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Research Article

Study of coral reef benthic foraminiferal assemblages in Qeshm Island, Persian Gulf

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Abstract

Benthic foraminifera are important in sediment production of coral reef environments and are excellent indicators of water quality and reef health. There is a lack of precise information about the foraminifer's fauna of the coral reefs in the Persian Gulf. In this study, sediment sampling was performed in June 2019 from two coral stations of Naz Island and Zeytoon Park. The surface sediment with three replicates for each location was collected using a mini corer and then were fixed in 70% ethanol. In this study, thirty species belong to 23 genera and 19 families of foraminifer's assemblages were identified based on morphological characters. Our results indicated that Foraminiferal assemblages were similar in both sampling localities. *Quinqueloculina* was the most abundant genera for both Naz Island and Zeytoon Park. Foraminifer's frequency of Zeytoon Park was higher than Naz Island. Symbiont-bearing foraminifera (e.g. *Peneroplis*) were observed just in Zeytoon Park. Higher frequency and the presence of symbiont-bearing foraminifera possibly indicate that Zeytoon Park has a more favorable condition for the coral reef growth in the future. Finally, we recommend that the structure of the foraminifer's community could be used as an early warning system for water quality around coral reefs and in particular, would help resource managers make better decisions about protecting coral habitats.

Keywords: Foraminifera, Coral reefs, Diversity index, Taxonomic distinctness, Qeshm Island, Persian Gulf, Iran

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Introduction

Foraminifera are planktonic or benthic unicellular protists that have distributed in all aquatic ecosystems (Amao *et al*., 2018). Benthic foraminifera constitute 30-50% of the most beach and reef flat sands. They play an important role in sediment production and the skeletal composition of coral reef environments (Dawson *et al*., 2012). Identification of benthic foraminifera particularly in coral reefs habitats provide basic knowledge that can be used, as bioindicator, by resource managers in their coral reef assessment and monitoring program (Hallock *et al*., 2003; Uthicke and Nobes, 2008; Arslan *et al*., 2016; Parsaian *et al*., 2018).

The coral reef habitats are distributed along 16 coastal and Inland waters of the Iranian parts of the Persian Gulf. Qeshm Island is considered a hotspot of biodiversity with a well-distribution of coral reef patch in the eastern side (Maghsoudlou *et al*., 2008). Environmental stress along with anthropic stressors (disease, destructive fishing practices) have adverse effect on coral reefs health in this area (Coles and Fadlallah, 1991; Sheppard *et al*., 2010).

The classification and identification of foraminifera are based on the composition and morphology of the wall composition, structure, chamber shape &arrangement, aperture and ornamentation (Pawlowski *et al*, 2013). Based on shell morphology, about 5 000 modern and 40 000 fossil species are described (Binczewska and Asteman, 2014).

Although a lot of studies (Murray, 1965, 1970; Hartmann *et al*. 1971; Lutze *et al*., 1971; Lutze, 1974; Cherif *et al*., 1997; Sohrabi-Mollayousefy *et al*, 2006; Saidova, 2010; Mooraki *et al*, 2013; Nabavi *et al*., 2014; Amao *et al*., 2018; Parsaian *et al*., 2018) have been done on benthic foraminifera identification in the Persian Gulf, this is the first study focus on identification of foraminifera communities in coral reefs of Qeshm Island. Our result also updated the previous list of recognized foraminifera for the studied area. We determined the frequency and constitution of foraminifera in coral reefs. These data provide basic information for future conservation coral reef programs of the Persian Gulf**.**

Materials and methods

All sediments were sampled from two coral reef localities in Naz Island (NI) (26° 48′54″N, 56° 07′28″E) and Zeytoon Park (ZP) (26° 55′54″ N, 56°16′22″ E) by scuba diving in June 2019 with depth range from 5 to 7 meter (Fig. 1). The sediment samples were collected with three replicates of each location using mini-corer (plastic syringes 3 cm in diameter). Only the top 2 cm of sediments were subsampled. So, the subsampled sediment volume for each station is 14 cm^3 calculated by following formula: ($V=\pi r^2.h=14cm^3$). Immediately, samples were fixed in 70% ethanol on the boat then for surveying foraminifera in the laboratory. All samples washed with water and sieved via a 63 μm mesh. Samples were dried in oven in

75ºC for 8 hours. Liquid of Thetra Chlorid Carbon (CCL_4) was used for floating and collection of foraminifera. The upper layer of the liquid consists of floated forams, other tested specimens were filtered by paper and allowed to be dried (Mooraki *et al*., 2013). Samples were identified and enumerated with stereomicroscope (Nikon SMZ1500) at Iranian National Institute for Oceanography and Atmospheric Science lab. Selected taxa were photographed using a scanning electron microscopy. (SEM Leo 440i) at Islamic Azad University Science and Research lab.

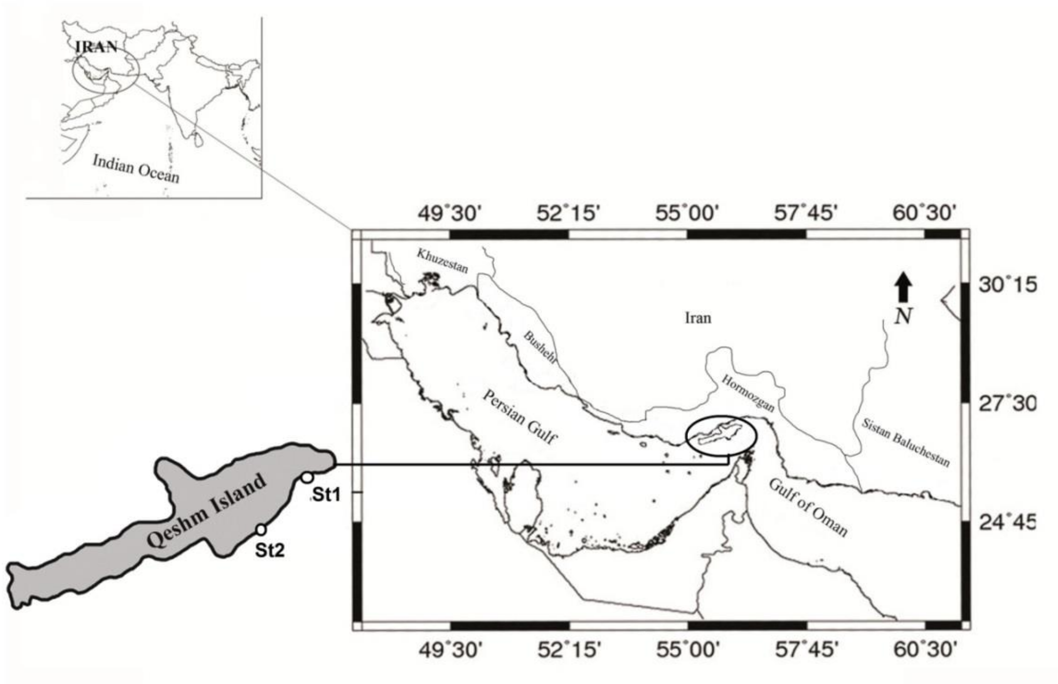

Figure 1: Locations of the studied area around the Qeshm Island (St1: Zeytoon Park; St2: Naz Island).

Foraminifera samples were identified at the species level as far as possible based on relevant literatures (Loeblich and Tappan, 1964; Hayward *et al*., 1999; Uthicke and Nobes, 2008; Debenay, 2012; Horton *et al*., 2017). In addition, we use online open access databank for identification.

(http://www.marinespecies.org/foraminifera/).

Statistical analysis

Benthic foraminifera data at each station were used to calculate species richness (S: number of different species in each station), Shannon-Wiener diversity index (H'), Pielou's Evenness index (*J'*) and Margalef's Richness (*d*) and Average taxonomic distinctness (AvTD, denoted by Δ^+ or delta+). All samples data were tested for normality using a Shapiro-Wilk test. Due to the non-normal distribution we used a non-

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parametric Kruskal–Wallis analysis to test differences in the abundance. SIMPER test was used to determine discriminating species between two stations. All of the above statistical analysis and diversity and taxonomic indices were computed using PRIMER-E v6.1.16 with PERMANOVA+ v1.0.6 (Clarke and Gorley, 2006; Anderson *et al*., 2008).

Results

A total of 3497 foraminifer's specimens were sorted. Thirty benthic species belong to 23 genera, 19 families and five orders were identified (Table .1). The Scanning electronic images of some species were illustrated in Figure 2. For both NI and ZP, a total of 905 and 2952 foraminifer's specimens occurred in 14 cm³.

Table 1: Classification of recognized benthic foraminifers in NI and ZP in Persian Gulf.

Order	Family	Genus	Recognized Species
Lituolida	Trochamminidae	*Trochammina*	*T. Inflata*
Miliolida	Peneroplidae	*Peneroplis*	*P.planatus, P. pertusus*
Miliolida	Hauerinidae	*Pyrgo*	*Pyrgo* sp
Miliolida	Hauerinidae	*Quinqueloculina*	*Q. costata, Q. seminula, Q. agglutinans, Quinqueloculina*.sp
Miliolida	Cribrolinoididae	*Adelosina*	*Adelosina* sp.
Miliolida	Hauerinidae	*Triloculina*	*T. inflata*
Miliolida	Spiroloculinidae	*Spiroloculina*	*S. excavata*
Miliolida	Soritidae	*Sorites*	*S.orbiculus*
Miliolida	Ophthalmidiidae	*Edentostomina*	*E. rupertiana*
Nodosariida	Lagenidae	*Lagena*	*Lagena* sp.
Rotaliida	Ammoniidae	*Ammonia*	*A. tepida, A. beccarii,*
Rotaliida	Rosalinidae	*Rosalina*	*Rosalina* sp.
Rotaliida	Cibicididae	*Cibicides*	*Cibicides* sp.
Rotaliida	Elphidiidae	*Cibroelphidium*	*C. excavatum Cribroelphidium* sp
Rotaliida	Bolivinitidae	*Bolivina*	*Bolivina* sp.
Rotaliida	Nonionidae	*Nonion*	*N. fabum*
Rotaliida	Murrayinellidae	*Murrayinella*	*M.murrayi*
Rotaliida	Bolivinitidae	*Pseudobrizalina*	*P. lobata*
Rotaliida	Cymbaloporidae	*Cymbaloporetta*	*C. bradyi*
Rotaliida	Discorbidae	*Discorbis*	*Discorbis* sp.
Rotaliida	Eponididae	*Eponides*	*E. repandus*
Rotaliida	Ammoniidae	*Asterorotalia*	*A. dentata*
Textulariida	Textulariidae	*Textularia*	*T. agglutinans* , *Textularia* sp.

As shown in Table 2, the total frequency of foraminifera in ZP is about three times higher than NI. *Quinqueloculin*a and *Textularia* are abundant genera for both stations and *Sorites* and *Lagena* are the rare genera with just a few occurrences in both stations. *Quinqueloculina* have the highest frequency with 335 and 902 occurrences in NI and ZP, respectively.

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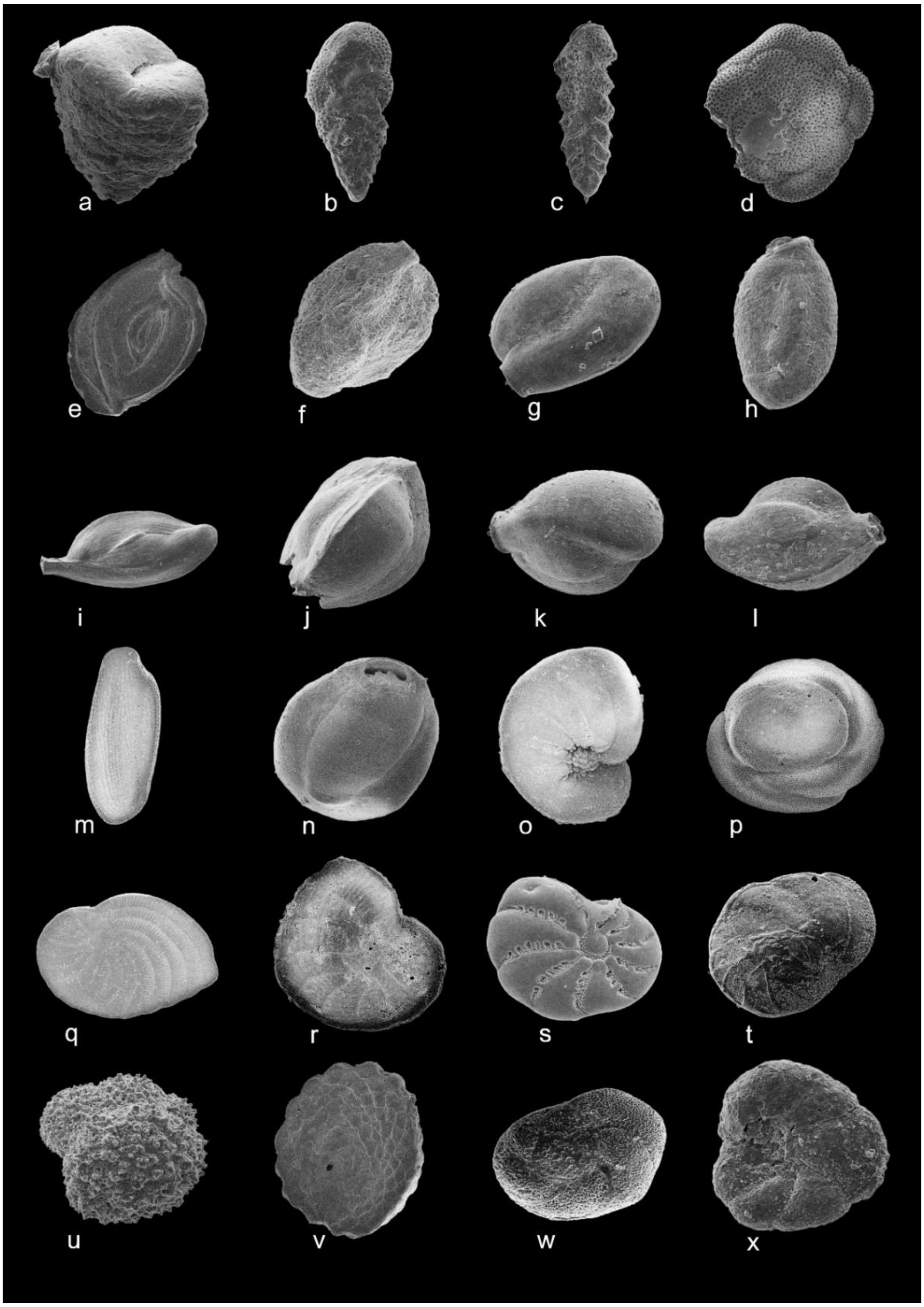

Figure 2: Scanning Electron Microscopy of some specimens in the present study (SEM Leo 440i) a.*Textularia* sp., b. *Bolivinia* sp., c. *Pseudobrizalina lobata*, d. *Cymbalopretta bradyi*, e. *Spiroloculina excavata*, f.*Quinqueloculina agglutinans*, g.*Quinqueloculina* sp., h. *Quinqueloculina seminula* i.*Adolesina* sp j.*Triloculina* sp., k-l. *Triloculina inflata* m. *Edentostomina repandus*, n.*pyrgo* sp. o. *Nonion fabum*, p. *Discorbis* sp. q. *Peneroplis planatus*, r. *Peneroplis pertusus* s. *Cibroelphidium* sp., t. *Eponides repandus*, u. *Murrayinella murrayi*, v. *Sorites orbiculus*, w.*Rosalina bradyi*, x.*Trochammina inflata*. All scale bars are 100µm.

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Table 2: Abundance and percentage of foraminifera genera identified from Qeshm Island.

Genera	NI individuals in 14cm^3	Percentage	ZP individuals (in 14cm^3)	Percentage
uinqueloculina	335	37.06	902	34.83
Spiroloculina	45	4.98	35	1.35
Triloculina	61	6.75	338	13.05
Pyrgo	4	0.44	15	0.58
Adelosina	20	2.21	40	1.54
Rosalina	18	1.99	58	2.24
Cibicides	11	1.22	7	0.27
Eponides	8	0.88	13	0.50
Textularia	139	15.38	471	18.19
Murrayinella	17	1.88	180	6.95
Cibroelphidium	24	2.65	49	1.89
Ammonia	79	8.74	89	3.44
Pseudobrizalina	69	7.63	41	1.58
Trochammina	7	0.77	5	0.19
Bolivina	49	5.42	23	0.89
Peneroplis	-	0.00	229	8.84
Asterorotalia	5	0.55	59	2.28
Discorbis	3	0.33	6	0.23
Cymbaloporetta	2	0.22	10	0.39
Sorites	1	0.11	2	0.08
Nonion	4	0.44	14	0.54
Edentostomina	3	0.33	4	0.15
Lagena	1	0.11	2	0.08
Total	905		2592	

At higher taxonomic level: Miliolida order shows the highest frequency in both stations, but Rotaliida is more diverse than others with 10 families and 12 genera (Fig. 3). At family level Hauerinidae and Textulariidae were the most abundant families, while Soritidae and Lagenidae had the lowest abundance in both stations. Bolivinitidae has a significantly higher frequency (13.05%) in NI compare to ZP with just 2.47% percentage of distribution (Fig. 4).

Results of calculated Indices for species diversity (number of taxa, Shannon Index, Pielou's evenness values: *J',* Margalef's Richness: *d*) and taxonomic distinctness (delta+) for each station are reported in Table 3.

Result of the Kruskal–Wallis test also revealed no significant difference of foraminifera mean abundance between two stations (p>0.05). In other words, both NI and ZP consist the same foraminifer's fauna. SIMPER analysis showed that the relative abundance of five taxa that contributed most to dissimilarity (21%) between two samples sites were as follows: *Peneroplis* (18.57%), *Quinqueloculina* (14.4%) *Triloculina* (12.98%) *Textularia* (12.17%) *Murrayinella* (11.41%). it is striking that no *Peneroplis* have found in NI.

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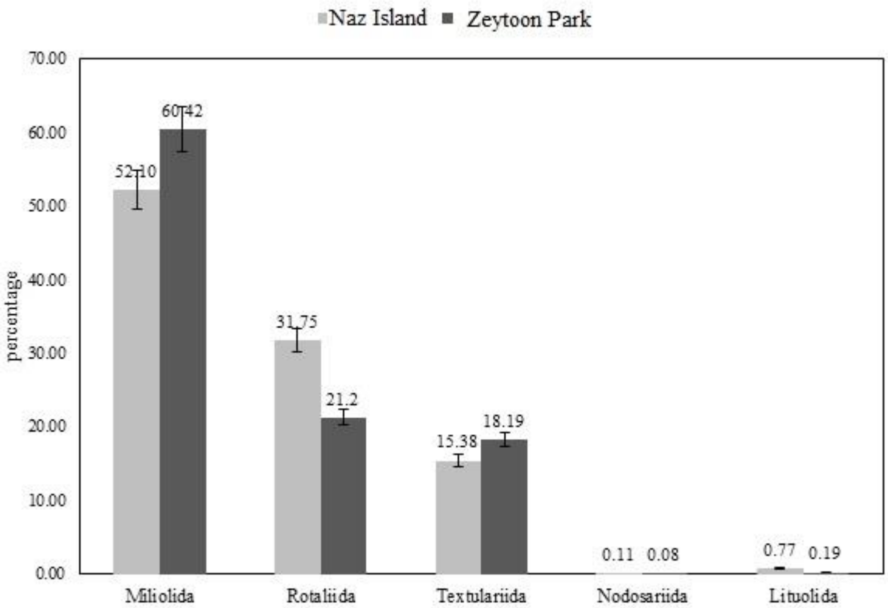

Figure 3: The percentage composition at Order level in Naz Island and Zeytoon Park.

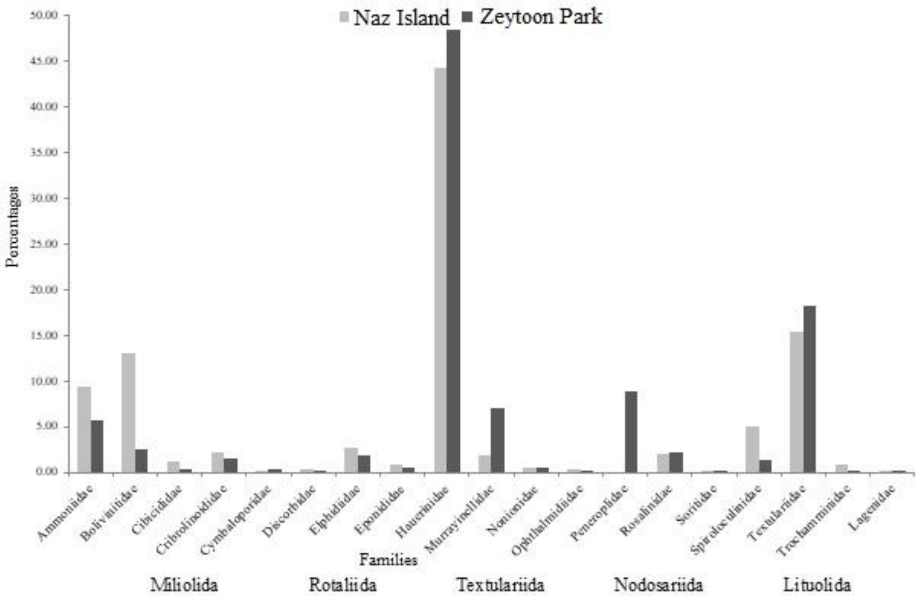

Figure 4: The percentage composition at Family level in Naz Island and Zeytoon Park.

Table 3: Diversity and taxonomic distinctness indices calculated for NI and ZP

Station	S	Margalef	J'	H'(log2)	Delta+
NI	19	2.647426	0.720796	3.061888	80.35088
ZP	20	2.41963	0.690342	2.983607	81.05263

Discussion

Benthic foraminifera are the major constituent of coral reef ecosystems that its community composition provides useful information as an early warning signs of stress for coral reef health and their resilience (Hallock *et al*. 2003). Although a lot of studies (Saidova, 2010; Nabavi *et al*., 2014; Amao *et al*., 2018) have been done on the Persian Gulf foraminifera, a huge amount of foraminifera diversity, especially in coral reef habitat, is still unknown (Maghsoudlou *et al*, 2019). In this study, we focused on foraminifera in hard coral of East and South-East coasts of the Qeshm Island where coral patches exist.

Foraminifera's assemblages of Qeshm Island, as the largest Persian Gulf Island, have been considered by Iran marine scientists. Sohrabi-Mollayousefy *et al*. (2006) identified 54 species belong to 27 genera in the northwestern part of Qeshm Island where mangrove forests are distributed. Based on their results, *Quinqueloculina* and *Ammonia* were the most abundant and diverse genera. Doustshenas *et al*. (2016), recognized 44 species belonging to 31 genera and 25 families for the eastern part of Qeshm Island, where *Quinqueloculina*, *Triloculina*, *Spiroloculina*, and *Ammonia* were the most frequent genera.

The list of Qeshm Island foraminifera will be updated to 89 species belonging to 43 genera and 39 families with the previous studies by reporting 15 records of nine genera (*Textularia agglutinans, Quinqueloculina agglutinans, Trochammina inflata, Discorbis* sp, *Cymbaloporetta bradyi, Murrayinella murrayi, Pseudobrizalina lobata, Cribroelphidium excavatum, Rosalina bradyi, Eponides repandus, Nonion* sp., *Asterorotalia dentata, Sorites orbiculus, Pyrgo* sp., *Peneroplis pertusus*) and 7 families (*Ophthalmidiidae, Nonionidae, Eponididae, Murrayinellidae, Cymbaloporidae, Discorbidae, Trochamminidae*) of this study.

In agreement with previous studies (Sohrabi-Mollayousefy *et al*., 2006; Saidova, 2010; Mooraki *et al*, 2013; Nabavi *et al*, 2014; Doustshenas *et al*., 2016; Amao *et al*., 2018; Parsaian *et al*, 2018) *Quinqueloculina* was one of the most abundant genera in our study as well. Hypersaline waters of the Persian Gulf increases high calcite saturation, which is correlated, with the formation of a porcelanous shell and consequently *Quinqueloculina* proliferation (Abu-zied *et al*, 2016). The genus is a heterotrophic miliolids dominant in nutrient-rich areas with low water transparency and likely to be resistant to stress-tolerant (Uthicke *et al*., 2010). It is suggested that the porcelanous shell of *Quinqueloculina* can play an important role in its proliferation, because this special wall is effective in its adaptation to environmental changes such as salinity and temperature (Cherif, 1973).

Results of Table 2 revealed that we did not find any *Peneroplis*, in NI while the genus was common in ZP. According to SIMPER analysis the genus was responsible for the highest dissimilarity between NI and ZP. *Peneroplis* is an algal symbiont-bearing large foraminiferal thriving in warm, clear, nutrient-poor, shallow environments and is sensitive to environmental changes (Hallock *et al*., 2003). As stated by Carnahan *et al.* (2009) symbiont-bearing foraminifera

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have host algal endosymbionts that prefer similar environmental conditions as corals, so they can be used as proxies of water quality in the coral reef ecosystem. Vice versa the frequency of *Bolivina* in NI was higher than ZP. The genus *Bolivina* is stress-tolerant taxa may be more tolerant of high pollution and associated with oxygen-deficient environments (Mojtahid *et al*., 2006; Coccioni *et al*., 2009; Dimiza *et al*., 2016).

The environmental condition of ZP was already reported unfavorable due to its vicinity to urban pollutants (Shirneshan *et al*., 2013; Darvishnia *et al*., 2016). Based on the above findings we suggest that the water quality of ZP for coral growth is better than NI, as it seems coral reef in ZP are under self-recovery, an issue which state by local diver's observations as well. In contrast water quality in coral reef habitats of Naz Island is not in a healthy condition for coral growth. Simultaneous parallel research by Maghsoudlou *et al* (unpublished data) as well as local diver observations on coral reefs in this area revealed high coral degradation of NI coral reefs.

In the present contribution, Shannon diversity index (H') of NI was higher than ZP, while average taxonomic distinctness (Delta+) of ZP was better than NI (Table 3). Some people believed that traditional diversity index (i.e. Shannon) may be greatly influenced by sample size or habitat type, and typically do not show monotonic responses to human impact (Leonard *et al*., 2006; Subida *et al*., 2012). Therefore, further biodiversity indices based on taxonomic relatedness of species have been developed in recent years. Warwick and Clarke introduced the concept of taxonomic distinctness (TD or Δ) into marine ecology. They offered 'average taxonomic distinctness' (AvTD, Δ^+) and they believed that these indices are useful in separating degraded and polluted sites from the control site (Warwick and Clarke, 1995; Clarke and Warwick, 2001). As a result, we suggest that AvTD index, instead of Shannon index, in foraminiferas' study of the Persian Gulf better reflect the environmental conditions of the region.

The results of this study can extend our information about foraminifer’s assemblage in coral reef habitats of the Persian Gulf and help us estimating the health of the coral reef habitat based on symbiont-bearing foraminifer’s richness in future studies. Finally, as stated by others, we recommend that the structure of the foraminifer’s community could be used as an early warning system for water quality around coral reefs. The results would help resource managers protect coral habitats.

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