*Vertebralina striata*
		Ophthalmidiidae	*Edentostomina*	*Edentostomina rupertiana*
	Milioloidea	Cribrolinoididae	*Adelosina*	*Adelosina carinatastriata*
				Adelosina intricata
				Adelosina longirostra
				Adelosina mediterrranensis
				Adelosina partschi
				Adelosina pulchella
				Adelosina sp. 1
				Adelosina sp. 2
				Adelosina sp. 3
		Spiroloculinidae	*Spiroloculina*	*Spiroloculina angulata*
				Spiroloculina antillarum
				Spiroloculina carinata
				Spiroloculina excavata
				Spiroloculina nummiformis
		Haueriniidae	*Pseudolachlanella*	*Pseudolachlanella eburnea*
			Siphonaperta	*Siphonaperta dilatata*
				Siphonaperta distorqueata
				Siphonaperta sp. 1
			Varidentella	*Varidentella neostriatula*
			Cycloforina	*Cycloforina contorta*
				Cycloforina macerata
				Cycloforina quinquecarinata
				Cycloforina sidebottomi
			Hauerina	*Hauerina* sp. 1
			Lachlanella	*Lachlanella cooki*
			Massilina	*Massilina* sp. 1
			Quinqueloculina	*Quinqueloculina agglutinans*
				Quinqueloculina akneriana
				Quinqueloculina bicarinata
				Quinqueloculina corrugata
				Quinqueloculina crassicarinata
				Quinqueloculina mosharrafai
				Quinqueloculina poeyana
				Quinqueloculina stelligera
				Quinqueloculina seminula
				Quinqueloculina schlumbergeri
				Quinqueloculina subcarinata
				Quinqueloculina variolata
				Quinqueloculina sp. 1
				Quinqueloculina sp. 2
				Quinqueloculina sp. 3
				Quinqueloculina sp. 4
			Affinetrina	*Affinetrina planciana*
			Flintinoides	*Flintinoides labiosa*
			Triloculinella	*Triloculinella dilatata*
			Miliolina	*Miliolina peregrina*
				Miliolina sp. 1
			Miliolinella	*Miliolinella subrotunda*
			Pseudomassilina	*Pseudomassilina robusta*
			Pseudotriloculina	*Pseudotriloculina granulocostat*
				Pseudotriloculina sp. 1
			Ptychomiliole	*Ptychomiliola* sp. 1
			Triloculina	*Triloculina barnardi*
				Triloculina marioni
				Triloculina schreiberiana
				Triloculina tricarinata
				Triloculina trigonula
				Triloculina sp. 1
			Biloculinella	*Biloculinella wiesneri*
			Varidentella	*Varidentella* sp. 1
				Varidentella sp. 2
			Articulina	*Articulina alticostata*
			Ishamella	*Ishamella apertura*
	Miliolacea	Riveroinidae	*Pseudohauerinella*	*Pseudohauerinella orientalis*
Lagenida	Nodosarioidea	Lagenidae	*Procerolagena*	*Procerolagena oceanica*
			Lagena	*Lagena spirata*
			Polymorphinid	Polymorphinid
Rotaliida	Bolivinitoidea	Bolivinitidae	*Parabrizalina*	*Parabrizalina porrecta*
			Sagrinella	*Sagrinella convallaria*
	Discorboidea	Eponididae	*Eponides*	*Eponides cribrorepandus*
		Rosalinidae	*Rosalina*	*Rosalina orientalis*
				Rosalina sp. 1
				Rosalina sp. 2
	Planorbulinoidea	Planorbulinidae	*Planorbulina*	*Planorbulina mediterranensis*
	Asterigerinoidea	Amphisteginidae	*Amphistegina*	*Amphistegina lessonii*
	Nonionoidea	Nonionidae	*Protelphidium*	*Protelphidium* sp. 1
			Pseudononion	*Pseudononion japonicum*
	Rotalioidea	Rotaliidae	*Ammonia*	*Ammonia* cf. *convexa*
				Ammonia tepida
				Ammonia sp. 1
				Ammonia sp. 2
				Ammonia sp. 3
			Asterorotalia	*Asterorotalia dentata*
				Asterorotalia milletti
			Challengerella	*Challengerella bradyi*
				Challengerella sp. 1
		Elphidiidae	*Cribroelphidium*	*Cribroelphidium clarum*
				Cribroelphidium excavatum
				Cribroelphidium poeyanum
			Elphidium	*Elphidium craticulatum*
				Elphidium margaritaceum
				Elphidium sp. 1
		Notorotaliidae	*Cristatavultus*	*Cristatavultus milletti*
	Nummulitoidea	Nummulitidae	*Assilina*	*Assilina ammonoides*
			Operculina	*Operculina complanata*

The highest numbers of living specimens were documented at the more distal stations, whereas relatively low values were found at the shallower station and around the southwestern part of the island (Figure 3). A total of 96 taxa were identified in the living benthic foraminiferal assemblages (Figure 4). The highest values of S and H' were found around the northern and southeastern parts of the island, particularly at the more distal stations, whereas the highest values of Fisher α index were documented around the northeastern part of the island (Figure 3). The E and J values showed a similar pattern of distribution with commonly higher values around the northwestern part of the island. The benthic foraminiferal assemblages were dominated by species with porcelaneous tests (63.5%), followed by hyaline tests (34.7%), only a minor part (1.8%) of the assemblages were represented by agglutinated foraminifera. Porcelaneous tests were found to be higher both around the northwestern part of the island at the more distal stations and in the eastern part at the more proximal one (Figure 3). On the other hand, hyaline tests were more abundant around the central-western part of the island (Figure 3). Planispiral morphotypes dominated at the more shallow-proximal stations, while milioline morphotypes dominated at an intermediate depth and trochospiral morphotypes were more abundant at a greater water depth (Figure 3).

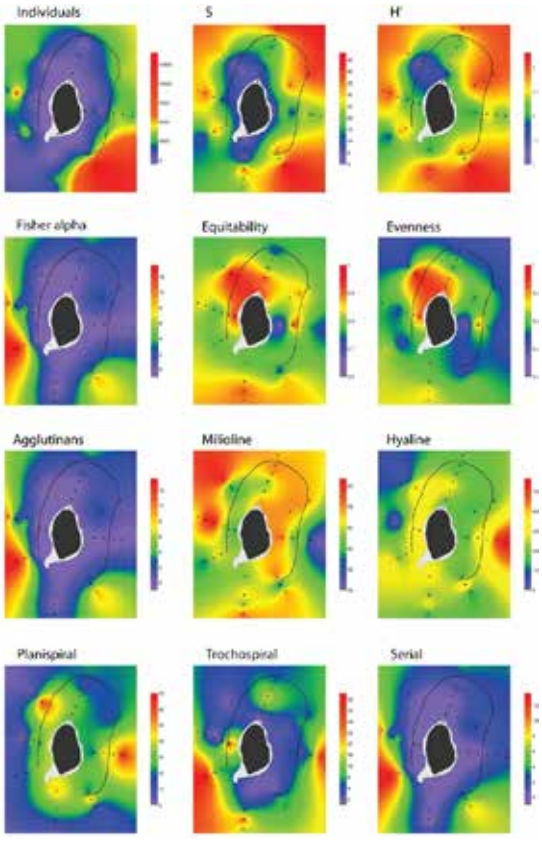

Fig. 3. Distribution of the living benthic foraminiferal parameters, foraminiferal wall types and the different coiling modes

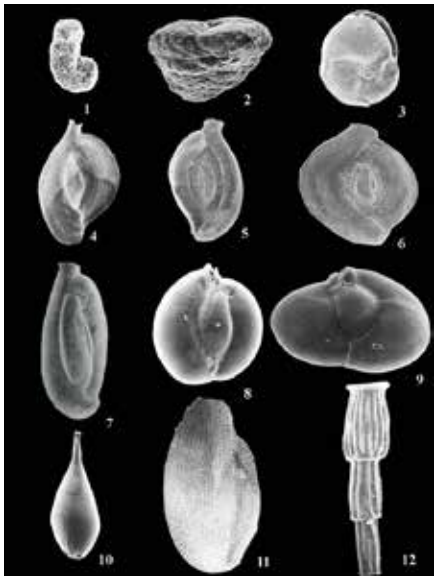

Fig. 4. 1. *Ammobaculites agglutinans* D'ORBIGNY 1826, X130. 2. *Sahulia barkeri* (HOFKER 1978), X95. 3. *Vertebralina striata* D'ORBIGNY 1826, X150. 4. *Adelosina partschi* (D'ORBIGNY 1846), X100. 5. *Spiroloculina excavata* D'ORBIGNY 1846, X65. 6. *Spiroloculina nummiformis* SAID 1948, X43. 7. *Cycloforina macerata* (CUSHMAN& TODD 1944), X130. 8. *Miliolinella subrotunda* (MONTAGU 1803), X140. 9. *Flintinoides labiosa* (D'ORBIGNY 1839), X130. 10. *Procerolagena oceanica* (ALBANI 1947), X110. 11. *Edentostomina repertiana* (BRADY 1881), X55. 12. *Articulina laticostata* CUSHMAN 1944, X85.

4.3 Statistical analyses

On the basis of the R-mode CA, two clusters (1 and 2) and two sub-clusters (2.1 and 2.2) were recognized (Figure 5). Cluster 1 is represented by *Siphonaperta* sp. 1, *S. dilatata, Quinqueloculina* sp. 2, *Quinqueloculina* sp. 1, *S. angulata, Triloculina* sp. 1, and O. *complanata.* The sub-cluster 2.2 is solely constituted by three species *(P. japonicum*, *P. mediterranensis* and *Elphidium* sp. 1), whereas sub-cluster 2.1 is made up all the other taxa (Figure 5).

The Q-mode CA results in the grouping of three groups of samples, namely cluster A and sub-clusters (B1 and B2) (Figure 6). Cluster A includes stations that are located around the central eastern and southern parts of the island (Figure 6). On the other hand, sub-cluster B2 comprises stations that are mainly located near the southwestern and northeastern parts of the island, far from the coasts. Sub-cluster B1.

5. Discussion

5.1 Umm al Maradim Island

The Arabian Gulf is a marginal shallow (<100 m water depth) sea enclosed between the Arabian Peninsula and Iran. In contrast to the other Kuwaiti island, Umm al Maradim is surrounded by deep waters and represents the largest and southernmost coral island in Kuwait (Al-Yamani *et al.*, 2004). All these features make Umm al Maradim unique. The physicochemical parameters around the island were quite homogeneous during the sampling. This homogeneity might be due to the water circulation and tidal movements. Sediments were dominated by sand representing ca. 85.1%, on mean, whereas gravel and mud constituted only minor parts of the sediment. The fine sand and mud fractions were restricted to the southeastern part of the island.

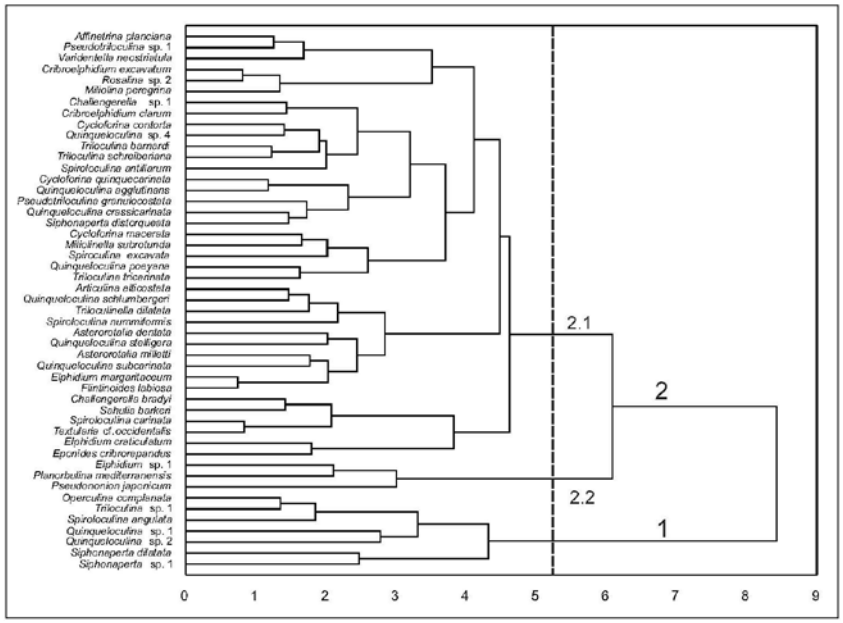

Fig. 5. R-mode cluster analysis

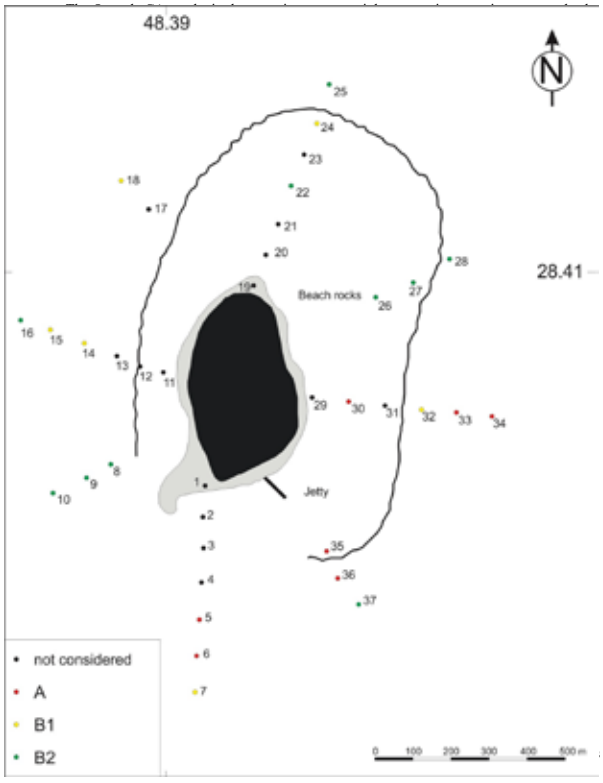

Fig. 6. Q-mode cluster analysis

Relatively higher values of gravel were found around the northeastern and southwestern parts of the island. In contrast, higher sand contents were commonly found around the southeastern and northwestern parts of the island. The northern and northwestern parts of the island have been suggested as erosional in nature, while the southern and southeastern part are inferred as sites of deposition, reflecting the action of predominant Shamal northwestern winds across the island.

5.2 Foraminiferal diversity around Umm al Maradim Island

The knowledge of the diversity and distribution of benthic foraminifera is quite limited in Kuwait because most studies have either been based on total assemblages or have focused on Kuwait›s northern marine environments. On the basis of the total assemblages, 101 species belonging to 48 genera were identified. The living part is instead represented by 96 taxa. These figures are sensibly higher than those documented in previous studies around Kuwait territorial waters (42 species by Al-Zamel *et al.* (1996), 46 species by Al-Zamel *et al.* (1998), 45 species by Al-Zamel *et al.* (2009), 59 species by Al-Enezi & Frontalini (2015)). Relatively higher values (141 species from the total assemblages) were documented along a water depth transect in the central-southern part of Kuwait (Parker & Gischler, 2015). It should be emphasized that most of previous studies have focused on the total assemblages (living and dead foraminifera). Accordingly, the total assemblages include autochthonous taxa as well as allochthonous ones that might have been transported from other environments (Frontalini *et al.*, 2015).

5.3 Foraminiferal distribution

Relatively higher values of foraminiferal abundances were documented at deeper stations, commonly exceeding 20 m, with a higher sand content. Low abundances of living foraminiferal specimens were normally associated with shallower environments and subtidal zone around the island. A much lower total foraminiferal abundance was found for the northern part of the Arabian Gulf compared to the shallow ramp on the south (Gischler & Lomando, 2005). This low abundance was tentatively explained by the peculiar geomorphological and the depositional energy patterns offshore of Kuwait coupled with the extreme environmental variability of the Gulf (Parker & Gischler, 2015). In our samples, relatively higher values of living foraminiferal abundance were commonly found at deeper stations.

Porcelaneous tests in terms of abundance dominates the foraminiferal assemblages followed by hyaline tests. Only a minor part of the assemblages was represented by agglutinated foraminifera. These percentages are quite different from those documented by Al-Zamel & Cherif (1998) in the western part of the Shatt Al-Arab Delta. Accordingly, the foraminiferal fauna in these subtidal and tidal creeks exhibited a lower abundance of agglutinated and porcelaneous forms but a much higher abundance of hyaline one. These differences might be explained by different salinity and physiographic settings when compared to the more open marine environment around Umm al Maradim Island and the presence of coral reefs.

The porcelaneous foraminifera were found to dominate at the eastern proximal and northwestern distal stations. Planispiral morphotypes dominated at the more shallow-proximal stations, whereas milioline morphotypes dominated at intermediate depth and trochospiral morphotypes were more abundant at a greater water depth. A similar pattern was found by Parker & Gischler (2015) who documented planispiral morphotypes dominating at shallower stations (0–5 m water depth), milioline morphotypes dominating at an intermediate depth (5 to 18 m water depth), and a mix of morphotypes (trochospiral, planispiral, and milioline) at a water depth exceeding 18 m.

Cluster A groups stations mainly located around the central eastern and southern parts of the island with intermediate values of depth and the highest content

of gravel and the lowest of sand. This group is also characterized by a relatively high abundance of *A. dentata, A. milletti, C. excavatum, E. margaritaceum, Elphidium sp. 1, M. subrotunda, P. mediterranensis, P. japonicum, Q. stelligera,* and *V. neostriatula* as well as the lowest values of diversity indexes, *E* and *J*. This group can be compared with the *Asterorotalia-Elphidium* assemblages documented by Parker & Gischler (2015). Sub-cluster B2 includes stations placed around southwestern and northeastern parts of the island far from the coast, where the water was deepest and had intermediate values of sand and gravel. This sub-cluster is also marked by the highest values of diversity indexes, *E, J* and of *C. bradyi, E. craticulatum, E. cribrorepandus, O. complanata, Quinqueloculina sp. 2, S. barkeri, S. angulata* and *Triloculina* sp. 1. This sub-cluster might be compared with the foraminiferal assemblages from the carbonate shoals of Parker & Gischler (2015) that is characterized by the presence of *Heterostegina depressa, E. craticulatum, Amphistegina lessonii, Acervulina* spp. and *Eponides repandus*. On the other hand, sub-cluster B1 mainly comprises stations in the central parts of the island that are characterized by the lowest water depth (18.7 m, on average) and which have low gravel content and the highest sand content. This group of stations shows slightly higher values of assemblages' parameters and of *A. alticostata, P. granulocostata, Q. poeyana, Quinqueloculina* sp. 1, *S. dilatata, Siphonaperta* sp. 1 and *S. nummiformis.* This cluster, which is dominated by porcelaneous wall type, can be compared to the Parker & Gischler (2015), though it was documented for Umm al Maradim Island at a greater water depth.

6. Conclusion

The present study focuses on the diversity and distribution of living benthic foraminifera around Umm al Maradim Island. Relatively high values of diversity have been documented. These figures are sensibly higher than those documented in most of the previous studies around Kuwait territorial waters. Porcelaneous tests in terms of abundance dominates the foraminiferal assemblages followed by hyaline tests. In addition, only a minor part of the assemblages was represented by agglutinated foraminifera. Very low foraminiferal abundances were associated with shallower environments and similar subtidal zone around the island, whereas higher values were found at deeper and more distal stations.

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جامعة أوربينو، أوربينو، إيطاليا [3]

الملخص

يركز البحث الحالي على جزيرة أم المرادم الفريدة من نوعها والتي تعتبر أكبر جزيرة شعاب مرجانية في جنوب الكويت. تم أخذ عينات من سبعة وثلاثون محطة حول الجزيرة لتحليل المنخربات القاعية الحية فيها. وقد تم توثيق كميات عالية التنوع نسبياً لكل من التجمعات الإجمالية والحية، وهي 101 و 96 نوعاً، على التوالي. وهذه الأرقام أعلى بشكل ملحوظ من تلك الموثقة في معظم الدراسات السابقة التي أُجريت حول المياه الإقليمية الكويتية. ومن حيث الوفرة، تسود تجمعات المنخربات ذات الأصداف الجيرية الفغفورية (porcelaneous tests) وتليها التجمعات ذات الأصداف الجيرية الزجاجية (hyaline test)، ولم تمثل المنخربات الملتصقة (agglutinated) سوى جزء بسيط فقط من التجمعات. ويمكن تفسير الهيمنة العالية للمنخربات ذات الأصداف الجيرية بسبب تواجدها في البيئة الفيزيوغرافية المميزة ووجود الشعاب المرجانية في جميع أنحاء الجزيرة. وارتبط تواجد المنخربات بكميات منخفضة جداً في بيئات ضحلة مثل المناطق المغمورة حول الجزيرة، بينما تم العثور على كميات أعلى في محطات أعمق وأكثر بعداً. وُجد أن الأنماط المورفولوجية ذات الالتفاف المستوي (planispiral) تهيمن على المحطات القريبة والأكثر ضحالة، في حين كانت الأنماط ذات الالتفاف المليولينى (milioline) أكثر وفرة في الأعماق المتوسطة، بينما كانت الأنماط ذات الالتفاف الحلزوني (tro-chospiral) أكثر وفرة في الأعماق البعيدة للمياه. ويساهم هذا البحث في توثيق تنوع المنخربات القاعية حول الجزر في المياه الإقليمية الكويتية.