The Environmental Impact of Sturgeon Pen Culture on Diversity and Spatial Distribution Patterns of the Benthic Macro Fauna Communities in Gorgan Bay

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Abstract

Community structure and biodiversity of benthic macro fauna in around pen culture of Sturgeon fish in Gorgan Bay were studied for period of one year from August 2015 to July 2016. Seasonal samplings were carried out at 5 stations in 3 transects. In addition, depth (D), water temperature (T^{oc}), dissolved oxygen (DO); pH, total dissolved solid (TDS), biological oxygen demand (BOD_5), chemical oxygen demand (COD), phosphorus (PO_4^{-3}), nitrite (NO_2^-) and total ammonia (NH_3^+) were measured in each station. Results of season variations of Physico – chemical factors of water showed that, there were no significant differences between PO_4^{-3} ($p > 0.05$). However, there were significant differences between BOD_5, COD, NO_2^-, NH_3^+ and TDS ($p < 0.05$). Totally, 11 genus's and 10 families belong to 3 phyla as Mollusks, Arthropods and Annelids were identified. The results showed, there were the maximum abundance percent belong to Hydrobiidae and Cochliopidae with 33.83% and 26.25% and the minimum abundance percent belong to Gammaridae with 0.05% respectively. However, the maximum abundance belongs to *Pyrgohydrobia sp.*, from Hydrobiidae with 3410 n/m^2. The results showed, there were the maximum and minimum abundance percent in autumn and spring with 1.07 and 0.88 % respectively. The results of distance-based redundancy analysis (db.-RDA) revealed that environmental factors such as depth, DO and TDS are all important in determining the distribution of macro benthic species in Gorgan Gulf. However, there were significant differences between abundance, species number (S), diversity (as Shannon–Wiener's, H´), species richness (as Margalef's, D), and evenness (as Pielou's, J) ($p < 0.05$). There were the most diversity species in 2 and 5 stations.

Keywords: biodiversity, Macro fauna, environmental factors, Gorgan bay

1. Introduction

Gorgan Bay is a unique ecosystem in the south-eastern part of the Caspian Sea. It is separated by Miankaleh peninsula from the sea. Sediment texture is different from west to east (Lahijani *et al*., 2002; Lahijani *et al.*, 2010). Salinity regime is different throughout the bay and it is influenced by internal current (Sharbaty, 2012) and some small rivers from east and west which created some freshwater marshes especially at the western part (Taheri *et al*., 2012). Therefore, different types of habitats are found in the bay (e.g., salt marsh, mud flat, sand flat, fresh and brackish water area) and each type is inhabited by different species (com- munity structure). These variable conditions made it the most important natural ecosystem in the south part of the Caspian Sea that serves as a nursery area for a lot of juvenile fishes and very good place for breeding and wintering of the water birds

The macro fauna play important roles in marine ecosystems, involving nutrient cycling, dispersion, sediment burial, and secondary production. Distribution patterns in general are related to environmental factors such as tidal currents, depth, food supply, salinity, sediment texture, organic matter content and current velocity (Gogina *et al.*, 2010; Nicastro and Bishop, 2013). Hence, any changes in environmental conditions can be reflected in macro fauna community characteristics. Response of macro benthic species to these conditions is different and related to their adaptation strategies (Baldanzi *et al.,* 2013; Conde *et al.,* 2013). In fact, most of the species

cannot migrate out of the habitat, and adapt to the changes of environmental conditions (Dauer, 1993). Therefore, there is a growing need to understand species-environment relationships due to increasing pressure on the marine environment (Snickars *et al.,* 2013). Although a few studies have described macro benthic fauna in the Gorgan Bay (Aghili *et al*., 2014; Dorostkar, 2007; Saghali *et al.,* 2012; Tajari *et al,* 2013) data about the species-environment relationships are almost absent. The purpose of this paper was to study of effects of Sturgeon pen culture on macro benthic community structure and study biodiversity of macro benthic in Gorgan Bay. These results can help us to evaluate environmental and man-made changes on fauna, and monitoring the effect of invasive species and manage this area in the future.

2. Materials and Methods

2.1 Study Area

Gorgan Bay is located in an east-west direction in the Golestan Province, southeast coast of the Caspian Sea, Iran. Its area is around 400 km2 with the maximum length of 70 km. Most part of the bay has low depth (less than 2 m), the maximum depth is 5 m and it decreases from east to west. The study was done around of Sturgeons pen culture sites in Ashoradeh peninsula, Bandar-Turkman, Golestan Province. The studied were conducted out one year from August 2015 to July 2016. Seasonal samplings were carried out at 5 stations in 3 transects (Fig. 1), which were in distance 0, 5, 25, 50 and 100 m from pen sites. Sampling was conducted on the Gorgan Bay within 36º 53´ 51.09´´ to 36º 52´ 53.59´´N and 53º 58´ 39.05´´ to 53º 58´ 43.85´´ E.

2.2 Environmental Factors

At each station, water temperature (T^{OC}), dissolved oxygen (DO), total dissolved solid (TDS) and pH were measured using a multi parameters (HACH- HQ 40d), depth (D) were measured using HANDEX- PS7 , biological oxygen demand (BOD_5) were measured using BOD meter (BOD track – HACH), chemical oxygen demand (COD) and phosphorus (PO_4^{-3}), nitrite (NO_2^-) and ammonia (NH_3^+) were measured using HACH–DRB 200 and HACH–DR 2800 respectively. Water samples were collected in triplicates using a water sampler (NESKIN model DENMARK A/S), from bottom waters. Water samples collected were kept in 0.5-L dark bottles and cooled in the cooler box with ice blocks to prevent oxidation of the samples and was brought back to the laboratory for analysis within 24h. (Nyanti *et al*, 2012; Sanz-Lázaro and Marín, 2011).

2.3 Data Collection

At each station, three replicate samples of benthos were collected using a van Veen grab (20*25 cm). In the field, the contents of each grab were stored in the separate plastic containers. In the laboratory, sediment of each container is gently sieved by 0.5 mm mesh and the retained material is fixed in 4% buffered formalin and stained with Rose Bengal (Abowei *et al.*, 2012; Taheri *et al.,* 2011). Then, in the laboratory macro fauna were separated, identified and counted under a stereomicroscope. Most specimens were identified to Genus.

Density, abundance percent and biomass were calculated for groups. Then, diversity (as Shannon–Wiener's, H´), species richness (as Margalef's, D), and evenness (as Pielou's, J) dominant (as Simpson's, 1-D) were Calculated per square meter.

2.4 Analysis Data

Collected data were tested for normality (using Shapiro–Wilk). Significance of all tests was accepted at P< 0.05. Whenever data were normal, one-way analysis of variance (ANOVA) was used to test the differences among Physico-chemical factors and the biological parameters (density, mean species number, diversity, richness and evenness). LSD test (P < 0.05) was used to assess the significant differences among the stations (in SPSS Version 16).

Distance-based redundancy analysis (db-RDA) was performed to identify the relationships among environmental variables and macro fauna assemblage structures using CANOCO software (Braak and Smilauer, 1998) with the software options set for forward selection to test the significance of environmental variables. All figures dependent of analysis were made by Excel and Primer programs.

Figure 1. Location of the sampling stations on the Gorgan Bay (Google Earth)

3. Results

3.1 Environmental Condition

Environmental conditions are shown in Table 1. There were no significant differences between T^{oc}, Turbidity, TDS, and PO_4^{-3} ($p>0.05$). However, there were significant differences between D, DO, pH, BOD_5, COD, NO_2^-, NH_3^+ and TDS ($p<0.05$). For example, BOD_5 values varied between 1.97±0.13 at station 3 in winter and 5.24 ± 73.5 at station 2 in spring.

3.2 Community Structure

Identified macro fauna in samples were belonging to ten families (Table 2). The maximum abundance percent belong to Hydrobiidae and Cochliopidae with 33.83% and 26.25% and the minimum abundance percent belong to Gammaridae with 0.05% respectively. *Balanus sp*., 11.90%, *Cerastoderma sp.,* 9.79% and *Cardium sp*.7.36% were the next abundant groups. Bivalvia, with 4 genus, had the highest diversity between other groups (Table 2, 3).

Average density and biomass percentage of each sample in each season were shown in Table 3. This table showed that, the most average density of macrofauna species was observed in autumn (*Pyrgohydrobia sp*.) and the least one was related to *Nematode sp*. in spring. *Gammarus sp*. just have seen in winter. The result shows, that maximum abundance between stations belong to station 3 (2469 n. $0.05m^2$). Also, the minimum frequency of all species was observed in station 4 (1653 n. $0.05m^2$).

One-way ANOVA showed significant differences in mean abundance, diversity, richness and evenness among stations. All frequency data were natural log (X + 1) transformed and normalized. The highest mean abundance of species (804.33 ± 24.88) was obtained at station 3 and the lowest (607.00± 94.33) were at stations 1. The highest diversity index (1.317±0.05) was obtained at station 4 while the lowest (1.095±0.06) was observed at station 1. The maximum and minimum of the evenness index were obtained at stations 4 and 1, respectively, while the maximum of the richness index was recorded in station 1, but stations (Table 5).

The results of distance-based redundancy analysis (db-RDA) revealed that, environmental variables had significant effects on the spatial distribution of macro benthic animals, (Fig.1). The RDA revealed relationships among 10 species and environmental variables (Fig. 1).

The lines of Shannon index showed that 3 station was more variable than others in all seasons except spring. The RDA demonstrated that in all seasons, depth, Turb, NH_3 were influential factors in stations while the other ones were less effective. Bivalves and Gastropods showed the most dependency to BOD_5 in spring and temperature in summer .*Cerastoderma sp.* and *Hypania sp.* were relationship with smaller depth, SD and EC in spring. *Cerastoderma sp.* and *Hypania sp.* showed the most dependency to salinity, temperature, pH and TDS in summer. Whereas *Dreissana sp.* indicated that it can be dependent to SD and EC in autumn. *Hypania* was found in regions with more NH_3 and Cyanobacteria in summer and winter.

Table 1. Mean environmental factors measured during this study

Season	Station	Temp.(C°)	D (Cm)	DO(mg/l)	pH	TDS (mg/l)
Spring	1	22.78 ±3.31	70.78 ± 10.08 [c]	8.48 ±0.23	9.04 ±0.06 [b]	9.90 ±0.55
	2	22.60 ±3.68	103.33 ± 15.21 [bc]	9.23 ±0.53	9.10 ±0.03 [a]	9.67 ±0.27
	3	22.38 ± 3.57	113.33 ± 26.92 [ab]	9.09 ±0.58	9.11 ±0.04 [a]	9.91 ±0.30
	4	22.46 ±4.49	146.11± 51.77[a]	9.07 ±0.68	9.12 ±0.04 [a]	9.87 ±0.32
	5	22.94 ± 3.71	119.89 ±49.85 [ab]	9.05 ±0.53	9.11 ±0.04 [a]	9.79 ±0.29
Summer	1	29.20 ±0.87	100.00 ± 15.61 [b]	8.46 ±0.13	8.73 ±0.24	13.19 ±0.16 [a]
	2	29.90 ± 2.26	102.89 ± 12.81 [b]	8.12 ±0.33	8.68 ±0.08	13.07 ±0.27 [a]
	3	30.30 ± 1.16	134.67 ± 38.82 [ab]	8.10 ±0.24	8.70 ±0.26	12.77 ±0.35 [b]
	4	29.99 ±1.11	147.11 ± 40.81[a]	7.99 ±0.25	8.87 ±0.08	12.78 ±0.30 [b]
	5	30.61 ± 0.68	124.33 ± 50.42 [ab]	8.27 ±0.21	8.76 ±0.23	12.64 ±0.42 [b]
Autumn	1	20.02 ±6.56	69.44 ± 19.76	9.82 ±1.36	8.87 ±0.33	12.49 ±0.55
	2	19.68 ±6.94	83.78 ±7.61	9.94 ±0.91	9.68 ±0.04	12.69 ±0.30
	3	20.11 ±7.24	92.78 ±14.39	10.05 ±0.36	9.09 ±0.13	12.58 ±0.23
	4	20.50 ±7.38	119.44 ±33.77	10.10 ±0.16	9.09 ±0.15	12.56 ±0.17
	5	20.21 ±7.67	103.89 ± 41.89	10.13 ±0.42	9.06 ±0.18	12.51 ±0.24
Winter	1	12.00 ±1.65	61.11 ± 16.16 [c]	10.91 ±0.81	8.89 ±0.10	10.10 ±0.92
	2	11.51 ±1.95	86.33 ± 13.54 [bc]	10.70 ±0.60	9.30 ±0.43	11.03 ±0.90
	3	11.59 ±1.94	95.55 ± 16.29 [b]	10.68 ±0.47	9.07 ±0.04	11.13 ±0.88
	4	11.72 ±1.86	131.31 ± 42.48 [a]	10.66 ±0.61	9.10 ±0.04	11.12 ±0.87
	5	11.64 ±1.79	109.00 ± 44.06 [ab]	10.61 ±0.57	9.05 ±0.06	11.10 ±0.89

- Different letters show significant difference between columns (p <0.05).

Table 1. Mean environmental factors measured during this study

Season	Station	BOD$_5$.(mg/l)	COD (mg/l)	NO$_2^-$ (mg/l)	NH$_3^+$ (mg/l)	PO$_4^{3-}$ (mg/l)
Spring	1	4.21 ±0.60 [b]	86.00 ± 6.24 [ab]	0.008 ±0.00 [bc]	0.40 ±0.01 [c]	0.007 ±0.00
	2	5.24 ±0.73 [a]	90.50 ± 2.73 [a]	0.020 ±0.00 [a]	0.81 ±0.13 [a]	0.037 ±0.01
	3	3.24 ±0.57 [c]	76.50 ± 0.56 [d]	0.009 ±0.00 [b]	0.72 ±0.07 [ab]	0.020 ±0.00
	4	3.78 ±0.34 [bc]	78.50 ± 6.02 [cd]	0.012 ±0.00 [b]	0.60 ±0.04 [abc]	0.037 ±0.01
	5	3.81 ±0.54 [bc]	82.00 ± 2.29 [bc]	0.004 ±0.00 [c]	0.50 ±0.06 [bc]	0.033 ±0.01
Summer	1	2.60 ±0.92	85.56 ± 25.29 [ab]	0.017 ±0.00 [a]	1.32 ± 0.53 [a]	0.360 ±0.2
	2	2.57 ±0.59	88.57 ± 27.16 [a]	0.014 ±0.00 [a]	0.16 ± 0.03 [b]	0.173 ±0.07
	3	2.53 ±0.26	64.71 ± 3.16 [b]	0.016 ±0.00 [a]	0.19 ± 0.07 [b]	0.023 ±0.00
	4	3.07 ±0.22	75.67 ± 1.51[ab]	0.012 ±0.00 [ab]	0.08 ± 0.02 [b]	0.360 ±0.24
	5	3.00 ±1.01	86.11 ± 15.38[ab]	0.007 ±0.00 [b]	0.11 ± 0.06 [b]	0.223 ±0.10
Autumn	1	2.73 ±0.02	76.33 ± 4.16 [ab]	0.022 ±0.00 [b]	2.30 ±0.06 [ab]	0.023 ±0.00 [a]
	2	2.83 ±0.54	83.00 ± 4.58 [a]	0.027 ±0.00 [a]	2.19 ±0.11 [b]	0.022 ±0.00 [a]
	3	2.50 ±0.43	64.33 ± 3.05 [c]	0.017 ±0.00 [c]	1.67 ±0.12 [c]	0.027 ±0.00 [a]
	4	3.17 ±0.31	74.00 ± 4.58 [b]	0.018 ±0.00 [c]	1.53 ±0.09 [c]	0.027 ±0.00 [a]
	5	3.20 ±0.56	75.33 ± 2.31 [b]	0.017 ±0.00 [c]	2.56 ±0.13 [a]	0.010 ±0.00 [b]

	1	2.44 ±0.20 [b]	74.25 ± 4.10 [ab]	0.028 ± 0.00 [b]	1.74 ±0.70	0.007 ±0.00
	2	3.16 ±0.42 [a]	81.50 ± 4.72 [a]	0.044 ± 0.01 [a]	1.85 ±0.54	0.010 ±0.00
Winter	3	1.97 ±0.39 [c]	64.50 ± 1.73 [c]	0.036 ± 0.01 [ab]	1.32 ±0.50	0.025 ±0.01
	4	2.04 ±0.32 [bc]	68.50 ± 6.95 [bc]	0.028 ± 0.01 [b]	1.52 ±0.52	0.022 ±0.01
	5	2.39 ±0.49 [bc]	76.83 ± 7.11 [ab]	0.028 ± 0.01 [b]	1.42 ±0.54	0.015 ±0.01

- Different letters show significant difference between columns (p <0.05).

Table 2. List of macro benthic invertebrate identified in Gorgan Bay

Phylum	Class	Family	Genus	Abundance %
Mollusca	Bivalvia	Cardiidae	*Cerastoderma sp.*	9.79
			Cardium sp.	7.36
		Semelidae	*Abra sp.*	4.43
		Dreisseniidae (Zebar mussels)	*Dreissana sp.*	0.23
	Gastropods (snails)	Hydrobiidae (Pyrgulidae)	*Pyrgohydrobia sp.*	33.83
		Cochliopidae	*Heleobia sp.*	26.25
Arthropods	Crustacean	Balanidae	*Balanus sp.*	11.90
		Gammaridae	*Gammarus sp.*	0.05
		Crab	-	0/19
Annelids	Polychaeta	Nereidae	*Nereis Sp.*	4.87
		Terebellida (Ampharetidae)	*Hypania sp.*	1.01
Nemathelminthes	Nematodes	-	*Nematode sp.*	0.1

Table 3. Average density and biomass percentage of each sample in each season in m²

Genus	Spring			Summer			Autumn			Winter		
	density	biomass	%	Density	biomass	%	density	biomass	%	density	biomass	%
Cerastoderma sp.	2570	233.87	31.15	2670	157.53	30.36	1640	109.88	19.73	2990	615.94	49.90
Cardium sp.	1880	169.2	22.54	2660	159.6	30.76	880	62.48	11.22	2010	203.01	16.44
Abra sp.	2670	224.28	29.88	550	24.2	4.66	550	39.95	8.79	700	91	7.37
Dreissana sp.	20	4.8	0.64	60	13.8	2.66	90	21.6	3.88	60	15	1.22
Pyrgohydrobia sp.	6160	36.96	4.49	7970	47.82	9.22	12480	4.88	13.45	7490	44.94	3.64
Heleobia sp.	4070	24.42	3.25	5870	35.22	6.79	11780	70.68	12.69	4740	43.44	2.30
Balanus sp.	2030	30.45	4.06	3320	49.8	9.60	3200	105.6	18.96	3440	72.24	5.85
Gammarus sp.	-	-	-	-	-	-	-	-	-	50	0.45	0.04
Crab sp.	20	4.6	0.61	20	19.4	3.74	40	22	3.95	110	113.3	9.18
Nereis Sp.	830	21.58	2.87	1190	10.71	2.06	1590	39.75	7.14	1300	49.4	4
Hypania	180	0.54	0.07	260	0.78	0.15	350	1.05	0.19	230	0.69	0.06
Nematode sp.	10	0.01	0.001	-	-	-	30	0.03	0.005	60	0.06	0.004
Total	20440	70.71	100	24570	518.86	100	32610	556.88	100	23180	1234.47	100

Table 4. Mean of species number (*S*), diversity (*H′*), richness (*D*), dominate (1-l) and evenness (*J*) within stations

Station	Species Number (S)	Pielou's (J)	Shannon–Wiener's (H´)	Simpson (1-D)	Margalef's (D)
1	607.00±94.34 [a]	0.79±0.05[b]	1.10±0.06[b]	0.40±0.03[a]	0.40±0.03[a]
2	651.00±25.55[a]	0.91±0.02[a]	1.25±0.02[a]	0.31±0.01[b]	0.31±0.01[b]
3	804.33±24.88[a]	0.92±0.03[a]	1.28±0.04[a]	0.31±0.02[b]	0.31±0.02[b]
4	505.67±123.43[a]	0.95±0.04[a]	1.33±0.05[a]	0.28±0.02[b]	0.28±0.02[b]
5	728.67±135.51[a]	0.95±0.01[a]	1.31±0.02[a]	0.29±0.01[b]	0.29±0.01[b]

Table 5. Mean of species number (*S*), diversity (*H′*), richness (*D*), dominate (1-l) and evenness (*J*) within seasons

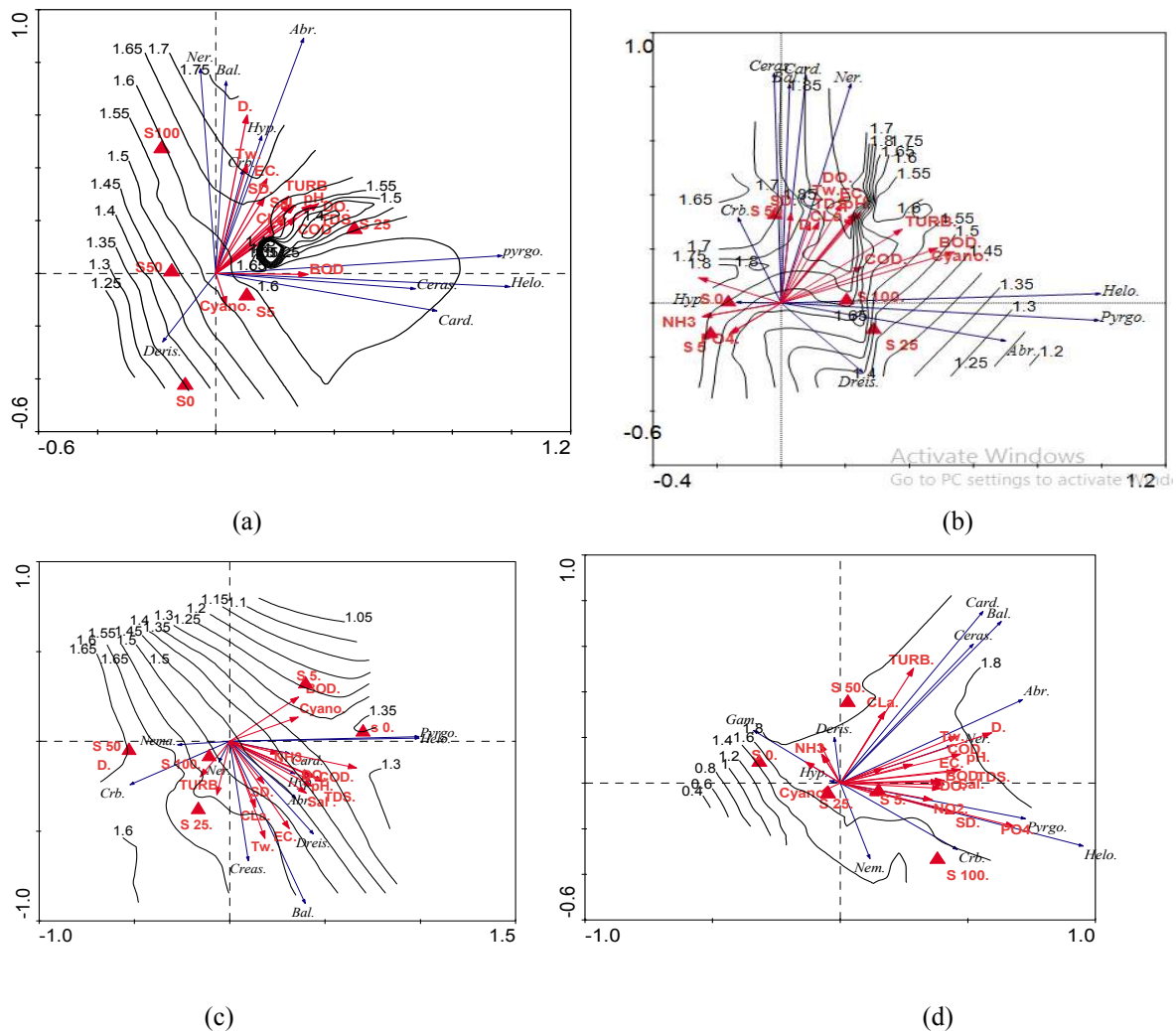| Station	Species Number (S)	Pielou's (J)	Shannon–Wiener's (H´)	Simpson (1-D)	Margalef's (D)
Spring	662.33±30.28[b]	0.88±0.05[a]	1.41±0.08[a]	0.28±0.03[a]	0.62±0.00[a]
Summer	819.00±2.27[ab]	0.93±0.04[a]	1.50±0.06[a]	0.24±0.02[a]	0.61±0.02[ab]
Autumn	1087.70±12.13[a]	0.94±0.01[a]	1.51±0.02[a]	0.24±0.01[a]	0.57±0.00[b]
Winter	772.67±70.92[ab]	0.94±0.03[a]	1.52±0.04[a]	0.24±0.02[a]	0.60±0.01[ab]

Figure 2. Results of distance-based redundancy analysis (db-RDA) biplots: (a) Spring (b) Summer (c) Autumn (d) Winter. Arrows indicate environmental variables and different species

4. Discussion

Although a lot of species of macrofauna were reported in the Gorgan bay and Caspian Sea (Birshtein *et al.*, 1968; Kasymov, 1994), in comparison, the biodiversity of Caspian is lower than the other seas like the Black Sea and the Barents Sea (Zenkevich, 1963). Low salinity, i.e., (maximum 15 ppt) probably is one of the main reasons, because for true freshwater species it is too high but for marine origin species it is too low. Therefore, these conditions are just favorable for brackish water species (Mordukhai-Boltovskoi, 1979; Karpinsky, 2005). Second reason may be the long geographical isolation of the Caspian Sea from the Black sea (open seas), which began about 5-6 million years ago, which is adequate time for the evolution of unique fauna (Zenkevich, 1963), means that great parts of the Caspian fauna are endemic (Dumont 2000). The south Caspian Sea, with 15 ppt salinity and the highest depth, is a unique ecosystem (Taheri *et al.,* 2012). In Iranian shallow waters, less than 22 species of macrofauna have been reported (Roohi, *et al.,* 2010; Taheri and Yazdani, 2011; Ghasemi, 2011). In the present study, 12 species of macrofauna were identified. In Gorgan Bay, Saghali *et al.* (2012) found 13 family while Taheri *et al.* (2012) obtained 8 family macrofauna in the south of Caspian Sea. In Baku Bay, Kasymov (1989) found 9 spices of macrobenthos while Tait *et al.* (2004) obtained 62 and Parr *et al.* (2007) identified 71 species of macrofauna at the south of Baku, Azerbaijan. It should be mentioned that the present study such as Saghali *et al.* (2012) and Taheri *et al.* (2012) studies were carried out at shallow water, but they sampled from shallow waters to waters nearly 800 m depth. Although, in the Gorgan Bay some different orders of macrofauna were reported, we did not find communities of small forms such as Cumacea and Mysidacea that had been reported by Kasymov (1994) for the south of Caspian Sea.

It is necessary to note that different parts of the Gorgan Bay have variable structures in terms of macrofauna communities, because of different environmental conditions (Kasymov, 1994). High species diversity among the macrofauna in marine ecosystems belongs to Polychaeta while fewer than 10 species have been known in the Gorgan Bay up to now (Birshtein *et al.*, 1968; Kasymov, 1989, 1994; Grigorovich *et al.*, 2003; Tait *et al.*, 2004). In this study, only 1 species of Polychaeta's was found. Similar results were observed in the Gorgan Bay and the south-west of the Caspian Sea (Taheri *et al.*, 2007; Bandany *et al.*, 2008), the Gorgan Bay and the south-east of the Caspian (Taheri *et al.*, 2012) and the south of Baku, Azerbaijan (Parr *et al.*, 2007). In our study, Bivalvia, with 4 species, in terms of diversity and density were in second place and they observed in most stations. In other studies, one species (*Cerastoderma lamarcki*) of Bivalvia was reported in Mazandaran province (Taheri and Yazdani, 2011; Ghasemi, 2011) and two species reported in Gorgan Bay (Taheri *et al.,* 2012). Also, we found some Gastropoda. Similar results were reported by: Ghasemi (2011), who that reported one species of *Pyrgula sp.* in Mazandaran province and Saghali *et al.,* (2012) reported 3 species in Gorgan Bay, while 16 species were observed in Azerbaijan (Parr *et al.,* 2007).

In this study, *Pyrgohydrobia sp.* with 33.83% of the total abundance was the numerically dominant species that they were observed at all of the stations, and *Nematode sp.* with 0 .1% of the total was the lowest species. Maximum diversity (1.33) and richness (0.40) were very low. Similar results were obtained in the south of Caspian Sea (Taheri et al., 2007; Bandany et al., 2008; Taheri and Yazdani, 2010). The value of these indices could be related to the small number of macrofauna in sampling and existence of the dominant species with very high density in each season.

Results obtained from Canoco software indicated clear spatial differences in macro benthic assemblage structures in relation to environmental variables such as depth, EC, NH^3 and other factors in Gorgan bay. Numerous research have shown that the spatial distribution of macro benthic invertebrates along shallow waters is related to environmental variables (Saghali *et al.* 2012; Taheri and Yazdani, 2010; Ghasemi *et al.,* 2014; Gogina and Zetller, 2010). Thus, the results of the present study are consistent with those of past studies. While Taheri *et al.* (2012) reported that they were not found any significant correlations between the density of macrofauna and all the environmental conditions. They offered macrofauna assemblages were controlled by other factors such as different kinds of pollution like heavy metals and rural and agricultural waste water. In this study, *Cerastoderma sp,* showed the most relevance with EC and SD factors in comparison to others in spring and summer.

Seasonal density variation of the macrofauna may be depended to many factors such as breeding activity of macrofauna and predator pressure (Kevrekidis, 2005; Taheri and Yazdani, 2011). The highest density of macrofauna was observed in autumn (32610). This may be related to density of *Pyrgohydrobia sp.* and *Heleobia sp.* that was maximal in this season. The lowest density of macrofauna was recorded in spring (29449); it may be related to the higher predation rate as reproduction season for many benthivore fish in the Gorgan Bay and Caspian Sea starts from late winter to late spring. Higher metabolic rate, because of increasing in temperature, associated with higher feeding intensity of predators can be the other reason of lowest density in summer.

In conclusion, the present results demonstrated very low biodiversity in terms of macrofauna in Gorgan bay and indicated significant correlations between the density of macrofauna and all various environment conditions.

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