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Spatial distribution and assemblage structure of foraminifera in Nayband Bay and Haleh Estuary, North-West of the Persian Gulf

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Abstract

The spatial distribution of benthic foraminiferal assemblage of Nayband Bay and Haleh Estuary in the North-West of the Persian Gulf, was explored during 2011-2012 . The relationship between spatial pattern of foraminifera assemblages and the ambient factors (i.e. water temperature, salinity, pH, dissolved oxygen, sediment grain size distribution, sediment organic content, and $CaCO_3$ concentration of sediments) was measured. The most abundant benthic foraminifera species which were found in the studied area include *Ammonia beccarii*, *Eponides repandus*, *Quinqueloculina* sp., *Elphidium* sp. The two most abundant species belongs to Rotaliidae family. The specimen groups presented in the study area were somehow the same, and their relative abundance did not vary tremendously in sites consisting of foraminifera assemblages. The fauna shows affinities to those of the southern coastline of the Persian Gulf and also the Oman Sea. The BIO-ENV analysis identified temperature, salinity, pH, and total organic matter as the major environmental variables influencing the infaunal pattern. Generally foraminiferal populations were sparse in the study area, which may be due to the low depth and consequently, low distribution of foraminiferal specimens.

Keywords: Benthic Foraminifera, Spatial distribution, Environmental parameters, Nayband Bay, Haleh Estuary, Persian Gulf

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Introduction

Foraminifera, unicellular eukaryotic organisms, have a worldwide distribution and could be found in a various range of aquatic environments, especially in tropics. Foraminifera could be found as a benthic or planktonic specimen. Benthic foraminifera as an epifaunal or infaunal species are considered as valuable palaeoenvironmental indicators as the ambient factors, including temperature, salinity, sediment texture, depth, oxygen level and flux of organic material are affected them (Murray, 1991; Van der zwaan et al., 1999). As it is mentioned by Moghadasi et al. (2009) the spatial and temporal distribution of benthic foraminifera are controlled effectively by ambient factors; however, these limiting effects is species-specific. Moreover, this group of organisms extensively used as a bioindicators for characterizing contaminated and hypoxic environments (Alve, 1990, 1991; Sharifi et al., 1991; Yanko et al., 1994, 1998; Samir, 2000; Pascual et al., 2002; Mikac, 2007).

Among various ranges of aquatic ecosystems, estuaries are important because of different aspects as they maintain a diverse array of organisms (Dobson and Frid, 1998; Currier and Small, 2005), and also being so impressible from anthropogenic activities. Mendes et al. (2004) showed that the spatial distribution of shallowest near shore species are clearly influenced by the outflow of the estuary and by local hydrodynamic conditions. Along the northern coastline of the Persian Gulf and Oman Sea despite some early endeavors which generally focused on identifying foraminifera of deep sections (Habibnejad, 1997; Rahmati, 1997; Sohrabi Mollayousefi, 2003; Nabavi, 2004; Nabavi et al., 2005; Moghadasi et al., 2009), the structure of benthic shallows near shore foraminifera assemblages and their spatial variation in Nayband Bay and Haleh Estuary have largely remained unknown. However, a considerable amount of studies had been done along the southern coastline of the Persian Gulf (Loeblich and Tappan, 1964; Murray, 1966a, b, 1970a, b). In this regard, to explore the assemblage of benthic foraminifera in Nayband Bay and Haleh Estuary, the present study based on two main objectives, has been conducted. The primary objectives of the present study were to explore the community structure and spatial pattern of benthic foraminifera in Nayband Gulf and Haleh Estuary. A further objective was to explore the relations between spatial pattern of benthic species with environmental variable (i.e. water temperature, salinity, pH, DO, sediment particle size distribution, sediment organic matter, and $CaCo_3$ concentration in sediment) in the mentioned zone. In this respect, the benthic assemblages and environmental variables were sampled in Nayband Bay and Haleh Estuary from March 2011 to March 2012.

Material and methods

This study was undertaken in Nayband Bay and Haleh estuary, Northwest of the

Persian Gulf, near to Assaluyeh in the North (27º 30´ S, 52º 35´ E) (Fig. 1). Nayband Bay is a subtropical tidal coast with an approximate tidal range of 3 m. Haleh estuary and Nayband Bay receive irregular freshwater following the seasonal precipitation occurring mainly from November to February. Samples (i.e. benthic foraminifera and environmental factors) were collected from six sites during high tide in depth of 20 m .

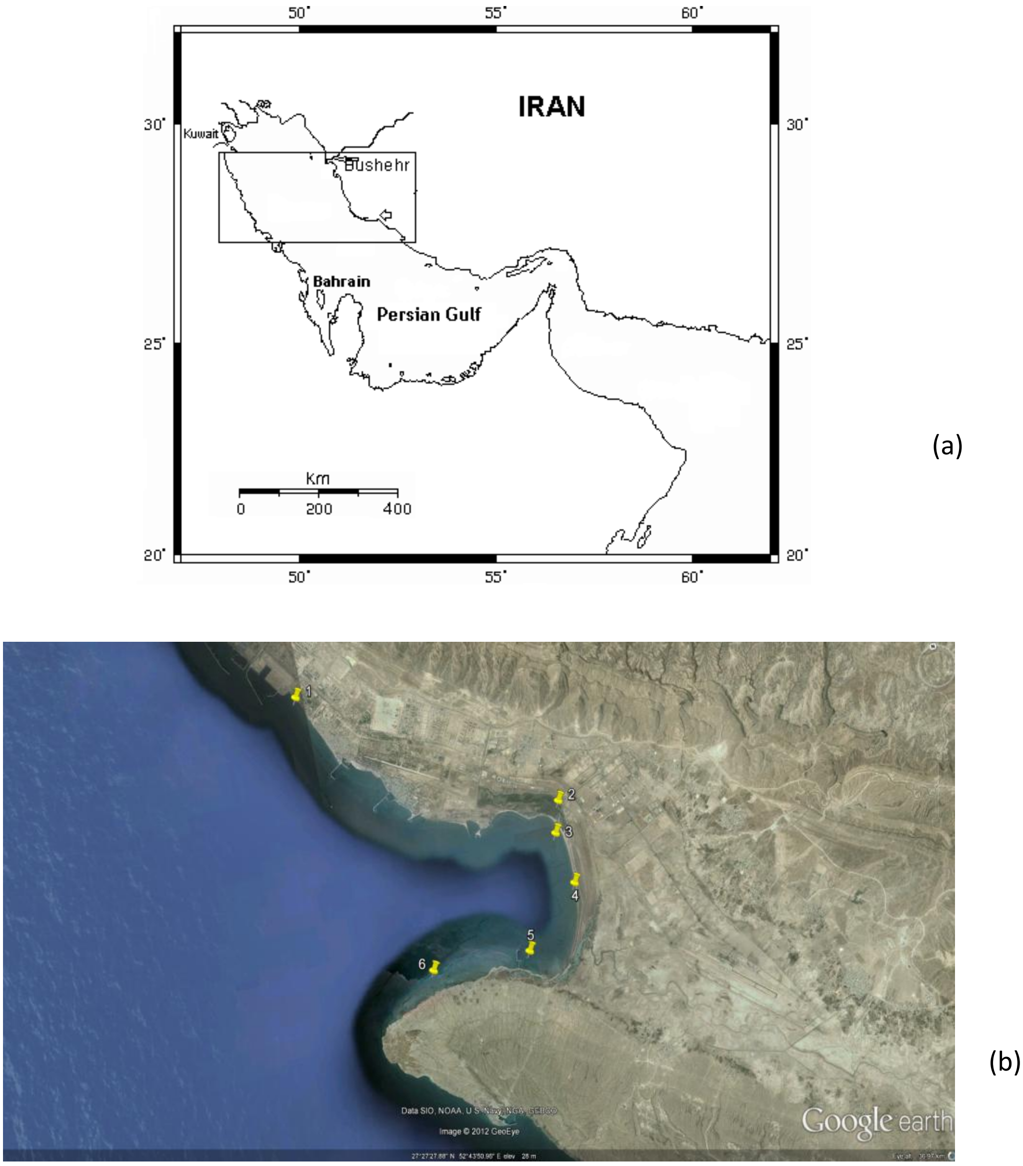

Figure 1: (a)The location of Nayband Bay and Haleh Estuary, and (b) the location of the sampling sites in Nayband Bay and Haleh Estuary, north-west of the Persian Gulf. 1,50000

The sites were chosen in a way to encompass the entire area (Fig. 1). Samplings were performed from bimonthly. Bottom samples were gathered using a 0. 1m^2 Van Veen grab; then 3 replicates were taken from each sample in six studied sites by 28.26 cm^2 area slender sampler. Collected sediments were mixed with 4% formalin buffered in sea water. Preserved samples were being washed with tap water and sieved through a 0.063 mm mesh, dried at 75° c for 3 h , floated by the heavy liquid CCl_4 and the upper layer on the liquid consist of target specimens were filtered by paper and allowed to dry. Samples were sorted under a stereomicroscope and specimens identified by use of systematic and classification keys (i.e. Loeblich and Tappan, 1964; Cushman, 1969; Loeblich and Tappan, 1988). One additional sediment sample was collected from each six sites for sediment particle size distribution, calcium carbonate concentration, and TOM content analyses. For determining sediment particle size distribution, sample was dried at 70° C for 48 h and sieved through a nested series of sieves Folk (1968). For measuring the concentration of Calcium carbonate the dried sediment (70º C, 8 h) was mixed with HCL (0.1 N) after 24 h soaking the upper liquid phase was discharged and the sediments filtered, dried and weighed. For determining the total organic matter content through weight loss, the samples were first dried at 70° C for 48 h and then combusted at 550° C for 60 min Regional Organization for the Protection of the Marine Environment, ROPME (1999). Water temperature (ºC), salinity (ppt), pH and DO (mg/l) were measured at each six sites during the sampling procedure using WTW conductimeter .

Data Analysis

Data analysis was done by use of PRIMER version 6 (Polymouth Marine Laboratories, Clark and Warwick (2001) and SPSS version 13. The hypothesis states that, the spatial patterns in the number of species were divided with respect to sedimental charactrestics was explored by measuring the relative Bray curits similarity of assemblage at the study area and was depicted using non-metric multidimensional scaling ordination (nMDS). The hypothesis that foraminifera assemblage differed among sites was tested using analysis of similarity (ANOSIM) to be evaluated whether any observed differences inforaminifera assemblages were statistically significant. The contribution of specific taxa to the differences in foraminifera assemblages among sites was examined using SIMPER analysis. 4th root transformation was used to reduce the influence of very abundant species. The objective as to which, environmental factor and to what extent was affected the composition of forams assemblages and their spatial pattern, was evaluated by BIOENV routine. The taxonomic richness, evenness, and Shannon-Wiener diversity index were measured using Diverse Routine in PRIMER. Differences in environmental variables between sites were examined using the non –parametric Kruscal-Wallis test in SPSS version13.

Results

A total of 40,597 foraminifera specimens were sampled over a one-year survey, representing two classes and six families. Ten species have been studied to characterize the recent foraminifera assemblages in Nayband Bay and Haleh Estuary (Table 1). The most abundant species (29% of the total) in the prepared samples are *Ammonia beccarii* followed by *Eponides repandus* (25.4 % of the total) and *Quinqueloculine* sp. (22.7 % of the total), respectively. The two most abundant species belongs to Rotaliidae family.

Table 1: Taxonomic list of benthic foraminifera taxa from Nayband Bay and Haleh Estuary

Class	Order	Suborder	Superfamily	Family	Genus	Species
Rotalidia	Rotaliida	Rotaliina	Rotaliacea	Rotaliidae	*Ammonia*	*Ammonia beccarii*(Linne, 1758)
					Eponides	*Eponides repandus*(Fichtel and Moll, 1798*)*
				Elphidiidae	*Elphidium*	*Elphidium* sp.
			Buliminacea	Buliminidae	*Bulimina*	*Bulimina marginata(*d'Orbigny, 1826*)*
Miliolidia	Miliolida		Soritacea	Peneroplidae	*Peneroplis*	*Peneroplis pertusus(*Forskal, 1775*)*
		Miliolina	Miliolacea	Hauerinidae	*Quinqueloculina*	*Quinqueloculina* spI
						Quinqueloculina spII
						Quinqueloculina spIII
					Triloculina	*Triloculina oblonga*(Montagu, 1803*)*
				Spiroloculinidae	*Spiroloculina*	*Spiroloculina* sp.

No significant difference was found in foraminifera assemblages among sites; however, in sites one, six and three no foraminifera individual was found during the sampling period, and the other three sites showed a variable composition of foraminiferal assemblages (Table 2).

Table 2: Summary of One-way ANOSIM of total benthic forams abundance comparison between six study sites in Nayband Bay and Haleh Estuary.

Comparisons	Pair wise R
Site 1 vs. Site 2	0.029
Site 1 vs. Site 3	1
Site 1 vs. Site 4	0.429
Site 1 vs. Site 5	0.029
Site 2 vs. Site 3	0.029
Site 2 vs. Site 4	0.514
Site 2 vs. Site 5	0.029
Site 2 vs. Site 6	0.029
Site 3 vs. Site 4	0.429
Site 3 vs. Site 5	0.029
Site 3 vs. Site 6	1
Site 4 vs. Site 5	0.029
Site 4 vs. Site 6	0.429
Site 5 vs. Site 6	0.029

*: Significant level $p< 0.001$ (Global $R=0.479$, $P= 0.001$).

Sites two and four were dominated by Rotaliidea family, species *Ammonia beccarii (*with 63.83 and 63.40% contribution in sites 2 and 4, respectively). Sites five was dominated by Rotaliidae and Elphididea family, species *Ammonia beccarii* and *Elphidiom* sp., respectively which the contribution of *Ammonia beccarii* decreased to half in comparison with the two other sites. The marked variation in forams abundance among sites was delineated clearly by the nonmetric Multidimensional Scaling ordination (nMDS) (Fig. 2).

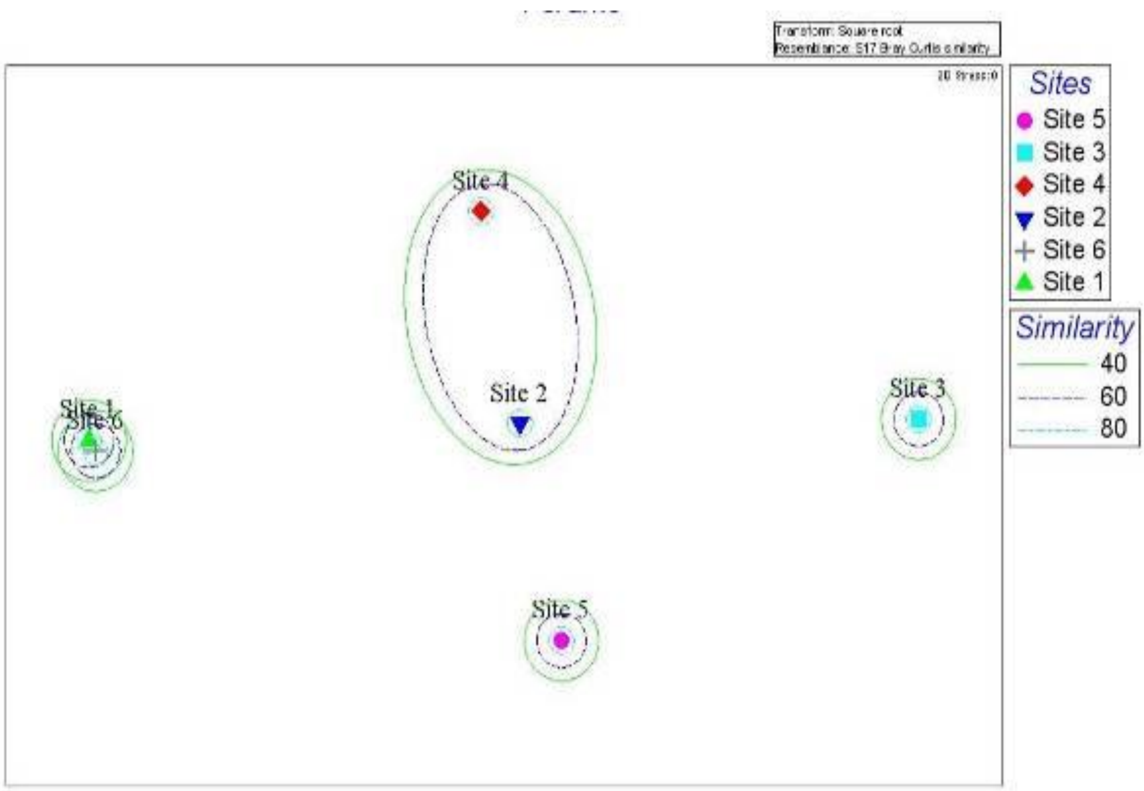

Figure 2: nMDS ordination of forams assemblages over six sites in Nayband Bay and Haleh Estuary.

These results are supported by their contribution percentage as it has shown in table 3 by implementing SIMPER routine. Margalef richness, Jevenness Pielous, and Shannon-Wiener diversity indices were calculated for the six study sites (Table 4).

Table 3: Contribution of the most influencing taxa to the average similarity between the forams assemblages over the six sites in Nayband Bay and Haleh Estuary by implementing SIMPER routine.

Sites	Species	Average abundance (ind/m^2)	Average similarity	Contribution	Average similarity
1	-		-	-	-
2	*Ammonia beccari*	4.61	18.02	63.83	**28.30**
	Quinqueloculina sp. III	1.00	2.89	10.22	
	Bulimina marginata	2.16	2.02	2.15	
	Elphidium sp.	2.93	1.56	5.52	
	Eponides repandus	2.14	1.56	5.52	
3	-		-	-	-
4	*Ammonia beccarii*	1.30	5.22	63.40	**8.23**
	Elphidium sp.	2.29	3.01	36.60	
5	*Ammonia beccari*	39.35	11.16	33.63	**28.88**
	Elphidium sp.	24.91	6.41	22.19	
	Peneroplis pertusus	6.36	3.26	11.26	
	Bulimina marginata	3.04	3.20	11.08	
	Quinqueloculina sp,III	8.25	3.03	10.65	
6	-	-	-	-	-

The highest value for Shannon-Wiener index was reported for site 5, as in this site the existing species had a normal ration in the whole assemblage despite to what is seen in the other sites, followed by sites 2 and 4, respectively. However, the highest evenness index of forams species were observed in site 4 and it is equal in sites two and five. Species richness was decreased from sites 2 to 4 and 5, respectively.

Table 4: Computed diverse indices for the six study sites in Nayband Bay and Haleh Estuary.

Site	Margalef species richness (d)	Pielous evenness (J')	Shannon-winner (H')
Site 1	**	**	**
Site 2	1.854	0.8946	1.860
Site 3	**	**	**
Site 4	1.601	0.9352	1.676
Site 5	1.438	0.8984	2.069
Site 6	**	**	**

**: The sites were void of forams assemblages.

Water salinity, temperature, DO and pH were not significantly different among the six study sites (Table 5). Total organic content and $CaCO_3$ concentration of sediments showed a variability among sites, but they were not significantly differed (Table 5); the textures of sediments were significantly differed among the sites as the site 2 had a high portion of Gravel, but sites 6 , 1 , and 3 , had a significant portion of sand, respectively. Site 4 had a high content of silt/clay (Table 6).

Table 5: Descriptive statistics and the results of non-parametric Kruscal-Wallis test for environmental variables in Nayband Bay and Haleh Estuary.

Source of variation Among Six Sites Factor	df	Chi-Square	P	Mean(±S.E) (Max.-Min.)
Temperature (°C)	5	6.57	0.58	27.57(±0.67) (29.7- 24)
Salinity[a]	5	55.13	0.72	38.65(±0.84) (39.9- 32.65)
pH[a]	5	25.22	0.32	8.17(±0.30) (8.03-8.22)
Dissolved[a] oxygen	5	44.72	0.56	6.19(±0.25) (10.30- 0.55)
Total[a] organic content	5	43.04	0.34	1.20 (±0.41) (2.33-0.33)
$CaCO_3$[a] Concentration	5	21.23	0.56	12.04(±2.3) (4.0-24.98)

Table 6: Descriptive statistics for grain-size distribution at sites studied in Nayband Bay and Haleh Estuary.

Site	Gravel% mean (± SE)	Sand% mean (± SE)	Silt/ Clay% mean (± SE)
1	0.32(±0.07)	85.27(±0.43)	14.40(±0.13)
2	2.47(±0.47)	57.19(±1.25)	0.33(±0.09)
3	1.69(±0.27)	96.34(±0.71)	1.96(±0.02)
4	0.64(±0.01)	89.05(±0.94)	10.32(±1.2)
5	25.00(±0.4)	74.38(±0.91)	0.61(±0.03)
6	0.69(±0.11)	98.52(±0.64)	0.78(±0.09)

Figure 3 shows the nonmetric Multi Dimensional Scaling ordination of sediment's texture among the six studied sites.

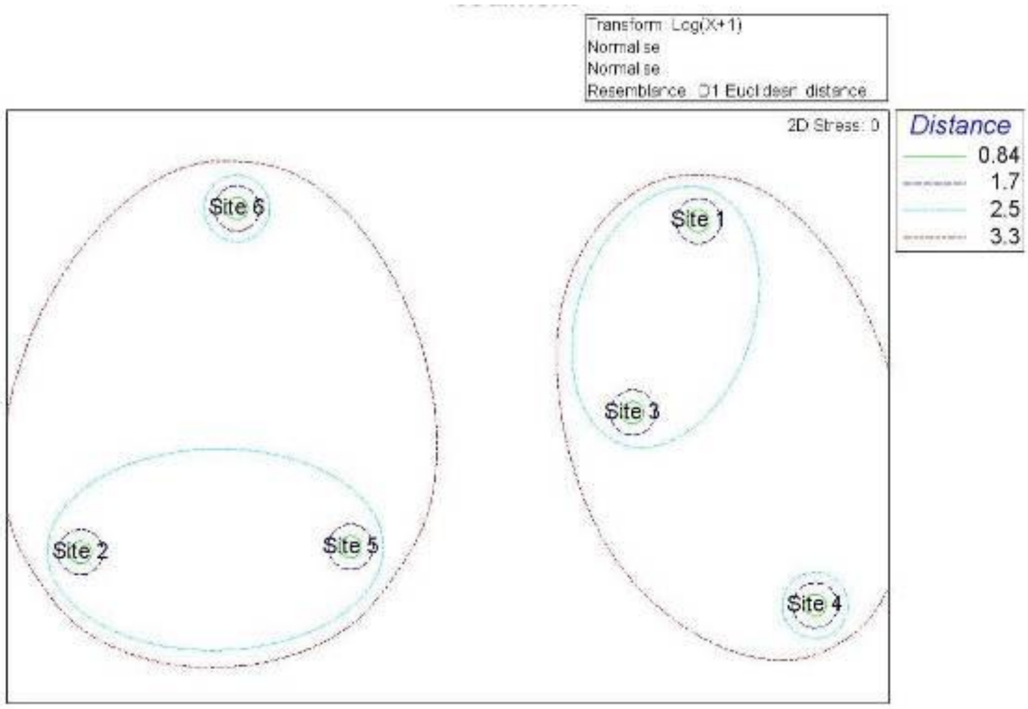

Figure 3: nMDS ordination of sediments texture over six sites in Nayband Bay and Haleh Estuary.

The BIOENV results showed that variation in forams assemblages were correlated strongly with the temperature, salinity, pH, and total organic matter, respectively (BIOENV Pw=0.661). Cluster analysis (Bray Curits Similarity) of the 6 selected sites regards to the foraminifera assemblages show the separation of four groupings at the level of 80% similarity; cluster one, combination of sites 4 and 2 ; cluster 2 include sites 5 and cluster 1 ; cluster 3 include site 3 and cluster 2 ; cluster 4 include sites 1, 6 and cluster 3 (Fig. 4).

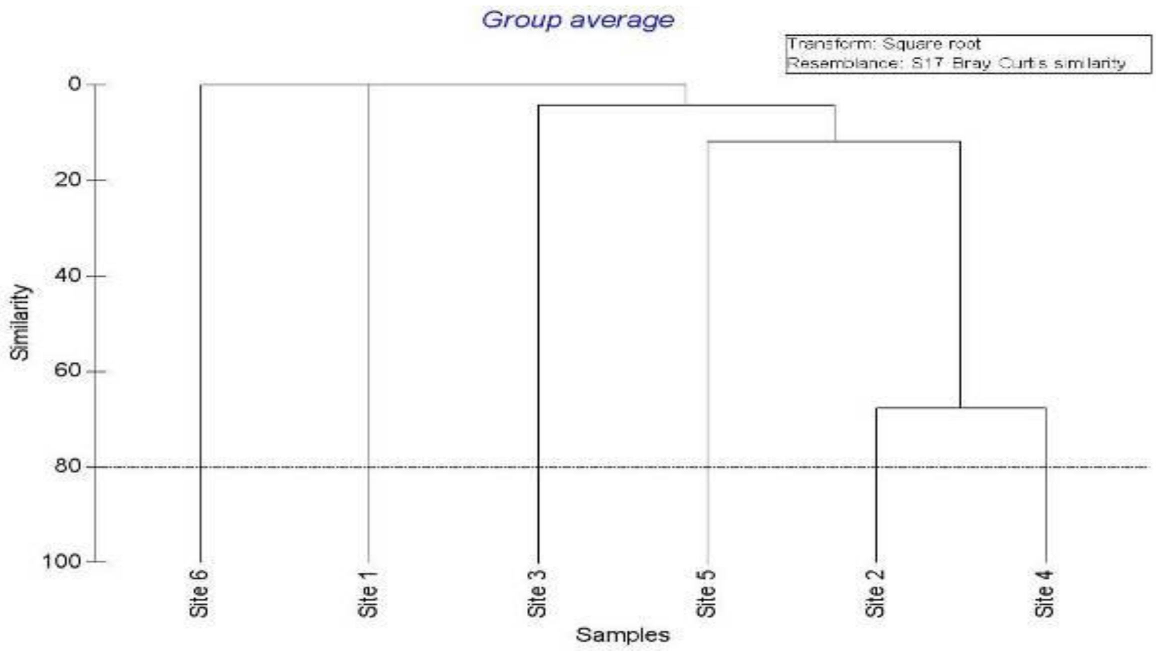

Figure 4: cluster analysis of benthic foraminifera species of Nayband Bay and Haleh Estuary.

Discussion

In this study, the spatial distributions of benthic foraminifera assemblage of Nayband Bay and Haleh Estuary in shallow depth were explored for the first time. The most abundant benthic foraminifera species which were found in the studied area include *Ammonia beccarii*, *Eponides repandus*, *Quinqueloculina* sp., *Elphidium* sp.. The most abundant species in the studied area, *Ammonia beccarii*, is a common cosmopolitan species which was also reported in previous studies in the Persian Gulf and Oman Sea (Murray, 1966a, b; Rahmati, 1997; Farahani, 1998; Moghadasi et al., 2009). In the previous studies, the presence of *A. beccarii* was reported from the coastal zone, which is in concurrence with the present study. On the other hand, some species belong to genera *Epodines*, *Quinqueloculina*, *Spiroloculina*, *Triloculina* were reported to be distributed in higher depths (Pascul et al., 2008; Moghadasi et al., 2009); but during the sampling procedure in the present study, they were found in lower depths. This occurrence was also seen by Murray (1966a, b, 1970a) in Abu Dhabi lagoon, Khor Al Bazam, and Halat Al Bahrani region. The presence of species *Ammonia beccari*, *Bulimina marginata*, *Elphidium* sp., *Eponides repandus* and *Elphidium* sp. were resulted in dissmilitarity of sites 2 and 3 which was devoid ed from specimens, regard to the simper analysis, although these two sites have similar condition with respect to their bordering with mangrove trees. Sites 2 and 4 were also dissimilar regards to the presence of *Ammonia beccarii*, *Elphidium* sp., *Bulimina marginata*, *Eponides repandus* which is expected because of the dissimilarity in sediment particle size distribution. Sites 2 and 5 were dissimilar by the presence of

Ammonia beccarii, *Elphidium* sp., *Eponides repands*, *Quinqueloculina* sp. and *Peneroplis pertusus*. The results are in concurrence with Murray (1966a, b) findings, as site 5 is protected by bulwark from tidal currents, in this regard, *Peneroplis pertusus* had a significant abundance and is being introduced as the third affective species for site five to be dissimilar with other sites. Sites four and five were dissimilar by the presence of *Peneroplis pertusus*, *Bulimina marginata*, and *Quinqueloculina* sp. in site 5. This dissimilarity could be also because of the differentiation in sediment particle size distribution; however, contrary to Murray (1966a, b) finding's genus, *Elphidium* which has a low abundance along the southern shore zone with muddy sediments, in site 4 with sediment size lower than 0.5 mm has a significant abundance. Consequently, the most abundant and also the more effective species in making the site selection significant are *Ammonia becarii*, *Elphidium* sp., Eponides *repandus*, respectively. At small spatial scale, pattern of foraminifera assemblages has been shown to be controlled by variation in underlying environmental variables (Alve, 1990, 1991; Murray, 1991; Sharifi et al., 1991; Van der Zwaan et al., 1999; Fontanier et al., 2002, 2005, 2006; Mikac, 2007). In the present study, significant correlations were found between foraminifera assemblages and temperature, salinity, pH, and total organic matter, respectively; moreover, the rate of water discharges during the low tide would also affect the species richness among the studied sites; as it is obvious, sites 1 , 3 , and 6 were devoid of any kinds of foraminifera specimens, but sites 2 , 4 and 5 were the most condense sites, this could be resulted from the situation of these sites as the aforementioned sites were sheltered by the presence of Mangrove trees, lunette topography, and presence of a bulwark, respectively. The effect of sheltering could be explained as a decrease in the intension of water discharges during the low tide so in these low depths species would have more chances to maintain in the sediments, but the ebb tidal currents draining the specimens and make the area devoid of any samples. As it was mentioned before multivariate analyses of samples, and species showed that the spatial distribution of benthic foraminifera in Nayband Bay and Haleh Estuary mainly controlled by ambient factors. The result of the present study is agreed with the fact that suborder Rotaliina is dominant in the estuaries and hypersaline environments (Murray, 1966a, b; Pascual et al., 2008; Moghadasi et al., 2009); but it should be mentioned that suborder Miliolina is also could be considered as abundant taxa in estuaries. Generally, the abundances of foraminifera assemblage were decreased to zero in three of sites with high rate of water displacement; however, their assemblage will become more abundant in the other three sites with a more stable condition; moreover, the dominate composition of sediments in three condense sites 2, 4 and 5 , was fine material, with silt and clay content, which also prepared a suitable bed for their settlement, in spite of discrimination of sediment texture of site 4 with sites 2 and 5 , probably the presence of mangrove trees caused the situation and have an affective role in species richness of site 2 . As a conclusion, the present study was conducted as a preliminary evaluation of near shore, shallow-water foraminifera benthic assemblages of the northern coastline of the Persian Gulf. The specimen groups present at each site are somehow the same, and their relative abundance does not vary tremendously in sites consisting of foraminifera assemblages; And it is therefore, worthwhile to look for similarities, dissimilarities and the affecting factors on the probable variations between the areas previously studied in the Persian Gulf. It could be said that there are some similarities between the foraminifera assemblages of the southern and northern coastline of the Persian Gulf because of the presence of *Quinqueloculina*, *Triloculina*, *Peneroplis*, and *Ammonia*; however, no specimen of *Spirolina* was found along the studied sites which Murray (1966a,b, 1970) reported from Abu Dhabi lagoon, Khor Al Bazam, and the Halat Al Bahrani regions. Moreover, because of the presence of *Quinqueloculina*, *Epodines*, *Spiroculina*,and *Triloculina* there are similarities between the study area and previously studied stations in higher depths in the Oman Sea by Moghadasi et al. (2009). It should be considered that periodic future surveys of the population dynamics of these assemblages is essential to provide evidence of the eventual alterations in the study area regard to anthropogenic and industrial activities, which are going to be held on extensively.

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