Ecological status assessment of Bidkhun mangrove swamp from Bushehr province, Persian Gulf, using macrofauna community structure

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Abstract. Mangrove ecosystems are known as productive ecosystems with high ecological and economic importance. Anthropogenic effects have destroyed these habitats in many cases. Evaluating ecological and environmental status help to find stress sources in order to conserve them against more destruction. Present study was designed to evaluate ecological health status of Bidkhun mangrove swamp, Bushehr province, Persian Gulf. This habitat is surrounded by industrial establishments and is affected by discharge of urban sewage. Investigating macrofauna structure and calculating ecological indices including Simpson, Shannon-Wiener, AMBI and M-AMBI, were performed to assess its ecological integrity. Sampling was done in six stations during four seasons. Macrofauna and environmental parameter were investigated. Totally 35 macrobenthic species where identified. Polychaeta was the main taxa. There were special and temporal changes in macrofauna composition. Generally, station four, which was located close to sewage canal opening, had different macrobenthic and environmental features. High concentration of nutrients as a result of sewage discharge, have led to algal bloom and decrease of macrofauna density, consequently. Ecological status of present habitat was good or high in most stations but it was poor and very bad in station four. Ecological indices showed that this station is extremely polluted. Besides, invasive freshwater reeds have surrounded the mangrove trees in mentioned station. It is concluded that discharge of sewage is main source of habitat degradation for Bidkhun mangrove swamp. Hence, it is necessary to decrease its impacts by sewage treatment or stopping sewage discharge.

Key Words: Persian Gulf, Bidkhun, Asaluyeh, mangrove, macrofauna, ecological assessment, sewage.

Introduction. Mangrove swamps as productive ecosystems (Lee 1999) are distributed circum-tropically. Their sediment may serve as habitat for a variety of invertebrates and generally support high densities of benthic organisms (Kathiresan & Bingham 2001). Macrofauna as an important live part of mangrove ecosystems, play vital role in ecosystem life cycling. Their burrowing activity provides oxygen for tree's roots and recycles nutrients to improve their availability for other producers. These activities also enhance flushing toxic substances through sediment particle (Kristensen et al 2008). Macrofauna are described as important index to assess ecological status of aquatic ecosystems (Engle & Summers 1999; Morrisey et al 2003; Jorgensen et al 2005). These organisms are strongly affected by natural and anthropogenic parameters (Chapman & Tolhurst 2007; Mooraki et al 2009). Their sensitivity to pollution (Gesteira & Dauvin 2000) and sedentary behavior make them suitable indices to reflect accumulated long periods pollution (Nixon et al 1986).

Bidkhun mangrove swamp as a part of the Persian Gulf, suffers from various kinds of destructive agents. Human activities related to oil and natural gas industries, huge shipping and increasing demand for urban and commercial establishments, have made the gulf one of the worst places for wild life (Vazirizadeh 1997). Bidkhun mangrove creek is surrounded by industrial and urban establishments of the biggest world's natural gas field (South Pars) and it seems to be affected by discharging swages and manipulating the hydrological features. Invasive plants including reeds and algae are developing through the ecosystem and its natural features are changing. However, there is poor information about ecological and environmental status of Bidkhun mangrove swamp, especially in the case of macrofauna. Present study was designed to evaluate benthic ecological status of the habitat using macrofauna assemblages in order to improve our knowledge in the way of conserving the habitat.

Material and Method

Study area. Present study was carried out from January to November, 2014 in Bidkhun mangrove swamp close to Asaluyeh town in Bushehr province, Iran (52º66'04'' E and 27º46'34'' N), with 171 hectares mangrove tree coverage (Amiri et al 2011) (Figure 1). The mangrove trees, consisting of patches of mature *Avicennia marina* fringe each side of the central canal. There is no natural constant waterway; however an artificial canal discharges urban sewages to the north part of the habitat.

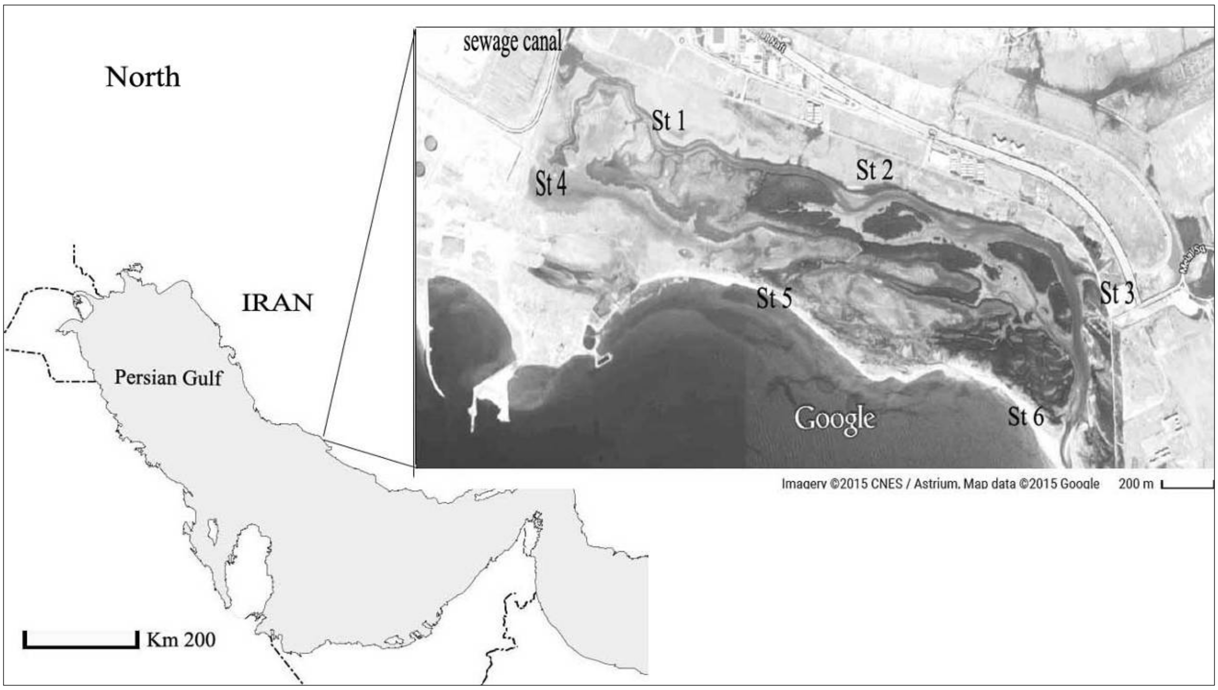

Figure 1. Sampling site, stations and sewage canal location.

Sampling design. Sampling was carried out during four seasons. Six stations were selected to cover the whole ecosystem according to distribution of mangrove trees. Stations one to three were near land area and other stations were in seaward places. Station four was near sewage canal opening (Figure 1). Sediment samples were taken randomly with three replicates using a 0.25 m^2 quadrate framework to the depth of 10 cm of sediment for macrofauna. Three samples of sediment were taken using core sampler for Grain Size (GS) and Total Organic Carbon (TOC) analysis. Physiochemical factors (including salinity, pH, temperature, and redox potential) were determined using portable instruments. Temperature, Eh and pH were measured using portable pH-meter (WTW). Salinity was determined using refractometer. Mentioned parameters were measured through gathered water in artificially excavated holes through sediment.

Laboratory analysis. Macrofauna were separated using 0.5 mm mesh size sieve and were preserved in 4% neutralized formalin until next step. Then, specimens were stained using 0.5 g L^{-1} Rose-Bengal for better separation. Separated specimens were identified until possible taxonomic levels, often to species or genus level, using identification references (Emerson & Jacobson 1976; Bosh et al 1995; Debelius 1999; Hosseinzadeh et al 2001; Poore 2004). Sieve series of 4 mm to 63 µm was used to determine sediment grain size (Eleftheriou & McIntyre 2005). Colorimetric method was used to determine TOC and water nutrients (Gupta 2001).

Data analysis. Shannon-Wiener (H'Log2), Simpson, presence/abundance of indicator species, absence of sensitive species (Wilson & Jeffrey 1994) as well as the indices AMBI (AZTI's Marine Biotic Index) (Borja et al 2000) and M-AMBI (Multivariate-AZTI's Marine Biotic Index) (Muxika et al 2007) were used to evaluate environmental and ecological status. AMBI and M-AMBI values were measured using "AMBI 5.0" software (available at www.AZTI.es that could be calculated using the formula:

$$\text{AMBI} = \left[\frac{0\times p_{\text{I}} + 1.5\times p_{\text{II}} + 3\times p_{\text{III}} + 4.5\times p_{\text{IV}} + 6\times p_{\text{V}}}{100}\right]$$

where pi, denote the percentage of individuals assigned to each ecological group. Ecological groups (EG) defined by Grall & Glémarec (1997) and used by Borja et al (2000) in the AMBI calculation: (i) EG I - species very sensitive to disturbance; (ii) EG II - species indifferent to disturbance; (iii) EG III - species tolerant to disturbance; (iv) EG IV - second-order opportunistic species; and (v) EG V - first-order opportunistic species.

Production of some problems in use of AMBI index alone in assessment, led to propose of factorial analysis including AMBI, richness and Shannon's diversity (Borja et al 2004). This calculation was refined and Multivariate-AMBI (M-AMBI) was made (Muxika et al 2007). Table 1 shows used indices with their pollution and ecological classification.

Table 1

Classification of ecological and environmental status according to ranges of AMBI, M-AMBI, Shannon-Wiener and Simpson. According to references: AMBI (Borja et al 2003), M-AMBI (Muxika et al 2007), Shannon-Wiener, and Simpson (Jorgensen et al 2005)

Ecological status	*Shannon-Wiener*	*Simpson*	*AMBI*	*M-AMBI*	*Pollution classification*
High	> 4	0-0.25	0-1.2	0.8-1	Unpolluted/normal
Good	3-4	0-0.25	1.2-3.3	0.6-0.8	Slightly polluted
Moderate	3-2	0.25-0.5	3.3-5	0.4-0.6	Moderately polluted
Poor	2-1	0.5-0.75	5-5.5	0.2-0.4	Heavily polluted
Bad	1-0	0.75-1	5.5-7	0-0.2	Extremely polluted/azoic

Results and Discussion

Abiotic parameters. Measured environmental parameters in Bidkhun mangrove swamp are summarized in Table 2. Mud (< 0125 µm) was major portion of sediments. So that it was used as reference for statistical analysis. Mud content ranged from 11.7 to 90.6% in various stations. There was significant difference in sediment texture of various stations ($p < 0.05$), but no difference within different seasons ($p > 0.05$). TOC was changed during different season and showed a significant difference among various seasons ($p < 0.05$). It reached to the maximum percentage in winter (18.4%) and the minimum in summer (6.4%). The lowest and the highest recorded temperature were 17.4ºC and 41ºC in winter and summer, respectively. Salinity reached to the highest level (65 psu) in the summer time. It was in average of 43 psu in other seasons. Acidity condition of pure water remained alkaline (pH = 7.8-9.1) during all sampling times. Redox potential (Eh) indicated reduction condition in sediments of all stations (-52 to -98 mv).

Table 2

Measured abiotic parameters (mean value ± SD) in various stations of four seasons

Season	Station	Parameter					
		Mud (%)	*TOC (%)*	*T (°C)*	*Salinity (psu)*	*pH*	*Eh (mv)*
Winter	1	83.2±2.2	17.4±1.6	20±0.5	23±1	7.9±0.5	-52±4
	2	74±3.9	16.2±1.5	22.7±1	33±1	8.6±0.4	-98±5
	3	23.8±2.8	17.7±1.2	17.4±1	50±1	8.7±0.4	-85±7
	4	74.9±3.1	18.2±1.6	20±0.5	17.6±1	8.6±0.3	-94±4
	5	70.9±4	17.7±1.3	20±0.7	43±1.5	7.9±0.4	-75±3
	6	82.4±3	18.4±1.3	20.3±0.3	48±1	8.4±0.5	-80±4
Spring	1	74.5±2.8	14.2±1.1	32±0.3	44±1.2	8±0.4	-78±3
	2	73.1±2.3	15.1±1.2	33±0.4	44±2.1	8.2±0.4	-88±2
	3	11.7±8.3	13.2±1.8	30.5±0.4	42±2.3	7.8±0.7	-87±6
	4	64.6±3.4	15.7±2.3	32±0.4	18.5±2.1	8.1±0.6	-87±5
	5	69.2±2	13.8±1.2	32±0.5	44±1	7.8±0.4	-80±2
	6	67.3±2.4	14.4±1.4	32±0.4	44±1	7.92±0.4	-76±2
Summer	1	74.2±2.6	6.4±0.5	40±0.6	56±2	8.3±0.3	-65±6
	2	82.98±2.2	6.5±0.2	40±0.5	55±3.4	8.1±0.5	-76±7
	3	25.24±1.5	6.5±0.3	41±0.4	61±2.3	8.2±0.3	-78±3
	4	65.5±6.3	6.4±0.2	40.5±.5	16±2.5	9.1±0.3	-87±4
	5	66±2.5	6.9±0.2	40±0.3	65±3	8.1±0.4	-85±3
	6	82.6±2.2	6.6±0.1	41±0.5	63±4	7.9±0.5	-64±6
Autumn	1	84.8±2.2	11.3±1.2	33±0.4	43±1	8.3±0.5	-58±4
	2	84.8±2	10.7±1.1	33.5±0.4	44±1	8.2±0.3	-75±3
	3	31.3±1.5	10.3±1.8	34±0.5	45±1.2	8±0.4	-67±7
	4	69.3±1.8	11.3±1.9	34±0.2	15.8±1.4	8.2±0.5	-84±2
	5	90.6±7.4	11.6±1.4	33±0.3	45±1.5	7.8±0.6	-78±4
	6	85.9±1.5	11.2±1.1	33.5±0.6	46±1.3	7.9±0.5	-81±3

Table 3 shows average value of measured water nutrients including nitrite, nitrate, ammoniac and phosphate as well as salinity through collected water from sewage canal, the nearest station to the sewage canal entrance (station 4) and the furthest station to the swage canal entrance (station 3). There are significant differences in nitrate and ammoniac concentration as well as salinity of stations with different distance to the sewage canal ($p < 0.05$). There are reduction trend in salinity from the furthest station toward sewage canal (Figure 2) and incremental trend in nutrients, except for phosphate (Figure 3). The measured concentration indicates huge discharge of nutrients especially ammoniac into habitat which provide suitable condition for algal bloom. Reduction of salinity by discharging fresh water also may aggravate this phenomenon. Field observation verified bloom of macro algae (*Rhizoclonium* sp.) at the substrate of station 4. The coverage of this algal bloom reduces by moving toward the farther places. This eutrophication has led to significant decrease in density and diversity of macrofauna.

Table 3

Average value (ppm±SD) of nutrient concentration and salinity in sewage canal and varied distance to the sewage canal opening

Position	Nutrient				
	Phosphate	*Nitrite*	*Nitrate*	*Ammoniac*	*Salinity*
Sewage canal	0.189±0.008	0.035±0.021	0.131±0.026	2.633±0.288	4.1±0.1
Nearest station	0.674±0.486	0.014±0.010	0.031±0.008	1.613±0.552	17.6±0.5
Furthest station	0.396±0.162	0.009±0.002	0.036±0.023	0.146±0.023	43.2±0.8

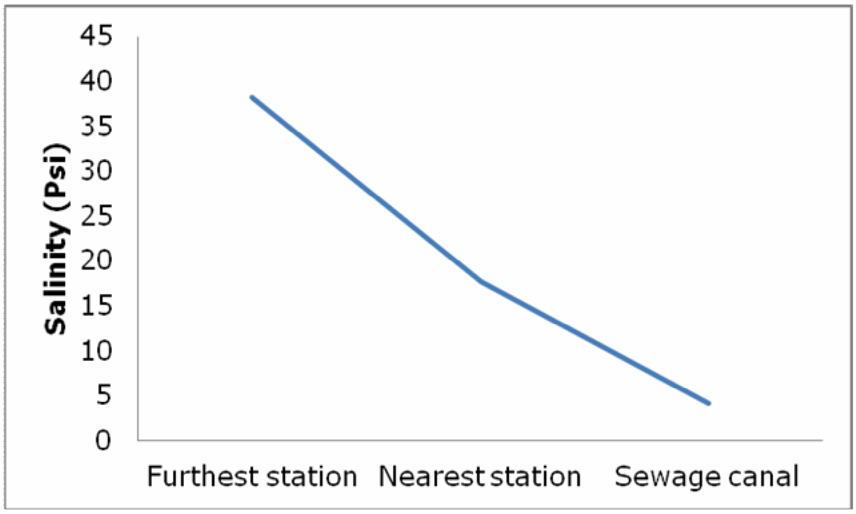

Figure 2. Salinity trend through varied distances to the sewage canal.

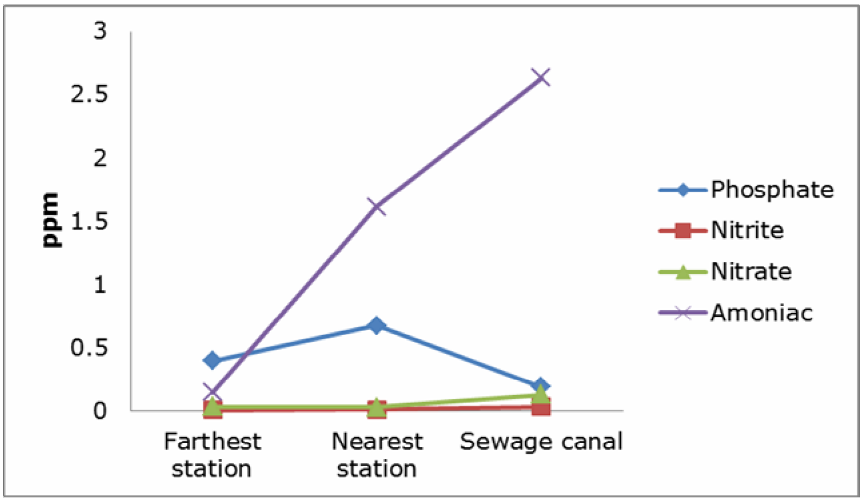

Figure 3. Nutrients concentration trend through varied distance to the sewage canal.

Macrofauna. Totally, 35 macrobenthic species belonging to seven taxonomic classes of Polychaeta (ten species); Gastropoda (nine species) Malacostraca (eight species) Insecta (four species) Bivalvia (two species) Turbellaria (one species) and Phascolosomatidea (one species) were identified. The number of identified species was approximately equal during all seasons (autumn and spring with 22, summer with 23 and winter with 24 species) nevertheless; their composition was changed by season. Eight species were observed during all season and eight species were identified occasionally only in one season (Table 4). The polychaets *Capitella capitata* and *Owenia* sp. with average density of 343±82 ind. m^{-2} and 267±60 ind. m^{-2} dominated all seasons. The species belong to Gastropoda class (*Hydrobia* sp. with 105±15 ind. m^{-2} and *Cerithidea cingulata* with 61±6 ind. m^{-2} and also species belong to Malacostraca class (*Macrophthalmus pectinipes* with 52±10 ind. m^{-2} and *Uca sindensis* with 39±10 ind. m^{-2}) were other dominant species. All identified species and their density are summarized in Table 4.

Table 4

Macrofauna density (inds m^{-2}) through different seasons in Bidkhun mangrove swamp

Class	Species	Summer	Autumn	Winter	Spring	Average
Polychaeta	*Capitella capitata*	113	152	824	286	343±82
	Glycera sp.	-	10	-	3.5	3.5±1.4
	Ceratonereis sp.	3.5	-	-	-	0.9±0.44
	Perinereis cultrifera	21	3.5	35	3.5	16±3.8
	Nereis sp.	25	3.5	38	3.5	17±4.3
	Sabella fusca	7	7	3.5	7	6.2±0.44
	Owenia sp.	152	201	626	92	267±60
	Haplosylis spongicola	3.5	-	3.5	-	1.8±0.5
	Syllis spongicola	2	-	2	-	1±1
	Eunicidae sp.	14	-	-	3.5	4.4±1.7
Turbellaria	*Polycladida* sp.	-	-	7	-	1.8±0.9
Phascolosomatidea	*Phascolosoma meteori*	-	7	-	-	1.8±0.9
Bivalvia	*Paphia gallus*	-	3.5	3.5	3.5	2.65±0.44
	Septifer bilocularis	-	-	17	7	4.4±2.2
	Phasionella solida	7	7	102	56	30±12
Gastropoda	*Umbonium* sp.	7	7	-	35	5.3±0.8
	Hydrobia sp.	187	53	123	-	105±16
	Onchidium peroni	24	14	-	56	18.5±3.8
	Acteocina involuta	-	-	7	3.5	1.8±0.9
	Cerithidea cingulata	42	46	102	-	61.8±6.9
	Clypeomerous bifasciatus	3.5	7	-	3.5	3.5±1.6
	Finella sp.	-	-	3.5	-	0.9±0.44
	Trochocerithium sp.	-	10.6	3.5	14	7±1.6
Malacostraca	*Dardanus tinctor*	-	35	-	24	15±4.5
	Macrophthalmus pectinipes	17.7	24	109	56	52±10.5
	Ocypode sp.	21	-	-	-	5.3±2.6
	Uca sindensis	102	21	10	21	39±10.7
	Grapsidae sp.	-	-	7	-	1.8±0.9
	Actaea sp.	3.5	-	14	-	4.4±1.7
	Tylos sp.	10.6	-	-	-	2.6±1.3
	Isopoda sp.	3.5	-	-	-	0.9±0.44
Insecta	*Insect Larve 1*	78	21	127	24	62.7±12.5
	Insect Larve 2	17.7	10	88	3.5	30±9.8
	Insect Larve 3	-	26	78	28	33.1±8.1
	Coleoptera sp.	-	21	3.5	42	16.8±4.8

Many studies reported Polychaeta as main taxa of mangrove ecosystems (Chapman 1998; Keshavarz 2008; Vazirizadeh et al 2011). Stable substrate provided by mangrove trees against desiccation (Divakaran et al 1981; Mishra & Choudhury 1985) and providing soft substrate for tube dwellers (Mishra & Choudhury 1985) lead to dominance of these taxa in mangroves. Statistical analysis indicated significant difference in density of macrofauna during four seasons ($p < 0.05$). Winter had the highest density of macrobenthic organisms and it decreased in warm seasons (Figure 4). It is reported that lower temperature and stability of environmental condition of tropical regions lead to increase of macrofauna density in cold seasons. In contrast; decrease of gametogenesis and reproduction as a result of high temperature and higher concentration of H_2S as well as decrease of oxygen availability causes decrease of macrofauna density in warm seasons (Saravanakumar et al 2007). Macrofauna were distributed relatively different through stations ($p < 0.05$). Tukey's statistical analysis showed that stations 1, 2, 5 and 6 had no significant difference between them. But station 3 had different macrofauna density and composition from stations 2 and 6. Station 4 was significantly different from all stations ($p < 0.5$). This station contained the lowest density and diversity of macrobenthic organisms and in some cases zero population (Figures 4 and 5). No macrofauna was observed in summer and spring of station 4. Other seasons also showed few numbers of one and two species for autumn and winter, respectively. *C. capitata*, *Owenia* sp. and *Glycera* sp. were the only species which were found in station four.

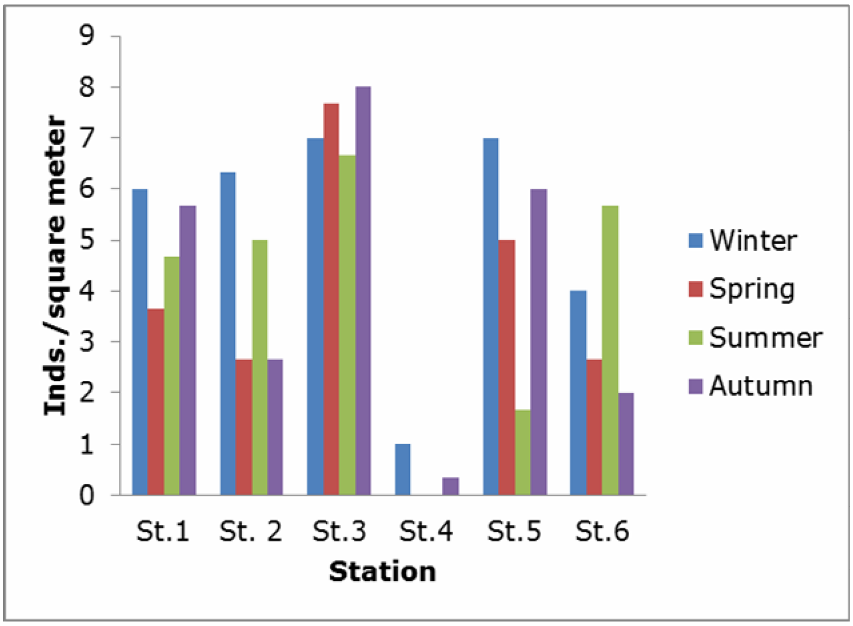

Figure 4. Total macrofauna density within different stations of four seasons.

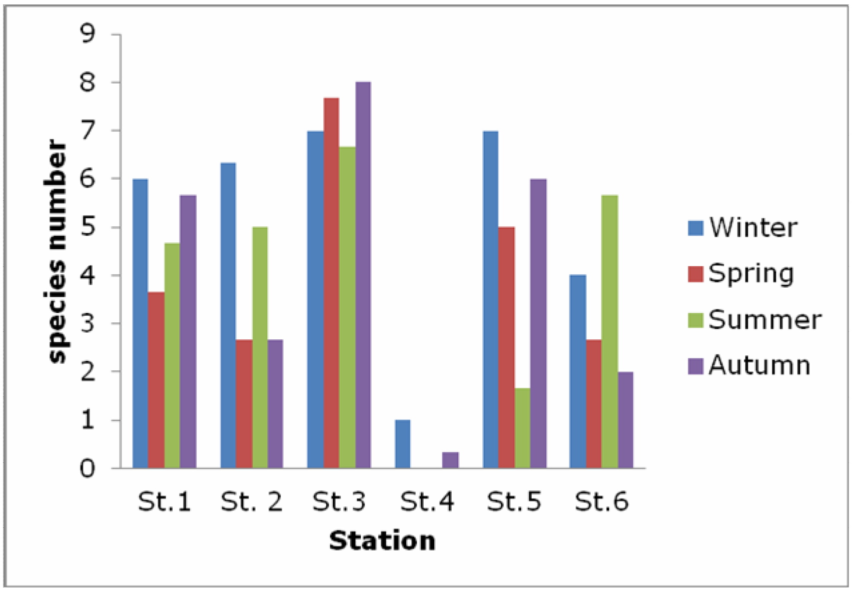

Figure 5. Species number within different stations of four seasons.

Although, there are many studies that reported Polychaeta as main taxa of mangrove ecosystems (Chapman 1998; Keshavarz 2008; Vazirizadeh et al 2011), but it is demonstrated that dominance of tolerant species of *C. capitata* could be index of high load of organic matters and depletion oxygen condition (Wilson & Jeffrey 1994; Bortone 2005). Hydrological difference (Little 2000), mangrove tree's composition (Edgar 1990), sediment properties including organic matter content, sediment texture and dissolved oxygen have been reported as environmental characters responsible for benthic composition and its special and temporal changes (Lee 2008). Biological parameters such as food source, competition and behavior also affect macrofauna structure (van Houte-Howes et al 2004; Gray & Elliot 2009). Table 5 shows Pearson correlation analysis among environmental parameters and macrofauna density. Mud percentage, TOC and temperature showed significant correlation with macrofauna density. Polychaeta, Bivalvia and Insecta were affected by mentioned parameters. Other taxa didn't have any correlation to the environmental parameters.

Table 5

Pearson correlation analysis between density of macrofauna and environmental parameters

		pH	*Eh*	*Salinity*	*Mud*	*TOC*	*T*
Gastropoda	Pearson	0.954	0.134	0.071	0.661	0.271	-0.46
	Correlation	0.046	0.867	0.929	0.339	0.729	0.54
	Sig. (2-tailed)	60	60	60	60	60	60
	N						
Bivalvia	Pearson	0.517	0.778	-0.66	**0.963**	**0.962**	**-0.96**
	Correlation	0.483	0.222	0.34	**0.037***	**0.038***	**0.4***
	Sig. (2-tailed)	60	60	60	60	60	60
	N						
Polychaeta	Pearson	0.627	0.692	-0.55	**0.98**	**0.969**	**-0.97**
	Correlation	0.373	0.308	0.45	**0.02***	**0.031***	**0.03***
	Sig. (2-tailed)	60	60	60	60	60	60
	N						
Malacostarca	Pearson	0.723	-0.35	0.551	0.316	-0.2	0.42
	Correlation	0.277	0.65	0.449	0.684	0.8	0.958
	Sig. (2-tailed)	60	60	60	60	60	60
	N						
Insecta	Pearson	0.672	0.653	-0.49	**0.971**	0.736	**-0.963**
	Correlation	0.328	0.347	0.51	**0.029***	0.264	**0.037***
	Sig. (2-tailed)	60	60	60	60	60	60
	N						

Statistically significant correlations in bold; * correlation is significant at the 0.05 level (2-tailed).

Ecological status*.* Ecological indices including Species Richness, Shannon-Wiener diversity, Simpson dominance, AMBI and M-AMBI were calculated to evaluate environmental and ecological status. The results are shown in Table 6. It shows that all stations except for station 4 are in good or high ecological status. Station 4 which is located near opening of sewage canal was in bad or poor ecological status that indicates extremely polluted status during the whole year. Generally, there were dissimilarity in macrofauna composition, ecological status and environmental features of station 4 comparing to other stations. This pattern occurred during all seasons. Other stations showed relatively normal condition in biological composition and ecological status. Field and laboratory analysis showed that abnormal environmental parameters such as low salinity (about 17 psu compare to 43 psu in other stations) and high levels of some nutrients such as ammoniac, nitrate, nitrite and phosphate (Tables 2 and 3) as a result of swage runoff, induced eutrophication and harmful algal bloom on the surface of sediment in station four. Dense coverage of algae *Rhizoclonium* sp. has occupied whole substrate and ecological niches of macrofauna. High alteration of dissolved oxygen as a result of eutrophication also makes harsh condition for organisms (Bruno et al 1989). However, there are several reasons for algal bloom, it is generally accepted that availability of nutrients is the main cause of this phenomenon (Howarth & Marino 2006). Anthropogenic nutrient enrichment and related alteration in nutrient ratio is introduced as main cause of algal bloom (Heisler et al 2008; Harrison et al 2012). It is demonstrated that N:P ratio rather than absolute concentration is the cause of algal bloom (Hodgkiss & Ho 1997). Harmful algal bloom and oxygen depletion are known as harmful consequence of eutrophication which threat live part of aquatic ecosystems (Anderson et al 2002; Diaz & Rozenberg 2008; Heisler et al 2008). Diminished salinity close to sewage canal opening as a result of fresh water discharge also provides suitable condition for freshwater reeds. The reeds have covered lands around the runoff opening. They are proceeding toward mangrove tree and surrounded them in some parts. It seems that future increase of runoff may causes more growth and more proceed of reeds and consequently more decrease of mangrove tree's coverage around sewage canal.

Table 6

Value of calculated indices at five sampling stations

Season	Index station	Indices				
		S	*H'*	*D*	*A*	*M-A*
Summer	Station 1	9	2.1	0.33	2	0.69
	Station 2	9	2.1	0.31	1.7	0.7
	Station 3	16	3.3	0.26	2.4	0.96
	Station 4	0	0	1	7	-0.06
	Station 5	3	1.2	0.53	5.2	0.24
	Station 6	12	2.9	0.29	1.9	0.85
Autumn	Station 1	9	2.8	0.18	2.2	0.78
	Station 2	5	1.8	0.41	1.8	0.62
	Station 3	16	3.1	0.18	1.8	1
	Station 4	1	0	1	6.2	0.01
	Station 5	12	3.4	0.2	3	0.82
	Station 6	2	1	0.37	3.3	0.35
Winter	Station 1	10	2.3	0.28	3.6	0.78
	Station 2	13	2.6	0.41	3.1	0.94
	Station 3	11	2.2	0.26	2.6	0.89
	Station 4	7	2.1	0.5	5.5	0.21
	Station 5	11	2	0.33	2.8	0.84
	Station 6	4	1.9	0.3	3.6	0.58
Spring	Station 1	5	1.9	0.4	4.1	0.53
	Station 2	4	1.7	0.3	3.5	0.52
	Station 3	13	2.5	0.2	2	0.98
	Station 4	0	0	1	7	-0.07
	Station 5	11	2.7	0.23	3.9	0.81
	Station 6	4	1.9	0.34	2.1	0.65

S: richness (ind.), H': Shannon-Wiener diversity, D: Simpson dominance, A: AMBI, M-A: M-AMBI.

Conclusions. Generally, there are spatial and temporal changes in environmental parameters, macrofauna composition and structure and also environmental health status. Macrofauna composition is significantly affected by environmental parameters such as sediment texture, TOC and seasonal temperature. All stations except for station 4 were in normal ecological status. This station is influenced by sewage canal. Discharge of freshwater sewages containing high concentration of nutrients induced an algal bloom and huge growth of reeds on the surface of substrate around the canal, where station 4 is located. This condition has led to weak or no population of macrofauna at the northern part of present habitat. Regarding essential role of macrofauna in nutrient cycling it may causes gradual destruction of mangrove trees too. So that, it is necessary to treat sewage before discharge to mangrove swamp or change its path to the other places with lower sensitivity.

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