Article

Effect of urban pollutants on distribution of benthic foraminifera in the Southern of Caspian Sea

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Abstract

The Caspian Sea has characteristics common to both seas and lakes and listed as the world's largest lake. This study investigates recent foraminifera from sediment samples collected during spring, summer, autumn and winter 2012 from 12 stations (ranging in depths 5, 10, 20 and 50 meters) in the Southern Caspian Sea from Behshahr to Ramsar. Associated factors includes: grain size, Total phosphate, Total nitrate, total organic matter and calcium carbonate concentration were also measured. The benthic environmental factors including temperature, dissolved oxygen, salinity and pH were measured by CTD during the sampling time. Recognized benthic foraminifera species belong to 6 genera of 5 families were identified. Eleven benthic foraminifer's taxa were identified from the samples. They were *Ammonia beccarii caspica*, *Ammonia tepida, Ammonia parkinsoniana, Elphidium littorale caspicus, Elphidium excuavatum, Criboelphidium* sp., *Ammobaculites agglutinans, Ammotium* sp., *Miliammina fusca, Milliammina* sp. *and Cornuspira* sp. The cosmopolitan *Ammonia beccarii caspica* was common in the studied area. The density of benthic foraminifera is significantly correlated with seasons, the highest density being observed in winter, most density of foraminifera was observed in Babolsar stations that showed a good situation for living there and we can use foraminifera such as bioindicator for pollutant area.

Keywords urban pollution; foraminifera; Caspian Sea; total organic matter; benthic.

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1 Introduction

The ecology of the Caspian Sea is threatened due to several issues such as petroleum extraction, river and sea pollution, water-level rise, biological damage, the decline of Caspian seals and lack of legal regime among the neighbors. Infrastructural developments have had serious impacts on the ecosystem around the Caspian Sea and have often imposed long term damage (Nasrollahzadeh, 2010). Foraminifera are tested protozoa, living in every aquatic environment (marine, brackish or fresh) and are distributed across all latitudes, but especially tropics (Moghaddasi et al., 2009), with an important role in transferring energy within the aquatic ecosystem (Mirzajani et al., 2002). Benthic foraminifera are common in marine sediments, often have good fossil preservation, and represent a useful tool for oceanographic and palaeooceanographic studies (Murgese and De Deckker, 2005). The fossil remains of Foraminifera maybe used for palaeoecological reconstructions of former environments (Murray, 2006), and also in marine biogeography and biodiversity across varying scales of space and time (Buzas et al., 2007). The response of benthic foraminifera to natural and anthropogenic stresses has several applications in the investigation of environmental changes in estuarine and reef studies (Carnahan et al., 2009; Sabean et al., 2009). Benthic foraminifera have exceptional utility as bio-indicators of coastal contamination, and understanding the impact of pollution (mainly by heavy metals and organic matter) on foraminifera has been the goal of an increasing number of research lines (Carnahan et al., 2009; Frontalini et al., 2011; Martins et al., 2011). Foraminifera are increasingly used in assessing marine environments and in resource monitoring (Roshni and Pandolfi, 2010), particularly in coastal regions where impacts from increasing human populations are leading to rapid degradation of near shore ecosystems (Lotze et al., 2006). The development of foraminiferal indices for use in regional ecological assessment and monitoring strategies have provided a useful tool for carrying out baseline studies and in understanding ecological changes in marine communities (Carnahan et al., 2009). Because of short life cycles, preservation in marine sediments, diversity and abundance, sensitivity to rapid changing of environmental conditions and easy collection with minimal impact to the environment, benthic foraminifera are recognized as exceptional bio-indicators (Murray, 2006; Carnahan et al., 2009). 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). It also provides a basis for future investigations aimed at unraveling the benthic foraminifera response to human-induced pollution in marine and transitional marine environments (Coccioni et al., 2009), and in coastal and transitional settings, such as aquaculture, oil spills, heavy metals, and urban sewage (Bouchet et al., 2012).

Humans have always relied on the oceans and their resources, first as a food source (fishing), later for transportation of raw materials. Today, our oceans are also exploited for mineral, gas, oil, and other natural resources of great economic importance. It is noticeable that 50% of the world population lives in coastal areas or nearby regions (Sherbinin et al., 2007). Such a high population density along the coastal areas results in high environmental stress due to the multiple activities that take place there (Agardy et al., 2005). The discharge of municipal and agriculture effluents, for instance, may result in functional changes of coastal environments due to the entry of excessive nutrients that in coastal environments, the contents of contaminants and organic matter in sediment, which might be capable of damaging biota, are mainly ascribed to human activities (Karlson et al., 2007; Diaz and Rosenberg, 2008; Zhang et al., 2011; Wu and Zhang, 2012; Al-Farraj et al., 2013). Rivers, estuaries, and marine waters have mainly served for final repositories of anthropic waste both organic and inorganic and where the sediment represents the final sink (Goher et al., 2014). Benthic foraminifera are an important component of oceanic systems and they are also widely used in marine environments, mainly transitional and coastal marine settings, as bioindicators of environmental quality (Frontalini and Coccioni, 2011; Martins et al., 2013). The distribution, abundance and diversity of benthic foraminifera are mostly controlled by physicochemical properties of water and sediment. These parameters encompassing salinity, pH, currents, temperature, DO in water and sediment, type of substrate, and organic carbon content represent the main factors regulating the foraminifera distribution (Murray, 2006). More recently, the quality of the organic matter has been inferred to play an important role in determining the distribution of benthic foraminifera assemblages in both open and marginal settings (Clemente et al., 2014;

Martins et al., 2015a, 2015b). In light of it, the characterization of the sources (marine vs. continental), the quantity and quality of the organic matter is considered crucial for benthic foraminifera ecological inference, particularly in the highly dynamic settings like transitional marine environments. Pollutants' inputs are due to municipal effluents coming from the bordering cities, from the naval port and the metallurgic factory and several other industries such as iron and steel plant, cement factory and refinery and are adsorbed by the sediments (Zaaboub et al., 2015; Martins et al., 2016).

Regionally, research on the diversity and distribution of benthic foraminifera in Oman Sea continental shelf sediments (Iran) identified 40 taxa belonging to 24 genera; Ammonia beccarii was common in the whole research region and water depth, salinity and the structure of the sediments seemed to be the most important abiotic factors controlling the distribution pattern of benthic foraminifera (Moghaddasi et al., 2009). In the researches on the benthic Caspian Sea foraminifera there were 13 species (*Ammobaculties* sp., *Ammotiumverae*, Mayer sp., *Miliammina fusca*, *Miliammina* sp.1, *Gaudrinellaperexilis*, *Cornuspira* sp., *Discorbisinstans*, *Florilustrochospiralis*, *Ammonia beccarii*, *Elphidum ishochinae*, *Elphidium littorale*, *Elphidiellabrotzkajae* belong to 10 genera identified (Birshtain et al., 1968) and 4 species (*Ammonia beccarii caspica* (Stshedrina), *Elphidium littorale caspicus* (Shokhina), *Milliammina fusca* (Brady), *Ammotium* sp.) belong to 4 genera in southern Caspian Sea sediment samples gathered from Fereidoonkenar to Babolsar (Sadoogh et al., 2013).

Foraminifera faunas of the Caspian Sea are poorly studied. The purpose of this study is to investigate benthic foraminifers' communities in the southern Caspian Sea (from Mazandaran - Iran) and establish foraminifers' density in relation to urban pollutants, seasonal changes and sediment conditions.

2 Study Area and Methodology

2.1 Site descriptions

The study was carried out in spring, summer, autumn and winter 2012 in Mazandaran province, from Behshar to Ramsar along the southern coast of the Caspian Sea (Fig. 1, Table 1). Sediment samples were collected from 12 stations, ranging in water depth from 5 to 50 m (Fig. 2).

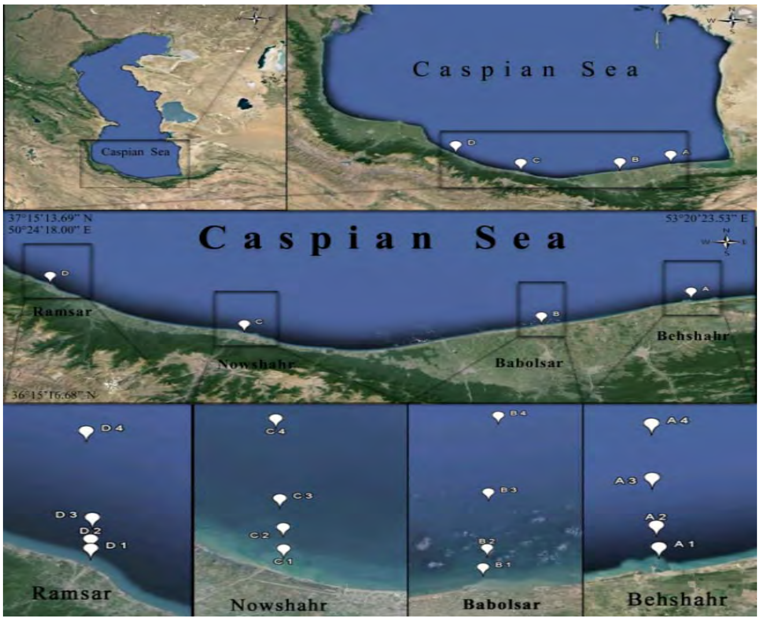

Fig. 1 Situation of sampling stations in the Southern Caspian Sea.

Table 1 Position of sampling stations.

stations	Depth(m)	Longitude (°N)	Latitude (°E)
A1	5	36° 51' 31"	**53° 16' 16. "**
A2	10	36° 53' 10"	**53° 16' 12"**
A3	20	36° 56' 48"	**53° 16' 09"**
A4	50	37° 00' 52"	**53° 16' 16"**
B1	5	36° 43' 18"	**52° 39' 33"**
B2	10	36° 43' 58"	**52° 39' 36"**
B3	20	36° 45' 55"	**52° 39' 28"**
B4	50	36° 48' 41"	**52° 39' 29"**
C1	5	36° 40' 32"	**51° 27' 43"**
C2	10	36° 41' 04"	**51° 27' 44"**
C3	20	36° 41' 47"	**51° 27' 42"**
C4	50	36° 43' 47"	**51° 27' 41"**
D1	5	36° 56' 47"	**50° 39' 20"**
D2	10	36° 57' 18"	**50° 39' 21"**
D3	20	36° 58' 29"	**50° 39' 26"**
D4	50	37° 03' 17"	**50° 39' 16"**

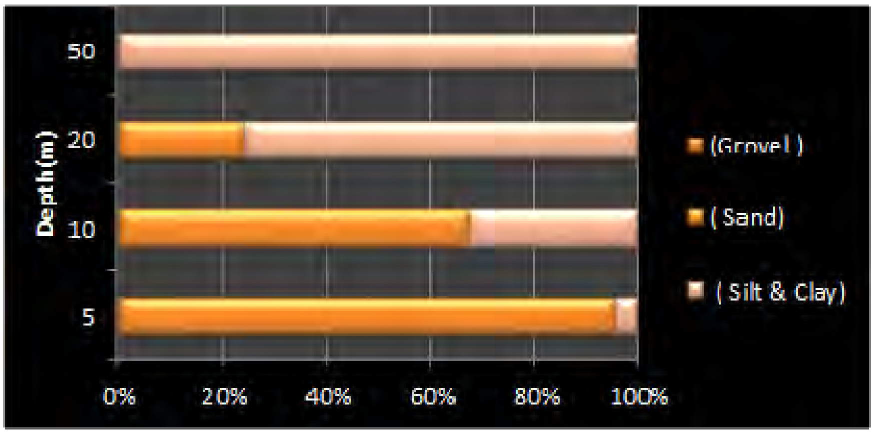

Fig. 2 Percentage of gravel, sand, silt and clay in different depth in the southern Caspian Sea, Behshahr to Ramsar.

2.2 Sampling method

Samples were collected by boat and stations depths were measured with echo sounder and sampling coordinates 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 6.60 cm^2 area core sampler with 5cm depth and were stored in plastic boxes. For benthic studies, each sediment (33 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 5% concentrated formalin solution (Moghaddasi et al., 2009, MOOPAM, 2010; Sadoogh et al., 2013; Zarghami et al., 2018).

Water samples were collected to measure total phosphate and total nitrate. Samples were taken from near-bottom of the stations using a Niskin sampler. After filtering in the field, the water samples were kept in a cool place over ice until for analysis in laboratory. Total nitrogen (TN) was measured colorimetrically after oxidation with peroxodisulfate and reduction in a Cu-Cd column. Total phosphorus (TP) was determined by the molybdenum blue method after digestion with peroxodisulfade (APHA, 2005). According with the APHA-standard methods digestion of samples for the determination of total nitrogen (TN, µg/l) and phosphorus (TP, µg/l) were done by the per-sulphate digestion procedure.

2.3 Foraminifera analysis

For determining foraminifera, in the laboratory, wet samples were washed through a 63 µm mesh sieve to remove any excess stain and were then oven dried (75 ºC, 8 h) (Schratzberger et al., 2002). Foraminferal tests were floated off using the heavy liquid CCl_4 with the upper layer of the liquid consisting of floated foraminiferal tests, which were then filtered by paper and allowed to dry. A stereomicroscope was used to examine and identify tests with reference to several previous studies (Birshtain et al., 1968; Murray, 1979; Loeblich and Tappan, 1988).

2.4 Environmental factors

The benthic environmental factors including temperature, dissolved oxygen, salinity and pH were measured by CTD during the sampling time. Sediment grain size, Total Organic Matter (TOM) and calcium carbonate concentration ($CaCO_3$) were measured. For the grain-size analysis, 100 g of oven-dried sediment (70 °C, 8 h) was mixed with 250 ml of tap water and 10 ml of sodium hexametaphosphate (6.2 g/L) to disaggregate the sediment. The sediment was then stirred mechanically (15 min), allowed to soak (8 h), stirred mechanically (15 min) and dried again (70 °C, 24 h). Fifty grams of dried material was then transferred 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. The material that remained on the sieves was removed and weighed. Finally, the percentage of each particle was calculated (Moghaddasi et al., 2009; MOOPAM, 2010).

TOM in each sample was measured by calculating the loss of weight during combustion. An empty crucible was weighed and then half-filled with wet sediment and dried in an oven (70 °C) until a constant weight was reached (about 24 hours). After removal from the oven, the sample was allowed to cool and was reweighed (A). It was then placed in a Muffle furnace (550 °C – 8 hours), removed, cooled and reweighed again (B). The TOM content was determined by the loss of weight on ignition at this temperature [%TOM =100(A-B) / (A-C)] (Moghaddasi et al., 2009; MOOPAM, 2010).

Calcium carbonate concentration was measured based on the reaction with dilute Hydrochloric Acid (HCl). Twenty-five grams (W1) of dried sediment (7 – 8 hrs.) was mixed with HCl (0.1.N) and stirred until no CO2 bubbles were discernible, and then allowed to soak (24 hrs.). The upper liquid phase was discharged and the remaining sediments were filtered (with filter paper), dried (7 – 8 hrs.) and reweighed again (W2). Calciumcarbonate percentage was measured by the following formula [$\%CaCO_3$= 100 (W1-W2) / W1] (Moghaddasi et al., 2009) (Table 2, 3 and 4).

2.5 Data analysis

Principal component analysis (PCA) was used to investigate the relationship between nine variables collected during seasonal sampling cruises in 2012 (temperature, pH, dissolved oxygen, salinity, %TOM, $\%CaCO_3$, TN, TP and granulometry). Discriminant Analysis (DA) was used in different depth and stations. One Way ANOVA was performed to test for possible differences. Shannon-Wiener (H/) diversity index and Peilou's Evenness Index have measured assaying species diversity and ecological assessment in this area (Marques et al., 2009). Amount of Shannon and Peilou’s indexes has been showed in Table 10, 11 and12.

3 Results and Discussion

3.1 Foraminifera

In this study from collective sediments, Foraminifera were observed in all stations. 11 species of benthic foraminifera species belong to 6 genera of 5 families were identified. *Ammonia beccariicaspica*, *Ammonia tepida*, *Ammonia parkinsoniana*, *Elphidium littoralecaspicus*, *Elphidium* sp., *Criboelphidium* sp., *Milliammina fusca*, *Milliammina* sp., *Ammobaculites agglutinans*, *Cornuspira* sp. and *Ammotium* sp. (Fig. 3, 4, 5 and 6).

The highest and lowest of density foraminifera respectively observed during winter at station B3 (1849.13 individual /0.1m^2) and in summer at station D4 (5.58 individual /0.1m^2). And the cosmopolitan foraminifera *Ammonia beccarii caspica* was the dominant species in all sampling stations.

Ammonia tepida and *Ammonia parkinsoniana* had not very abundance such as *Ammonia beccarii*. *Elphidium littoralecaspicus* was observed in all stations and had the most abundance after *Ammonia beccarii caspica* in the sampling area. *Elphidium excuavatum* and *Criboelphidium* sp. were rarely to compare with *Elphidium littorale*. *Elphidium excuavatum*, *Ammotium* sp., *Ammobaculites agglutinans*, and *Miliammina fusca* were not observed in spring. *Ammotium* sp., *Ammobaculites agglutinans* and *Miliammina fusca* were not observed in winter. *Cornuspira* sp. only was observed in autumn in B3 (Tables 5, 6, 7 and 8).

The result of Pearson correlation showed the density of benthic foraminifera had a significantly correlation with season (at $P<0.05$) and did not showed Correlation between the density of benthic foraminifera and other factors.

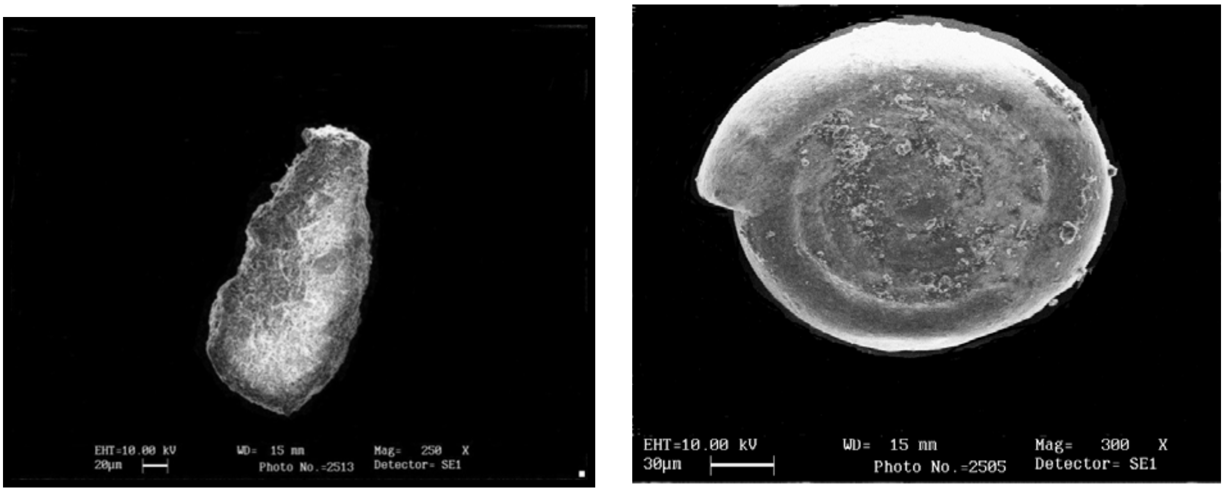

Fig. 3 SEM photographs of 2 identified species of benthic foraminifera. 1: *Ammobaculites agglutinans* (250X) and 2*: Cornuspira* sp.(300X).

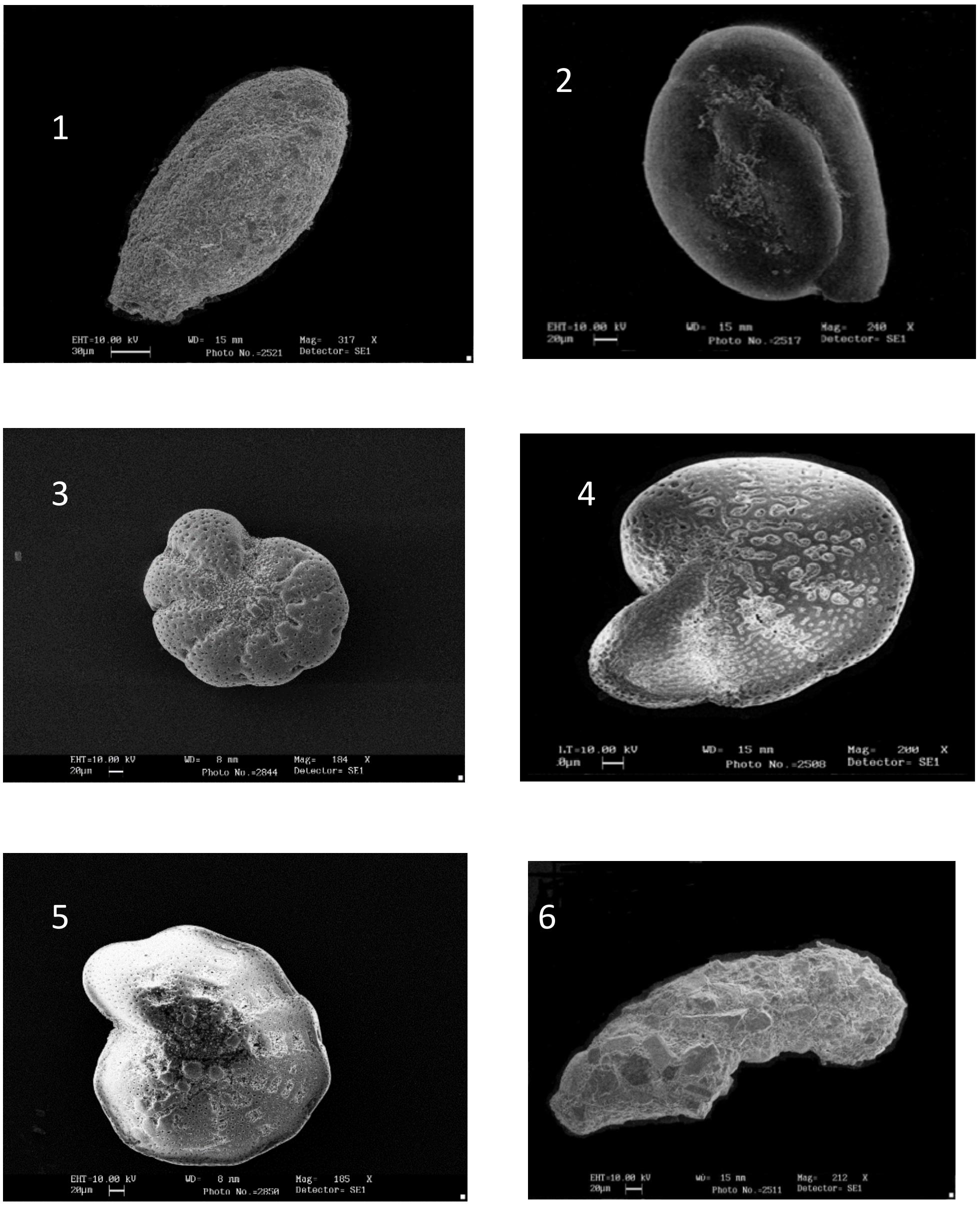

Fig. 4 SEM photographs of 6 identified species of benthic foraminifera.1: *Milliammina* sp. (317X) 2: *Milliammina fusca (*240X), 3: *Elphidium littoralecaspicus* (184X), 4: *Elphidium excuavatum* sp. (200x), 5: *Criboelphidium* sp. (185X), 6: *Ammotium*sp (212X).

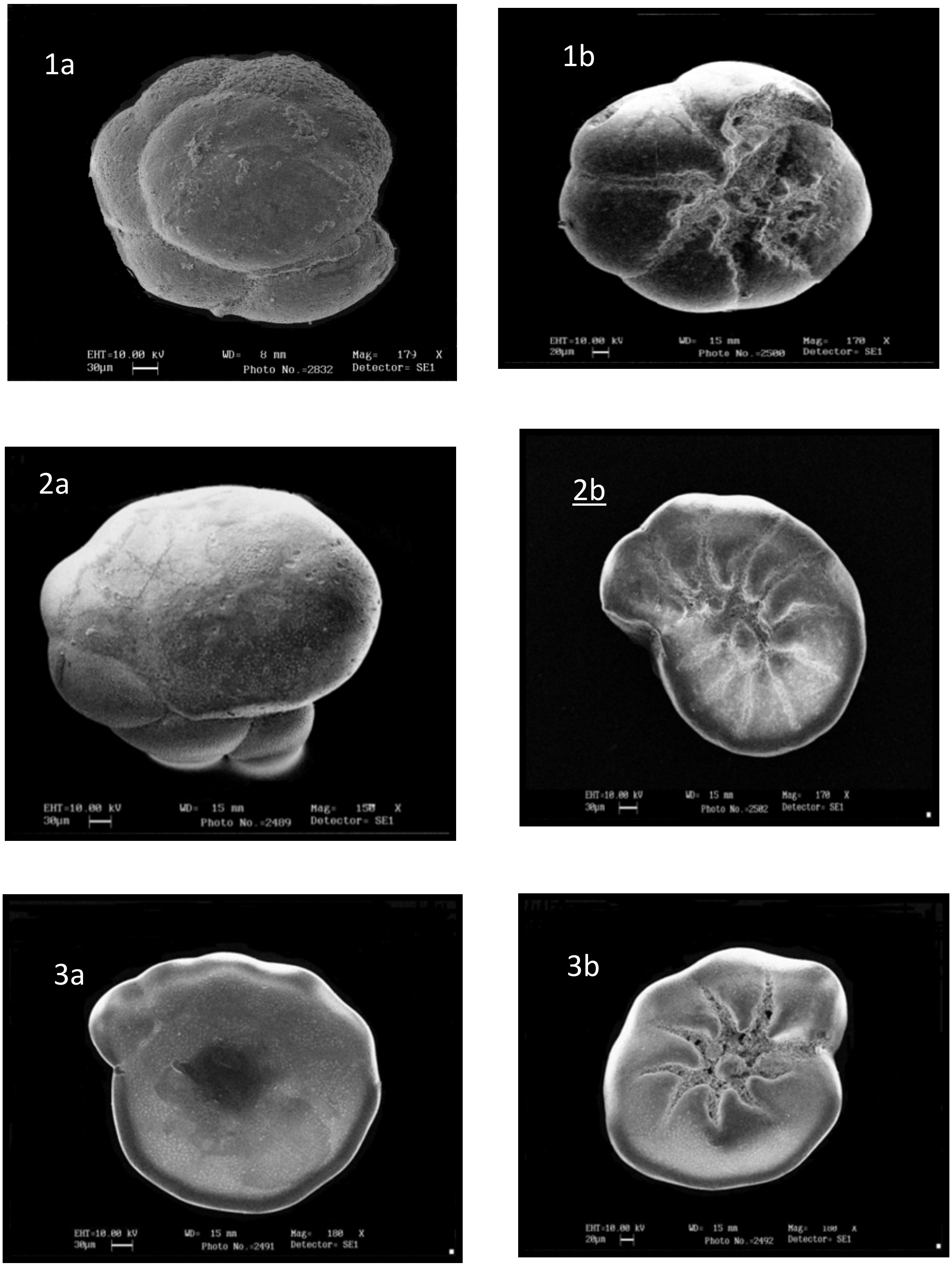

Fig. 5 SEM photographs of 3 identified species of benthic foraminifera (a: Dorsal and b: Ventral view).1a, b: *Ammonia beccarii caspica* (179X,170X), 2a,b: *Ammonia tepida* (170X,150X), 3a,b: *Ammonia parkinsoniana* (180X).

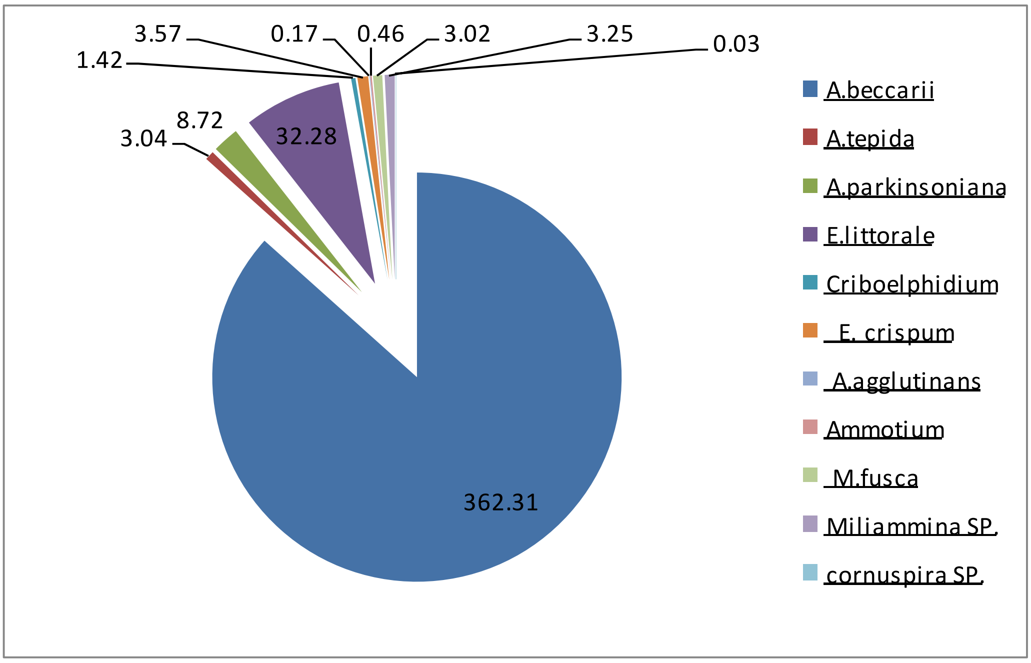

Fig. 6 Mean density of species of foraminifera in the south of Caspian Sea.

3.2 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 mass in the Caspian Sea, as well as in any other water body (Aladin and Plotnikov, 2004). The results 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 Jamshidi et al. (2009) in south of Caspian Sea, DO concentrations through the vertical and horizontal directions were not homogenously varied in this study. Concentrations of DO were found to range between 8.1 and 10.5 mg/ l.

According to results pH was nearly equal in all stations. In summer, when the surface water temperature was highest and the strongest seasonal thermo cline existed, the maximum value for pH was observed. In this season, pH had a value of 8.43 in bottom. The results of Hajizadeh and Araghi (2009) showed that seasonal variations of pH in the southern Caspian Shelf and the coastal waters adjacent to Iran is a function of seasonal variations in water temperature, characteristics of thermo cline, local rivers chemical characteristics and discharges, and production or degradation processes.

The result of TP and TN in this study was showed in Tables 2, 3 and 4 that maximum amount of TP and TN were observed Ramsar (65.7 and 438.2 µg/l) and minimum amount of them were observed in Noshahr (54.5 and 373.1 µg/l).

The grain size analysis of the sediments showed that the structure of the sediment samples mostly consisted of sand; silt and clay that are 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 et al. (2012), a slight decrease of grain size observed with water depth in the Whittard Canyon area (NE Atlantic). In the area, such as Thailand golf the grain size of the sediments does not play a significant role on the foraminifers distribution and according in Mielis and Violanti (2006). The result of PCA showed that granulometry had been important role (Table 9 and Fig. 7).

Total Organic Matter (TOM) was higher in station in stations D4 in spring that is related to increasing silt-clay rate, because according to Moghaddasi (2009) and Sadoogh et al .(2013) organic compounds increased in silt-clay sediments. The result of Pearson correlation showed the significantly positive correlation between depth and TOM ($P<0.05$).

Table 2 The mean of temperature, salinity, DO, pH, total organic matter (TOM), Caco$_3$, TP and TN in different Seasons the southern Caspian Sea from Behshahr to Ramsar (±SD).

Factors / Season	Temperature(C^0)	Salinity(ppt)	DO(mg/l)	pH	%TOM	%Caco$_3$	TP(µg/l)	TN(µg/l)
spring	20.74±0.02^{b}	11.01±0.01^{a}	10.23±0.04^{b}	8.27±0.01^{bc}	7±1^{a}	9±4.47^{a}	54.9±5.52^{a}	391.7±48.39^{a}
summer	23.93±0.008^{b}	11.22±0.005^{b}	8.17±0.014^{a}	8.56±0.005^{c}	8.52±1.64^{a}	9.61±3.29^{a}	65.9±2.54^{b}	413.6±42.82^{b}
autumn	17.34±0.007^{a}	11.14±0.01^{b}	8.1±0.007^{b}	8.11±0.051^{b}	8.08±1.03^{a}	9.19±2.22^{a}	53.3±4.67^{a}	344.3±57.76^{a}
winter	9.52±0.009^{c}	11.39±0.02^{a}	10.53±0.01^{b}	8.41±0.01^{a}	8.23±1.6^{a}	9.72±3.92^{a}	70.2±1.59^{b}	496.6±31.21^{c}

Table 3 The Mean of Temperature, Salinity, DO, pH, Total Organic Matter (TOM), Caco$_3$,TP and TN in different depthsof the southern Caspian Sea (±SD).

Factors / Depth	Temperature(C^0)	Salinity(ppt)	DO(mg/l)	pH	%TOM	%Caco$_3$	TP(µg/l)	TN(µg/l)
5	20.83±0.011^{a}	11.08±0.019^{a}	8.71±0.034^{a}	8.28±0.016^{a}	3.41±0.66^{a}	3.33±0.653^{a}	61.5±7.04^{a}	382.48±59.47^{a}
10	20.71±0.023^{a}	11.2±0.008^{b}	8.72±0.015^{a}	8.29±0.019^{a}	6.43±1.14^{b}	7.09±1.968^{b}	64.9±6.29^{a}	425.24±48.02^{a}
20	18.8±0.019^{a}	11.25±0.009^{b}	8.6±0.03^{a}	8.35±0.03^{a}	7.86±0.881^{b}	13.4±5.873^{c}	58.4±12.36^{a}	418±39.26^{a}
50	11.27±0.013^{b}	11.21±0.04^{b}	9.20±0.007^{b}	8.48±0.01^{a}	14.56±2.77^{c}	12.76±4.572^{c}	62.7±8.87^{a}	388.83±110.5^{a}

Table 4 The Mean of Temperature, Salinity, DO, pH, Total Organic Matter (TOM) ,Caco$_3$,TP and TN in different stations in the southern Caspian Sea from Behshahr to Ramsar (±SD).

Factors / Stations	Temperature (C^0)	Salinity (ppt)	DO(mg/l)	pH	%TOM	%Caco$_3$	TP(µg/l)	TN(µg/l)
A	18.52±0.34^{a}	10.97±0.032^{a}	8.69±0.036^{a}	8.4±0.024^{a}	10.59±1.88^{a}	14.73±6.26^{a}	63.45±3.33^{ab}	419.7±42.95^{a}
B	18.18±0.011^{a}	11.24±0.024^{a}	8.42±0.036^{a}	8.3±0.033^{a}	7.78±1.1^{b}	7.95±2.59^{b}	60.71±3.34^{ab}	388.2±46.82^{ab}
C	17.37±0.01^{a}	11.28±0.014^{b}	9.01±0.007^{a}	8.43±0.013^{b}	7.04±0.95^{b}	7.27±1.66^{b}	54.56±4.23^{b}	373.17±50.96^{b}
D	17.54±0.017^{a}	11.24±0.01^{a}	9.1±0.006^{a}	8.28±0.005^{a}	6.85±1.52^{b}	6.63±2.544^{b}	65.76±3.43^{a}	438.2±39.45^{a}

3.3 Foraminifera

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 (Sadoogh et al., 2013). *Ammonia tepida* was observed in all seasons but it had not very frequency in the previous studied (Hayward, 1999) is reported in the surface sediments of Nueces Bay, Laguna Madree Arroyo Colorado and in Laguna Atascosa. In the research of Melis and Violanti (2006), 73 species, pertaining to 37 genera have been identified. The frequent dominance of brackish-water species, such as *Ammonia tepida* was not high, the variability of the environmental conditions and explains the lowest biodiversity in respect to other tropical zones. In surface sediments, *Ammonia parkinsoniana* is recorded in all seasons in sampling area. In the last study this species is recorded mainly in northern waters such as the Mediterranean, the northeastern Atlantic and the western Atlantic near Cape Cod. They also occur in Texas estuaries and near shore in the Gulf of Mexico (Walton and Sloan 1990). *Elphidium littoralecaspicus* was observed in all seasons and had the most abundance after *Ammonia beccarii caspica* in sampling area and is reported in several studies (Birshtain et al., 1968; Sadoogh et al., 2013). *Elphidium excuavatum* was observed in all seasons except in spring. *Criboelphidium* sp. was observed in all seasons but it was rarely during spring and summer. Ammotium sp. abundance increase with depth that according to Buzas et al. (2007) this species is reported in earlier research in the Caspian Sea (Birshtain et al., 1968; Sadoogh et al., 2013). According to Sadoogh et al. (2013) in the Caspian Sea *Ammotium* sp. had the lowest abundance. *Milliammina fusca* was observed in at two stations (A2 andA3) and is reported in earlier research in the Caspian Sea (Birshtain et al., 1968; Sadoogh et al., 2013). The abundance of *Miliammina fusca* was not high and it increased with adding silt and clay rate and depth. According to Armynot du Châtelet et al. (2009), *Miliammina fusca* only found that the sediment is naked and is mainly composed of silt. *Miliammina* sp. was observed in all season and stations expect 50 m. It is reported in earlier research in the Caspian Sea (Birshtain et al., 1968). According to Sadoogh et al. (2013) in Caspian Sea this species had the lowest abundance. *Ammobaculoides agglutinans* was not observed in spring and winter this species only observed in depth of 5 and 10 m. *Cornuspira* sp. only was observed in autumn in B3 and this species was very rare.

In the present study there was no correlation between abundance of foraminifera and total organic matter, percentage of silt in substrate sediment, percentage of $CaCO_3$, DO, pH, TP, TN, temperature and salinity. According previous environmental conditions studies of the benthic zone including structure of sediment particles, flux of total organic matter and enough dissolved oxygen were suitable for the benthic foraminifera. According to past research (Moghaddasi et al., 2009; Armynot du Châtelet et al., 2003), sediments structure is the most important factor, effected density and diversity of benthic foraminifera and according to(Fontanier et al. (2016) 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. In present study, the highest density and diversity of benthic foraminifera was observed in station Babolsar (B) in depth of 20 m that has probably the best condition for the foraminifera populations, is also related to the fine structure of sediment particles (75% silt and clay) and in addition to the high concentration of calcium carbonate (13.4%). In the previous study by Sadogh et al. (2013) in south of Caspian Sea in depth of 5,10,15 and 20 m results showed that most density was observed in depth of 20 m.

The Pearson correlation analysis was conducted to clarify the relationships between different season and abundance of benthic foraminifera. The result showed the abundance of benthic foraminifera had a significantly correlation with season ($P<0.05$). Highest density of foraminifera was observed in winter. Babolsar (B) station had a good situation for living there. In this station that was located in next to Babol River, it thus had different situation. Shannon-Wiener (H/) diversity index gives a measure of faunal diversity Values <1 according (Molvaert et al., 1997) if the value of Shannon-Wiener (H/) is <1 showed bad ecological situation in totally but this index was high in station B rather other stations. That result showed high diversity observed in autumn. According results of TP and TN Behshahr and Ramsar were polluted that cause of Amir Abad port in behshar (A) and tourism area in Ramsar (D).

The effective application of benthic foraminifera in pollution monitoring also depends on understanding the specific response of benthic foraminifera to a particular pollutant. Teodoro et al. (2010) combined geochemical and foraminiferal data to classify sewage submarine outfalls with a different mix of pollutants.

Ammonia tepida and *Galvinopsis praegeri* were the most abundant species at all affected sites. The health of Rodrigo de Freitas Lagoon, in Brazil was evaluated by Gutterres et al. (2011) by using foraminiferal abundance. At the highest impacted area, *A. tepida –Elphidium excavatum* assemblage exhibited low diversity with weak, dwarf and corroded tests. Agglutinated species like *Ammobaculites dilatatus* and *Ammotium salsum* were abundant at less impacted area. Koukousioura et al. (2011) also identified three assemblages reflecting various environmental conditions. Increase tolerant taxa *Ammonia* spp. And *Elphidium* sp. reflected the influence of sewage pollution. Eichler et al. (2012) noted higher foraminifer's diversity at the mouth of the estuarine system, which was under the influence of the domestic sewage discharged from a submarine outfall. In our result not only highest density of *Ammonia* spp. and *Elphidium* sp. were observed in Babolsar but also a Highest diversity observed in this area.

Each species of foraminifera has its own threshold of sensitivity to different environmental parameters and to different types of pollution. Varying compositions of foraminiferal assemblages on the south Brazil shelf, the variability presents strong dependence upon seasonal nutrient variations in accordance to coastal freshwater intrusions and the upwelling of deeper water masses (Eichler et al., 2008). However in present study in station with highest amount of TN and TP we observed lowest density of foraminifera that showed pollutant factors decrease the density of foraminifera

Results of Martins et al. (2016) work highlight characterization of a coastal system using bio indicators. It is also important not only to use physicochemical parameters and metals' concentrations or other kind of pollutants but also to access the quantity and the quality of organic matter. This could be also important to understand the tolerance of opportunistic species to the environmental stress. According our results, we can use foraminifera as bioindicator for polluted area because of result showed the density of them were decreased in stations that recived a lot of containing of TP and TN.

Urbanisation induced pollution variation in foraminiferal assemblages from more stressed to less stressed area. Also urbanisation increased abundance of stress-tolerant taxa (Carboni et al., 2009). In our study we observed this and the lowest density of foraminifera were observed in sites with highest tourism and urbanization.

Table 5 Density of stained foraminifera (individual /0.1m^2) of southern Caspian Sea (Mazndaran) (spring, 2012) (±SD).

stations species	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
Ammonia beccarii	22.34±18.86	332.4±127.71	72.62±43.27	159.22±133.23	5.58±4.32	477.66±110.92	553.08±172.88	298.88±256.85	36.31±11.44	67.04±73.82	287.71±222.38	55.86±42.62	544.7±278.53	189.94±109.21	189.94±69.64	16.76±14.99
Ammonia tepida	2.79±4.32	13.96±4.32		29.33±24.19	5.58±4.32	11.17±8.65	5.58±8.65									
Ammonia parkinsoniana	5.58±8.65	16.76±0		2.79±4.32	5.58±8.65		13.96±21.63	2.79±4.32					5.58±8.65			
Elphidium littorale	2.79±4.32	44.69±4.32	2.79±4.32			106.14±68.01	36.31±4.32	19.55±30.29		11.17±17.3	36.31±15.6	2.79±4.32	19.55±24.09	5.58±8.65		
Criboelphidium sp.										2.79±4.32						
Elphidium excuav																

atum																
Ammobaculitesagglutinans																
***Ammotium*sp.**																
Miliamminafusca																
***Miliammina*sp.**			2.79±4.32	5.58±4.32												
***Cornuspira*sp.**																
Total	33.52	407.82	78.21	196.93	16.76	594.98	608.94	321.23	36.31	81	324.02	58.66	569.84	195.53	189.94	16.76

Table 6 Density of stained foraminifera (individual /0.1m^2) of southern Caspian Sea (Mazndaran) (summer, 2012) (±SD).

stations / species	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
Ammonia beccarii	452.52±113.42	620.12±467.42	290.5±167.65	600.56±165.8	55.86±35.42	670.4±506.3	1025.15±786.3	340.78±48.76	55.86±43.27	273.74±159.05	1069.84±312.86	410.62±184.05	136.87±45.79	458.1±489.87	223.46±63.74	5.58±8.65
Ammonia tepida	8.38±12.98	0	2.79±4.32		11.17±11.44	2.79±4.32					2.79±4.32		2.79±4.32			
Ammonia parkinsoniana					8.38±7.49	30.72±11.44	2.79±4.83			11.17±11.44	22.34±22.89					
Elphidiumlittorale	25.14±19.83	25.14±27.02			5.58±8.65	22.34±21.63	382.68±470.05	2.79±4.32		27.93±30.29	22.34±8.65	11.17±11.44	5.58±4.32	2.79±4.32	5.58±8.65	
Criboelphidiumsp.											2.79±4.32					
Elphidiumexcuavatum	5.58±8.65	5.58±4.32				8.38±7.49	13.96±24.19				2.79±4.32					
Ammobaculitesagglutinans		2.79±4.32														
***Ammotium*sp.**						11.17±11.44										
Miliamminafusca		19.55±30.29	125.7±124.74													
Miliammina sp.		2.79±4.32					2.79±4.83									
***Cornuspira*sp.**																
Total	491.62	675.98	419	600.56	81	745.82	1427.3	343.58	55.86	312.85	1122.92	421.79	145.2	460.9	229.05	5.58

Table 7 Density of stained foraminifera (individual /0.1m^2) of southern Caspian Sea (Mazndaran) (autumn, 2012) (±SD).

stations / species	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
Ammonia beccarii	346.37±86.22	335.2±135.12	64.24±34.61	463.69±300.95	153.63±48.18	368.72±202.09	405.03±249.53	181.56±164.59	371.51±119.53	164.8±78.73	991.63±249.08	1198.34±399.92	215.08±102.31	136.87±162.89	768.16±165.97	103.35±147.32
Ammonia tepida	36.31±18.86			2.79±4.32	19.55±4.32	2.79±4.32	2.79±4.32		13.96±15.6		5.58±4.32		8.38±7.49	2.79±4.32	8.38±7.49	
Ammonia parkinsoniana	25.14±9.67				33.52±0	61.45±28.37	30.72±41.28		11.17±4.32			22.34±15.6	33.52±27.02	13.96±11.44	125.7±52.46	
Elphidiumlittorale	71.23±24.19	8.38±12.98			27.93±11.44	8.38±7.49	128.49±108.7	5.58±8.65	33.52±14.99	13.96±8.65	36.31±36.97	53.07±31.2	13.96±11.44	2.79±4.32	41.9±41.73	2.79±4.32
Criboelphidium sp.	16.76±7.49				2.79±4.32	0	22.34±11.44		5.58±4.32			8.38±0	8.38±0	0	8.38±0	
Elphidiumexcuavatum	20.95±4.83				8.38±12.98	8.38±12.98			5.58±4.32		19.55±24.09	2.79±4.32	8.38±0	16.76±14.99	11.17±8.65	
Ammobaculitesagglutinans									8.38±12.98				2.79±4.32			
Ammotiumsp.					2.79±4.32	11.17±13.3						2.79±4.32				
Miliamminafusca																
Miliamminasp.		11.17±17.3				11.17±11.44	5.58±8.65		2.79±4.32	8.38±12.98	8.38±7.49		2.79±4.32			
Cornuspirasp.							2.79±4.32									
Total	516.76	354.75	64.24	466.48	248.6	472.07	597.77	187.15	452.52	187.15	1061.46	1287.72	293.3	173.18	963.7	106.14

Table 8 Density of stained foraminifera (individual /0.1m^2) of southern Caspian Sea (Mazndaran) (winter, 2012) (±SD).

stations / species	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
Ammonia beccarii	78.21±38.46	715.09±153.66	1022.36±627.5	81±60.11	1424.6±388.67	715.09±153.66	1022.36±627.5	81±60.11	1564.21±247.61	715.09±153.66	1022.36±627.5	81±60.11	424.58±168.49	173.18±97.82	181.56±57.24	16.76±14.99
Ammonia tepida	2.79±4.32	5.58±8.65	2.79±4.32		8.38±0	5.58±8.65	2.79±4.32		2.79±4.32	5.58±8.65	4.19±4.83		2.79±4.32	5.58±8.65	4.19±4.83	
Ammonia parkinsoniana	8.38± 0	44.69±36.97	13.96±15.6		8.38± 0	44.69±36.97	13.96±15.6		8.38±0	44.69±36.97	13.96±15.6		8.38±0	44.69±36.97	13.96±15.6	
Elphidiumlittorale	195.53±21.63	27.93±11.44	50.28±25.96	8.38±7.4	189.94±30.29	27.93±11.44	50.28±25.96	8.38±7.4	206.7±36.97	27.93±11.44	50.28±25.96	8.38±7.4	178.77±24.09	27.93±11.44	50.28±25.96	8.38±7.49

				9				9				9				
***Criboelphidium* sp.**	16.76±9.67				11.17±11.44				11.17±11.44				11.17±11.44			
Elphidium excuavatum	16.76±19.83	8.38±7.49	13.96±11.44		19.55±24.09	8.38±7.49	13.96±11.44		19.55±24.09	8.38±7.49	13.96±11.44		19.55±24.09	8.38±7.49	13.96±11.44	
Ammobaculitesagglutinans																
***Ammotium* sp.**																
Miliammina fusca																
***Miliammina*sp.**	16.76±0		27.93±15.6		11.17±8.65		53.07±8.65		36.31±4.32		25.14±12.98		27.93±4.32		44.69±4.32	
***Cornuspira*sp.**																
Total	335.2	801.68	1131.3	89.38	1673.20	801.68	1156.44	89.38	1849.13	801.68	1129.9	89.38	673.19	259.78	308.66	25.14

3.4 Data analysis

The result of PCA showed that granulometry, %TOM and % $CaCO_3$ and temperature had been important role (Table 9 and Fig. 7). ANOVA results showed no significant differences (at P>0.05). The result of Shannon Index was showed (Table 10, 11 and 12).

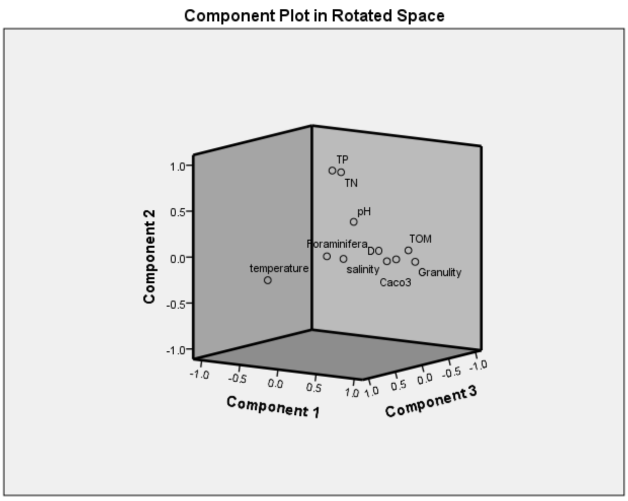

Fig. 7 PCA of environmental factors in southern of Caspian Sea.

Table 9 Component matrix in PCA.

Component Matrix[a]

	Component 1	Component 2	Component 3	Component 4
Granulity	.854	-.206	.205	.112
TOM	.780	-.181	.228	-.143
Caco3	.728		.436	.178
temperature	-.682		.617	
TP	.191	.837		-.307
TN	.261	.763		-.343
Ph	.328	.498	-.197	.397
DO	.310	-.472	-.708	
Salinity	.154		.387	.130
Foraminifera		.337	-.274	.780

Extraction Method: Principal Component Analysis.

a. 4 components extracted.

Table 10 Shannon-Weiner Index for foraminifera in different seasons in southern of Caspian Sea.

Season / Index	spring	Summer	autumn	winter
Shannon	0.08[b]	0.36[a]	0.59[a]	0.58[a]

Table 11 Shannon-Weiner Index for foraminifera different depths in the southern Caspian Sea.

Index / Depth(m)	Shannon
5	0.47[a]
10	0.41[a]
20	0.37[ab]
50	0.15[b]

Table 12 Shannon-Weiner Index for foraminifera in different stations in southern of Caspian Sea.

Index / Stations	Shannon
Behshahr	0.51
Babolsar	0.3
Noshahr	0.31
Ramsar	0.28

4 Conclusion

This study shows that the recent foraminifers of the Caspian Sea are characterized by a group of common brackish water. The results have 11 species, pertaining to 7 genera have been identified. The frequent dominance of brackish-water species were *Ammonia beccarii* and *Ephidium littorale*. In the area, the TOM and the grain size of the sediments do not play a significant role on the foraminifer's distribution. The result of PCA showed that granulometry, %TOM and %$CaCO_3$ and temperature had important role in distribution of foraminifera. According Shannon-Wiener index this area had not good ecological condition. According our results, we can use foraminifera such as bioindicator for pollutant area that result showed the density of them decreased in stations that amount of TP and TN were high.

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