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# Distribution, Diversity and Abundance of Benthic Foraminifera of the Northwstern Persian Gulf

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## Abstract

During ROPME Winter Cruise 2006, twenty six surface sediment samples taken from the Northwestern part of the Persian Gulf at depths of 13-77m were analyzed for their foraminifera content. A total of 93 species of benthic foraminifera were found in the study area. The foraminifera assemblages were dominated by *Ammonia beccarii, Spiroloculina excavata, S. depressa, Quinqueloculina dimidiata, Q. seminula, Q. costata, Triloculina s*p. and Bolivina spp. The dominant species constituted from 52 to 88%, sub- dominant species from 4 to 34% and rare species from 0.27 to 1.37%. Compound diversity (H ) was uniformly low at all stations ranging from 0.90 to 1.66 at stations 8 and 7, respectively. Low species diversity values indicated stress conditions in the study area according to Welch model. There was no correlation ($p \leq 0.05$) between total foraminifera assemblages and environmental parameters.

Keywords: *Benthic foraminifera, Persian Gulf, Dominant species, Environmental parameters, ROPME-2004*

## 1. Introduction

The Persian Gulf is a shallow semi-enclosed ecosystem situated in the subtropical and tropical biogeographical area with the average water depth of 35m and maximum depth of more than 100m in some localities. The extremely high salinity is usually above 39% but rises to 50% in some areas and even exceeds 70‰ in some localities (Purser and Seibold, 1973). Fine (mud) sediments predominate in the north-western part of the Persian Gulf (RSA) and reflect the influence of the river inputs in the area. Much of the study area is biogenic sediment, produced by micro-organisms, predominantly Foraminifera (ROPME, 2004).

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The diversity and distribution of benthic foraminifera species in the Persian Gulf are known from the works of Murray (1936, 1965, 1966, 1970, 1973); Lutz (1974, 1975) and Saidova (2010). According to some workers (Sarnthein, 1973; Price et al. 1993; Mostafawi, 2003), the main factors determining the distribution of the fauna in the area are obviously salinity and water depth. With increasing salinity and depth in the area, both the number of specimens and the number of species decline. The objective of the present paper is to describe the foraminifera fauna, particularly the dominant foraminiferal species, of the northwestern area of the Persian Gulf (Inner ROPME Sea Area), and to relate foraminifers assemblages to environmental factors, such as salinity, depth, TOM, temperature and types of substrates.

## 2. Materials and Methods

Twenty six bottom sediment samples were collected, using a Van Veen grab with $0.1m^2$ during the ROPME Winter Cruise 2006. The locations of the sampling area and stations are shown in Table 1 and Figures1 and 2. At each station, three sub-samples were taken from grabbed samples using plexiglass corer (3.3cm in diameter X3cm height) from the upper most 3cm stratum of the sediments collected by Van-Veen grab. Core samples were then transferred into labeled polyethylene containers and preserved in buffered formalin (4-5%) for later examination in the laboratory. To separate the Foraminiferal assemblages from debris and lighter materials, the Rose Bengal (1 gr/l) technique (Walton, 1952) was used in the laboratory. Carbon tetrachloride ($CCl_4$) also was used for floatation and collection of foraminifera. To identify the foraminiferal species, the scanning Electron Microscope (SEM) was used. The identification of species was done using Loeblich and Tappan (1964), Cushman (1969) and Murray (1971) keys. Other Foraminifera communities were allocated and named after the dominant species. The subdominant and rare species were the species following the dominant ones by their abundance as percentage of total number. *In situ* benthic environmental parameters including water depth, temperature, dissolved oxygen, salinity and pH were measured using CTD system and multimeter Horiba U 10 analyzer.

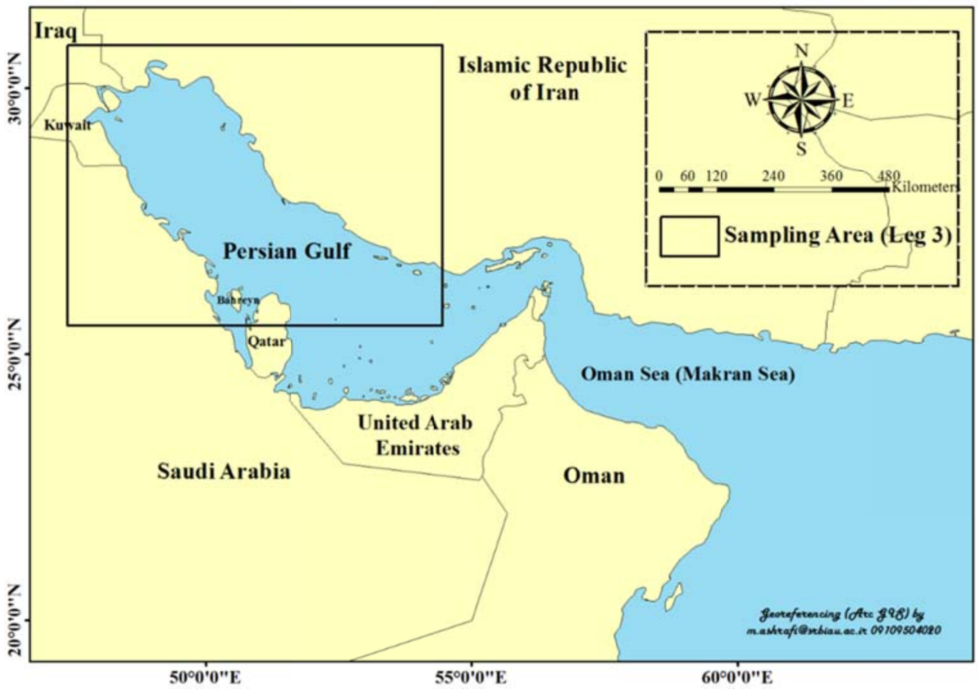

Fig 1: Map of the sampling area in NW Persian Gulf during Winter Cruise 2006

Fig 2: Map of the sampling stations

Grain size analysis was carried out using standard technique outlined by Buchannan (1984) and the percentage of each particle fraction was calculated.

The Total Organic Matter (TOM) in each sample was measured by calculating the loss of weight during combustion (Neira & Hopner, 1994). To analyze the benthic foraminifera assemblages, Shannon function (H′) and Simpson diversity index (λ) were employed. A correlation coefficient analysis was used to examine the relationship between species densities and environmental parameters.

## 3. Results

During our investigation, physicochemical characteristics of water including depth, pH, temperature, salinity and oxygen content of water were measured (Table 1). The water depth changed from minimum 13 (m) at the station 1 to maximum of 77 (m) at the station 39. The pH value ranged from minimum of 7.47 at the station 9a to the maximum of 8.49 at the station 1. The temperature ranged from minimum 17.08°C at the station 1 to the maximum of 21.47o°C at the station 27. The minimum salinity was 37.77 ppt at the station 1 and maximum salinity was 44.07 ppt at the station 33. Dissolved oxygen ranged from minimum of 5.82 ml/l at the station 39 and maximum of 8.25 ml/l at the station 1.

The silt+clay fraction in most stations comprised 45.52 to 98.88% of the sediment.

The lower percentages of silt+clay fractions were found in stations 36, 15, 10a and 5a having values of 4.12, 6.80, 10.68 and 27.88, respectively. The grain size analysis of the sediments showed that distribution of sediments were muddy, muddy-sand, sandy and sandy-mud. The results of organic matter content of the sediment showed that minimum (28.96%) and maximum (3.16%) values occurred in stations 34, and 23, respectively.

A total of 93 species of benthic foraminifera were found in the study area. Dominant, sub-dominant and rare species found in the study area are listed in Table 2. The minimum and maximum number of individuals were counted in stations 23 (978 ind./25.65 $cm^3$) and 36 (2509 ind./25.65 $cm^3$), respectively. The most common and dominant species were *Ammonia beccarii, Spiroloculina excavata, Sprioloculina depressa, Quinqueloculina dimidiata, Q. seminula, Q.*

*costata, Triloculina sp.* and *Bolivina* spp. Most foraminifer assemblages were dominated by species belonging to Rotaliidae and Miliolidae fallowed by Nubeculariidae families. The dominant species usually constituted from 52 to 88%, sub-dominant species from 4 to 34% and rare species from 0.27 to 1.37%. The most dominant, sub- dominant and rare species are presented in Plates 1 to 3.

Compound diversity (H′) was uniformly low at all stations. Minimum and maximum value of H′ ranged between 0.90 and 1.66 at stations 8 and 7, respectively. The Simpson (λ) index values ranged between 0.23 and 0.52 in stations 7 and 8.

Correlation coefficient data between environmental parameters was analyzed. The correlation between different environmental parameters measured as follows: between temperature and salinity (r=0.62), between temperature and DO (r=-0.81), between salinity and DO (r=0.53), between pH and DO (r=0.53), between temperature and pH (r=0.49), between salinity and pH (r=0.54), between silt-clay fraction and TOM (r=0.30). There was not significant correlation between total foraminifera assemblages and environmental parameters (Table 3).

Table 1: Location and Oceanographic Parameters of Bottom Water at the Sampling Stations

| Station Number | Lat(N) | Long (E) | Depth (m) | Sediment Type | Organic Matter (%) | Temp. (°C) | Salinity (‰) | pH | Diversity Indices Values | | Number of Individuals in 25.65 cm³ | DO (ml/l) | % of Silty - Clay Fraction |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | H' | λ | | | |
| 34 | 26°02.500 | 051°31.200 | 14 | Sand | 3.16 | 19.63 | 41.03 | 8.16 | 1.35 | 0.35 | 2089 | 7 | 4.12 |
| 36 | 26°28.190 | 051°54.900 | 52 | Muddy Sand | 5.95 | 19.99 | 40.78 | 8.15 | 1.09 | 0.44 | 2509 | 6.69 | 53.6 |
| 39 | 27°07.000 | 052°34.100 | 77 | Mud | 12.01 | 21.3 | 40.23 | 8.1 | 1.23 | 0.37 | 1893 | 5.82 | 91.2 |
| 27 | 27°29.200 | 051°57.000 | 54 | Mud | 9.55 | 21.46 | 39.98 | 8.14 | 1.4 | 0.32 | 1126 | 7.01 | 80.92 |
| 30 | 26°57.100 | 051°18.500 | 71 | Mud | 8.29 | 20.18 | 40.52 | 8.16 | 1.39 | 0.33 | 1229 | 6.72 | 75.52 |
| 33 | 26°21.800 | 050°45.500 | 14 | Mud | 8.17 | 18.93 | 44.07 | 8.17 | 1.19 | 0.4 | 1059 | 7.31 | 76.32 |
| 10a | 26°59.800 | 050°23.700 | 26 | Sand | 4.39 | 19.24 | 40.89 | 8.19 | 1.11 | 0.43 | 2112 | 7.27 | 10.68 |
| 24 | 27°10.100 | 050°23.700 | 65 | Muddy Sand | 7.19 | 19.29 | 40.78 | 8.2 | 1.21 | 0.41 | 1641 | 6.8 | 51.96 |
| 25 | 27°18.290 | 050°43.500 | 67 | Mud | 10.92 | 19.68 | 40.54 | 8.18 | 1.19 | 0.4 | 1658 | 6.51 | 80.16 |
| 26 | 27°30.497 | 051°11.060 | 73 | Mud | 8.34 | 19.43 | 40.31 | 8.19 | 1.29 | 0.37 | 1235 | 6.96 | 76.28 |
| 11a | 27°43.179 | 051°27.088 | 17 | Mud | 13.84 | 20.97 | 39.94 | 8.2 | 1.13 | 0.37 | 1565 | 6.92 | 98.88 |
| 20 | 27°54.410 | 050°59.518 | 63 | Mud | 13.45 | 18.77 | 40.36 | 8.2 | 1.14 | 0.38 | 1371 | 7.18 | 86.4 |
| 22 | 27°23.887 | 050°13.952 | 57 | Muddy Sand | 8.24 | 19.4 | 40.75 | 8.2 | 1.13 | 0.41 | 1685 | 6.56 | 50.16 |
| 23 | 27°09.561 | 049°30.928 | 43 | Muddy Sand | 28.96 | 18.59 | 40.97 | 8.2 | 1.11 | 0.42 | 978 | 6.59 | 54.56 |
| 15 | 27°39.842 | 050°07.896 | 21 | Sand | 5.55 | 18.93 | 40.96 | 8.21 | 1.05 | 0.44 | 1850 | 6.98 | 6.8 |
| 17 | 28°01.115 | 050°07.896 | 60 | Muddy Sand | 10.28 | 19.03 | 40.78 | 8.24 | 1.22 | 0.4 | 2618 | 6.94 | 63.12 |
| 19 | 28°21.033 | 050°44.312 | 57 | Mud | 12.13 | 18.89 | 40.53 | 8.22 | 1.14 | 0.4 | 1542 | 7.06 | 75.64 |
| 9a | 28°51.200 | 050°24.200 | 48 | Sandy Mud | 8.51 | 18.56 | 40.62 | 7.47 | 0.96 | 0.51 | 1461 | 7.47 | 49.96 |
| 7a | 28°31.145 | 049°49.321 | 55 | Muddy Sand | 5.36 | 17.97 | 41.07 | 8.24 | 1.1 | 0.47 | 1544 | 7.14 | 58.08 |
| 5a | 28°08.501 | 049°05.508 | 21 | Sand | 3.53 | 17.62 | 41.07 | 8.25 | 1.13 | 0.42 | 1800 | 8.07 | 27.88 |
| 14 | 28°33.885 | 048°45.702 | 25 | Sandy Mud | 6.08 | 18.58 | 40.43 | 8.28 | 1.39 | 0.32 | 1730 | 7.54 | 45.52 |
| 11 | 28°49.120 | 049°25.120 | 44 | Sandy Mud | 6.42 | 18.38 | 40.98 | 8.24 | 1.13 | 0.41 | 1522 | 7.05 | 46.52 |
| 8 | 29°17.580 | 050°05.490 | 42 | Mud | 22.75 | 18.05 | 40.79 | 8.41 | 0.9 | 0.52 | 1060 | 7.46 | 80.16 |
| 7 | 29°52.106 | 049°52.049 | 13 | Mud | 23.78 | 17.41 | 40.49 | 8.42 | 1.6 | 0.23 | 1778 | 7.96 | 95.16 |
| 4 | 29°13.245 | 049°26.487 | 41 | Mud | 8.76 | 17.97 | 41.07 | 8.42 | 1.4 | 0.32 | 2184 | 7.39 | 83.4 |
| 1 | 29°21.000 | 048°29.000 | 13 | Mud | 9.98 | 17.08 | 37.77 | 8.49 | 1.13 | 0.43 | 1131 | 8.25 | 90.16 |

Table 2.1: Species list of the benthic foraminifera of the NW Persian Gulf

| St. No. | Dominant Species | No. Ind. | Subdominant Species | No. Ind. | Rare Species | No. Ind. | Depth (m) |
|---|---|---|---|---|---|---|---|
| 34 | *Ammonia beccarii* | 823 | *Bolivina multicostata* | 91 | *Elphidium excavatum* | 7 | 14 |
| | *Spiroloculina excavata* | 315 | *Triloculina* sp. | 86 | *Lagena sulcata* | 6 | |
| | *Spiroloculina* sp.5 | 208 | *Quinqueloculina* sp.2 | 82 | *Lagena semistriata* | 3 | |
| | *Quinqueloculina seminula* | 142 | | | | | |
| 36 | *Spiroloculina excavata* | 642 | *Triloculina* sp. | 94 | *Lagena* sp.2 | 6 | 52 |
| | *Ammonia beccarii* | 315 | *Quinqueloculina dimidiata* | 81 | *Elphidium articulatum* | 9 | |
| | *Bolivina* sp.2 | 301 | *Spiroloculina* sp.4 | 67 | | | |
| | *Bolivina multicostata* | 263 | *Textulariopsis indistincta* | 60 | | | |
| | *Quinqueloculina seminula* | 160 | | | | | |
| 39 | *Bolivina multicostata* | 621 | *Bolivina* aff. *variabilis* | 167 | *Elphidium crispum* | 12 | 77 |
| | *Spiroloculina* sp.2 | 318 | *Textulariopsis earlandi* | 151 | *Lagena sulcata* | 9 | |
| | *Quinqueloculina seminula* | 205 | *Brizalina spathulata* | 84 | | | |
| | | | *Cibicides lobatulus* | 59 | | | |
| 27 | *Quinqueloculina* sp.4 | 329 | *Protelphidium anglicum* | 92 | *Laguna semistriata* | 7 | 54 |
| | *Quinqueloculina dimidiata* | 241 | *Bolivina* sp.3 | 90 | *Nodosaria* sp.1 | 6 | |
| | | | *Brizalina spathulata* | 84 | *Laguna clavata* | 5 | |
| | | | *Textularia* sp.4 | 61 | | | |
| | | | *Textularia earlandi* | 47 | | | |
| 30 | *Ammonia beccarii* | 289 | *Bolivina multicostata* | 88 | *Laguna* sp.5 | 6 | 71 |
| | *Quinqueloculina costata* | 211 | *Textularia* sp. | 64 | *Laguna* sp.8 | 5 | |
| | *Quinqueloculina* sp.1 | 183 | *Triloculina* sp. | 56 | *Spiroloculina excavata* | 5 | |
| | *Spiroloculina depressa* | 105 | *Triloculina sidebottomi* | 50 | | | |
| | | | *Bolivina tectiformis* | 47 | | | |
| 33 | *Ammonia beccarii* | 291 | *Spiroloculina* sp.2 | 68 | *Elphidium excavatum* | 3 | 14 |
| | *Quinqueloculina dimidiata* | 175 | *Bolivina multicostata* | 61 | *Turkmenella granata* | 3 | |
| | *Quinqueloculina seminula* | 143 | *Sculptobaculites* sp. | 22 | *Laguna* sp.2 | 2 | |
| | *Triloculina* sp. | 130 | *Ammobaculites stenomeca* | 19 | *Nodosaria* sp.2 | 1 | |
| | *Spiroloculina excavata* | 92 | | | | | |
| 10a | *Quinqueloculina costata* | 721 | *Spiroloculina depressa* | 79 | *Nodopthalmidium* sp.2 | 10 | 26 |
| | *Quinqueloculina* sp.2 | 411 | *Textularia* sp.2 | 72 | *Laguna* sp.4 | 7 | |
| | *Spiroloculina excavata* | 287 | *Bolivina spissa* | 63 | *Nodosaria* sp.3 | 4 | |
| | *Triloculina* sp. | 115 | *Bolivina tectiformis* | 60 | | | |
| | *Bolivina multicostata* | 101 | | | | | |
| 24 | *Ammonia beccarii* | 803 | *Bolivina* sp.2 | 94 | *Paracibicides* sp. | 5 | 65 |
| | *Quinqueloculina seminula* | 214 | *Q. costata* | 81 | *L.perlucida* | 3 | |
| | *Spiroloculina excavata* | 109 | *Textularia* sp.2 | 65 | *E.* sp.1 | 3 | |
| | | | *Triloculina sidebottomi* | 52 | | | |
| | | | *Q.* sp.7 | | | | |

Table 2.2: Species list of the benthic foraminifera of the NW Persian Gulf

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | *Ammonia beccarii* | 464 | *Spiroloculina* sp.3 | 97 | *Lagena calvata* | 6 | |
| | *Spiroloculina depressa* | 276 | *Triloculina sidebottomi* | 66 | *L.* sp.1 | 2 | |
| 25 | *Quinqueloculina dimidiata* | 151 | *Q. seminula* | 60 | | | 67 |
| | *Spiroloculina* sp.2 | 138 | *Q. costata* | 47 | | | |
| | *Spiroloculina excavata* | 112 | *Textularia* sp.5 | 41 | | | |
| | | | *Textularia conica* | 39 | | | |
| | *Quinqueloculina dimidiata* | 315 | *Bolivina* aff. *variabilis* | 88 | *L.* sp3 | 8 | |
| | *Triloculina* sp. | 209 | *Q. poeyana* | 67 | *L. semistriata* | 6 | |
| 26 | *Quinqueloculina* sp.2 | 173 | *Bolivina* sp.5 | 65 | *Nodosaria* sp.3 | 3 | 73 |
| | | | *Spiroloculina depressa* | 60 | | | |
| | | | *Trochammina inflata* | 46 | | | |
| | | | *Protelphidium anglicum* | 40 | | | |
| | *Quinqueloculina* sp.2 | 334 | *Adelosina honghensis* | 91 | *Bojarkaella firma* | 8 | |
| | *Quinqueloculina dimidiata* | 169 | *Trochammina inflata* | 83 | *Nodosaria* sp.4 | 7 | |
| 11a | *Discorbis nitida* | 147 | *Spiroloculina* sp.7 | 82 | *L.* sp.7 | 2 | 17 |
| | *Ammonia beccarii* | 124 | *Adelosina laevigata* | 69 | | | |
| | *Globorotalia* sp. | 108 | | | | | |
| | *Quinqueloculina dimidiata* | 318 | *Textularia* sp.2 | 74 | *Pyramidolina* sp. | 6 | |
| | *Bolivina spissa* | 205 | *Textulariopsis indistincta* | 68 | *L .perlucida* | 5 | |
| 20 | *Spiroloculina depressa* | 183 | *Ammonia beccarii* | 51 | *L.* sp.2 | 3 | 63 |
| | *Quinqueloculina* sp.1 | 160 | | | | | |
| | *Triloculinellus* sp. | 137 | | | | | |
| | *Quinqueloculina* sp.2 | 710 | *Spiroloculina depressa* | 72 | *Adelosina laevigata* | 9 | |
| 22 | *Ammonia beccarii* | 283 | *Textularia* sp.1 | 65 | *L.* sp.3 | 3 | 57 |
| | *Quinqueloculina dimidiata* | 154 | *Spiroculina excavata* | 60 | *Nodosaria* sp.2 | 2 | |
| | *Bolivina tectiformis* | 98 | *Reophax scorpiurus* | 49 | *Dendritina arbuscula* | 1 | |
| | *Quinqueloculina dimidiata* | 314 | *Triculinellus* sp. | 45 | *Elphidium* sp.2 | 7 | |
| 23 | *Quinqueloculina* sp.2 | 181 | *Triloculina* sp. | 40 | *L.* sp.3 | 2 | 43 |
| | *Textularia* sp.2 | 76 | *Ammonia beccarii* | 38 | *L.* sp.1 | 1 | |
| | *Triloculina sidebottomi* | 71 | *Bolivina multicostata* | 34 | | | |
| | *Spiroloculina excavata* | 415 | *Triloculina* sp. | 85 | *Nodophthalmidium* sp. | 6 | |
| | *Ammonia beccarii* | 317 | *Q. dimidiata* | 71 | *L. semistriata* | 1 | |
| 15 | *Bolivina* sp.1 | 210 | *Q. seminula* | 70 | | | 21 |
| | *Spiroloculina* sp.2 | 202 | *Q. costata* | 66 | | | |
| | *Spiroloculina depressa* | 187 | *Adelosina laevigata* | 42 | | | |
| | *Ammonia beccarii* | 726 | *Triloculina sidebottomi* | 98 | *Procerolagena gracilis* | 2 | |
| | *Spiroloculina excavata* | 518 | *Triloculinellus* sp. | 91 | *Discorbis nitida* | 2 | |
| 17 | *Q. dimidiata* | 305 | *Q. seminula* | 88 | | | 60 |
| | *Spiroloculina depressa* | 229 | *Bolivina multicostata* | 66 | | | |
| | *Q.* sp.2 | 161 | *Q. poeyana* | 64 | | | |
| | *Triloculina* sp. | 144 | | | | | |

Table 2.3: Species list of the benthic foraminifera of the NW Persian Gulf

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 19 | *Q. dimidiata* | 710 | *Spirophthalmidium acutimargo* | 31 | *E. crispum* | 4 | 57 |
| | *Q.* sp.8 | 425 | *Spiroloculina depressa* | 26 | *Nodosaria affinis* | 2 | |
| | *Bolivina* aff. *variabilis* | 116 | *Textularia* sp.1 | 20 | *L.* sp.5 | 1 | |
| | *Spiroloculina* sp.2 | 96 | | | | | |
| 9a | *Spiroloculina* sp. | 391 | *Q. costata* | 44 | *Lagena* sp.3 | 5 | 48 |
| | *Spiroloculina depressa* | 284 | *Textularia* sp.5 | 37 | *L.* sp.5 | 4 | |
| | *Q. dimidiata* | 195 | *Spiroplectinella wrightii* | 21 | *Nodosaria* sp.4 | 2 | |
| | *Triloculina* sp. | 160 | *Cibicides lobatulus* | 18 | *E. crispum* | 2 | |
| | *Triloculinellus* sp. | 63 | | | *Peneroplis planatus* | 2 | |
| | | | | | *Bajarkaella firna* | 1 | |
| 7a | *Ammonia beccarii* | 642 | *Triloculina* sp. | 87 | *Textularia conica* | 5 | 55 |
| | *Q.* sp.1 | 218 | *E. articulatum* | 63 | *L.* sp.3 | 4 | |
| | *Spiroloculina excavata* | 133 | *Discorbis nitida* | 49 | *Nodosaria* sp.4 | 2 | |
| | *Q. dimidiata* | 101 | *Globorotalia* sp. | 44 | *Eoguttulina* sp. | 2 | |
| | | | *E.* sp.1 | 41 | *Procerolagena gracilis* | 1 | |
| 5a | *Spiroloculina depressa* | 401 | *Triloculina* sp. | 97 | *E.* sp.3 | 5 | 21 |
| | *Spiroloculina excavata* | 272 | *Bolivina multicostata* | 91 | *Textularia* sp.3 | 4 | |
| | *Q. dimidiata* | 169 | *Q. poeyana* | 85 | *Lobatula* sp. | 2 | |
| | *Ammonia beccarii* | 165 | *Q. costata* | 73 | *L.* sp.8 | 1 | |
| 14 | *Ammonia beccarii* | 482 | *Discorbis nitida* | 91 | *Nonionella* sp.1 | 7 | 25 |
| | *Q. costata* | 216 | *E. excavatum* | 82 | *Bolivina* sp.2 | 5 | |
| | *Q. dimidiata* | 193 | *Anomalinella rostrata* | 64 | *L.* sp.3 | 1 | |
| | *Spiroloculina depressa* | 158 | *Textularia conica* | 51 | | | |
| | *Spiroloculina excavata* | 129 | *Cibicides* sp. | 42 | | | |
| 11 | *Q.* sp.7 | 328 | *Textularia* sp.1 | 92 | *E. articulatum* | 4 | 44 |
| | *Q. costata* | 267 | *Texturariopsis indistincta* | 65 | *Peneroplis planatus* | 3 | |
| | *Q. dimidiata* | 209 | *Bolivina tectiformis* | 55 | *Nodosoria* sp.1 | 1 | |
| | *Spiroloculina depressa* | 196 | *Spirotextularia* sp. | 47 | | | |
| | *Spiroloculina excavata* | 116 | *Bolivina spissa* | 39 | | | |
| 8 | *Bolivina* aff. *variabilis* | 287 | *Ammonia beccarii* | 88 | *Pyramaidolina* sp. | 4 | 42 |
| | *Q. costata* | 204 | *Spiroloculina* sp.3 | 61 | *Pseudopyrgo milletti* | 4 | |
| | *Spiroloculina depressa* | 166 | *Q. seminula* | 45 | *Adelosina honghensis* | 3 | |
| | | | *Triloculinellus* sp. | 30 | | | |
| 7 | *Ammonia beccarii* | 820 | *Spiroloculina* sp.1 | 71 | *L.* sp.8 | 3 | 13 |
| | *Q. dimidiata* | 283 | *Triloculina* sp. | 62 | *L. semistriata* | 2 | |
| | *Q. seminula* | 170 | *Textularia* sp.3 | 53 | *Dendritina arbuscula* | 1 | |
| | *Spiroloculina depressa* | 94 | *Spirotextularia* sp. | 38 | | | |
| | | | *Reophax textana* | 31 | | | |

Table 2.4: Species list of the benthic foraminifera of the NW Persian Gulf

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | *Ammonia beccarii* | 649 | *Q. seminula* | 108 | *Reophax gracilis* | 4 | |
| | *Spiroloculina depressa* | 219 | *Q.* sp.5 | 82 | *Nodosaria* sp.2 | 2 | |
| | *Spiroloculina excavata* | 202 | *Trochammina inflata* | 70 | | | |
| 4 | *Triloculina sidebottomi* | 181 | *E. excavatum* | 66 | | | 41 |
| | *Q. costata* | 165 | *Protelphidium* sp. | 42 | | | |
| | *Triloculinellus* sp. | 123 | *E. articulatum* | 45 | | | |
| | *Q. dimidiata* | 108 | | | | | |
| | *Spiroloculina depressa* | 296 | *Ammonia beccarii* | 90 | *Pyramidolina* sp. | 5 | |
| | *Q. dimidiata* | 144 | *Spirophthalmidium acutimargo* | 61 | *Nodosaria* sp.3 | 4 | |
| 1 | *Spiroloculina* sp.1 | 112 | *Q. seminula* | 47 | *L.* sp.6 | 2 | 13 |
| | *Bolivina* sp.2 | 97 | *Q. costata* | 41 | | | |
| | *Triloculina* sp. | 95 | *Textularia* sp.5 | 34 | | | |

Table 3: Correlation coefficient data between environmental parameters and total foraminifera

| | Salinity (ppt) | T (°C) | DO (mg/l) | pH | Silt & clay (%) | TOM (%) |
|---|---|---|---|---|---|---|
| T (°C) | 0.619 * | | | | | |
| DO | 0.534 | -0.814 * | | | | |
| pH | 0.543* | -0.49 | 0.531 * | | | |
| Silty & clay | 0.063 | -0.265 | 0.364 * | 0.321 * | | |
| TOM (%) | -0.196 | -0.092 | -0.029 | 0.153 | 0.303 * | |
| Total foraminifera | -0.24 | 0.163 | -0.265 | -0.183 | 0.169 | 0.165 |

## 4. Discussion

Marine benthic organism, especially foraminifera play a significant role in global biochemical cycles of inorganic and organic compounds (Anderson, 1988; Lee and Anderson, 1991a). Among meiofauna, foraminifera have received the most attention by researchers and there was no exception in the Persian Gulf region (Murray, 1936, 1965, 1966, 1970; Al-Zamel et al., 1996; Nabavi, 1996, 2000, 2001 and Nabavi et al., 2005). While Saidova (2010) has reported 80 species of foraminifera for the Persian Gulf, our cruise of 2006 reported 93 foraminifera species for the northwestern Persian Gulf.

The sediment type and the nutrient component available in the sediment are considered as the most important factors in distribution and abundance of the foraminifera. Sediment grain size was similar in all stations with a trend composition of 63 µm, which may indicate comparable hydrodynamic conditions. The same trend was found in relation to foraminifera assemblages having similar number of individuals with uniformly low species diversity (H′) at all stations. As Gray (1981) stated, reduced diversity values resulted in increased domination by a single or group of opportunistic species. This situation could be because of environmental stresses as well as pollution input in the region we studied. We used the Welch model (1992) for pollution analysis. According to this model, the region with no pollution has the value of 3 or more for H′. The value 1 or less than 1 is an indication of heavy pollution and hence, low species diversity value. Our result reported moderate pollution for the study area.

As it is stated by several workers including Arnal and others (1970), Akpati (1975), Nabavi (1988), there is a positive relationship between grain size and organic carbon of the sediment with foraminifer assemblages. Parker (1952a), Phleger (1952) and Buzas (1965), on the other hand, have found no relationship between particle size and foraminifera patterns. This contradictory result is not surprising, considering the inherent problems in preservation and sampling, and also our lack of understanding of the degree and extent to which each individual environmental variable affects foraminifer aggregation (Akpati, 1975).

It has been noted by some authors (Alve, 1995a; Sen Gupa, 1999) that a number of foraminifera species, such as *Ammonia beccarii*, *Quinqueloculina seminula*, *Spiroloculina excavata* and *Triloculina sp.* are likely resistant to the pollutants.

Dominant species including *Ammonia becarii*, *Spiroloculina excavata*, *Spiroloculina depressa*, *Quinqueloculina dimidiata*, *Q. seminula*, *Q. costata*, *Triloculina sp*. and Bolivina sp. constituted 52 to 88% of the total number of individuals in the study area. It is concluded that study area is under stress condition as absence or reducing number of individuals of sensitive species and survival of tolerant species indicates. The presence of the above- mentioned species of foraminifera in the northwestern Persian Gulf (Inner ROPME Sea Area) and their tolerability could serve as bioindicators in the environment. According to the ROPME latest report (2013), the species diversity of meiofauna including Foraminifera in northwestwern part of the Persian Gulf is low. The available data (ROPME 2013) indicated that mud and mudysand sediments are predominate in most parts of the study area with high capacity in absorption and accumulation of organic materials and chemicals. This excess of organic materials can result in oxygen depletion in upper most layer of the sediment and reduce benthic species diversity and dominance of few species as shown in our results. Saidova (2010) has also reported low species diversity for Foraminiferal assemblages towards the northhwestern Persian Gulf.

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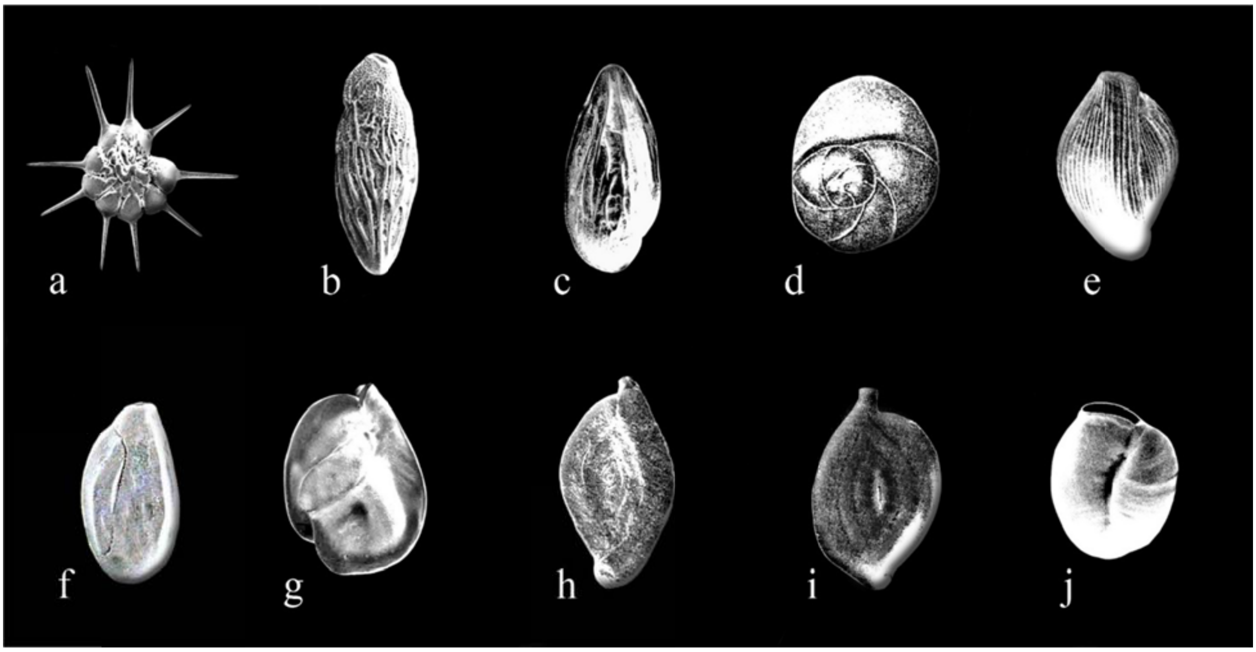

Plate 1: SEM photographs of some dominant species, *a. Ammonia beccarii* (Linnaeus, 1758); b. *Bolivina* aff. *variabilis* Williamson, 1858; c. *Bolivina multicostata* Cushman, 1918; d. *Discorbis nitida* (Williamson, 1858); e. *Quinqueloculina costata* d'*Orbigny*, 1826; f. *Quinqueloculina* dimidiata Terquem, 1876; g. *Quinqueloculina seminula* (Linne); h. *Spiroloculina depressa* d'Orbigny, 1826; i. *Spiroloculina excavata* d'*Orbign*y, 1846; j. *Triloculina sidebottomi* (Martinotti).

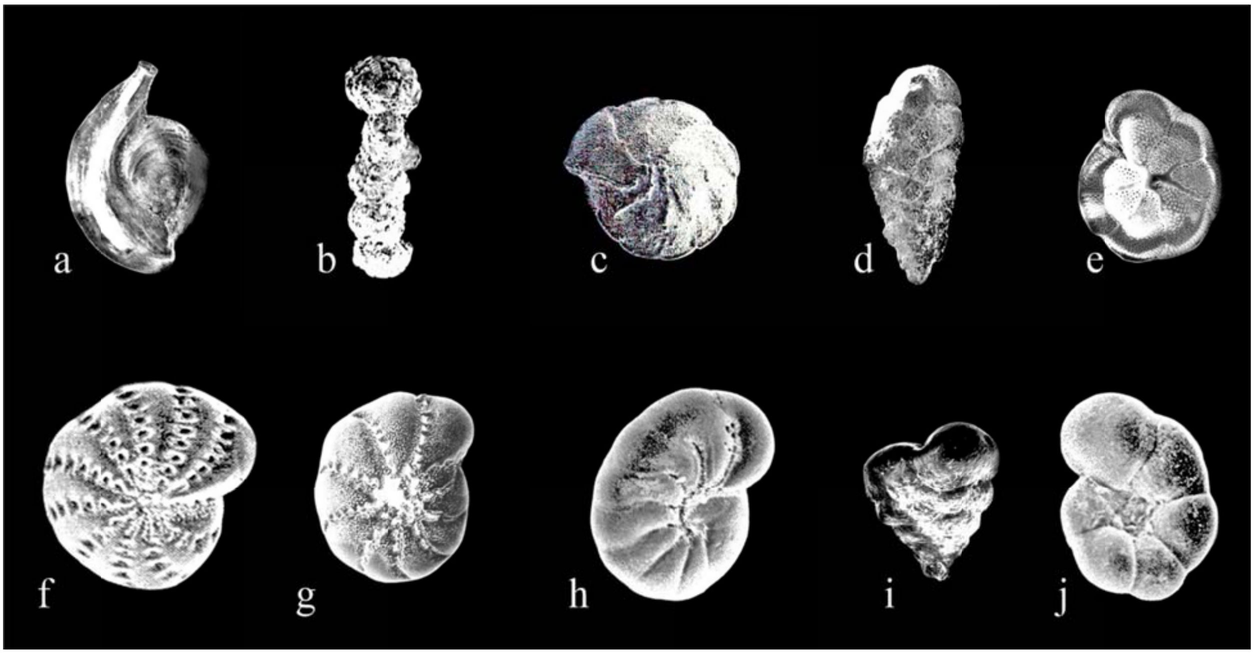

Plate 2: SEM photographs of some subdominant species, a. *Adelosina laevigata* d'*Orbigny*, 1826; b. *Ammobaculites stenomeca* Cushman and *Waters*; c. *Anomalinella rostrata* (Brady, 1881); d. *Brizalina spathulata* (Williamson); e. *Cibicides lobatulus* (Walker and Jacob, 1798); f. *Elphidium articulatum* (d'Orbigny, 1839); g. *Elphidium excavatum* (Terquem, 1875); h. *Protelphidium anglicum* Murray, 1965b ; i. *Textulariopsis indistincta* (Akimets); j. *Trochammina inflata* (Montagu).

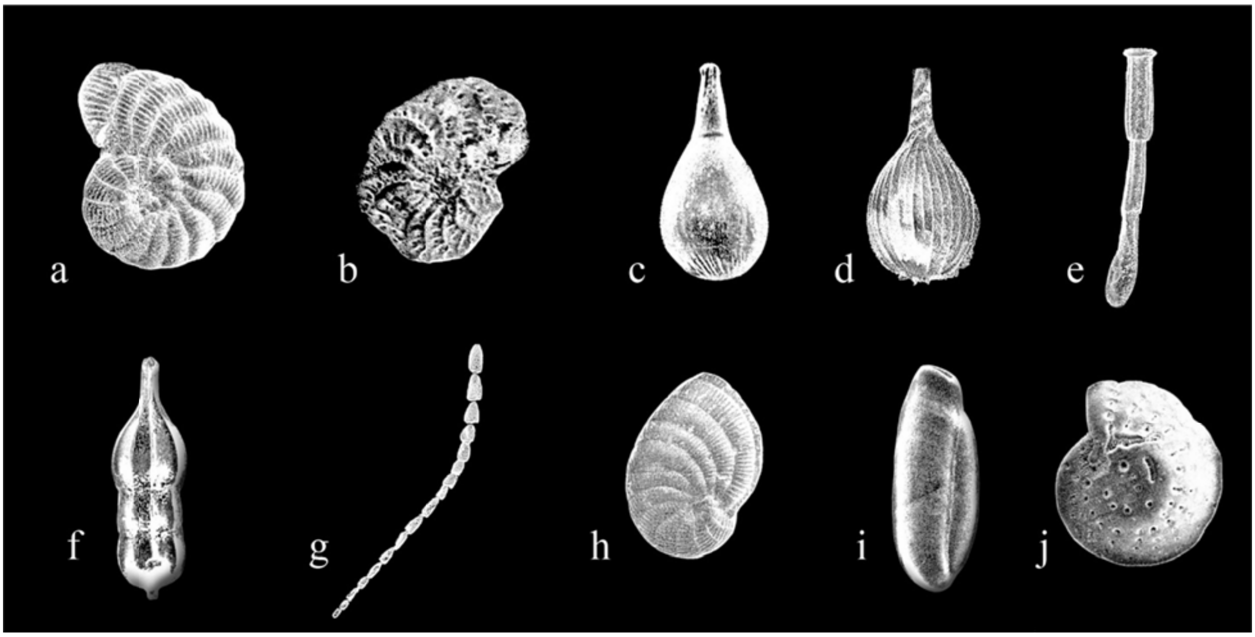


Plate 3: SEM photographs of some rare species, a. *Dendritina arbuscula* d'*Orbigny*, 1826; b. *Elphidium crispum* (Linne, 1758); c. *Lagena semistriata* Williamson, 1848; d. *Lagena sulcata* (Walker and Jacob, 1798); e. *Nodophthalmidium* sp.; f. *Nodosaria affinis* Reuss, 1846; g. *Nodulina gracilis* Kiaer, 1900; h. *Peneroplis planatus* (Fichtel and Moll, 1798); i. *Pseudopyrgo milletti* (Cushman, 1917); j. *Turkmenella granata* Bugrova, 1985