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Identification and Abundance of Benthic Foraminifera in the Sediments from Fereidoonkenar to Babolsar of Southern Caspian Sea

Mina Sadough[1,*], Fatemeh Ghane[1], Hamed Manouchehri[1], Babak Moghaddasi[2], Houri Beikaee[1]

[1] Islamic Azad University, Babol Branch, Department of Fisheries and Aquaculture, Babol, Iran.
[2] Islamic Azad University, Savadkooh Branch, Departments of Natural Resources, Savadkooh, Iran.

* Corresponding Author: Tel.: +98.09112145604; Fax: +98.09112145604;
E-mail: m.sadough84@gmail.com

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Abstract

In this study in order to introducing Foraminifera species and determining their relationship with the environmental factors, sediment samples were gathered in spring 2011 from 12 stations (ranging in depths 5, 10, 15 and 20 meters) in the Southern Caspian Sea from Fereidoonkenar to Babolsar. Environmental factors of water near the bottom including temperature, salinity, dissolved Oxygen, pH were measured during sampling and grain size and total organic matter and calcium carbonate concentration were measured in laboratory. Structure of the sediment samples mostly consisted of fine sand; very fine sand, silt and clay and 4 species of benthic foraminifera species belong to 4 genera of 4 families were identified. *Ammonia beccarii caspica*, *Elphidium littorale caspicus*, *Milliammina fusca* and *Ammotium* sp. The cosmopolitan foraminifer, *Ammonia beccarii caspica* was common in all sampling stations. Density of benthic forams had a significantly correlation with grain size, that their density were increased with adding silt and clay rate. The structure of the sediments was the most important abiotic factors controlling the distribution pattern of benthic forams in the sampling stations. Structural abnormalities in the testes of the benthic foraminifera indicated the comparatively polluted benthic environment from Fereidoonkenar to Babolsar of Southern Caspian Sea.

Keywords: Southern Caspian Sea, environmental factors, benthic.

Introduction

Foraminifera are the worldwide tested protozoa, living in aquatic environments including marine, brackish or fresh water and are distributed in all latitude especially in tropics (Moghaddasi *et al.*, 2009a), with an important role on transferring energy in aquatic ecosystem (Mirzajani *et al.*, 2002). Benthic foraminifera are common in marine sediments; they are cosmopolitan, have a good fossil preservation and represent a useful tool for oceanographic and palaeoceanographic studies (Murgese and De Deckker, 2005) and their fossil remains can be used for palaeoecological reconstructions of former environments (Murray, 2001). For studies of marine biogeography and biodiversity, in small and large amounts of space and time, they are ideal organisms (Buzas *et al*., 2007).

Forams are benthic or planktonic in the mode of life and useful in the exploration of the petroleum and natural gas sources. Several research forams fossil, compared with the recent forms, leading to the understanding of the earth paleo-environmental conditions (Moghaddasi *et al.*, 2009a).

Benthic foraminifera are particularly useful at reconstructing bottom water temperature, the exported flux of organic carbon to the sea floor and bottom-water oxygenation (Duros *et al*., 2012). Benthic foraminifera can be used as useful and relatively speedy and inexpensive bio-indicators. It also provides a basis for future investigations aimed at unraveling the benthic foraminiferal response to human-induced pollution in marine and transitional marine environments (Coccioni *et al*., 2009), in costal and transitional such as aquacul-ture, oil spills, heavy metals, and urban sewage (Bouchet *et al.*, 2012). The aim of ecological studies is to determine the relationship between the biota and the environment. Despite repeated ecological studies of benthic foraminifera, the exact control of environmental forcing on benthic foraminifera are still not fully understood (Armynot du Châtelet *et al*., 2009), but foraminifera can provide quantitative data with a small (a few cm^3) volume of sediment. Considering their shorter generation time, foraminifera have the potential to respond faster than macro fauna to changes in the environmental conditions (Bouchet *et al.*, 2012) and distribution of the benthic foraminifera can affected highly with the environmental conditions of the benthic zone (Moghaddasi *et al*., 2009a). The structure of the benthic zone, including the grain size of sediments, pH and organic carbon has an important role on the forams population, also it appears that two usually inversely related parameters, the flux of organic particulate matter (food) to the sea floor and oxygen concentrations of bottom water and pore waters, are major controlling variables (Murray, 2001; Fontanier *et al.*, 2005). Other factors which have been suggested (and some of which are not independent of these two) include the type of food supply, bathymetry, sediment type, chemistry of bottom waters (e.g., carbonate under saturation), current flow intensity and hydrostatic pressure (W. smart, 2008).

In the previous study of benthic foraminifera in the sediments of Caspian Sea, 13 species belong to 10 genera were identified (Birshtain *et al*., 1968).

The main objectives of this recent study are to identification benthic foraminifera communities in the southern Caspian Sea from Fereidoonkenar to Babolsar for the first time and study their abundance relation with the environmental conditions of the benthic zone.

Materials and Methods

Study Area

The study was carried out in spring 2011 in the southern Caspian Sea, Mazandaran state, from Fereidoonkenar to Babolsar (Table 1, Figure 1). Sediment samples were collected from 12 stations, ranging in depth from 5 to 20 m.

Sampling Method

Stations depths were measured with scaled rope and sampling latitudes were recorded with the Global Positioning System. At each station, a 0.1 m^2 Van-Veen grab sampler was used to collect bottom sediments. Three sets of samples were taken at each station by a 6.15 cm^2 area core sampler and were stored in plastic boxes. Each sediment for foraminiferal studies (30.77 cm^3 volume) was treated with 1 g/L Rose Bengal solution immediately after its arrival on boat to distinguish living specimens, and then being mixed with 4% concentrated formalin solution (Moghaddasi *et al*., 2009a).

The benthic environmental factors including temperature, dissolved oxygen, salinity and pH were measured by an electrical portable molt meter during the sampling time.

Table 1. Position of sampling stations

Station No.	Longitude (N)	Latitude (E)
A1	52 31′ 38/3"	36 41′ 54/2″
A2	52 31′ 16/9″	36 42′ 20/2″
A3	52 31′ 21/5″	36 42′ 56/9″
A4	52 31′ 13/0″	36 43′ 45/1″
B1	52 34′ 58/7″	36 42′ 32/7″
B2	52 35′ 11 /2″	36 43′ 04/2″
B3	52 34′ 25/9″	36 43′ 39/2″
B4	52 34′ 26/8″	36 44′ 25/3″
C1	52 37′ 59/8″	36 42′ 56/0″
C2	52 37′ 36/8″	36 43′ 33/9″
C3	52 37′ 32/2″	36 44′ 18/6″
C4	52 37′ 08/8″	36 44′ 29/9″

Foraminifera Analysis

For determining foraminifera, in the laboratory, wet samples were washed through 63 µm mesh sieve to remove any excess stain and were then Oven dried (75ºC, 8 h), floated by the heavy liquid CCl_4 and the upper layer of the liquid consist of floated forams and other tested specimens were filtered by paper and allowed to dry. A stereomicroscope and several studies (Birshtain *et al*., 1968; Murray, 1979; Loeblich and Tappan, 1988) were used for studying and determining of foraminifera.

Sediment Analysis

Sediment grain size, Total Organic Matter (TOM) and calcium carbonate concentration. For the grain-size analysis, 100 g of dried sediments (70°C, 8h) in Oven was mixed with 250 ml of tap water and 10 ml of sodium hexametaphosphat (6.2 g/L) to disaggregate the sediment. Then according to Moghaddasi *et al*. (2009a) the sediment were stirred mechanically (15 min), allowed to soak (8 h), stirred mechanically (15 min) and dried again (70°C, 24 h). 50 g of dried material transferred in to the uppermost of a stacked series of graded sand sieves with 4, 2, 1, 0.5, 0.25, 0.125 and 0.063 mm mesh. Then the material that remained on the sieves was removed and weighed carefully. Finally the percentage of each particle was calculated.

Total Organic Matter (TOM) was measured based on standard method in Holm and Machintyre (1984) and MOOPAM (1999). At first wet sediment samples dried in Oven (70°C, 24 h). After removing from the Oven, 10 g of dried sediments was powdered with mortar. Each crucible was numbured with pencil and then was weighed (M) with digital scale (±0.001 accuracy) and was filled with 2 g of powdered sediments. Crucibles were then placed in furnace (550°C, 6 h), after that should wait to cool, then removed and reweighed again (W). The Total Organic Matter (TOM) was determined by the loss of weight during combustion, according following formula:

$$\%TOM = [(2.000-N)/2.000] \times 100 \qquad N=W-M$$

Calcium carbonate concentration was measured based on (Moghaddasi *et al*., 2009a) method. In this method 25 g (W_1) of dried sediments (70°C, 8h) was mixed with HCL (0.1 N) and stirred until no CO_2

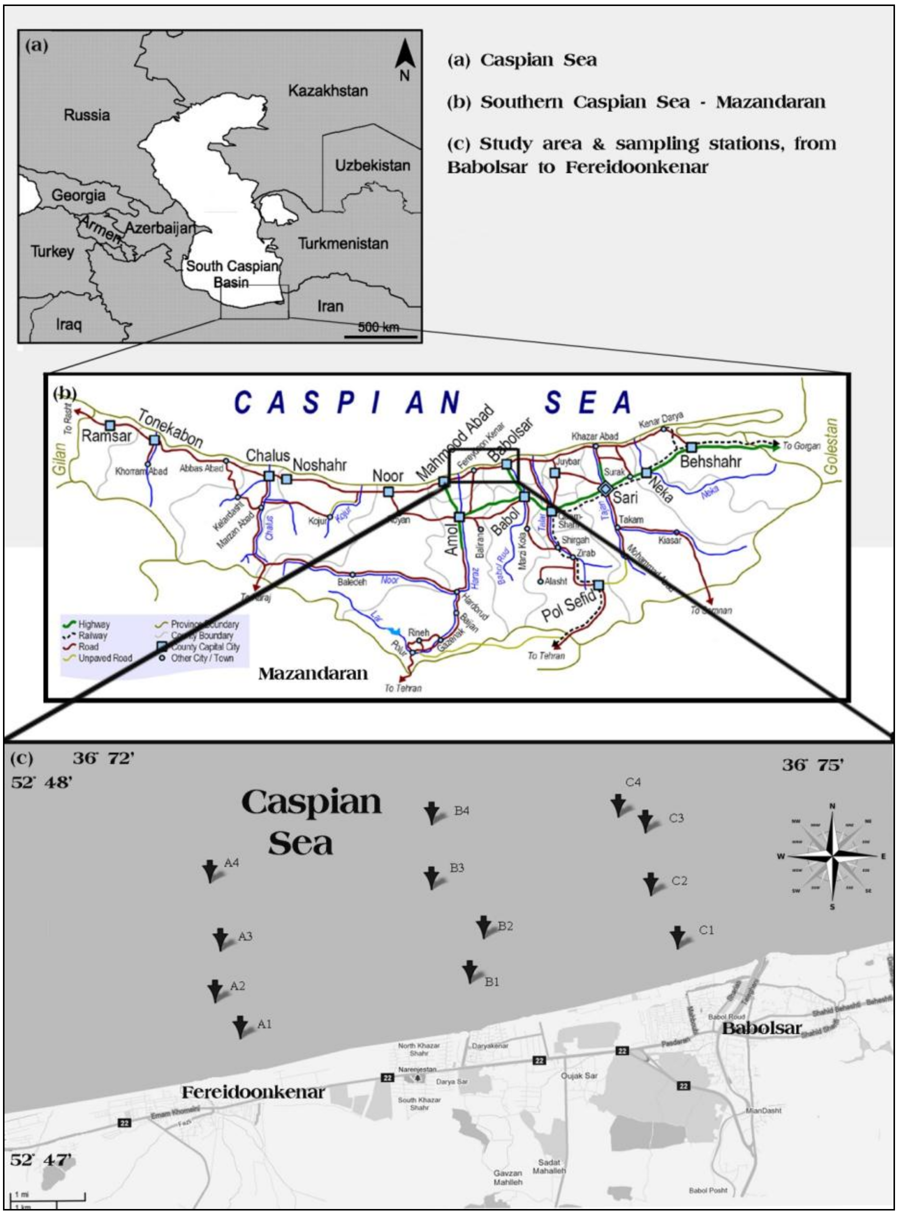

Figure1. Location of sampling stations, Mazandaran state, from fereidoonkenar to babolsar.

bobbles appearing and then allowed to soak for 24 hour. The upper liquid phase was drained and the remaining sediments were filtered by paper, dried in Oven (70°C, 8h) and was weighed again (W_2). Calcium carbonate concentration was determined according following formula:

$$CaCO_3 (\%) = 100 (W_1-W_2) / W_1$$

Results

Environmental Factors

In this study, the quantities of the environmental factors, including water depth, temperature, dissolved oxygen (DO), salinity, pH and benthic zone sedimentary results including Total Organic Matter (TOM) and Calcium carbonate concentration ($CaCo_3$) are shown in the Table 2 and the grain size analysis is shown in the Table 3.

The temperature of the water near the bottom was nearly similar in all stations (20.2 to 22.2). The results of measuring dissolved oxygen concentration indicated enough oxygen in water near the bottom and the high average of dissolved oxygen concentration was in B transect.

Salinity was also had low difference between stations (10.6 to 11) and increased with the depth increasing. pH was nearly equal in all stations (7.02 to 7.60), except, it was high (9.8) in the station B2.

The grain size analysis of the sediments showed that the structure of the sediment samples mostly consisted of fine sand; very fine sand, silt and most of sediment particles in C transect was consisted of very fine sand (>65%), that are carried by the wind from sandy shore of this transect. The silt and clay rate

Table 2. Temperature, dissolved oxygen (DO), salinity, pH, TOM and $CaCo_3$ in the Southern Caspian Sea from Fereidoonkenar to Babolsar

Station No.	Depth (m)	Temperature (ºC)	DO (mg/L)	Salinity (ppt)	pH	TOM (%)	$CaCO_3$ (%)
A1	5	20.2	6.72	10.7	7.02	2.0	1.24
A2	10	20.5	6.90	10.8	7.20	9.0	1.52
A3	15	20.7	7.08	10.9	7.22	6.0	1.72
A4	20	20.4	7.10	11.0	7.16	10.5	1.56
B1	5	21.6	8.00	10.6	7.60	9.5	1.04
B2	10	21.3	8.60	10.8	9.80	4.5	1.00
B3	15	21.0	7.80	11.0	7.30	3.5	2.08
B4	20	20.9	7.80	10.6	7.14	10.0	3.20
C1	5	21.7	6.40	10.6	7.30	10.0	1.40
C2	10	22.2	7.50	10.6	7.10	1.5	1.08
C3	15	21.9	7.90	10.7	7.10	3.0	1.76
C4	20	22.0	8.02	10.8	7.08	5.5	2.64

Table 3. The grain size analysis and percentage of each size group of the sediment particles

Station No.	Diameter of sediment particles (mm)							
	d<0.063	0.063-0.125	0.125-0.25	0.25-0.5	0.5-1	1-2	2-4	d>4
A1	5.28	85.42	9.20	0.08	0.02	0.00	0.00	0.00
A2	4.12	76.52	14.86	2.88	1.02	0.40	0.20	0.00
A3	10.20	70.96	15.66	2.94	0.24	0.00	0.00	0.00
A4	24.04	47.82	20.22	3.76	2.80	1.36	0.00	0.00
B1	3.16	68.30	26.30	1.80	0.38	0.04	0.00	0.00
B2	5.30	67.28	25.46	1.90	0.00	0.04	0.00	0.00
B3	38.90	50.62	8.68	0.78	0.50	0.36	0.00	0.00
B4	28.90	64.64	3.58	1.30	0.88	0.70	0.00	0.00
C1	3.02	85.22	11.54	0.16	0.04	0.02	0.00	0.00
C2	3.32	92.48	4.20	0.00	0.00	0.00	0.00	0.00
C3	15.96	67.88	8.96	3.16	3.46	0.54	0.00	0.00
C4	19.12	75.98	2.68	1.42	0.80	0.00	0.00	0.00

increased in depth 15 and 20 m (see A3, A4, B3, B4, C3, and C4) and the grain size decreased with water depth.

Total Organic Matter (TOM) was higher in stations A4 and B4 with depth 20m and in station C1 with depth 5m.

Calcium carbonate concentration was high in station B4 and this station had the most abundance of benthic foraminifera.

Foraminifera

In this study from collective sediments, 3 groups including Foraminifera (benthic and planktonic), Bivalvia and Gastropoda were separated and the benthic Foraminifera were observed in all stations and had the most abundance among the other groups. From 6 separated benthic foraminifera, 4 species belong to 4 genera of 4 families were identified (Figure 2). Species were *Ammonia beccarii caspica*, *Elphidium littorale caspicus*, *Milliammina fusca* and *Ammotium* sp. The abundance of meiobenthic and forams species in the sediment samples are shown in Table 4 and 5 respectively.

Benthic foraminifera were the dominant group between the other meiobenthos and they were very small, also Gastropoda and Bivalvia were presented in most station.

The most abundance of benthic foraminifera observed in station B4 and the cosmopolitan foraminifera *Ammonia beccarii caspica* was the dominant species in all sampling stations and The result of Pearson correlation showed the abundance of benthic foraminifera had a significantly correlation with silt and clay rate (at $P<0.05$).

Structural abnormalities in the testes of the benthic foraminifera (Figure 3) indicated the comparatively polluted benthic environment in some stations from Fereidoonkenar to Babolsar of Southern Caspian Sea.

Discussion

Environmental Factors

The temperature of the water near the bottom was nearly similar in all stations that related to a system of horizontal and vertical movements of water masses in the Caspian Sea, as well as in any other water body (Aladin and Plotnikov, 2004). The results

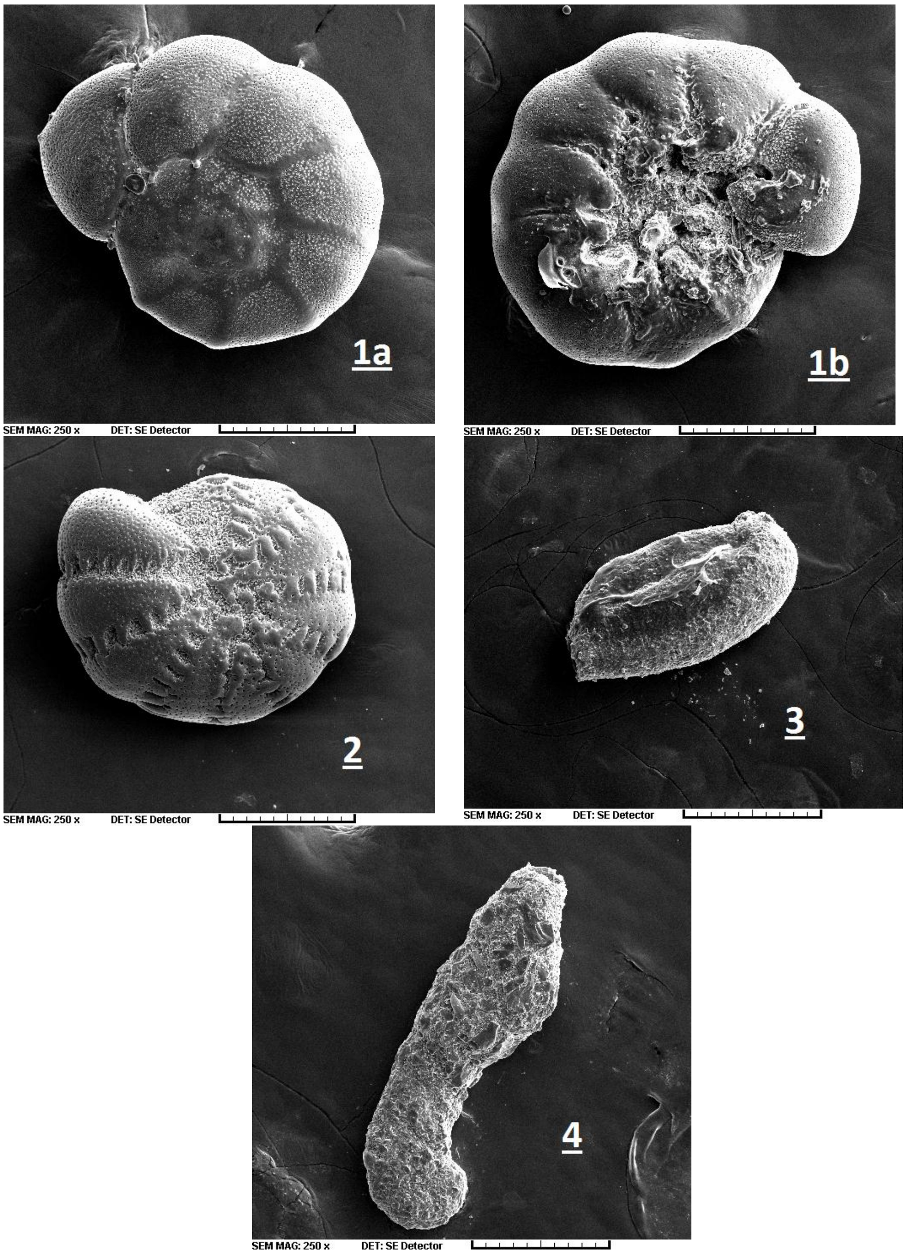

Figure 2. SEM photographs of 4 identified species of benthic foraminifera. 250 X. 1a, 1b: *Ammonia beccarii caspica* (Stshedrina). 2: *Elphidium littorale caspicus* (Shokhina). 3: *Milliammina fusca* (Brady). 4: *Ammotium* sp. (Loeblich and Tappan).

Table 4. Abundance of meiobenthic in the sediment samples of southern Caspian Sea from Fereidoonkenar to Babolsar

Station	Foraminifera	Bivalvia	Gastropoda	Total abundance
A1	1049	4	0	1053
A2	2594	20	10	2624
A3	23474	41	70	23587
A4	21094	1164	1083	23345
B1	1656	52	21	1729
B2	6443	21	6	6470
B3	17578	57	41	17677
B4	58794	2244	366	61408
C1	201	0	1	202
C2	2209	64	0	2273
C3	40754	610	313	41687
C4	27171	189	348	27722

Table 5. Abundance of foraminifera in the sediment samples of southern Caspian Sea from Fereidoonkenar to Babolsar

Foraminifera	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
Ammonia beccarii caspica	1014	2512	21926	19839	1558	6209	15921	50895	183	2131	37468	24137
Miliammina fusca	2	11	693	45	12	48	456	770	3	8	590	132
Ammotium sp.	2	0	55	8	5	16	75	72	1	3	49	6
Elphidium littorale caspicus	30	64	705	1080	74	152	999	6480	12	58	2405	2715
Unidentified sp.I	1	7	72	120	5	16	102	564	2	8	200	175
Unidentified sp.II	0	0	21	4	0	2	25	11	0	0	42	5
Total species numbers of Foraminifera	5	5	6	6	5	6	6	6	5	5	6	6
Total pelagic foraminifera numbers	0	0	2	0	2	0	0	2	0	1	0	1
Total numbers of Foraminifera	1049	2594	23474	21094	1656	6443	17578	58794	201	2209	40754	27171
Structural test abnormalities	1	10	144	70	5	42	96	204	1	3	146	126

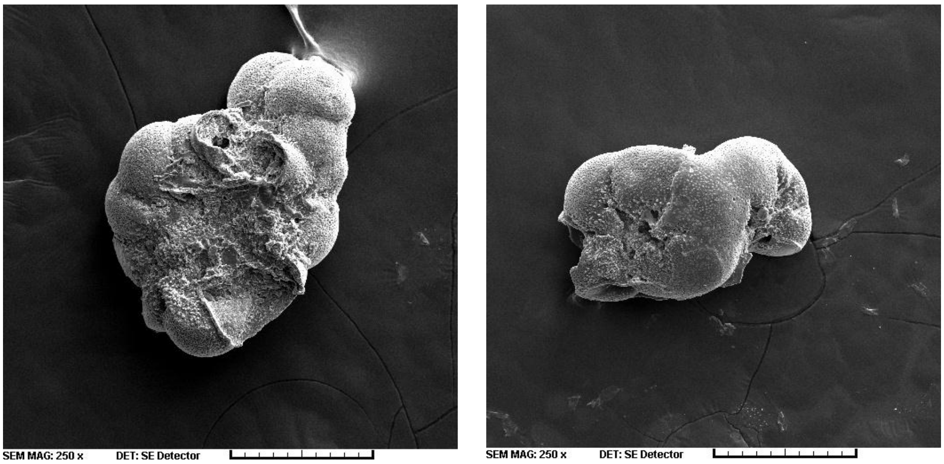

Figure 3. SEM images of structural abnormalities in the testes of the benthic foraminifera. 250

indicated that enough oxygen presented in water near the bottom that good intermixing of water is observed in this lake, causes the bottom waters to be rich in oxygen (Aladin and Plotnikov, 2004).

According to results pH was nearly equal in all stations except, it was high in the station B2 that is probably related to constructive activities in the quay, placed near this transect and caused western-eastern water currents carrying fine sand and calcareous compounds to this station and increasing pH.

The grain size analysis of the sediments showed that the structure of the sediment samples mostly consisted of fine sand; very fine sand, silt and clay that is probably related to nonexistence of rivers follows, which causes reduced the coarse grain-size in this confined. The grain size decreased with water depth, according to Duros (2011) a slight decrease of grain size observed with water depth in the Whittard Canyon area (NE Atlantic).

Total Organic Matter (TOM) was higher in stations A4 and B4 that is related to increasing silt-clay rate, because according to Moghaddasi (2008) organic compounds increased in silt-clay sediments. Also TOM was high in station C1, which is probably related to the situation of this station that placed near the river (Babol). Because in spring the river water volume increases and transfers a lot organic compounds in to the sea.

Foraminifera

The cosmopolitan foraminifera *Ammonia beccarii caspica* was the dominant species in all sampling stations and is reported in earlier research in the Caspian Sea (Birshtain *et al*., 1968). *Ammonia beccarii* is a common cosmopolitan species dwelling in littoral and neritic environments. It has been extensively studied in various aspects, such as, geographic distribution, ecology, biology, life-cycles, morphology, structure, and environmental applications from all over the world (Debenay *et al*., 1998).

Milliammina fusca was observed in all stations and is reported in earlier research in the Caspian Sea (Birshtain *et al*., 1968). The abundance of *Miliammina fusca* was not high and it's increased with adding silt and clay rate. According to Armynot du Châtelet *et al*. (2009) *Miliammina fusca* only found at two stations that, the sediment is naked and is mainly composed of silt (78% of grains less than 63 μm).

Elphidium littorale caspicus was observed in all stations and had the most abundance after *Ammonia beccarii caspica* in sampling area and is reported in earlier research in the Caspian Sea (Birshtain *et al*., 1968). *Ammotium* sp. was observed in all stations except in A2 and had the lowest abundance. This species is reported in earlier research in the Caspian Sea (Birshtain *et al*., 1968).

Abundance and species richness increase with depth that according to Buzas *et al*. (2007), Like most other organisms, they often show an increase in species richness with depth.

Structural abnormalities in the testes of the benthic foraminifera indicated the comparatively polluted benthic environment in some stations, is probably related to enter metropolitan, industrial and agricultural sewage from the rivers placed in sides of this area.

According Table 4 the highest abundance of benthic foraminifera was observed in station B4 has probably the best condition for the foram populations, is also related to the fine structure of sediment particles in addition to the high concentration of total organic matter and calcium carbonate concentration.

The Pearson correlation analysis was conducted to clarify the relationships between grain size and abundance of benthic foraminifera. The result of Pearson correlation showed the abundance of benthic foraminifera had a significantly correlation with silt and clay rate (at $P<0.05$), is probably related to dominant species *Ammonia beccarii caspica* belong to suborder ROTALINA preferred silt-clay and very fine sand of benthic zone structure (Moghaddasi *et al*., 2009b), also *Ammonia beccarii* has played an important role in environmental and geological studies because of its great abundance, wide geographic distribution (Debenay *et al*., 1998).

The huge number of very small benthic foraminifera is related perhaps to suitable conditions for reproduction in spring season, according to reference Spatial and seasonal variability may be natural (Morvan *et al*., 2006), reproduction mode (Stouff *et al*., 1999), sources and distribution pattern of food particles (Fontanier *et al*., 2003).

By the result of present study the density and diversity of benthic foraminifera in this area was lower than tropical. The environmental conditions of the benthic zone including fine, very find sand and silt-clay structure of sediment particles, flux of total organic matter and enough dissolved Oxygen were suitable for the benthic foraminifera. According to (Moghaddasi *et al*., 2009a; Armynot du Châtelet *et al*., 2009) sediments structure is the most important factor, effected density and diversity of benthic foraminifera and According to (Fontanier *et al*., 2002) the exported flux of organic matter appears to be the main parameter controlling the composition and the vertical distribution of benthic foraminiferal faunas below the sediment-water interface.

It seems in recent study, sediment structure had an important role, controlling abundance of benthic foraminifera, Conversely, relatively fine grain-size (mode inferior to 95µm) is associated with a high density and richness foraminifera (Armynot du Châtelet *et al*., 2009).

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