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Original Article

Benthic community structure in the Gorgan Bay (Southeast of the Caspian Sea, Iran): Correlation to water physiochemical factors and heavy metal concentration of sediment

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Abstract: Macrobentos frequency and biomass was investigated in the Gorgan Bay in 2011. Five sampling sites were chosen to collect benthos and sediment from the Bay using a Van Veen grab sampler. Samples were collected seasonally. Macrobenthos were indentified and their biomass was recorded. Sediment heavy metals concentration were measured using Atomic Absorption Spectroscopy. A total of 11 families belonging to three phyla of invertebrates were found. The phyla were Annelids (Nereidae, Naididae, Ampharetidae, Lumbriculidae, Tubificidae and Amphiporidae), Arthropods (Pontogammaridae, Balanidae and Chironomidae) and Mollusks (Cardiidae and Scrobicularidae). Lumbriculidae (413 individuals m^{-2}, corresponding to 18.7%) and Cardiidae (55.2 g m^{-2}, corresponding to 82.4%) had the highest frequency and biomass, respectively. Annelids with an average of 1557 individuals m^{-2} was the most frequent groups, while, mollusks with the average of 141 g per m^2 had the highest biomass. Results showed that macrobenthos frequency in summer was significantly higher than those of the other seasons, however, in the case of biomass, there was a significantly higher biomass in the spring than the other seasons. The maximum metal concentration was related to Zn and Pb, whereas, Cr and Cd had the lowest values. There was no significant difference in Zn and Cr concentrations among the sampling seasons. Pb concentration in winter was significantly lower than the other seasons, whereas, Cd concentrations in the spring and summer were significantly lower than the autumn and winter. There were some correlations between benthos frequency and water physiochemical characteristics and sediment heavy metal levels. This study indicated that benthic fauna of the Gorgan Bay and the Caspian Sea are not similar. Also, results showed that benthic fauna communities are affected by sediment heavy metal concentrations and water physiochemical characteristics, however, different benthos groups show unsimilar relationship with heavy metal concentration.

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Introduction

Studying the biological and ecological aspects of water resources is very important in the ecosystem studies. The initial step of such surveys is the identification of organisms living in the ecosystem (Ahmadi and Mousavi, 2002). Macrobenthic communities are a part of food chain and supply the required energy for the majority of aquatic species, particularly fishes (Soleimanroodi, 1994). Thus, as the secondary producers, they are one of the energy suppliers and distributor in the ecosystem. The aquatic organisms are exposed to anthropogenic disturbances and natural changes in their habitats, which make them react in different ways. Therefore, aquatic organisms have an important role in bioassessment (Mooraki et al., 2009; Girgin, 2010).

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Benthic fauna's structure is affected by environmental factors such as temperature, pH, dissolved oxygen and pollution. The relationship between benthic fauna's structure and heavy metal contamination has been studied previously (Rygg, 1985; Hall et al., 1996; Warwick, 2001; Guerra-García and García-Góme, 2004; Harriague et al., 2007; Dauvin, 2008). Rygg (1985) studied the relationship between benthic fauna diversity and concentrations of Cu, Pb and Zn in the sediments from Norwegian fjords and found a strong negative correlation between species diversity and heavy metals concentration. Hall et al. (1996) studied the effects of metal contamination on macrobenthos in two North Sea estuaries and found a decrease in the community at the polluted sites. Warwick (2001) studied the effects of metal contamination on the intertidal macrobenthic communities at the Fal Estuary and reported that sediments' heavy metal concentrations were correlated most strongly with the composition of the communities.

The Gorgan Bay is located at the southeast of the Caspian Sea with an area about 400 km^2. Due to the clayey bed, shallow depth and lack of heavy waves, the Gorgan Bay is considered as a suitable habitat for benthic communities. The Bay is the major site of fish stock rehabilitation in the southern Caspian Sea, receiving huge number of fish fingerlings originated from the artificial propagation and rearing, yearly. The fish species are sturgeons (Acipenseridae), Caspian kutum (*Rutilus frisii kutum*), common carp (*Cyprinus carpio*) and Caspian roach (*Rutilus rutilus caspicus*), all feed on macrobenthic fauna. Thus, condition of macrobenthic fauna in the Gorgan Bay is important for stock rehabilitation program that is performed by Iranian Fisheries Organization. In addition, some species use the Grorgan Bay as the spawning and nursery ground with their off springs being associated with benthic fauna as food. Despite the aforementioned importance, there are limited studies on the Bay benthic fauna communities, necessitating the need for such studies. Therefore, the aim of this study was to investigate frequency, biomass and seasonal variation in the macrobenthic fauna of the Gorgan Bay and its correlation with water physiochemical factors and sediment heavy metals (Zn, Cd, Cr and Pb) levels.

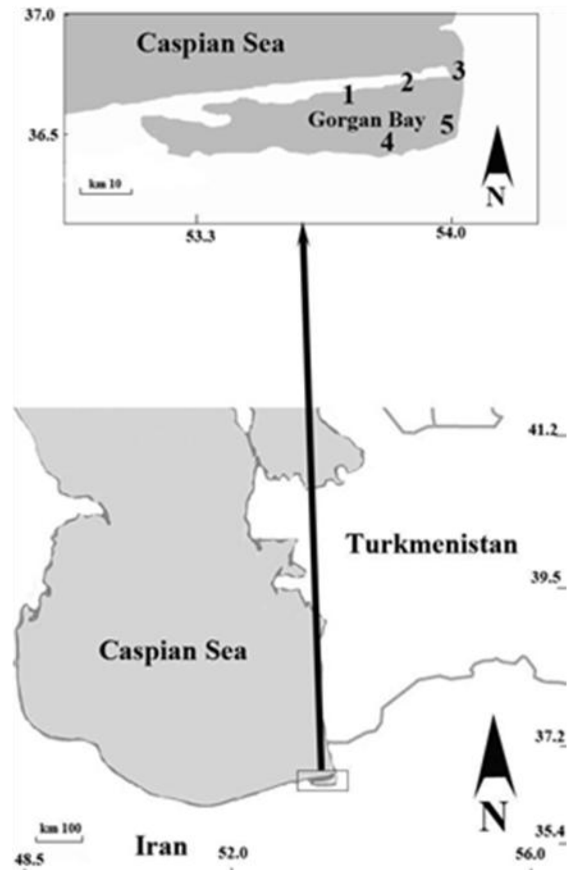


Figure 1. The sampling sites in the Gorgan Bay.

Materials and methods

Samples were collected during 2011, from 5 sampling sites (Fig. 1). Samples were collected monthly from each site. Monthly data were averaged to represent seasonal data of the site, thus, there were 5 samples per season for the whole study area. Benthos and sediment sampling was performed using a Van Veen grab (area = 225 cm^2).

Benthos samples were sieved using a 63-micron sieve and macrobenthic organisms were fixed with 4% formalin. Macrobenthos were identified taxonomically and their number and biomass were determined per m^2.

Table 1. Sediment heavy metal concentrations in different seasons. Different Latin letters show significant difference. (ANOVA and Duncan's test; *P*< 0.05).

Metal	Season	Concentration
Zn	Spring	731.6 ± 78.6 a
	Summer	787.8 ± 55.8 a
	Autumn	816.6 ± 89.5 a
	Winter	766.2 ± 91.4 a
Cr	Spring	165.6 ± 18.2 c
	Summer	159.6 ± 22.5 c
	Autumn	230.8 ± 34.7 c
	Winter	192.4 ± 41.3 c
Cd	Spring	103.8 ± 5.89 d
	Summer	107.2 ± 10.7 d
	Autumn	178.8 ± 21.9 c
	Winter	184.2 ± 30.8 c
Pb	Spring	771.8 ± 89.6 a
	Summer	693.4 ± 120.7 a
	Autumn	683.4 ± 79.9 a
	Winter	520.4 ± 71.2 b

Sediment sample preparation and heavy metals concentration (Atomic Absorption Device) was measured according to Saghali et al. (2013).

Water physicochemical characteristics including temperature, pH, dissolved oxygen, turbidity and salinity were recorded at each sampling site. Water dissolved oxygen, salinity and pH were determined using a portable multiparameter meter (sensION 156, USA). Turbidity was measured using a secchi disk.

Data were subjected to Shapiro-Wilk's test to assess normality. Normal data were analyzed by one way ANOVA and Duncan's tests, whereas non-normal data were analyzed by Kruskal-Wallis and Mann–Whitney U. To examine correlation between benthos frequency and water and sediment factors, data were analyzed using the Spearman's test. Data are presented as mean ± SE. *P*<0.05 considered as the significant difference.

Results

Heavy metal concentrations of sediment are presented in Table 1. The maximum metal concentration was related to Zn and Pb, whereas, Cr and Cd had the lowest values. There was no significant difference in Zn and Cr concentrations among the sampling seasons. Pb concentration in winter was significantly lower than that of the other seasons, whereas, Cd concentrations in the spring and summer were significantly lower than the autumn and winter.

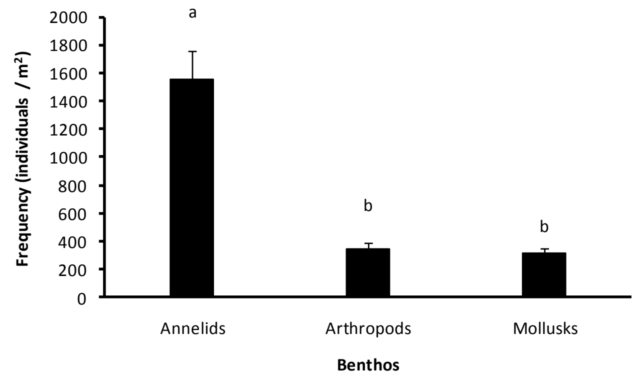


Figure 2. Mean yearly frequency of different phyla of macrobenthos collected from the Gorgan Bay. n = 20. Different letters above the bars show significant difference (Kruskal-Wallis and Mann Whitney U tests, α<0.05).

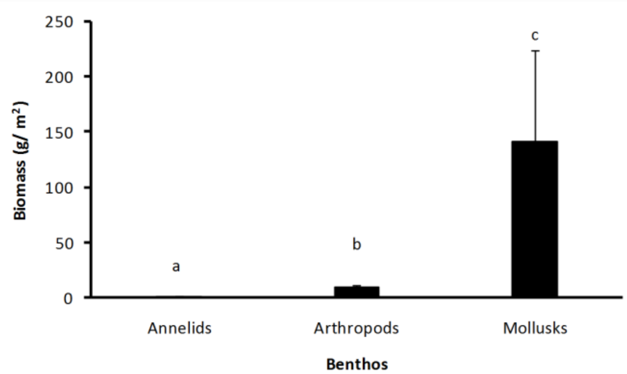


Figure 3. Mean yearly biomass of different phyla of macrobenthos collected from the Gorgan Bay. n = 20. Different letters above the bars show significant difference (Kruskal-Wallis and Mann Whitney U tests, α=0.05)

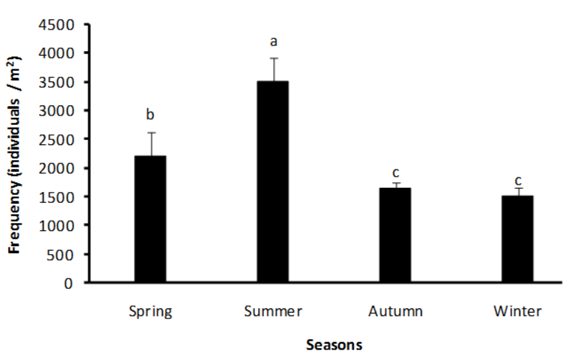
A total of 11 families were found belonging to 3 phyla of invertebrates (Table 2). The phyla were Annelids (Nereidae, Naididae, Ampharetidae, Lumbriculidae, Tubificidae and Amphiporidae), Arthropods (Pontogammaridae, Balanidae and Chironomidae) and mullusks (Cardiidae and Scrobicularidae). The dominant groups, in the case of frequency, were Lumbriculidae (413 individuals m^{-2}, corresponding to 18.7%), followed by Ampharetidae (338 individuals m^{-2}, corresponding

Table 2. Seasonal and yearly frequencies of different macrobenthos groups collected from the Gorgan Bay.

	Spring	Summer	Autumn	Winter	Year
Annelids					
Nereidae	186 ± 55.1	173 ± 47.2	122 ± 26.1	280 ± 36.2	190 ± 23.5
Naididae	44.4 ± 34.4	17.6 ± 5.54	61.2 ± 22.6	53.2 ± 8.95	44.3 ± 10.5
Ampharetidae	274 ± 80.40	656 ± 102	241 ± 31.1	181 ± 47.6	338 ± 52.9
Lumbriculidae	391 ± 134	710 ± 96.9	264 ± 36.1	289 ± 40.6	413 ± 57.1
Tubificidae	289 ± 107	457 ± 56.6	122 ± 13.5	166 ± 28.1	258 ± 41.3
Amphiporidae	279 ± 92.3	623 ± 128	146 ± 11.90	198 ± 28.6	311 ± 56.5
Arthropods					
Pontogammaridae	-	177 ± 29.2	124 ± 24.9	146 ± 33.5	111 ± 18.9
Balanidae	417 ± 135	228 ± 33.4	285 ± 55.8	17.8 ± 17.8	230 ± 47.6
Chironomidae	8.80 ± 8.80	-	-	-	2.20 ± 8.80
Mollusks					
Cardiidae	293 ± 113	196 ± 50.6	188 ± 38.9	135 ± 33.1	203 ± 33.5
Serobiculariidae	17.8± 17.8	246 ± 47.6	115 ± 30.2	44.8 ± 11.8	110 ± 25.9

Table 3. Seasonal and yearly biomass of different macrobenthos groups collected from the Gorgan Bay (g m^{-2}).

	Spring	Summer	Autumn	Winter	Year
Annelids					
Nereidae	0.86 ± 0.25	0.80 ± 0.22	0.56 ± 0.12	1.29 ± 0.17	0.87 ± 0.11
Naididae	0.01 ± 0.007	0.003 ± 0.001	0.01 ± 0.005	0.01 ± 0.001	0.01 ± 0.002
Ampharetidae	0.10 ± 0.03	0.24 ± 0.04	0.09 ± 0.01	0.06 ± 0.01	0.12 ± 0.02
Lumbriculidae	0.22 ± 0.07	0.39 ± 0.05	0.15 ± 0.02	0.16 ± 0.02	0.23 ± 0.03
Tubificidae	0.24 ± 0.09	0.37 ± 0.05	0.10 ± 0.01	0.14 ± 0.02	0.21 ± 0.03
Amphiporidae	0.15 ± 0.05	0.35 ± 0.07	0.08 ± 0.01	0.10 ± 0.02	0.17 ± 0.03
Arthropods					
Pontogammaridae	-	0.09 ± 0.01	0.06 ± 0.01	0.07 ± 0.02	0.05 ± 0.01
Balanidae	17.1 ± 5.54	9.38 ± 1.37	10.6 ± 2.29	0.73 ± 0.73	9.45 ± 1.95
Chironomidae	0.02 ± 0.02	-	-	-	0.005 ± 0.005
Mollusks					
Cardiidae	115 ± 30.2	15.0 ± 5.69	49.5 ± 17.8	40.6 ± 19.8	55.2 ± 16.1
Serobiculariidae	0.13± 0.13	1.98 ± 0.36	0.86 ± 0.23	0.34 ± 0.08	0.83 ± 0.19



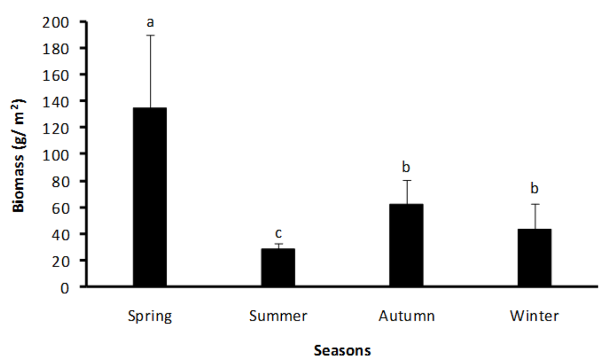


Figure 4. Mean (± SD) seasonal frequency (left figure) and biomass (right figure) of total macrobenthos collected from the Gorgan Bay. n = 5. Different letters above the bars show significant difference (Duncant's test for benthos frequency and Kruskal-Wallis and Mann Whitney U tests for benthos biomass, α=0.05).

to 15.3%), Amphiporidae (311 individuals m^{-2}, corresponding to 14.1%), Tubificidae (258 individuals m^{-2}, corresponding to 11.7%) and Balanidae (230 individuals m^{-2}, corresponding to 10.4%) (Table 2). The other families contributed less than 10% of the total number of collected macrobenthos. Annelids with an average of 1557 individuals per m^2 was the most frequent groups,

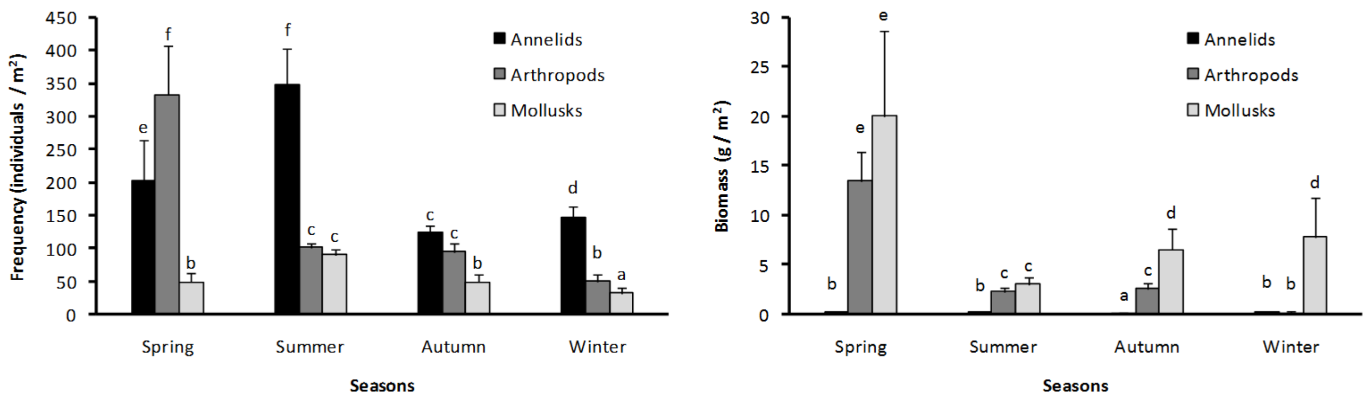


Figure 4. Mean (± SD) seasonal frequency (Left figure) and biomass (Right figure) of different macrobenthos collected from the Gorgan Bay. n = 5. Different letters above the bars show significant difference (Kruskal-Wallis and Mann Whitney U tests, α=0.05).

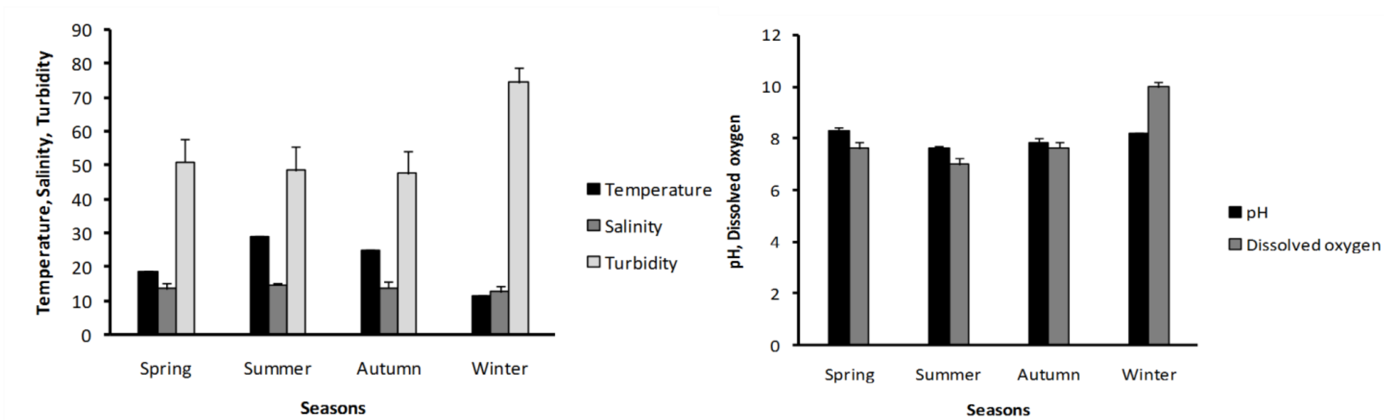


Figure 5. (Left figure): Mean (± SD) seasonal temperature (ºC), salinity (ppt) and turbidity (Cm) of the Gorgan Bay. (Right figure): Mean (± SD) seasonal pH and dissolved oxygen (ppm) of the Gorgan Bay. n = 5.

followed by Arthropods (344 individuals m^{-2}) and mollusks (314 individuals m^{-2}) (Fig. 2).

Table 3 shows the biomass of different macrobenthos groups. The dominant groups, in the case of biomass, were Cardiidae (55.2 g m^{-2}, corresponding to 82.4%), followed by Balanidae (9.45 individuals m^{-2}, corresponding to 14.1%). The other families had less than 2% of the total biomass (Table 3). Mollusks with the average of 141 g per m^2 had the highest biomass, followed by Arthropods (9.5 g m^{-2}) and Annelids (1.6 g m^{-2}) (Fig. 3).

Results showed that macrobenthos frequency in summer was significantly higher than that of the spring, which was significantly higher than those of the autumn and winter (Fig. 3). However, there was significantly a higher biomass in the spring than those of the autumn and winter, which were significantly higher than that of the summer (Fig. 3).

The most frequent macrobenthos were Arthropods during the spring and Annelids during the summer, followed by Annelids during the spring and winter (Fig. 4). The highest biomass was observed in Mollusks and Arthropods during spring, followed by Mollusks in autumn and winter (Fig. 4).

Water physicochemical characteristics are presented in Figure 5. Range of temperature, salinity, turbidity, pH and dissolved oxygen were 11.7-29 ºC, 12.7-14.8 (ppt), 47.5-74.2 (cm), 7.6-8.3 and 7-9.9 (ppm), respectively.

There were significant correlations between benthos frequency and water physiochemical characteristics and sediment heavy metal levels (Table 4). The following correlations were found: between

Table 4. Correlation of benthos frequency with water physiochemical characteristics and sediment heavy metal concentrations. Asterisks show significant correlations (T = temperature, DO = dissolved oxygen, TUR = turbidity, SAL = salinity).

		Zn	Pb	Cr	Cd	T	DO	pH	TUR	SAL
Nereidae	Correlation Coefficient	-0.8	-0.2	-0.2	0.2	-0.8	0.4	0.6	0.5	-0.8
	Sig.	0.2	0.8	0.8	0.8	0.2	0.6	0.4	0.5	0.2
Naididae	Correlation Coefficient	0.4	-0.6	0.3	0.6	-0.4	0.8	0.2	-0.2	-0.4
	Sig.	0.6	0.4	0.7	0.4	0.6	0.2	0.8	0.8	0.6
Ampharetidae	Correlation Coefficient	0	0.8	-0.8	-0.8	0.8	-1*	-0.4	-0.4	0.8
	Sig.	1	0.2	0.2	0.2	0.2	0.000	0.6	0.6	0.2
Lumbriculidae	Correlation Coefficient	-0.4	0.6	-1*	-0.6	0.4	-0.8	-0.2	0.2	0.4
	Sig.	0.6	0.4	0.000	0.4	0.6	0.2	0.8	0.8	0.6
Tubificidae	Correlation Coefficient	-0.4	0.6	-1*	-0.6	0.4	-0.8	-0.2	0.2	0.4
	Sig.	0.6	0.4	0.000	0.4	0.6	0.2	0.8	0.8	0.6
Amphiporidae	Correlation Coefficient	-0.4	0.6	-1*	-0.6	0.4	-0.8	-0.2	0.2	0.4
	Sig.	0.6	0.4	0.000	0.4	0.6	0.2	0.8	0.8	0.6
Pontogammaridae	Correlation Coefficient	0.4	-0.4	-0.4	0.4	0.4	-0.2	-0.8	0	0.4
	Sig.	0.6	0.6	0.6	0.6	0.6	0.8	0.2	1	0.6
Balanidae	Correlation Coefficient	-0.2	0.8	0	-0.8	0.2	-0.4	0.4	-0.4	0.2
	Sig.	0.8	0.2	1	0.2	0.8	0.6	0.6	0.6	0.8
Chironomidae	Correlation Coefficient	-0.93	0.32	-0.10	-0.32	-0.74	0.21	0.94	0.73	-0.73
	Sig.	0.07	0.68	0.90	0.68	0.26	0.78	0.06	0.26	0.26
Cardiidae	Correlation Coefficient	-0.4	-0.3	-0.6	-1*	0.4	-0.8	0.2	-0.2	0.4
	Sig.	0.6	0.7	0.4	0.000	0.6	0.2	0.8	0.8	0.6
Serobiculariidae	Correlation Coefficient	0.8	-0.2	-0.2	0.2	0.8	-0.4	-1*	-0.6	0.8
	Sig.	0.2	0.8	0.8	0.8	0.2	0.6	0.000	0.4	0.2

Ampharetidae and water dissolved oxygen, between Lumbriculidae and sediment Cr, between Tubificidae and sediment Cr, between Amphiporidae and sediment Cr, between Cardiidae and sediment Cd, and between Serobiculariidae and water pH.

Discussion

The Gorgan Bay is an important in terms of fisheries. It is the habitat of commercial fishes, which are consumed local people. In addition, it is an important habitat for fish stock rehabilitation program conducted by the Iranian Fisheries Organization. Macrobenthos of the Bay play an important role in feeding of the fish inhabiting this region. However, there are limited studies on macrobenthos communities of the Gorgan Bay, which makes it difficult to compare the results.

In this study, Annelids were the most diverse group (6 families) and Mollusks were the less diverse one (2 families). Reverse trend was observed in the case of biomass. Akrami et al. (2007) studied on the benthic fauna of northern coasts of the Gorgan Bay at 2003. They reported that there were 10 families in the Bay and that the most and less frequent groups were Ostracoda and Amphipoda, respectively.

Hashemian (1998) reported that the highest and lowest frequencies of benthos was observed in spring (7356 individuals m^{-2}) and winter (4309 individuals m^{-2}), respectively, in the southern coast of the Caspian Sea. These differences between the present study and others may be due to changes in the benthic fauna structure over time as well as differences between the Gorgan Bay and the Caspian Sea environment, plus ecological and hydrological features.

Kousari (2009) reported that the most frequent macrobenthos group on the Caspian Sea (Mazandaran Province) was Annelids followed by Mollusks and Arthropods. In addition, Chironimids formed a small part of the macrobenthic fauna of Mazandaran province coasts (Kousari, 2009). Such higher frequency of Mollusks, in Kousari (2009) study compared to the present study, shows difference in the environmental condition of the Gorgan Bay and the Caspian Sea. Factors such as food availability, substrate structure, physicochemical conditions of the habitat, organic materials, competition and hunting affect macrobenthos structure (Rosenberg et al., 1992; Nyhakken, 1993; Dobson, 1998; Akrami et al., 2007)

The increased frequency of macrobenthos in the summer can be associated with the rise in temperature in the late spring and summer, when the number of phytoplanktonic products increases. Therefore, greater amounts of food will be available to organisms due to the fall of planktons. Thus, these organisms will intensify their activities such as nutrition and reproduction during this period of time. Hence their frequency and variance will certainly rise (Burstein et al., 1968). However, the lowest biomass observed in summer could be related to increased benthivorous fish feeding activity due to rise in temperature and metabolism.

The higher biomass of mollusks compared to the other groups seems to be related to their heavy shells, increasing their biomass. In contrast, Annelids are small benthos making their biomass less than other groups, despite their great frequency.

There were large statistical variations in some data including mollusks' biomass in the spring, autumn and winter, Annelids frequencies in the spring and summer, and Arthropods frequency in the summer. This shows that there was a large variation among the sampling sites, which needs to be considered in the future studies.

Ampharetidae showed a significant negative correlation with water dissolved oxygen, indicating the high tolerance of this family to low oxygen. Serobiculariidae had a significant negative correlation with water pH suggesting the suitability of lower pH for this species. Lumbriculidae, Tubificidae and Amphiporidae were significantly and negatively correlated to the sediment Cr, while, Cardiidae were significantly and negatively correlated to the sediment Cd. It is well established that heavy metal contamination seriously affects benthos richness (Dauvin 2008). Similarly, Chen et al. (2010) reported significant and negative correlation between heavy metals (copper, Cd and Pb) and benthic fauna richness.

The present study indicated that Annelids had the highest frequency and lowest biomass in the Gorgan Bay. Mollusks had the highest biomass and lowest frequency in the Bay. The highest macrobenthos frequency was observed in summer and the lowest was observed in autumn and winter. The highest biomass of macrobenthos was observed in spring and the lowest was observed in summer. The highest heavy metal concentration was related to Pb and Zn. Zn and Cr showed no significant variability among the sampling seasons, whereas, Cd and Pb did. Among the studied heavy metals and water characteristics, sediment Cr showed a greater role in benthic community structure.

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