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Ecological status assessment of intertidal zone of the Persian Gulf coastal field using Gastropod biodiversity (a case study of Deylam County, Bushehr Province, Iran)

Hadis Salehi, Abdol R. Pazira, Hanieh Z. Noorbakhsh

Department of Fisheries Sciences, College of Natural Resources, Bushehr Branch, Islamic Azad University, Bushehr, Iran. Corresponding author: H. Salehi, h.salehi_12@yahoo.com

Abstract. The aim of this study was identification and determination of diversity and density of Gastropods of intertidal zone of coastal field of Deylam County (Bushehr Province) and assessment of ecological status of the area using Welch index. Sampling was carried out in summer and winter seasons during 2013-2014. Sampling bed sediments was done three times in each station. Gastropod samples were collected using Quadrate (25×25 cm) and were preserved by using 4% buffered formalin and transported to the laboratory and counted and identified. Moreover physicochemical properties of water such as temperature, pH, dissolved oxygen (DO) and water salinity were also measured in each station. Diversity index was investigated by using Shannon-Weaver formula, dominancy index was investigated using Simpson formula, and determination of ecological status of each station was investigated by using Welch index. The identified samples were totally 7 species from 7 families and 4 orders. The most frequent identified species in each station were *Nassarius arcularius plicatus*, *Cerithidea cingulata* and *Anachis misera*. The results of the study showed that according to the identified species and also Welch index studied stations in Deylam County have average and rather poor pollution status.
Key Words: diversity, intertidal zone, Gastropod, Welch index.

Introduction. Different aquatic ecosystems including oceans, seas, lakes, gulfs and rivers form over 70% of the Earth surface. These aquatic frameworks having relationships with each other in different ways play a principal part in the global system of the environment (Welch 1992). The coastal zones include about 18% of the Earth surface and have about 60% of the world's population. About 90% of the world's fishing is obtained from these regions (Balasubramanian 1999). Coastal zones have devoted about 18 to 33% of the total primary production to themselves. This zone has a high biological potential since it acts as a bed for feeding, culturing larva and spawning and also is considered an interstitial biotope between the marine environment and the fresh water (Nabavi et al 2011; Nybakken 1995; Webber 1995; Balasubramanian 1999).

Coasts and intertidal zones are one of important marine ecosystems having environmental, ecological and economic significance (Balasubramanian 1999). Intertidal zone is a unique marine environment since it is constantly exposed to the air. Thus, organisms living in this region should be able to adapt to its difficult conditions (Vazirizadeh & Arebi 2011). Macro-invertebrates (Macrobenthos) are invertebrates animals which are observable with unarmed eyes and spend at least a part of their life in aquatic resource bed (Moghdani et al 2013; Rosenberg et al 1999). Macrobenthos have an especial position in food chains due to diversity of food (nutrition) and habitat. The absorption of energy and matter in wide parts of the low levels of the food pyramid by consuming Phytoplanktons, Zooplanktons and the other benthics and their transport to the higher levels of the food pyramid by being consumed by the other fishes clarify significance of these organisms in food chains more than before (Nybakken 1997). Most

benthic organisms such as bivalves and Gastropods are the main food of benthic fish or even pelagic fish (Gerking 1994). Gastropods can be an important index in order for determination of destruction effects of human activities on coasts due to their presence at bed and their low capability to change place (Petraco et al 2014; Kohan et al 2012). Gastropod class is the biggest class of Mollusca. This class includes 40000 to 75000 species living in seas, fresh waters and land. Some of them are herbivorous, some are carnivorous and some are parasites (Sørensen & Surlyk 2011; Pechenik 2000).

Study and investigation of the structure of benthic communities in different aquatic ecosystems has an especial position in ecological studies of aquatic organisms. The significance of bivalves and Gastropods in sea not only is due to their presence in a main part of marine food chain as the main food of the benthic fish but also presence or absence of some of benthic species in some waters is an indicator of water quality from the viewpoint of pollution or lack of pollution (Tabatabaei & Amiri 2011). Identification and determination of frequencies of these species that called biological indices (Hilly & Glemarec 1991), is always considered by marine ecologists in these kinds of studies.

Study and investigation of benthic animals especially Gastropods is one of the most important issues of ecological sciences. Due to the fact that Gastropods are considered as one of the most important benthic groups of an aquatic ecosystem, any changes in coastal ecosystem and intertidal zone cause changes in factors governing mentioned communities (Peura et al 2013; Andrew et al 1996).

Persian Gulf is a shallow basin with an average depth of 35-40 meters and an area about 240 km^2. This region is linked to the international waters through the Strait of Hormuz (Anon 1995; Banat et al 1998; Saeidi et al 2008).

The water replacement time in this basin is between 3 to 5 years showing pollutants remain in the Persian Gulf for a significant time. North parts of the Persian Gulf are more under the influence of the pollutants due to low depth, finite rotation, salinity and high temperature (Saeed et al 1995). On the other hand, according to the occurrence of different environmental events in this region during recent years including the world's largest oil spill in 1991, ship traffic, transport and discharge of oil contaminations and also oil spills, this region has got in crisis. Generally speaking it is clarified that about 30% of the world's oil transport is carried out in the Persian Gulf (Pourang et al 2005).

Deylam County is one of Bushehr province counties in the South of Iran. Its center is Deylam harbor. Imam Hassan city is one of the other cities of this county. Deylam harbor lies at 30º03'N and 50º09'E and an altitude of 10 meters. This harbor lies at a distance of 232 kilometers of the northwest of Bushehr province and 72 kilometers of the South of Behbahan County (in Khuzestan province) in the Persian Gulf shore. Deylam climate is warm and humid (Salehi 2014).

This study is carried out according to the above mentioned reasons. It based on the importance of the intertidal zone in ecological terms of reproduction and culture of marine aquatic animals. This research is done according to this animal class and importance of shores of Bushehr province in terms of frequencies and species diversity of invertebrates especially Gastropods, as well as lack of knowledge in this respect in order to access basic information to environmental control and supervise these shores and to obtain information concerning Gastropods' dispersion in coastal zone.

Material and Method

Study area. This study was carried out on the shores of Deylam County located in Bushehr province during summer 2013 and winter 2014. Investigations showed that according to the aims of the study, just two sampling periods during warm season (summer) and cold season (winter) suffice in order to have more recent information in the study limits. Location of the study stations and geographical location of the stations are specified in Figure 1 and Table 1, respectively.

Table 1

Geographical location of the stations in the study limits

Sampling point	*Longitude E*	*Latitude N*
1	50° 08' 43.60"	30° 03' 9.60"
2	50° 08' 57.38"	29° 58' 15.78"
3	50° 15' 27.03"	29° 49' 59.39"
4	50° 17' 49.70"	29° 46' 49.89"

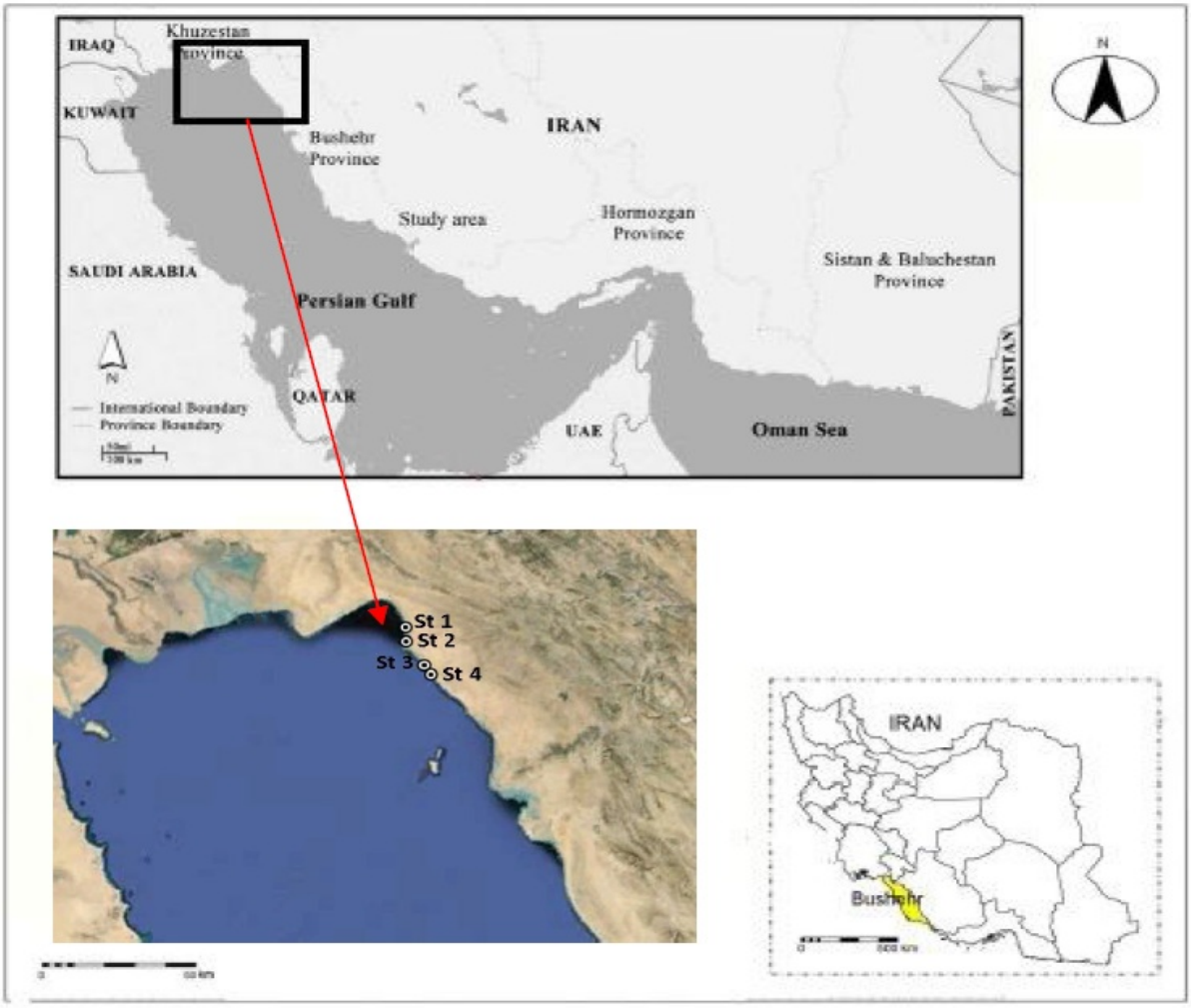

Figure 1. Location of the study stations (original drawing).

Sampling sediments and determining physicochemical parameters. Sampling sediments of the mentioned shores was carried out during both the warm season (September) and the cold season (February) using Quadrate (25×25 cm) based on the present methods at different sources (Walton 1952; Eleftheriou & McIntyre 2005; Kohan et al 2012). In each station first geographical location was specified using GPS and then sampling sediments of determined stations on the shores as well as sampling water samples in order to evaluate chemical and physical parameters (pH, salinity, temperature, dissolved oxygen) was done. In each station three sediment samples were taken using Quadrate to study Gastropod in order for identification, separation and determination of diversity and density of the communities. In order for sampling first from the surface to a depth of 5 centimeters sediments were taken by shovel and were washed in a 0.5 mm sieve and after recording specifications of each station on the sampling containers, samples were transported to the Environmental Sciences laboratory of Persiam Gulf University. After transporting the samples to the laboratory, samples were washed using water so that the extra materials existing on the samples were

completely cleaned. Then samples were transported to a Petri dish and all the present Gastropods were separated by a pair of forceps and using a stereo microscope. Each gastropod was put inside a video can containing formalin 4% related to certain groups in order to be identified and counted. Then frequencies of each group of Gastropods during different seasons were calculated and important biological indexes concerning them were calculated. In this study it was tried to identify Gastropods within the limits of the family at the first stage and within the limits of genus and species if possible using the present sources and identification keys. In order to identify gastropods species, valid identification keys were also used (Taylor & Sohl 1962; Opresko et al 1976; Angeletti 1978; Jones 1986; Bosch et al 1995; Abbott et al 2001; Abbott & Morris 2001; Bouchet et al 2005; Tunnell et al 2010).

Species diversity index. Shannon-Wiener diversity index was calculated by equation (1) (Shannon & Weaver 1963).

$$H' = -\sum_{i=1}^{R} \rho_i \ln \rho_i \quad (1)$$

Where, ρ_i is the relative frequency, i is in the community and R is the total number of the community.

Species dominancy index. Simpson index was represented by Simpson in 1949 and Krebs has presented its calculation equation in 1972 (Krebs 1994).

$$\lambda = -\sum_{i=1}^{R} \rho_i^2 \quad (2)$$

where, ρ_i is relative frequency, i is in the community, and R is the total number of the community.

The assessment of pollution status of the area. After determining diversity indexes, Welch index was used to determine pollution status of the area (Table 2) (Welch 1992).

Table 2

Pattern of assessment of the area pollution

Water quality class	*Welch index*
Low pollution	3-5
Average pollution	1-3
High pollution	< 1

Statistical analysis. In order for statistical investigation of the data, first data normality was analyzed by using Kolmogorov-Smirnov test and the difference between stations and seasons were determined using one-way ANOVA in the environment of SPSS®15 software (Zar 1999). Excel software was also used in order to draw diagrams.

Results

Physicochemical parameters. Based on the carried out investigations, it was specified that there are no significant differences between mean temperature in 4 stations ($p = 0.958$) but mean temperature parameter in both warm and cold seasons has significant difference ($p = 0.001$). The highest temperature degree in station number 1 during summer was recorded with a degree of 35.5°C and the lowest temperature degree in stations number 2, 3 and 4 was recorded with a degree of 20°C (Figure 2). According to the investigations done, it was specified that there are no significant differences between dissolved oxygen in fourfold stations of sampling ($p = 0.285$) and also dissolved oxygen in both warm and cold seasons ($p = 0.172$). The highest rate of oxygen in station

number 4 in winter was recorded 8.20 mg L^{-1} and the lowest rate of oxygen in station number 2 in summer was recorded 5.10 mg L^{-1} (Figure 3). Based on the investigations carried out, it was specified that there are no significant differences between mean salinity in fourfold stations of sampling ($p = 0.981$) but significant differences between salinity rate during both summer and winter seasons were observed ($p = 0.006$) (Figure 4). According to the carried out studies it was specified that there are no significant differences between mean pH in stations ($p = 0.460$) but there are significant differences between mean pH in sampling seasons ($p = 0.038$). The amount of mean pH for both cold and warm seasons was recorded 8.03 and 7.82 respectively (Figure 5).

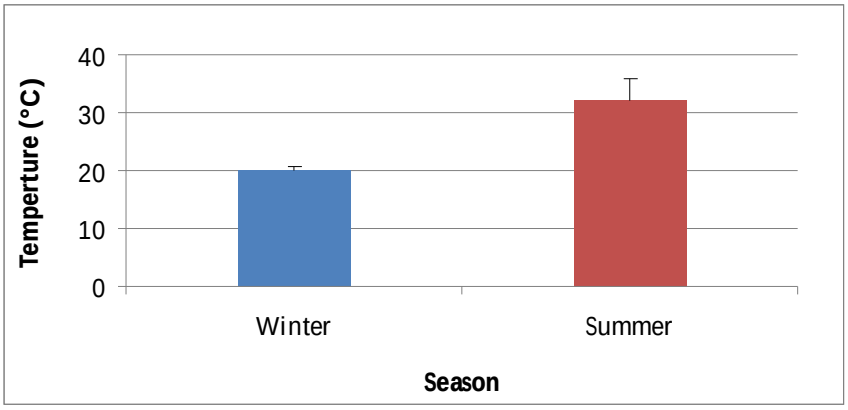

Figure 2. Water temperature changes in both cold and warm seasons.

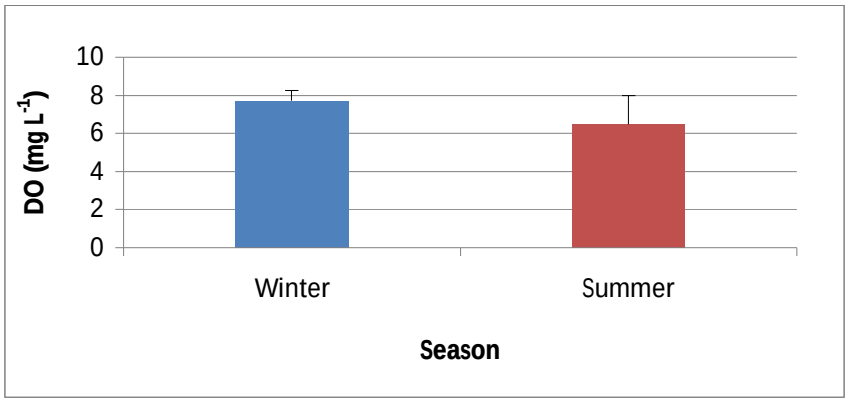

Figure 3. Dissolved oxygen changes in both cold and warm seasons.

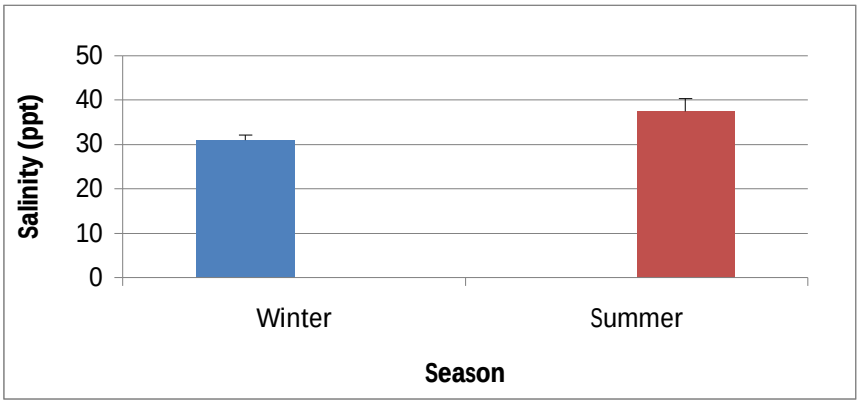

Figure 4. Salinity changes in both cold and warm seasons.

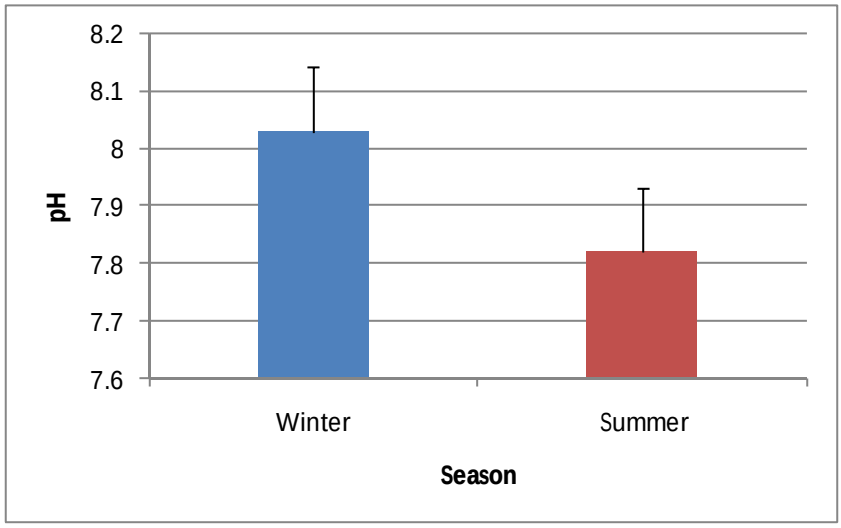

Figure 5. pH changes in both cold and warm seasons.

Density and dispersion of Gastropods. Seven species from 7 families and 4 orders from Gastropods were totally identified during sampling (Table 3) that the results of frequencies of benthic groups are represented based on cold and warm seasons separately. Figure 6 shows frequency changes of Gastropods counted in different stations. Based on the results ($p = 0.762$), there were no significant differences between frequency changes in both summer and winter seasons.

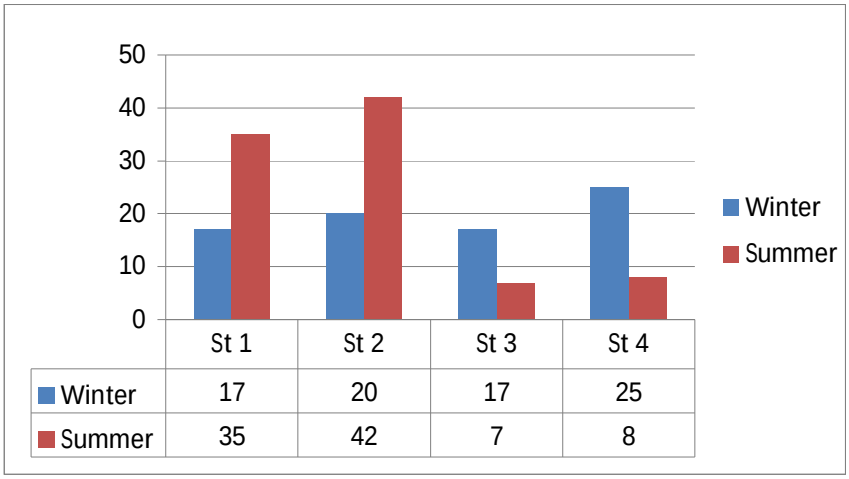

Figure 6. Frequency changes between stations during cold and warm seasons.

Table 3

Gastropod faunal communities during cold and warm seasons

Order	*Family*	*Species*
Neogastropoda	Columbellidae	*Anachis misera*
	Nassariidae	*Nassarius arcularius plicatus*
	Terebridae	*Terebra cingulifera*
Sorbeoconcha	Potamididae	*Cerithidea cingulata*
	Cerithiidae	*Clypeomorus* sp.
Trochoidea	Chilodontidae	*Euchelus asper*
	Trochidae	*Trochus erythraeus*

Shannon index. Based on the results of ANOVA ($p = 0.008$), significant differences between mean Shannon index in sampling stations were observed, but there were no

significant differences between mean Shannon index in sampling seasons (p = 0.631) (Figure 7).

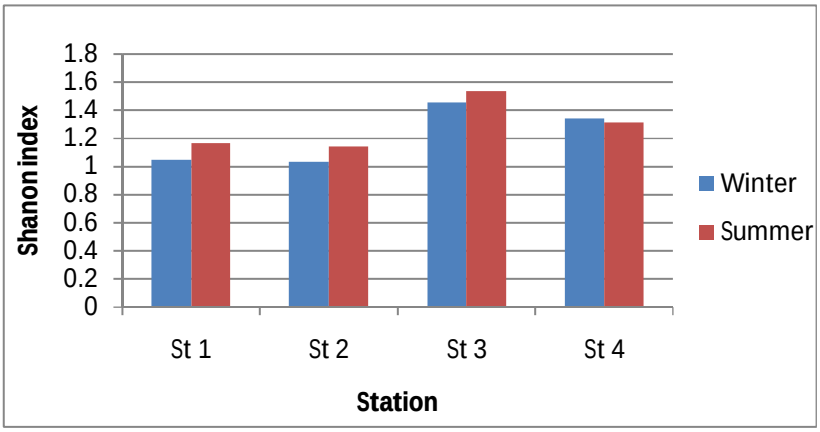

Figure 7. Shannon index changes between stations during cold and warm seasons.

Simpson index. According to the results of ANOVA, no significant differences were observed between mean Simpson index among sampling seasons (p = 0.398), but in sampling stations significant differences were observed between mean Simpson index (p = 0.034) (Figure 8).

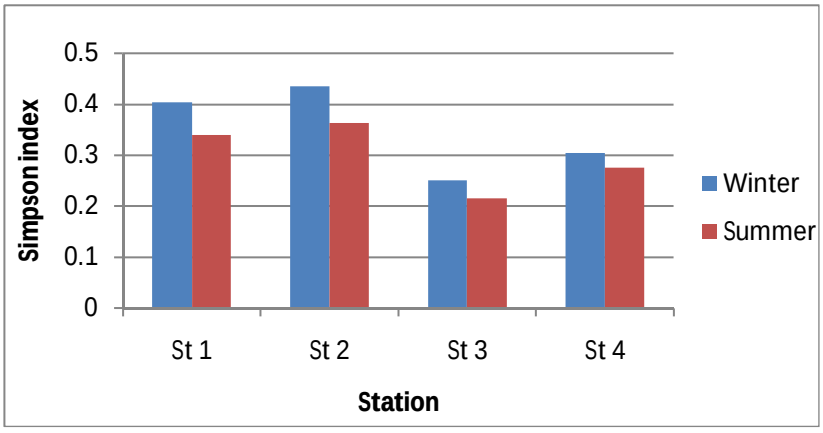

Figure 8. Simpson index changes among stations during cold and warm seasons.

Determination of pollution status of the area. Welch index was used in order to determine pollution status. Pollution status of each station is determined based on the rate of Shannon diversity index changes in this index. Pollution status in these areas has generally an average level (Table 4).

Table 4

Gastropod faunal communities during cold and warm seasons

Welch index	*Stations*			
	1	*2*	*3*	*4*
Cold season	1.046	1.033	1.453	1.341
Warm season	1.164	1.139	1.538	1.315

Discussion. This study provides new informations of water properties and a baseline survey of macrobenthic fauna within Deylam County in two season term assessment. Benthic macro-invertebrates formed a very important part of the sea bed-fauna which frequently include polychaetes, crustacean and seashells. Some species due to their adaptation to the environmental conditions despite pollutants and most species due to

being non-immigrant and residence are considered as biological indexes of aquatic ecosystems (Tabatabaei & Amiri 2011).

According to the results of this study it can be concluded that macrobenthos are a good index in order to assessment of ecological status of the aquatic resources corresponding with the results of the studies of Dehghan (2007), Anbuchezhian et al (2009), Mooraki et al (2009) and Moghdani et al (2013).

One of useful applications of Shannon species diversity index is ecological assessment in relation to pollution of the areas (Welch 1992) that the obtained results of Welch index (Welch 1992) shows that water quality in the study areas has generally an average level. In this study, mean of Simpson index in cold and warm seasons were 0.348 and 0.298 respectively, which indicates that macrobenthose in Deylam County shores has good variations. The results of Shanon–Wiener indices confirm the results of Simpson index. The diversity of macrobenthose was highest in summer and lowest in winter. Based on this index all stations have an average quality during both cold and warm seasons. The most frequent identified Gastropods include species of *Nassarius arcularius plicatus, Cerithidea cingulata, Anachis misera*. The reason for the frequencies of these groups in both seasons can be due to suitable environmental conditions for this species to live and reproduce. Since these species are rather resistant to pollution it can be stated that the study stations have no desirable status qualitatively. *C. cingulata* is a part of biological indicators in polluted areas, because in spite of the high density of pollution they have been able to live up to continue. This species is also capable of decaying food and organic materials used, get fed and live on the cover of algal mats. As well as this, in terms of ecology, is known as euryhaline and is capable of tolerating sudden environmental changes, a marked lack of oxygen and high levels of hydrogen sulfide (Pearson & Rosenberg 1978). Based on the statistical analysis between mean Shannon index in summer season and winter season, no significant differences were observed.

Studies of Misra & Kundu (2005) shows that seasonal density of Gastropods does not show perceptible changes in regions located near equator and seasonal changes are not perceptible. In this study which is carried out concerning 5 species of seashells in coastal lines of the South of India, spatial changes can cause significant differences in density and these seasonal changes do not cause any perceptible density differences.

Generally speaking, it can be stated that different factors were reported as controlling factors of frequencies in communities' spread in tropical and sub-tropical regions including the Persian Gulf by researchers so far (Sheppard et al 1992). Among the mentioned factors, parameters of sediment particle size (Basson et al 1977), water salinity (Coles & McCain 1990), water flow (Sheppard et al 1992; Basson et al 1977) and water polluting factors (Coles & McCain 1990) have the most effects on spread of benthic fauna in these regions. In such condition determination of the effect of only one factor on dispersion and frequency of benthic communities is not free of uncertainty and fault while a collection of different environmental factors can have significant effects on dispersion and diversity of these creatures (Neubauer et al 2015; Parsons et al 1977).

According to the study of Saunders et al (2007) an increase in pollution causes a decrease in diversity and frequency of benthic macro-invertebrate species. Also the study of Carvalho et al (2006) showed that an increase in the rate of pollution causes dominancy of opportunist species. There are some pollution sources in all study statios in this research, so it cause to relative increase of pollutant and effect on the macrobenthos fauna. Because of that in all study stations the diversity index and welch index were average.

Abu-Hilal et al (1994) and El-Sammak (2001) studied the pollution status in Dubai estuary by studying benthos. The results of their study indicated that in the study stations diversity of the benthic macro-invertebrates decreases as the pollution increases. Environmental factors involved in diversity or dispersion of benthic creatures in a small ecosystem are as follows: physical and chemical factors include the size of the sediment forming particles, the rate of dissolved oxygen in sediments (Johansson 1997) and the rate of sediment pollution and biological factors include the way of benthos feeding, the

effects of benthic creatures feeding on the other smaller species and the effects of biological disturbance in the environment bed (Gray 1981).

Human activities cause a change in the environment variables and this change causes a change in combination and species diversity of macro-benthos (Warwick & Clarke 1993). Thus according to this fact that polluting resources of these coasts are the discharge of domestic wastewaters and oil tankers' activities done on these coasts, it can be concluded that the main factor of the pollution of the study coasts results from activities including effluents resulting from domestic wastewaters and oil tankers transportation.

Benthic communities' diversity was affected by different natural and anthropogenic factors. Physical disturbances are the most important impacts which can decrease the benthic diversity in the study area (Mohammadi Roozbahani et al 2010). One of the most important activities in Deylam county is commercial fishing. Fishing activities must be considered as a physical disturbance which can affect the diversity of species. The results of diversity indices showed that fishing activities affected the macrobenthos fauna. Fishing constitutes one of the most significant threats to marine biodiversity. It may also reduce the structural complexity of habitats or change competition and predation among the organisms.

Conclusions. Human activities cause a change in the environment variables and this change causes a change in combination and species diversity of macro-benthos. Thus according to this fact that polluting resources of these coasts are the discharge of domestic wastewaters and oil tankers' activities done on these coasts, it can be concluded that the main factor of the pollution of the study coasts results from activities including effluents resulting from domestic wastewaters and oil tankers transportation.

The most frequent identified Gastropods include species of *Nassarius arcularius plicatus, Cerithidea cingulata,* and *Anachis misera*. The reason for the frequencies of these groups in both seasons can be due to suitable environmental conditions for this species to live and reproduce. Since these species are rather resistant to pollution it can be stated that the study stations have no desirable status qualitatively. One of species observed in this study was *Cerithidea cingulata* which is a part of biological indicators in polluted areas, because in spite of the high density of pollution it is able to live up to continue. This species is also capable of decaying food and organic materials used, get fed and live on the cover of algal biology. As well as this, in terms of ecology, it is known as euryhaline and is capable of tolerating sudden environmental changes, a marked lack of oxygen and high levels of hydrogen sulfide.

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Authors:
Hadis Salehi, Department of Fisheries Sciences, College of Natural Resources, Bushehr Branch, Islamic Azad University, Bushehr, Iran, Aalishahr, postal code 75196-19555, e-mail: h.salehi_12@yahoo.com
Abdol-Rahim Pazira, Department of Fisheries Sciences, College of Natural Resources, Bushehr Branch, Islamic Azad University, Bushehr, Iran, Aalishahr, postal code 75196-19555, e-mail: abpzira@gmail.com
Hanieh Ziaeian Noorbakhsh, Department of Fisheries Sciences, College of Natural Resources, Bushehr Branch, Islamic Azad University, Bushehr, Iran, Aalishahr, postal code 75196-19555, e-mail: hziaeian@yahoo.com

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