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Study on the Meiofauna Community Structure in Sajafi Shores as the Bio-Indicator of Environmental Pollution

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Abstract

In order to investigate the health of the coastal environments, we collected Meiofauna assemblages along intertidal muddy shores of Sajafi in the northwest of Persian Gulf in two seasons (February 2013 and July 2014) from three horizontal transects. Meiofauna are the metazoan components of the benthos, defined by their body size (<500 μm) and are the most diversified elements of the marine biota. They are so sensitive against adverse environmental changes and represent the ecological conditions. Environmental factors (temperature, salinity, DO, and pH), diversity and distribution of Meiofauna and their relationship with each other and with the grain size and TOM in both cold and warm seasons were evaluated. In this study, 56 meiofaunal species were identified in which foraminifera were abundant. The result of Shannon-Wiener in summer 2014 showed the highest value ($H' = 3.148$) while the lowest value occurred in winter 2014 ($H' = 1.5$). At the same time, the highest and lowest values of Simpson index (λ) were 0.43 and 0.05 respectively. Sajafi area, according to the Welch model, has a moderate ($H' = 1$ - 3) to unpolluted ($H' > 3$) condition compared to neighboring regions.

Keywords

Meiofauna, Benthic, Sajafi Area, Bio-Indicator, Persian Gulf

1. Introduction

Since human health depends on moving, development and application of ecosystems, loss of ecosystem components such as clean air, potable water and more, tightly focused our attention on the health of natural ecosystems. As almost all species can tolerate only a limited range of changes in chemical, physical and biological conditions, they tend to assess the quality of the environmental parameters [1]. Meiofauna formed one of the major groups of benthic metazoan organisms, larger than 100 microns and smaller than 500 micrometers, in the bed of oceans and seas, 82 percent of which are present at the 3 cm surface of the substrate [2]. They are most diversified elements of the marine biota [3].

Benthic Meiofauna are important members of coastal ecosystems and estuaries that fed by micro Algal and bacteria, affect the primary production cycle and bio mineralization and other parts of benthic metabolism [4]-[8]. Due to great abundance, low mobility, rapid replication, short life cycle, and extreme sensitivity to entering materials, Meiofauna are most appropriate bio-indicators of health of the marine environment [9] [10]. The major groups of benthic Meiofauna are Foraminifera, Ostracoda, Nematoda, Gastropoda, bivalve's larvae, larval shellfish, foam kits, and tube worms.

Meiofauna's close relationship with the environment wherein they grow, considered them as an important tool for biomonitoring the environmental parameters such as temperature, salinity, substrate type and concentration of different elements in the water and sediment [11] [12]. The presence of these organisms on the seabed is particularly susceptible to stress-related deposits [13].

The overall objective of this study was to investigate the possibility of using meiofaunal benthic communities as a bio-indicator of environmental pollution. By comparing the diversity in different areas, environmental situation and potential contamination of the region can be realized [14].

Drawing a clear picture of the environmental situation in the Persian Gulf due to increased tanker traffic, release of ballast water, exposure to many environmental threats, always was a concern for environmentalists. The Persian Gulf is a marginal basin in the extreme northwest of the Indian Ocean, affected mainly by the extra-tropical weather systems from the northwest [15]. The most well-known weather phenomenon is the Shamal, a Northwest wind which occurs year round [16] [17]. Water retention time in the Persian Gulf is estimated between 2 and 5 years [18]. The salinity ranges between 27 and 41 mg/l by temperature more than 20˚C [19] [20]. Because of high evaporation, and therefore high salinity, surface sediments in Persian Gulf become smaller from the beach to the depth. Limestone marl is the recent deepest facies of Persian Gulf [21].

Sajafi area in the northern Persian Gulf (**Figure 1**) biologically has some features that cause certain plant and animal communities in the region to be seen.

[22] had studied the distribution of Meiofauna in the south coast of East India. The results show that human disturbances and pollution influence species diversity in coastal intertidal areas. They study Meiofauna that can be important indicators of overall productivity of fish. [23] had introduced Meiofauna as a tool for the study of marine ecosystems. [24] had evaluated several indicators of Meiofauna in the sediments of three Mediterranean harbors with different environmental conditions in order to estimate the

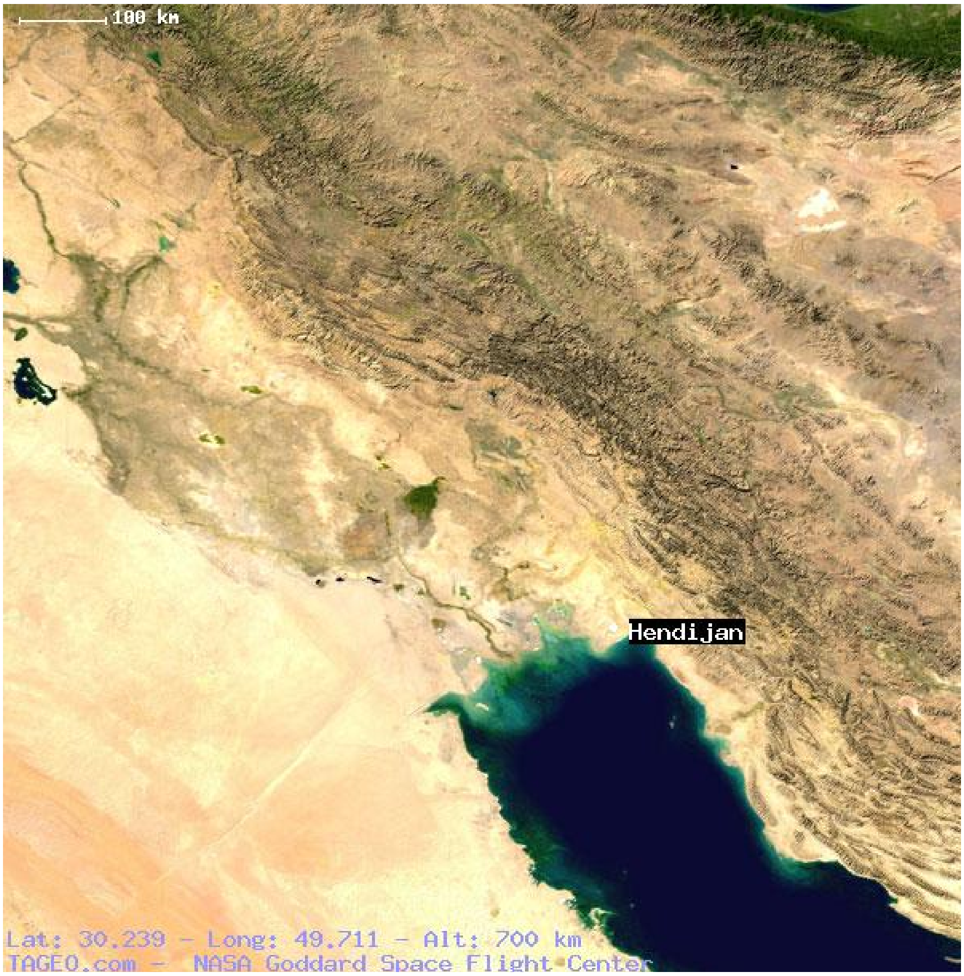

Figure 1. Location map of sampling and overview on sampling sites.

effectiveness and identify the types of pollution index that describes better the quality of the environment. The relationship between indices based on specific taxa Meiofauna with pollutant concentrations, especially polycyclic aromatic hydrocarbons (PAHs) has been accessed [25] and provided a report on the Meiofauna in protected Mangrove forests area in the Persian Gulf. The results showed that the foraminifera were dominant societies. [26] conducted a qualitative study on Mayobentoz in the Persian Gulf. In a qualitative study on nematodes, then, Foraminifera, Cope Poda, Polychaeta and Oligochaeta were dominant, respectively.

Meiofauna's rich and diverse communities in this study show that they can be used in the future plans of environmental monitoring, marine pollution and study the food chain.

2. Materials and Methods

The study area is located on Sajafi intertidal beaches in the north Persian Gulf, south to southwest Hendijan city in Khuzestan province, Iran (**Figure 1**). Sampling in both cold seasons (February 2013; average temperature 14.74˚C) and warm (July 2014; average temperature 31.9˚C) was conducted. To determine the position of three transects and 3 stations in each, a satellite positioning system (GPS) was used (**Table 1**).

First, surface sediment was sampled at each station with a Van Veen Grab cross-section 0.025 square meters. Then, with the cylindrical in diameter and height of 3 cm, sediment sampling with three replications was conducted.

To prevent the corruption of living species, the samples were fixed in formalin 5% to reach up to the lab were stored in polyethylene containers. Water from the adjacent seabed at each station immediately picked up and by the sensors of environmental parameters, temperature, salinity, DO and pH were measured in the field, each with three replications. A sample from each station, about 200 to 300 grams wet sediment in separate polyethylene containers for grain study and the total organic matter (TOM) sediments were removed and kept in plastic bags and transported to the laboratory on ice. To measure the total amount of organic matter in sediments, combustion method [27] were used. The standard method to determine the grain size distributions of passing a series of sieves [28] was used.

To extract Meiofauna in the laboratory, the stabilized sediments by using a sieve of 5.0 and 63 microns (5.0 mm sieve above and below 63 microns) were washed and then Meiofauna samples were stained by 1 gram per liter solution of Rose Bengal. In order to isolate shellfish Meiofauna, the container to container method was used and samples were identified and counted by optical microscopy [29]. All Meiofauna were identified to genus based on the pictorial keys of [30], the online information system WoRMS [30] [31].

In order to calculate the relationship between environmental factors and Meiofauna density in all seasons and stations, basic statistical correlation coefficient is used. Statistical analysis of the data was carried out using SPSS (version 19). Differences between controls and treatments were compared by parametric one-way ANOVA tests (significance level of $\alpha = 0.05$). A posteriori paired multiple-comparisons were performed

Table 1. Station coordinations.

Station	Coordinate 39 R	
	N	E
T1-St1	30˚45'10"	49˚37'2.95"
T1-St2	30˚45'11"	49˚37'21.68"
T1-St3	30˚45'11"	49˚37'32.12"
T2-St1	30˚36'96"	49˚36'43.27"
T2-St2	30˚0'25.59"	49˚36'43.29"
T2-St3	30˚0'16.66"	49˚36'46.10"
T3-St1	30˚0'11"	49˚36'29.23"
T3-St2	30˚0'11.78"	49˚36'30.18"
T3-St3	30˚0'9.34"	49˚36'35.80"

using Tukey HSD test. Relation between various metals was established via Pearson correlation.

To calculate the species diversity and dominance the Shannon diversity index (H′) based on the natural logarithm (ln); N2 = 1/λ, where λ is Simpson's dominance index; to calculate the species richness Menhinic index and to express the species dispersal among the area of study, the Hill's evenness index was used respectively, all using the PAST V.1 [1]-[15]. To realize the situation in the region in terms of diversity and pollution, Welch model 1992 was used.

3. Results

With the aim of tracking the effects of pollution, identification as top groups (genus, family, class, order) took place. In this study, a total of 56 species in the warm season and, 48 species in the cool season belonging to 31 genera were observed, the highest species diversity in foraminifera, gastropods and Ostracoda and Nematodes were seen. The greatest number of species related to foraminifera and then high species diversity belongs to Ostracoda and Gostropoda. Ammonia beccarii species in all stations were abundant with a significant difference ($p < 0.005$) from other Meiofauna.

According to **Figure 2**, most frequency of Meiofauna in the warm season was in T1S3 station and the lowest was observed in T2S2 station. In the cold season, a significant difference can be seen in the first Transect stations, so that the highest frequency and lowest was in T1S2, T1S1 respectively.

In all three transects studied in the warm season in 2014, DO and temperature were not significantly different ($p > 0.05$). Water salinity in T3S1 station is less than other stations. The average salinity from 0.31 ± 43.18 in the warm season to 0.18 ± 38.05 in the cold season has been measured (**Table 2**). Changes in sampling sites showed significant differences in different seasons. In the cold season temperature and pH at three stations ($p > 0.05$) were not significantly different. The highest percentage of aggregate deposits was 0.063 > mm in the warm season in T2-S3 stations and the amount of 99.53% and the lowest percentage in T3-S3 Station and the amount of 81.271%, respectively.

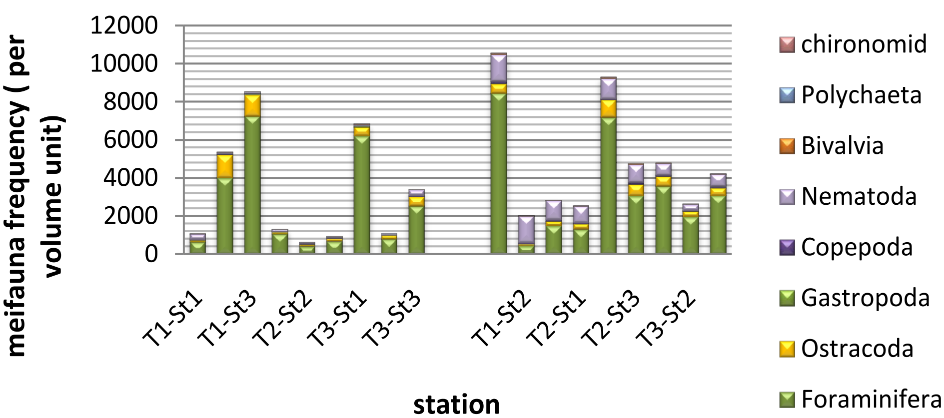

Figure 2. Comparison Meiofauna frequency separating in sampling sites in both summer and winter seasons.

Table 2. Mean environmental parameters, total organic matter content and aggregation stations in the two warm and cold seasons.

	Summer	Winter
Temperature (˚C)	31.90 ± 1.04 a	14.75 ± 0.10 b
DO (mg/L)	4.42 ± 0.95 a	8.36 ± 1.07 b
pH	7.91 ± 0.002 a	7.92 ± 0.43 a
TOM (%)	15.72 ± 3.32 a	12.16 ± 1.93 b
Salinity (mg/L)	43.18 ± 0.31 a	38.05 ± 0.18 b
Grain size > 0.125(%)	4.1 ± 5.9 a	0.405 ± 0.509 a
Grain size 0.063 - 0.125(%)	0.58 ± 0.337 a	0.887 ± 0.51 a
Grain size < 0.063(%)	95.3 ± 6.2 a	98.7 ± 0.72 a

Dissimilar letters indicate significant differences ($p < 0.05$).

The highest percentage of aggregate deposits in the cold season was 0.063 > mm in T3-S3 stations with the amount of 99.621% and the lowest percentage in the station T1-S1 with the amount of 97.568%.

The mean percentage of total organic matter was obtained in the sediments in the warm season 32.3 ± 72.15 and in the cold season 93.1 ± 16.12 (Table 2). There is a negative correlation between most Meiofauna species in winter with total organic matter content (at 0.01 and 0.05), but in the hot season there is a negative correlation between Bivalves and the percentage of total organic matter at 0.05 level (Table 3).

To show the correlation between Meiofauna frequency and organic matter in two hot and cold seasons, in summer all stations had a negative correlation at 0.01 with percentage of total organic matter (Table 4).

Among the three selected Transects the most dominance was in the T2 and the lowest in T1, most indicators of diversity value among T1 and the lowest in T2, greatest Menhinic enrichment and Hill evenness values in T2 and the lowest were seen in T1 (Table 5).

T1S1 station has the most dominance in summer (00.17) that the figure in winter reduced to 00.11. In winter most dominant index in T1S2 station and approximately was 00.4 that show a sharp increase in dominant and reducing the diversity in the hot season. Shannon index at all stations between 1 and 3 were calculated at several stations (stations T1S2 and T3S1 in summer) values above 3 obtained and conditions in the region in terms of pollution compared to the Welch model, partially semi-infected were detected (Table 6). Diversity indices showed no correlation with any of the environmental parameters.

4. Discussion and Conclusion

In any ecosystem, if there is no stress on ecosystems, specified seasonal and time changes in the major physical and chemical parameters of water and sediments are the

Table 3. Correlation between environmental parameters and frequency bands of Meiofauna in the cold season 2014 and warm season 2014.

	Temperature		EC		DO		pH		TOM		salinity		Grain size < 0.063(%)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Foraminifera	−0.050	00	−0.037	−0.373	0.151	−0.291	−0.223	−0.463*	−0.439*	−0.270	0.058	0.231	−0.109	0.016
Ostracoda	−0.058	00	−0.037	−0.723**	0.15	0.013	−0.22	−0.685**	0.430*	0.074	0.057	0.083	0.295	−0.210
Gastropoda	−0.332	00	0.008	−0.329	−0.151	−0.416*	−0.093	−0.317	−0.013	−0.253	0.227	0.218	−0.601	0.004
Bivalvia	0.407*	00	−0.228	−0.228	−0.266	−0.266	−0.327	−0.327	−0.459*	−0.459*	0.359	0.359	−0.298	0.17
Nematoda	0.292	00	−0.208	0.041	0.293	0.301	−0.145	0.190	−0.415*	−0.274	0.096	0.162	−0.506	0.085
harpacticoida copepoda sp.	0.112	00	0.010	−0.468*	0.313	0.165	−0.225	−0.198	−0.586**	0.138	−0.007	0.015	−0.692*	0.240

*Correlation at 0.05 **Correlation at 0.01.

Table 4. Correlation between environmental parameters and frequency of Meiofauna in the cold and warm season 2014.

Grain size < 0.063(%)		Salinity		TOM		pH		DO		EC		Temperature		
Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	
−0.977	0.254	0.183	−0.254	−0.803**	−0.779**	−0.095	−0.337	0.411	0.442	0.165	0.149	0/000	0.194	T1S1
0.308	0.853	0.149	0.286	−0.708**	0.276	−0.162	0.104	0.407	0.082	0.017	−0.120	0/000	−0.124	T1S2
0.267	0.588	0.217	−0.211	−0.759**	−0.438	−0.110	−0.072	0.336	0.508*	0.081	0.099	0/000	0.313	T1S3
0.623	−0.752	0.161	−0.276	−0.744**	−0.381	−0.072	0.039	0.362	0.520*	0.127	0.104	0/000	0.363	T2S1
−0.556	−0.981	0.360	−0.474*	−0.732**	−0.502*	−0.099	0.053	0.391	0.586*	0.139	0.211	0/000	0.629**	T2S2
−0.521	0.948	0.050	−0.236	−0.607**	−0.441	0.073	−0.071	0.333	0.594**	0.102	0.183	0/000	0.619**	T2S3
0.888	−0.01	0.384	−0.317	−0.815**	−0.762**	−0.096	−0.275	0.223	0.569*	0.085	0.187	0/000	0.401	T3S1
−0.708	0.818	0.285	−0.479*	−0.707**	−0.604**	−0.131	−0.031	0.427	0.6090**	0.080	0.215	0/000	0.570*	T3S2
−0.347	0.532	0.154	−0.392	−0.699**	−0.570*	−0.104	−0.045	0.460	0.638**	0.106	0.213	0/000	0.632**	T3s3

*Correlation at 0.05 **Correlation at 0.01.

Table 5. Evaluation of biological indicators in T1, T2, T3 transects in the winter 2014 and summer 2014.

Transect index	T1		T2		T3	
	Winter	Summer	Winter	Summer	Winter	Summer
Simpson dominance index	0.137	0.111	0.120	0.14	0.140	0.138
Simpson diversity index	0.862	0.888	0.879	0.86	0.859	0.868
Menhinick index	0.687	0.821	0.717	1.6	0.818	0.941
Shannon Wiener diversity index	2.563	2.953	2.787	2.796	2.652	2.836
Hill evenness index	0.264	0.32	0.551	0.33	0.276	0.29

most important factors in generating a sequence of changes in the composition of species and communities. Human activities such as industry, agriculture, mining, dredging and sewage discharge large amounts of pollutants into the marine environments; causing obvious temporary impairments and imposing enormous impact on the ecosystem.

Table 6. Compare diversity index stations with Welch model in winter and summer 2014.

	Winter		Summer	
Station	Shanon wiener diversity index	Condition	Shanon wiener diversity index	Condition
T1S1	2.69	moderate	2.47	Moderate
T1S2	1.58	Moderate	3.148	unpolluted
T1S3	2.44	Moderate	2.694	Moderate
T2S1	2.51	Moderate	2.579	Moderate
T2S2	2.75	Moderate	2.739	Moderate
T2S3	2.77	Moderate	2.868	Moderate
T3S1	2.171	Moderate	3.21	unpolluted
T3S2	2.705	Moderate	2.849	Moderate
T3s3	2.49	moderate	2.897	moderate

$H' > 3$ Unpolluted; $H' = 1 - 3$ Moderate; $H' < 1$ Polluted.

Benthic communities generally respond to changes in ecological conditions [18]. Benthos study in the sediments of the sea is one of the most ecological phenomena. Meiofauna are considered as a food source for juvenile and higher marine trophic levels, as well as helping to recycle nutrients. They have oceanography, biology and geology features; therefore, identifying and determining the density and distribution of meiofaunal assemblages and their changes in different seasons and stations is important. Currently the most commonly method used in studies of the effects of pollution is community response test, which is a combination of all the species found in the region. According to the results of this study, it is inferred that the benthic condition of Persian Gulf is appropriate for Foraminifera because almost all stations surveyed, therefore foraminifera was the most abundant phylum (51.21%), similar to results of Meiofauna study in Naiband shore (Persian Gulf) by [27]-[29]; and in the next sequence placed were the crustaceans, gastropods, nematodes and bivalves [30]. After that, Foraminifera, Cope Poda, Polychaeta and Oligochaeta were dominant.

Ammonia beccarii species in all stations was more abundant than other Meiofauna species, cosmopolitan species found in all marine ecosystems, estuaries, coastal lagoons and even in fresh water leading to the sea, well adapted to different salinities. In similar studies [27] reported this species in deposits of Nayband forests, Musa estuary, Hendijan beaches and even Zohreh River to distances far from the sea. Studies of [32] showed that the sediments along the northern continental shelf of Oman were the dominant species belonging to the Rotalina suborder.

Entzia sp. species are reported for the first time in the region. In addition to European rivers and lakes, this species has reported from the Gulf of Mexico, Mediterranean and the North East Atlantic [33] and likely by cargo ships and oil tankers ballast water that went to the area, entered the area beaches and is compatible with the northern coast of Persian Gulf, or that is native to the region but had not been reported [29].

To estimate the abundance and distribution pattern, the bio monitoring indices were applied. Comparing three transects in hot and cold weather, the highest Simpson dominance index value was observed in third transect that is closer to the mouth of the Zohreh River and the lowest was in the first transect. Close to zero values of dominance index and high value of of Shannon-Wiener diversity index H′(near to 3) represent the high diversity in the region.

[30] in studying bivalves of Hendijan beaches reported most Shannon index value in the summer (0.29) and the lowest in autumn (0.044) and investigated Meiofauna in Naiband protected area in Persian Gulf (2008) maximum Shannon value 2.84 and minimum H′to 1.421 obtained.

According to the results of Menhinic's enrichment index the studying area has high species richness. Hill's evenness index shown the distribution of species was not balanced and tend to a species (*Ammonia Beccaria*) was higher. Because of dominant species was higher in summer, Simpson index showed the highest value obtained in this chapter.

Dominance decreased with distance from the shoreline and diversity increased that due to intertidal conditions in the region was expected. Meiofauna is one of the most important communities of muddy sediment shores and are dependent on substrate properties [33].

Differences in sediment texture of sampling stations may be the most important factors in these areas are in conflict with the distribution pattern of benthos [27]-[30]. In this study, percent of silt and clay in winter is more than summer, that it could be due to seasonal rainfall and runoff and sedimentation in the sea.

None of the species showed any significant correlation with sediment and homogeneous soft-bottom, so they're not influencing factors on diversity of Meiofauna. The main food source for benthic Meiofauna (except endosymbiotic species) is organic materials (particularly fragments) and all the bacterial communities on which they are reproduced.

Increasing the amount of organic matter in coastal areas could increase the biomass of the benthic Foraminifera [27]-[34]. Amount of organic material in Sajafi area sediments was high that's probably because of the silt clay particle size in the region. Comparing reduction of organic matter in winter and summer can be due to primary producers, reducing bacteria, activities of most of the creatures on the beach and being smaller than the particle size in this season. [15] observed inverse relationship between species richness and the amount of intertidal sediments organic matter in Bushehr.

A negative correlation was found between Meiofauna and TOM amount that can be due to high levels of organic matter in sediments which affect the oxygen concentration [14]. Depletion of dissolved oxygen in summer observed.

Physical and chemical parameters influence on the composition and density of benthic environment. Totally the benthos population is controlled by a set of factors and not only a single on that can be considered as the main factor involved in the distribution of these organisms [8]-[28].

In the study area, the temperature changes between stations are surprisingly limited that it could be due to the close proximity to each sampling sites and not enough to have a significant effect on the distribution or Meiofauna density. But seasonal variations in temperature which has an impact on the amount of dissolved oxygen can cause the differences in population structure and Meiofauna species composition. Meiofauna communities in the cold season in four stations showed a positive correlation with temperature. Since intertidal muddy shores are under the influence of weather conditions such as drought and high heat rejection located, it could be created problems of lack of oxygen in the surface layers of sediments [2]. The results of this study indicate high levels of oxygen in the sediments. Reducing oxygen and increasing in salinity and temperature in the summer is important that the dissolution of gases correspond with chemical laws, as the amount of salinity and temperature will increase the solubility of oxygen in water is reduced. Salinity in muddy beds shows fewer changes than the rest of the context. Salinity between 43.3 - 38.4 in the ports of Hendijan measured by [29]. [5], considered the salinity and sediment structure as two significant factors influencing the structure of Mayobentoz communities. In winter, most species showed significant correlations with organic matter. In the warm season species richness and diversity increased. New species of gastropods were observed and since the amount of organic matter reduces the diversity and reduction in species diversity was observed in the cold season.

Nematodes in the cold season were much more plentiful than the warm season. Babachahi [20] in Bushehr on the Soltani estuaries and Lashkari in Persian Gulf coast has reported most frequency of Meiofauna in summer. [29] [30] in the Nayband coast have reported seasonal changes in Meiofauna communities because of correlation with environmental factors. With increasing depth in the cold season, species richness increased and in warm season decreased. This can be due to changing water temperature and Plankton activity that are the food source of Meiofauna [31]-[34]. In the winter, more fine-grain, reduced organic matter and increase dissolved oxygen was found. It can be concluded that the amount of organic matter and sediments grain size are important in determining the diversity and dispersion of Meiofauna. Compared with the Welch model, the area was found partially moderate and unpolluted, which it could be due to region conditions and the river output. According to Ropme technical report in the region, most physical pressures are demands of sailing activities and fishing. Finally, the results of this study showed that the species diversity in intertidal Sajafi coasts, located in the region Hendijan is high, indicating the relative stability of the environment. Diversity indices compared with similar regions had relatively high values. High organic matter content affects the Meiofauna communities. Physical and chemical environmental parameters such as salinity and dissolved oxygen, distribution and diversity of Meiofauna in Sajafi area have been influential and regional and seasonal changes have led to significant differences in diversity of Meiofauna. So Meiofauna can be used as a useful tool for monitoring the environmental situation in muddy shores.

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