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Effect of Environmental Conditions on Spatial Distribution of Macrobenthic Community in the Bushehr Coasts of the Persian Gulf

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Abstract

The spatial distribution of the macrobenthic community was studied along the Iranian coasts of Bushehr province during January and February 2013. Samples were collected with van Veen grab from intertidal (0 m) and subtidal (5 m and 10 m depths) zones at 16 stations designated in 6 transects, including 4 main harbors (Genaveh, Bandargah, Rostami and Asaluyeh) and 2 creeks (Farakeh and Shif). A total of 17 groups (taxa) of macrobenthos were identified, of which the most dominant assemblages belonged to Mollusca, Annelida and Arthropoda. Abundance and biomass are significantly higher in some stations and depths than others, which could be correlated with combination of factors. The average macrofaunal abundance and biomass ranged from 450 to 4380 indm^{-2} and its from 9 to 165 gm^{-2}, respectively. The highest abundance and biomass were observed at 10 m and intertidal depths, respectively.

Keywords: Macrobenthic, spatial distribution, environmental factors, Persian Gulf, Bushehr.

Introduction

Benthic fauna is a source of food for secondary consumers; as most of the species that comprise this group are deposit feeders; their activity usually results in the repeated reworking of bottom sediments over time (Meadows and Campbell, 1993; Nybakken, 1993). These organisms are often used as bio-indicators, helping to assess changes in coastal ecosystems and to monitor marine environment health, particularly in zones suffering anthropogenic influences (Desroy *et al*., 2002). The significant role of benthic invertebrates for the detection of long-term environmental effects and theirs correlation with depth, sediment composition and organic matter in both soft and hard substrates have been corroborated in many studies (Jayaraj *et al*., 2007; Ingole *et al*., 2008).

The coastal zones include about 18% of the earth surface and 90% of the world's fishing is obtained from these regions (Balasubramanian, 1999). In fact, the coastal zones have devoted about 18 to 33% of the total primary production to themselves. These zones have a high biological potential since they acts as bed for feeding, culturing larva and spawning and also are considered an interstitial biotope between the marine environment and the fresh water (Nabavi *et al.*, 2011; Balasubramanian 1999).

The coastal areas along the Bushehr coasts of Iran are suitable ecosystem to observe the impact of harbor activities by studying the macrobenthic community. Some studies have been conducted on the macrobenthic structure of Bushehr coastal waters (Samani, 1991; Izadpanahi *et al*., 2007; Mirdar *et al*., 2009). To our knowledge, there are no data on the benthos spatial distribution shallow water soft bottom sediments (5 m to 10 m depths). Therefore, the main objectives of the present study were: (i) to estimate abundance and biomass of shallow water communities in order to obtain data base for future comparisons; (ii) to describe the structure and spatial distribution of macrobenthic assemblages; (iii) to identify the main environmental factors determining the distribution patterns; and (iv) to analyze the environmental influence (e.g., depth and sediment characteristics) on the structure of the macrozoobenthic assemblages.

Materials and Methods

Study Area

The study area covers almost 600 km of coastal stretch of the Persian Gulf (Figure 1), between Genaveh and Asaluyeh along the Bushehr province (27°28′-29°34′ N and 50°22′-52°36′ E). The sites

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were selected on soft bottoms submitted to different environmental conditions. Genaveh is a commercial shipping port; Farakeh creek receives freshwater from the Hellehriver; Shif creek is an important fishing area; Bandargah receives sewage effluent waters from Bushehr city and the adjacent Nuclear Power Plant; Rostami is also affected by fishing activities; Asaluyeh is an oil and gas industrial centre. The area is under the influence of microtidal (≤ 2 m tidal height), with a mixed or semidiurnal regime.

Sample Collection and Processing

Samples were collected during January and February 2013 along six transects, each with 3 sampling sites, intertidal (5 m depth and 10 m depth), except for transects 2 and 3 that lacked 10 m depth (Table 1). A total of 80 samples were taken with 5 replicates per site, 4 for macrobenthos fauna and 1 for sediment. Samples were collected with van Veen grab (225 cm^2) and poured into plastic jars. In the laboratory, the sediments were washed in fresh water through a 0.5 mm mesh sieve; the particles remaining on the sieves were preserved in 4% formalin and stained with Rose Bengal solution. Then, the macrofauna were separated, counted and identified to order level under a microscope, using appropriate identification guide (Jones 1986). The average abundance (abundance) of macrobenthos of the samples ($indm^{-2}$) and the wet biomass (gm^{-2} shell on) were estimated (Eleftheriou and McIntyre 2005). The percentages of sand, silt and clay were calculated and

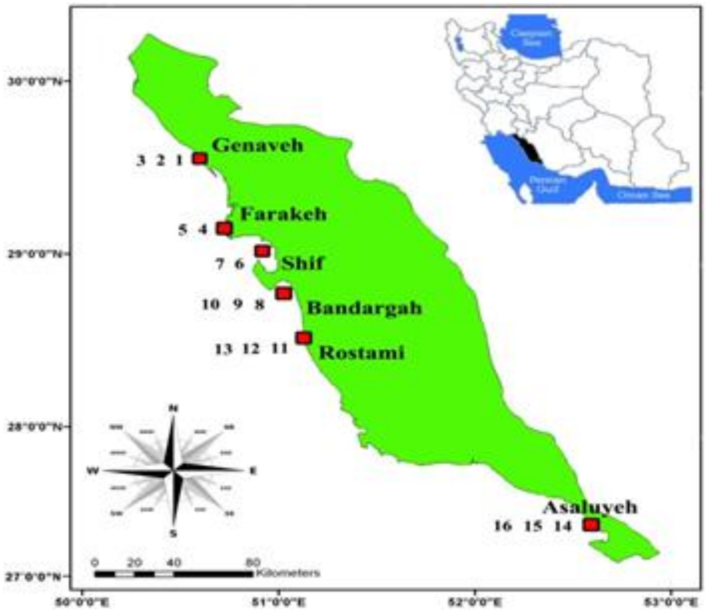

Figure 1. Map of the study area in the Bushehr coasts showing location of the macrobenthic sampling stations.

Table 1. The locations of sampling stations

Transect	Station	Depth (m)	Latitude (E)	Longitude (N)
	1	0		
Genaveh	2	5	50° 22′ 00″	29° 34′ 05″
	3	10		
Farakeh	4	0	50° 38′ 18″	29° 08′ 96″
	5	5		
Shif	6	0	50° 50′ 30″	29° 03′ 00″
	7	5		
	8	0		
Bandargah	9	5	50° 55′ 24″	28° 49′ 30″
	10	10		
	11	0		
Rostami	12	5	51° 03′ 16″	28° 41′ 60″
	13	10		
	14	0		
Asaluyeh	15	5	52° 36′ 72″	27° 28′ 10″
	16	10		

expressed with Talwin 4.2 software according to Shepard's classification (1954). Organic matter (OM) was measured by Modified Walkley-Black method (Nelson and Sommers 1996).

Statistical Analyses

Data on macrobenthic communities were compared within and between stations, using GLM univariate from SPSS 16 software. The normality of the data was verified using the Kolmogorov-Smirnov test and the homogeneity of variance by the Leven's test. Duncan's test was used to identify significant differences between mean data. Macrobenthic community structure was analyzed on the basis of both biological (abundance and biomass) and ecological indices (diversity and richness). Shannon-Weaver diversity index (Shannon and Weaver 1963) and Margalef's richness index (Margalef 1968) were calculated using Past program. Pearson's correlation coefficient was used to test between biological and ecological indices and environmental parameters. Bray-Curtis and Multidimensional Scaling (MDS) were performed based on macrobenthos number of individuals per known surface area (abundance) from Past program to obtain stations similarity and distribution clusters.

Results

Sediment Patterns

Five types of sediment textures were observed along the covered area (Figure 2), namely sand, silt, silty clay, clayey sand and sand silt clay. The distributions of sediments were relatively heterogeneous throughout the stations, but sand gradually increased from west to east. Coarse sediments dominated in the intertidal zone whereas the subtidal was characterized by fine sediments. OM was higher in silty than in sandy sediments, ranging from 0.6 to 3.5%. OM was higher in subtidal zones. Bandargah region had the highest OM and silt contents (Figure 3).

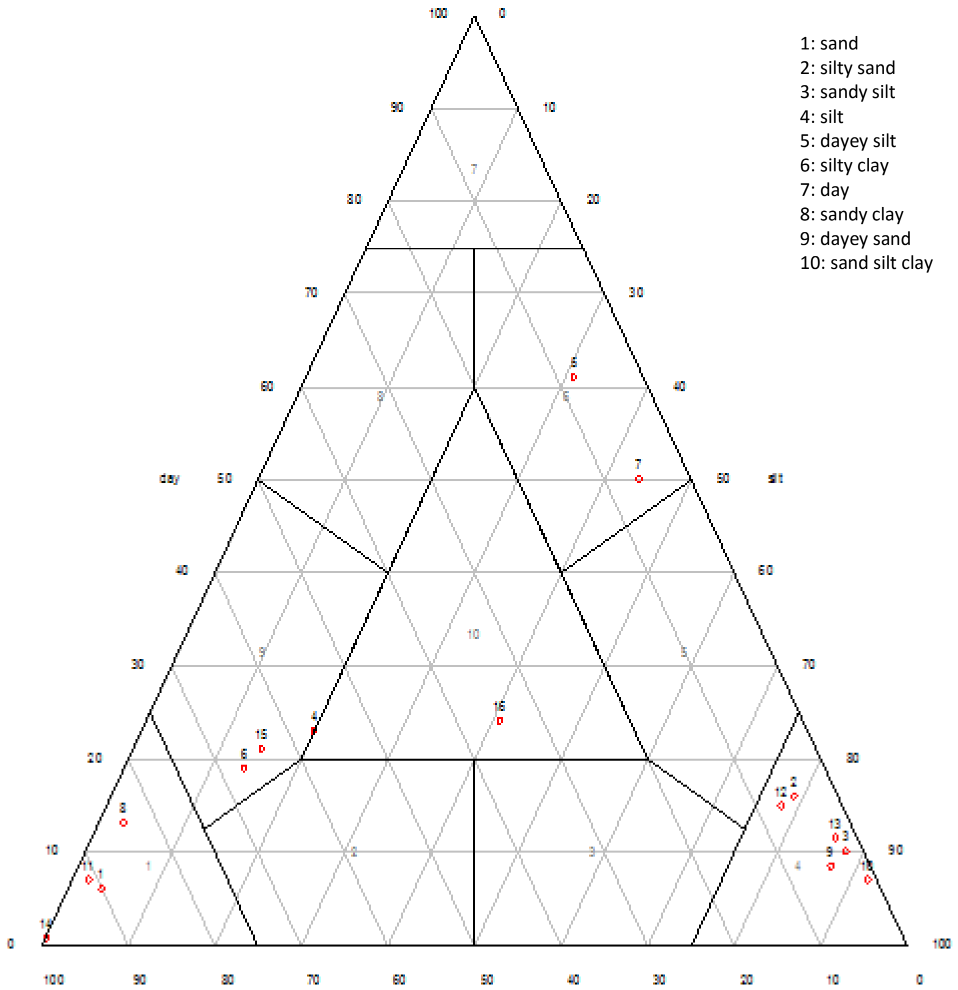

Figure 2. Triangular diagram showing sediment texture in the study area.

Abundance and Biomass

Total abundance of macrobenthos was significantly ($P<0.05$) higher in Rostami and Asaluyeh and also significantly lower in Genaveh and Farakeh (Duncan's test). The highest abundance of Polychaeta occurred in Bandargah and the lowest in Shif. The abundances of Mollusca, Arthropoda and Miscellaneous groups were as high in Rostami, Asaluyeh and Shif, and low in Bandargah. The highest total biomasses were observed in Shif and Asaluyeh and the lowest in Bandargah (Table 2). Total abundance was higher at 10 m depth and lower in the intertidal, while biomass decreased from intertidal to 10 m depth (Table 3). In general, the abundance varied among stations and depths from 450 to 4380 nm^{-2}, The lowest being at station 8 (intertidal) and the highest at station 13 (10 m depth). The minimum biomass (9 g m^{-2}) was recorded at 5 m depth and the maximum (165 gm^{-2}) at station 14 (intertidal) (Figure 4).

Ecological Indices

Diversity index of macrobenthos was significantly ($P<0.05$) lower in Bandargah, but richness did not show significant difference ($P>0.05$). Diversity ranged from 1.24 in Bandargah to 1.83 in Farakeh and richness ranged from 0.88 in Bandargah to 1.30 in Genaveh (Table 4). The highest diversity was observed at station 16 and the lowest at station 10. The maximum and minimum taxa richnesses were recorded at stations 3 and 14, respectively (Figure 5).

Correlation of Biological and Ecological Indices with Environmental Parameters

Total abundance and biomass were positively and negatively correlated ($P<0.01$) with water depth, respectively. Annelida abundance and biomass had a significantly positive correlation with silt ($P<0.01$ and $P<0.05$). Meanwhile, the biomass of Mollusca, Arthopoda and Miscellaneous group were positively

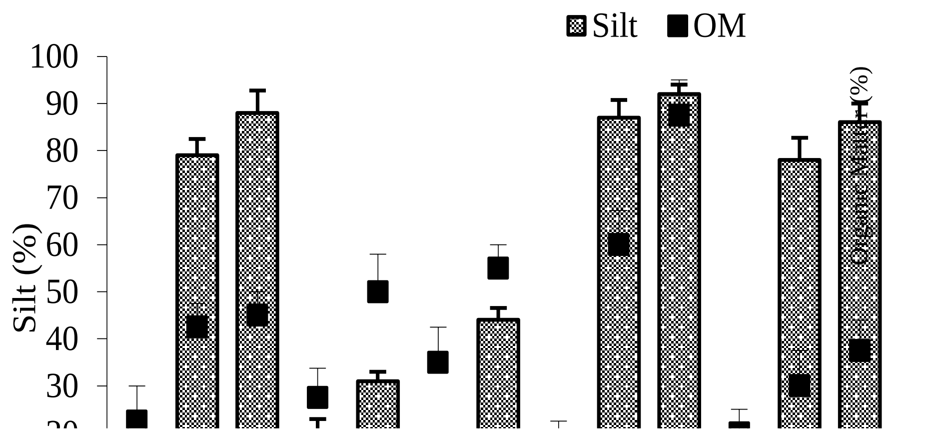

Figure 3. Comparison of silt and organic matter contents between the stations (vertical bars indicate standard errors).

Table 2. Average abundance (ind. m^{-2}) and biomass (gm^{-2}) of major groups in the various transects

Transects	Polychaetes	Crustaceans	Molluscs	Others	Total
Genaveh	383 (2.80)	327 (5.78)	557 (15.17)	73 (7.32)	1340 (31.07)
Farakeh	310 (2.45)	290 (8.35)	760 (26.44)	35 (1.59)	1395 (38.83)
Shif	290 (2.55)	270 (6.02)	995 (35.47)	160 (7.88)	1715 (51.92)
Bandargah	950 (0.91)	137 (2.23)	420 (8.43)	20 (0.66)	1527 (12.23)
Rostami	867 (3.78)	310 (9.46)	1603 (23.73)	100 (4.48)	2880 (41.45)
Asaluyeh	587 (2.41)	583 (12.77)	1283 (40.51)	150 (14.81)	2603 (70.50)
Average	565 (2.48)	319 (7.44)	936 (24.96)	90 (6.12)	1910 (41)
S.E.	75 (0.35)	36 (2.21)	90 (3.52)	14 (1.91)	157 (4.94)

Table 3. Average abundance (ind. m^{-2}) and biomass (g m^{-2}) in the various depths

Depth	Polychaetes	Crustaceans	Molluscs	Others	Total
Intertidal	50 (0.45)	140 (14.07)	464 (39.52)	70 (12.08)	724 (66.12)
5 m	725 (3.95)	384 (5.15)	1005 (21.61)	75 (1.88)	2189 (32.59)
10 m	919 (3.05)	435 (3.11)	1340 (13.77)	124 (4.40)	2818 (24.33)

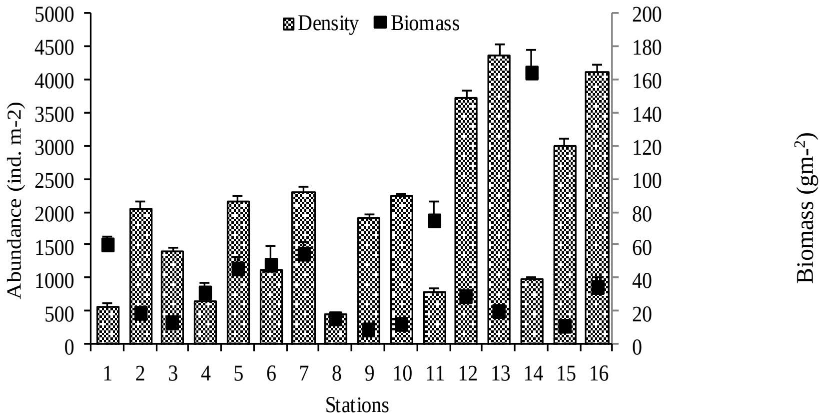

Figure 4. Comparison of macrobenthic abundance and biomass between the stations (vertical bars indicated standard error).

Table 4. Diversity and richness indices of macrobenthos in the harbors and creeks (± SE)

Transects	Diversity	Richness
Genaveh	1.81 ± 0.05 [a]	1.30 ± 0.20 [a]
Farakeh	1.83 ± 0.02 [a]	1.14 ± 0.10 [a]
Shif	1.73 ± 0.07 [a]	1.29 ± 0.01 [a]
Bandargah	1.24 ± 0.20 [b]	0.88 ± 0.03 [a]
Rostami	1.54 ± 0.09 [ab]	0.98 ± 0.05 [a]
Asaluyeh	1.69 ± 0.14 [a]	1.22 ± 0.25 [a]
Average	1.64 ± 0.09	1.13 ± 0.11

Values with the same superscripts are not significantly different (P>0.05)

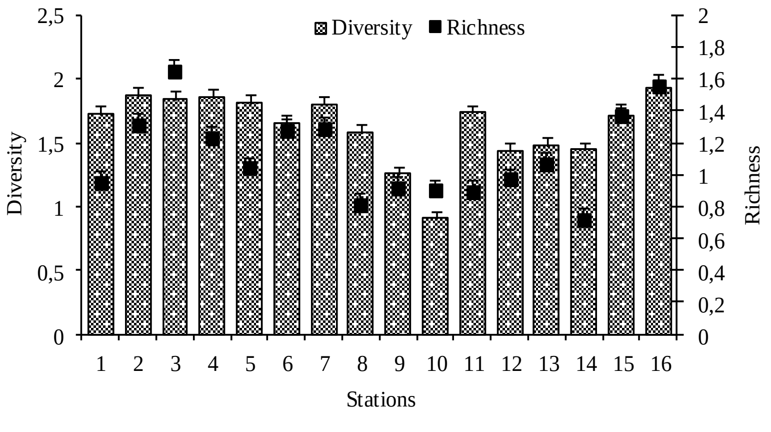

Figure 5. Comparison of diversity and richness between the stations (vertical bars indicate standard errors).

correlated with sand (P<0.01 and P<0.05). Total abundance showed a significantly negative correlation with OM (P<0.05). Diversity was negatively correlated with OM (P<0.05). Richness also tends to increase with the increasing silt, clay and OM contents, but the correlation was not significant (Table 5).

Community Structure

A total of 17 groups (taxa) of macrobenthic community were identified and classified into 4 major groups, namely Mollusca, Annelida, Arthropoda and miscellaneous groups. Mollusca and Annelida were formed of Gastropoda and Bivalvia and also Polychaeta and Oligochaeta, respectively. Among the Arthropoda, Crustacea (Amphipoda, Isopoda,

Table 5. Correlation coefficient between benthic groups (abundance and biomass in parentheses) and environmental variables

Taxa	Depth (m)	Sand (%)	Silt (%)	Clay (%)	OM (%)
Polychaetes	0.68**(0.52**)	-0.74**(-0.69**)	0.80** (0.53*)	-0.03 (0.46)	0.64** (0.24)
Crustaceans	0.43**(-0.26*)	-0.32 (0.63**)	0.18 (-0.56*)	0.37 (-0.25)	-0.02 (-0.51*)
Molluscs	0.50**(-0.46**)	-0.40 (0.51*)	0.32 (-0.54*)	0.24 (-0.02)	-0.03 (-0.35)
Others	0.15 (-0.22)	0.06 (0.70**)	-0.15 (-0.59*)	0.20 (-0.35)	-0.16 (-0.54*)
Total	0.75** (-0.48**)	0.17 (-0.35)	-0.38 (0.24)	0.44 (0.30)	-0.50* (0.10)
Diversity	0.39	0.18	-0.38	0.44	-0.5*
Richness	0.47	-0.35	0.24	0.3	0.1

Significance levels: *: P<0.05,**: P<0.01

Decapoda, Cumacea, Mysidacea and Tanaidacea) were dominant, followed by Pycnogonida. Other groups consist of Nemertinea, Echiura, Sipuncula, Echinodermata (Echinoidea), Cnidaria (Hydrozoa) and Protozoa (Foraminifera). In this study, molluscs had the most macrofauna abundance (53% of the total), followed by annelids (22%), arthropods (18%) and miscellaneous groups (7%). The biomass pattern indicated the distribution of the molluscs (57.5%), arthropods (19%), miscellaneous groups (15%) and annelids (8.5%) of the total biomass (Table 6).

Cluster Analysis

The macrobenthic communities were separated in three distinct clusters around 70% similarity. Group A, represented by two stations (i.e. 9 and 10 based on abundance). Group B involve eight stations (two subcluster), four from the western region and the other four the eastern one, all them subtidal. Group C contain six stations (two subcluster), all them intertidal (Figure 6a, Figure 6b).

Discussion

Macrobenthic abundance and biomass in the present survey were higher than an earlier work by Bushehr coasts (Izadpanahi *et al*., 2007), which may be due to the differences in depth, sediment properties and other environmental conditions. Furthermore, abundance and biomass were generally high in the depths 5 m and 10 m (Table 3), which corresponded with a work conducted in the coastal waters of India (Saraladevi *et al*., 1996). The low abundance of macrobenthic community in the Farakeh creek (Table 2) could be attributed to the Helleh river run off that carries heavy load of sediments. Sediment load of rivers has also been blamed for the low abundance of macrobenthos in the northern creeks of Bushehr (Mirdar *et al*., 2009) and other parts of the world (Dittmann, 2000; Spruzen *et al*., 2008). Moreover, the macrobenthic assemblage in Farakeh was characterized by a higher abundance of some brackish water species, namely brackish oligochaetes, which was similar to Mogias and Kevrekidis (2005). The high abundance in the Shif creek, probably due to the weak water currents as well as being assigned as a preserved area, was indicative of healthy benthic community and constant environment (suitable habitat in terms of sediment and water).

It has been assumed that much organic content in sediment can reduce the abundance of sensitive benthos and promote some tolerant species such as polychaetes (Sarkar *et al*., 2005; Ingole *et al*., 2008). The polychaete abundance in the Bandargah was higher than other transects (Table 2), which could be mainly due to the sewage discharge. In fact, some species of polychaetes may indicate the presence of organic inputs (anthropogenic or not). Although the warm water currents (thermal pollution) from the Nuclear Power Plant could change benthos metabolism (Cheng *et al*., 2004), no adverse effect on abundance and diversity of macrobenthos was evident, but it was not operational at the time of sampling in Bandargah.

The eastern coasts showed relatively higher macrobenthic abundance than the western ones, especially in Asaluyeh, which could be attributed to the sediments being more heterogeneous in the eastern parts. Saraladevi *et al*., 1996; Shakori *et al*., 2001; Jayaraj *et al*., 2007; Jayaraj *et al*., 2008 confirmed that muddy sand can support high abundance of macrofauna and one of the factors governing on abundance is sediment texture.

Presence of large organisms can lead to increasing macrobenthic biomasses (Desroy *et al*., 2002; Ganmanee *et al*., 2004; Gappa and Sueiro 2007), as it occurred in the eastern studied regions due to a higher occurrence of molluscs and echinoderms. The presence of polychaetes with low individual biomass in Bandargah was due to the sewage effluent from Bushehr city, which was comparable to what was found in the west coast of India (Ingole *et al*., 2008).

Molluscs, annelids and arthropods were found to be the dominant macrobenthic groups, which correspond to findings from the Chabahar bay of Iran (Nikoueian, 2001) and all soft bottoms in the world. While a positive relationship was evident between polychaete abundance and biomass with silt (Table 5) that corresponded with earlier works (Shakori *et al*., 2001; Ingole *et al*. 2008), this relationship was observed between the biomass and sandy bottom in other of macrobenthic groups. The ratio of molluscs

Table 6. Macrobenthic species list of the study area and abundance in transects

Phylum	Subphylum	Class	Order	Family	Species	1	2	3	4	5	6
				Aphroditidae	*Lepidonotuscarinulatus*	25	0	0	9	20	36
				Capitellidae	*Capitellacapitata–Mediomastus sp.–Notomastuslatericeus*	71	28	43	510	285	100
				Cirratulidae	*Cirratuluscirratus–Thanyx sp.*	32	47	61	24	118	76
				Eunicidae	*Eunice sp.*	4	8	14	39	0	0
Annelida		*Polychaeta*		*Glyceridae*	*Glycera alba–G. convolute*–unidentified	57	68	42	40	95	99
				Lumbrineridae	*Lumbriconereislatereilli*	15	0	8	22	0	0
				Nephtyidae	*Nephtyscirrosa–N. dibranchis*	94	77	55	82	101	65
				Nereidae	*Nereis sp.*	26	17	25	50	0	30
				Phyllodocidae	*Phyllodocemaculata–Teonepicta*	19	0	18	8	20	13
				Pilargiidae	*Ancistronsyllisconstricta*	13	0	3	29	8	15
				Sabellidae	*Hypsicomus sp.–Jasmineria sp.*	0	0	2	37	7	33
				Serpulidae	*Hydroides sp.*	27	0	10	23	51	28
				Spionidae	*Prionospiopinnata–P. polybranchiata*	0	0	6	31	88	10
				Syllidae	*Syllisspongicola*	0	65	3	30	44	44
				Terebellidae	*Terebella sp.*	0	0	1	16	30	38
		Oligochaeta				0	151	0	0	0	0
ollusca		*Gastropoda*			*Cerithidae sp.–Hydrobiaulvae–Littotinalittorea–Polinicescatenus*–unidentified	105	128	290	135	1346	382
		Bivalvia			*Abra alba–Cerastodermaedule–Mysellabidentata–Mytilusgalloprovincialis–Scrobiculariaplana–Tellinatenuis*	452	632	705	285	257	901
Arthropoda	*Crustacea*	*Malacostraca*	*Amphipoda*	*Ampeliscidae*	*Ampelisca sp.*	162	29	72	10	23	85
				Ampithoidae	*Ampithoe sp.*	22	0	15	0	23	0
				Caprellidae	unidentified	91	13	45	6	41	32
				Haustoriidae	*Urothoe sp.*	0	9	20	0	5	0
				Hyalidae	*Hyale sp.*	0	9	16	0	15	0
				Liljeborgiidae	*Liljeborgia sp.*	25	19	11	0	0	58
				unidentified		0	69	47	25	148	345
			Isopoda		*Cyathuracarinata*	27	30	10	18	0	0
			Decapoda		*Brachyurans sp.–Carcinusmaenas*	0	49	9	27	55	63
			Cumacea		*Diastylis sp.–Squillasp*	0	24	2	18	0	0
			Mysidacea		unidentified	0	11	0	20	0	0
			Tanaidacea		*Allotanaishirsutus*	0	18	2	9	0	0
	Chelicerata	*Pycnogonida*			*Acheliaparvula*	0	10	21	4	0	0
Nemertinea					unidentified	4	0	39	0	9	0
Echiura					unidentified	8	0	0	0	21	0
Sipuncula					*Golfingiamargaritacea*	11	0	0	0	17	0
Echinodermata		*Echinoidea*			unidentified	33	15	52	13	18	123
Cnidaria		*Hydrozoa*			*Actinia ecuina*	17	20	61	7	20	27
Protozoa			*Foraminifera*		unidentified	0	0	8	0	15	0

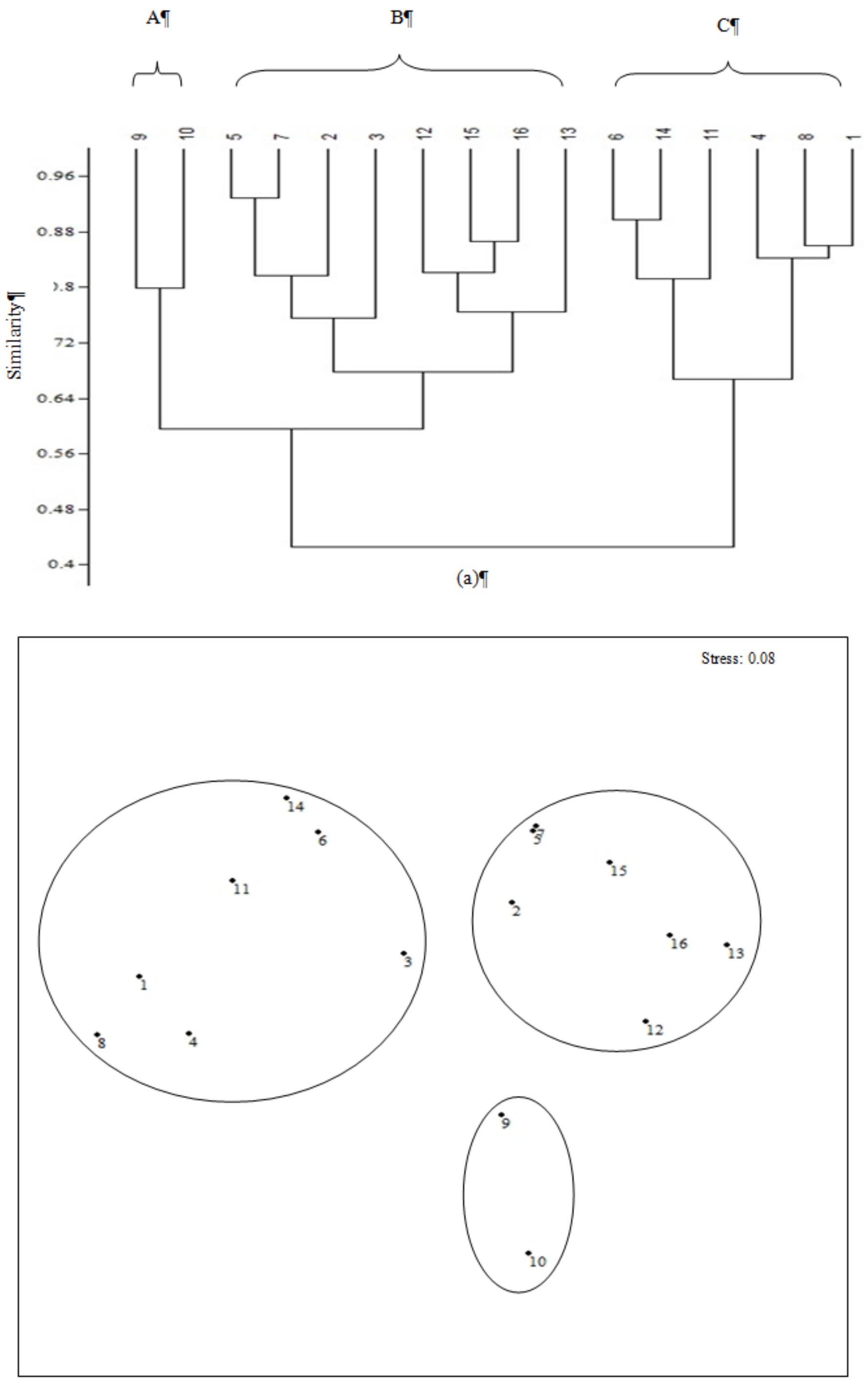

Figure 6. Cluster of Bray-Curtis similarity (a) and MDS plot (b) base on macrobenthos abundance.

plus crustaceans to polychaetes in this research is 7.5, which falls in the reported range of 3.5 to 8.2 for tropical to temperate areas (Rodrigues *et al*., 2006).

According to Sanders (1968) stability hypothesis, hydrodynamic conditions, particularly depth as a primary factor, play an important role in the macro-invertebrates distribution. The shallower the depth higher is the influence of currents and waves, so that abundance and diversity were higher at depth 10 m than the depth 5 m in the research area.

The high diversity in Farakeh could be attributed to river flow with nutrients load that was in agreement with earlier reports (Saraladevi *et al*., 1996; Dittmann 2000; Desroy *et al*., 2002; Ingole *et al*., 2008), the high diversity in Asaluyeh it could be related to habitat heterogeneity. Sediment mixed up with fine and coarse particles tend to harbour more diverse assemblages than the sand or silt-clay alone, because they can host greater habitat diversity (Yu *et al*., 2006). Muddy-sand substrates often harbour the highest macro-faunal diversity (Sousa *et al*. 2006; Wang *et al*., 2009). Organic matter enrichment is one of the most common disturbances leading to a decrease in abundance and diversity in macro-benthic assemblages (Junoy and Vieitez, 1990; Sarkar *et al*., 2005; Jayaraj *et al*., 2007).

The unexpected position of stations 9 and 10 in the classification cluster could be attributed to pollution (Figure 6a, Figure 6b). Bustamante *et al*. (2007) pointed out that water contamination effects could cause of distribution of the clusters. According to Wilhm-Dorris index, values between 1.0 and 3.0, indicates moderate water pollution. Diversity values in the study ranged from 1.24 to 1.83, suggesting that coasts along Bushehr province were moderately polluted and the macrobenthic community is under stress due to natural and/or anthropogenic factors, which was in agreement with Vazirizadeh and Hosseini (2006).

Conclusion

Most of environmental parameters were not significantly correlated with both biological and ecological indices, suggesting that macrobenthic spatial distribution in the coasts of Bushehr province was controlled by a combination of several factors (depth (different hydrodynamic conditions), sediment texture, organic matter related to marine pollution) and no single factor. Finally, the long-term monitoring and assessment of harbors and creeks is required to determine the future temporal changes in the benthic community and marine environment.

Author Contribution

P. Farsi, J. Seyfabadi and F. Owfi carried out sampling and wrote the draft manuscript. P. Farsi, J. Seyfabadi and M.S. Aramli organized and supported the field survey, and discussed the results and the written manuscript. All authors read and approved the final version of the manuscript.

Conflict of Interest

All authors declared that they have no conflict of interest.

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