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A survey on influence of summer monsoon on diversity and density of bivalves in the Iranian Coasts of Oman Sea

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Abstract

Seasonal winds (Monsoon) significantly affect the ecological and environmental characteristics of Oman Sea and its sea-bed; in fact monsoon, being the obvious seasonal feature of the area, are the major factor in changing the dynamics of Oman Sea by causing storms or turbulent seas. Oman Sea the most important ecosystems with wide expanse and variety of marine animals, especially mollusks. This paper aims to study the diversity and density (Congestion and contraction) of Bivalves in sea-bed sediments of Oman Sea (Hormoz strait – Quater Bay), and in order to fulfill this purpose, 10 stable stations were selected (the dimension of each is 30 sea-miles) within marked locations along Iranian shores of Oman's sea-bed. Sampling was done by choosing a '0.1 m^2 Van-Veen grab sampler' to collect sediments, the same was performed three times. The physical and chemical parameters of water such as temperature, salinity, dissolved oxygen and pH were measured by using a CTD module. As a result of this study 43 genera of 19 families of Bivalves were identified. Among the identified groups, Lucinidae 55%, Nuculidae 13%, Tellinidae 7%, Veneridae 5% and Yoldiidae 5% were the dominant groups. Results show that diversity and density of Bivalves in Oman Sea, are affected by the southwest Indian Ocean monsoon winds in such a way that their frequency (numbers) is decreased but their diversity is increased after summer monsoon. Therefore, more study should be carried out, on Bivalves in particular to assess demersal fishery and to evaluate natural and anthropogenic stress.

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Introduction

Geographically Oman sea is (delimits Iranian south-eastern coast boundary) located to the south of Iran, delimiting internal Iranian waters belonging to provinces of Sistan -Baluchestan and Hormozgan. From the south Oman Sea is connected to the Indian Ocean, and therefore, Oman Sea is affected by ocean current in the Indian Ocean. The seasonally blowing winds (monsoon) are a salient characteristic of the region, the same having a significant/major effect/influence on the environmental characteristics or the ecosystem of Oman Sea. (Sanjarani, 2010).

During the South-west monsoon the sea-currents are so severe and so as to make fishing impossible, forcing out fisher-men to migrate to the Persian Gulf and its surrounding islands, or they have to take refuge in the nearest sea tributaries and estuaries for protection and in search of fish. (Sari, 1991).

Ecologically sea-bed mollusks, such as Bivalves, existing in the coastal waters, have a particular rank in the sea-bed oceanic food chains. In addition to providing food for sea-bed fishes, importance of Bivalves lies in their ready availability as a well - spread and well-propagated (re-cycled) nutritional source of food materials in the world oceans. (Nybakken, 1997).

A parallel study of Macro-Benthos, alongside this study of Bivalves, being a species type of Macro-Benthos, has had an added important outcome of identifying marine food chains as well as establishing their role as pollution indicator, which index is very important in examining their pollution effects on marine eco-systems. (Mathew, 1988).

The variance/diversity and spreading of Bivalves species, which account for an important part of Benthos, are affected by such physical factors as :

a) Temperature, b)salinity, c)dissolved oxygen, d)sea-bed structure, e)depth, etc. (other factors such as feeding, competition and habitat) (Nevesskaja, 2006).

Since scientific studies that thoroughly investigate Bivalves' ecology in Oman Sea (delimited by Iranian waters) have been lacking, therefore, the above-mentioned project was performed in order to answer some questions such as the variance/diversity method and the density of Bivalves, and whether or not there is a relation between these above-mentioned features /particulars and the environmental factors that have been proposed and addressed in this paper. This study has aimed to probe the effects of summery monsoons on the abundance (numbers/frequency) and variance (diversity) of Bivalves alongside determining the relevant physical and chemical factors of water.

Materials and methods

- Study area

The study performed in2009 entailed two sampling seasons (one before and one after the summer monsoon) from the afore-mentioned 10 sea-bed stations (the dimension of each is 30 sea-miles) within marked locations along Oman Sea (Hormoz strait – Quater Bay in Sistan and Baluchestan province). Please refer to Fig. No. 1.

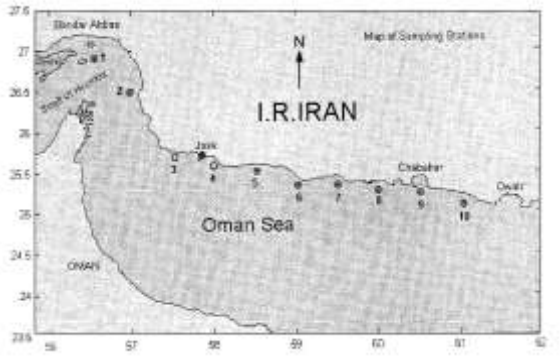

Fig. 1. The Condition of Sampling Stations in Oman Sea.

- Sampling methodology

Sampling was taken from sea-bed sediments for quantitative and qualitative analysis to study Mollusks by using a Van Veen Grab Sampler with a cross section of 0.1m². In each station three separate grabs (samples) were prepared from the sediments, and then, the contents of each separate grab/sample

were placed inside sieves measuring 50×50 cm, and the same contents were depleted/decanted and made uniform by passing through meshes with thickness of 0.5 mm, and then they were washed with sea-water.

The washed samples were transferred from the sieve to polyethylene vessels and were stained with 0.2 g/liter of "Rosebengal", and they were fixed with 95% Ethanol. When sampling was ended, the samples were transferred to a laboratory, and after re-washing through decantation (vessel-to-vessel transfer), they were separated by using a stereo-Microscope (Standard methods for the examination of water and wastewater, 2005). By using the available resources such as (Sterrer, 1986), (Bosch *et al.*, 1995), (Hosseinzadeh *et al.*, 2002) and (Debruyne, 2003) they were identified.

Shannon and weaver (1949), and Simpson (1949) indices were used to determine species diversity, species richness in order to compare totals species among Mollusks assemblage, and biologic Evenness for determining and calculating frequency (rampancy or numbers) of species types, and also their distribution method as to how the frequency (numbers) are spread in a given one sample both before and after the seasonal monsoon (Ludwing and Reynolds, 1988). The chemical and physical parameters of water, such as temperature, salinity, dissolved oxygen and pH were measured by the CTD instrument, model 316, "Ocean-Seven", and granular properties of sediments were determined by Hydrometric method, which is based on the density difference of grains (Holme and Mcintyre, 1984).

- Statistical analysis

The attained results were analyzed by SPSS20 statistical program and by using the 'One-way Variance/diversity Analysis' (ANOVA); Excel2010 software was used for preparing the graphs.

Results

In this study number of 43 genera belonging to 19 families of Bivalves were identified. The families: Lucinidae 55%, Nuculidae 13%, Tellinidae 7%, Veneridae 5% and Yoldiidae with 5% consecutively were the prominent Bivalve families. From Considering Lucindae family the genus "*Pillucina*" was seen before and after monsoon periods, that is, in relation to the other genus "*Pillucina*" was dominant. Also, the genus "*Nucula*" of Nuculidae family was the second dominant genus before monsoon, which of course has been seen after monsoon too.

The third dominant group is Tellinidae family, *Tellina* being its genus, and is the second dominant one of the families after monsoon. From the genera of this family the following results were noted and seen as below:

1. *Tellina* and Tellinimactra in both periods of sampling,
2. *Pinguitellina* before monsoon,
3. *Tellinides* after monsoon.

Fig. 2 shows the comparison of frequency of Bivalves during the two periods of sampling. Based on this graph frequency of Bivalves before monsoon was 6226 ind/m²and their frequency after the monsoon was found to number 1901 ind/m². The average frequency of Bivalves in different stations in all periods of sampling is shown in fig. 3. Considering results station-wise (station-to-station) and annually, station No. 5 was found to have the highest frequency, having annual frequency rate (number) of 3527 ind/m²; and station 2 scored lowest with 50 ind/m².

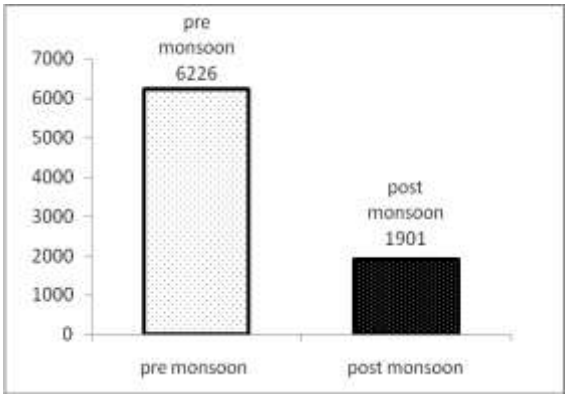

Fig. 2. Comparison of Bivalves' Frequency before and after monsoon in all sampling Stations.

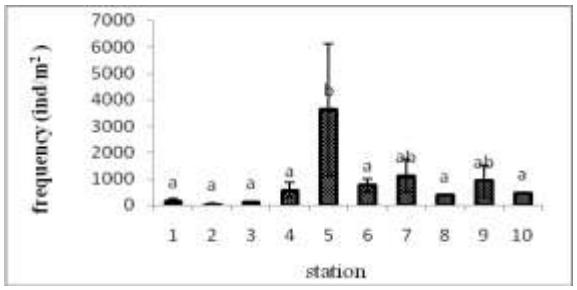

Fig. 3. Average of Frequency of Bivalves in a whole year according to Sampling Stations. *Dissimilar Letters are a sign of significance at 5% Level.

Regarding location-wise spreading of Bivalves before monsoon station 5 scored the highest with 3567 ind/m²and Station 2 scored 43 ind/m²as the lowest. After monsoon period station No.7 scored the highest number: 1003 ind/m² and station 2 scored lowest with 7 ind/m². Bivalves frequency/rampancy in a station-wise manner for periods both before and after monsoon is shown in Table 1.

Table 1. Comparison of Frequency of Bivalves (ind/m²) before and after monsoon for each separate sampling station.

Station number / Time	1	2	3	4	5	6	7	8	9	10
Pre monsoon	137	43	69	490	3567	547	113	170	887	203
Post monsoon	20	7	43	77	60	207	1003	205	30	250

Also, the comparison of diversity of assemblage richness index and 'Shannon' Index in the two sampling periods are shown individually and station-wise in fig. 4 and 5.

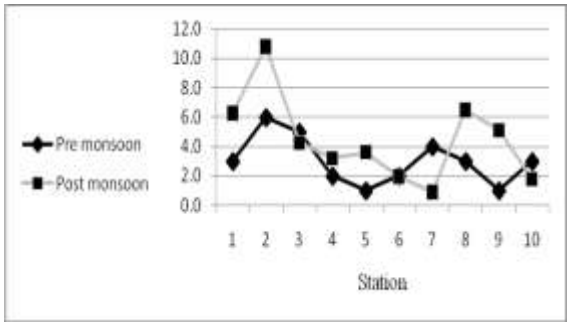

Fig. 4. Pattern of Changes in Genus Richness Index of Bivalves in separate stations.

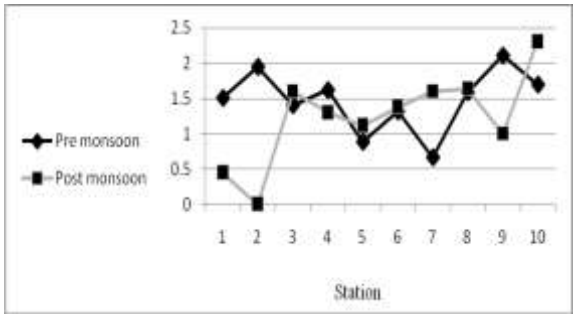

Fig. 5. Pattern of changes in Shannon Index for Bivalves in separate stations.

Table 2 presents results of calculation of indices including assemblage richness index (R) ,diversity index, which includes 'Simpson Index (λ) and 'Shannon' index (H') and the Evenness Index (E) for each of the sampling periods.

Table 2. Comparison of Indices for Richness, Diversity and Evenness of Bivalves in the Region under Study.

Indexes	Bivalves	
	Pre monsoon	Post monsoon
Shannon (H´)	1.6	2.1
Simpson(λ)	0.4	0.2
Evenness (E)	0.4	0.6
Richness (R)	0.5	1

Table 3 presents the average values of physical and chemical factors including water temperature, salinity, PH, dissolved oxygen and the granule count of sediments for each station for every one of the sampling periods.

Considering the effect of sampling season on Mollusk's frequency, the experiment T (T Test) showed that the difference in Bivalves' frequency in the two conditions: 'before monsoon' and 'after monsoon' is statistically

significant (P< 0.05). The One-way variance/diversity analysis results showed significant annual statistical difference between the numbers of Bivalves found in station 5 (frequency) in comparison to other station (P<0.05), and such significance has not been found in other stations (P>0.05).

Table 3. The Level of Physical and Chemical Parameters and Particle size Determination of Sediments in Separate Stations in Sampling Periods.

Station number	Temperature (°c)		Salinity (g/l)		pH		Dissolved oxygen (mg/l)		Clay%		Silt%		Sand%	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
1	36.1	25.4	36.9	37.5	8.3	8.03	4.1	5.05	25.4	34.6	69.4	54.7	5.2	10.7
2	25.3	25.7	36.7	37.2	8.4	7.9	4.5	4.6	41.4	42.6	55.2	52.7	3.4	4.4
3	25.9	25.5	36.8	36.7	8.4	7.9	5.6	3.2	29.4	33.3	66.6	63.7	4	3
4	25.1	24.9	36.7	36.7	8.3	7.9	5.2	4.7	25.4	27.3	71.4	65.7	3.2	7
5	24.5	24.2	36.6	36.5	8.3	7.8	5.9	5.4	22.4	37.3	70.9	59.7	6.7	3
6	24.8	24	36.6	36.6	8.3	7.8	5.6	4.9	13.4	27.3	75.9	63.7	10.7	9
7	25.1	24.8	36.5	36.6	8.3	7.9	5.5	4.2	16	15.3	72	67.7	12	17
8	23.9	24.9	36.6	36.6	8.1	7.9	4.3	4.1	12	39.3	51.3	49.7	36.7	11
9	24.5	25.3	36.6	36.7	8.1	8	4.7	4.5	10	13.3	63.3	60.7	26.7	26
10	24.6	25.5	36.6	36.7	8.1	7.9	4.1	4.7	11.4	13.3	73.9	55.7	14.7	31

Before monsoon period between station 5 and other stations a 5% difference was noticed. Also, between station 7 and other stations there was a 5% difference for the after monsoon period (P<0.05) whereas there is no other significant difference among other stations (P>0.05). The effect of changeable causes such as station and time of sampling on frequency and density (congestion and compilation) of Bivalves via bilateral Variance/diversity Analysis (ANOVA) were statistically tested.

The results of this test shows that the difference level for the cause: "station-Time" for the above-mentioned groups are significant. Also the obtained results from this test shows a significant correlation existing (Pearson) between pH and dissolved Oxygen with frequency of bivalves at a level of 5% (P<0.05; r = 0.2). Also a strong correlation is found between depth and frequency of Bivalves at a level of 1%, which correlation is shown in all stations (P<0.01; r = - 0.4) (refer to Fig. 6 and 7). There is a significant correlation between frequency / numbers of Bivalves and silt grains (P<0.05; r = 0.2).

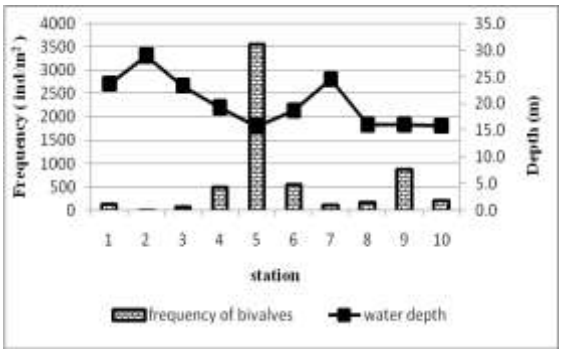

Fig. 6. Bivalves Frequency Distribution in consideration of Water Depth in different stations Before Monsoon.

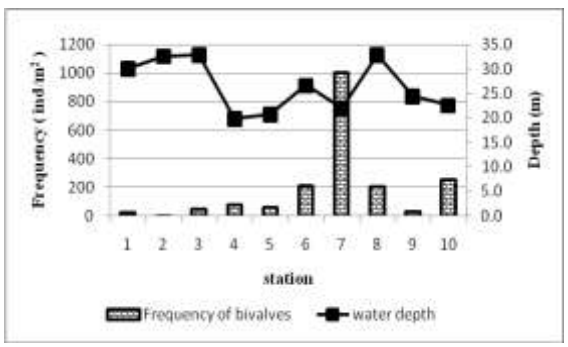

Fig. 7. Bivalves Frequency Distribution in consideration of Water Depth in different stations After Monsoon.

Discussion

Study and review of Benthic Congregational Structures in different marine ecosystems has allocated to itself a special rank among investigations of ecologic Study of marine animals. The importance of Benthos in oceans and sea, not only for their presence only as the major food supply/chain for seabed fishes, but also their presence or lack of their presence of some types/species of Benthos such as Bivalves in some waters is a sign or mark of water quality in terms of the pollution level or lack of pollution. (Jessen and Sparck, 1949).

Decrease in frequency of Benthos assemblages during monsoon has been proven in almost all the previous studies that were performed in the Indian Ocean and its coastal waters as well as Chabahar gulf (Parulekar and Dwivedi, 1980), (Harkantra *et al.*, 1982), (Prabhu *et al.*, 1993), (Ansari *et al.*, 1994) (Nikoeyan, 1997).

During monsoon season when Indian Ocean's south-west winds start blowing at speeds sometimes reaching to 35-40 knots, the affected waters become turbulent with very high waves and as a result of the sechanges the sea bed stability is disturbed, ultimately causing erosion of sediments and a decrease in Benthos assemblage density. This change could be due to such events as death, migration to other regions or other factors. On the other hand the internal severe currents and turbulent waters during monsoon will cause many marine animals, inclusive of Mollusks to be removed and driven into deeper waters, in which case their vulnerability in being hunted by other sea animals will be increased (Suresh *et al.*, 1992).

Therefore, it could be said that the Indian Ocean's south-west monsoon has an important role in expansion and assemblage density of fauna-benthos in the coastal waters of the Indian Ocean including the Oman Sea. The present study of the T-test results show a significant difference between the frequency of Bivalves before and after monsoon period ($P<0.05$).

The density and the location expansion of the Bivalves in Oman Sea indicate that the highest density exists in stations having sea-beds mostly composed of loam and silt (Stations 5 and 7). Most experts believe that given the conditions of non-disturbance in environmental factors, then the material-type of sediments is one of the determining factors causing displacement or dispersing and gathering (density) of Benthos marine animals (Lawrence & Walters, 1979), (Gray, 1981), (Alongi, 1989), (Harkantra and Parulekar, 1994), (Nikoeyan, 1997), (Dauvin, 2004), (Schmid, 2006), (Karthikeyan, 2009).

In this present study, the least frequency of assemblage numbers was seen in station no.2. This finding is probably due to an increase of depth, being a feature of this station, and on the other hand it can also be due to sea-bed sediments' high clay content thereby decreasing the numbers of Benthos marine animals within the sea-bed.

The overall results of the previous studies regarding the ecology of Benthic animals indicate that density and numbers Benthic assemblages decrease with the increase of water depth and change in structure of the sediments (Vinogradov, 1962), (Harkantra, 1982), (Alongi, 1989), (Roweand Pariente, 1992), (Guzman, 1996), (Nikoeyan, 1997), (Ebrahimi, 2005), (Schmid, 2006).

The results of the present study show that the diversity of various groups of Mollusks in Oman Sea is considerable. This diversity regarding Bivalves in terms of numbers is greater after monsoon period than before monsoon period. Accordingly, there is an inverse correlation between Shannon diversity index and frequency (numbers), meaning that as frequency increases diversity decreases. Obviously the cause for the decrease in the Shannon index of Bivalves during pre-monsoon period has been due to the genus types and genera types belonging to Nuculidae and Lucinidae families, these being found in relatively large numbers/frequency. The diversity increase of

Macro-Benthos in after monsoon period has been shown by several studies which were performed within the water boundaries of the Indian Ocean. In one of these studies, done in coastal waters of Gangolli (Prabhu, 1993), situated in west coasts of India, spread/expansion of Benthos over time indicates that their genera diversity in the after monsoon period is increased. Comparing of Evenness Index (table 2) shows a maximum numerical index of 0.6 for Bivalves after the monsoon period (an increase of 0.2 from 'before monsoon period'). The above mentioned result indicates that Bivalves (among others) have a more uniform scattering (dispersion) after monsoon period. Also, Nikoeyan (1997) in his study of Chahbahar Gulf's Macro-Benthos found similar results, in which study he stated that the reason for their higher scattering/dispersion is probably due to their abundance and probably a more uniform scattering/dispersion of Bivalves of certain genera (among others), which have a greater resistance to environmental changes resulting and occurring after monsoon. Richness index is used to indicate the suitability of one station for growth of different genera, and usually the value of the index decreases whenever the relevant conditions of the environment becomes undesirable and unsuitable. The increase of genera richness after monsoon can be due to favorable biological and environmental conditions, where by the mixing of sea waters during monsoon period causes a renewal of food materials' supply, which factor together with sea-bed physical stability and enrichment of waters with dissolved oxygen content will cause an increase in Fauna-Benthos diversity in the after monsoon period. Jegadeesan and Ayyakkannu (1992) in their study of south-eastern coasts of India concluded that a decrease in diversity in sandy and gritty sea-beds is by far more than such decrease in clay-silt sea-beds, the reason being that the former is more prone to turbulence and erosion caused by severe monsoon current than (in comparison to) the latter sea-bed content /com-position under same turbulent conditions. In the current study as well, considering the Shanon diversity indices, it's concluded that the highest degree of these indices occur in stations where their sea-beds have a high percentage of clay-silt content. Considering the above finding it can be derived that changes in diversity indices in a given water ecosystem in consecutive time-periods are indicative of (natural) factors/changes causing upheavals in the environmental conditions of sea-beds. Therefore in ecologic studies, using diversity indices for describing environmental conditions, as being dominant on water ecosystems, should be considered as having a particular importance (as a method or criteria of study).

The result of correlation test existing between abundance of Bivalves and environmental parameters is indicative of correlation between abundance of Bivalves and dissolved Oxygen at a level of 5%. The interrelation between the water depth and Bivalves' numbers (abundance) , as found in most sampling stations in Oman Sea, shows an existing recognizable pattern in such a way that with increase in water depth their density is decreased.

In this present study of bivalves' abundance and depth, there is a noticeable strong correlation at a 1% level.

Similar results have been found in several studies such as Vinogradov (1962), Row (1992) and Guzman (1996), which have shown that both abundance and fauna-Benthos diversity in subtidal regions decrease with water depth. On the contrary, Gomes *et al* while they carried out some studies in continental shelf region of Cabo Frio in Brazil in 2005, they concluded that water depth had no effect, whatsoever, on density and diversity of Bivalves.

Schmid (2006) in his studies on variance of Macro-benthos in Laptev Sea has mentioned his views on effect of water depth on variance pattern of Macro-benthos. Rezaie Marnani (1995) in studying mollusks in some Iranian islands in Persian Gulf region has stated that probably decrease in diversity and lower frequency of mollusks is probably caused by

unsuitable conditions burdening the habitat such as increase in water pressure and decrease in light reaching the depths, which in fact control food supply. Nikoeyan in his reviews on density of Macro-Benthos in Chahbahar gulf region in Iran (1997) and Ebrahimi (2005) also proposed their views on the effect of water depth on density of mollusks.

The large and small sizes of grains (granule, pebbles or particles) forming the sediments is one of the important factors in studying expansion and gathering methods of Benthos. Change in composition of grain/granule sizes of sediments even at very short distances in a given region is effective in distribution and expansion of Benthos animals having minimal motions (Tabatabaie, 2009). In their midst, those sea-beds that are composed of silt or sand particles have higher concentration/density of mollusks (Mohammed, 1995). Mollusks are always inclined to choose sea-beds that make easy and greater burrowing/penetration into the seabed surface or seafloor substrate (Hossein Khezri, 2000). In this present investigation of Bivalves living in sea-beds composed of silt-particles there is weak correlation at a level of 5%. Pillai (1977) did extensive studies on Macro-benthos in Cochin Region and concluded that quality or kind of seabed composition has a considerable effect on density and variance of Fauna-Benthos. He also stated that density of Benthos is lessened in sea-beds made of clay. As noted density of Bivalves in station No. 2, which has a high percentage of clay, has decreased. In studies performed by Jegadeesan and Ayyakkannu in western coasts of India (1992) density and frequency of Macro-benthos in silt-sandy sea-beds has been reported. Dauvin *et al* (2004) have determined that kind of sediments in sea-bed and water depth are the most important factors affecting density and diversity of Macro-Benthos. Michael. K Schmid (2006) in his studies on distribution of Macro-benthos in Laptev Sea, stated that the kind of sea-bed is involved in the distribution pattern of Macro-benthos. His statement is as follows:

The sea-beds with the very small size of grains (granules) have very low diversity and Evenness index. Karthikeyan (2009) in his studies of Macro-Benthos in south-western coasts of India stated the effect of kind of sea-bed sediments on Fauna-Benthos' density. Nikoeyan in reviewing the Macro-Benthos in Chahbahar gulf concluded that the kind and size of particles of sea-bed are involved in determining density and diversity of mollusks. Thus in sandy sea-beds diversity and density of different Macro-fauna creatures such as mollusks is more than the clay and mud sea-beds, because bigger sized particles (sandy and sea-beds made of silts composites) are better suited for being a habitat of most mollusks.

In general it can be said that so far different factors as controlling parameters of frequency and expansion of Benthos assemblage have been reported in tropical and semi-tropical regions such as Persian Gulf and Oman Sea by the expert investigators. Among discussed factors such parameters like size of sediment particles (Schmid, 2006), water salinity (Pillai, 1977), water currents (Basson *et al.*, 1977), depth (Currie and Small, 2005) and water pollutants (Coles and Mc caine, 1990) have the highest effect on density and expansion of Fauna-Benthos in these regions. In such conditions determining the effect of one environmental factor alone on distribution and frequency of Benthos assemblages would not be free from ambiguity and defect. Whereas it is the totality and process of different environmental factors that have a considerable effect on diversity and diversity of Benthos animals.

Conclusions

It is concluded from the above study that multiple environmental parameter exhibited significant impact over the macrobenthic organisms in the in the Iranian Coasts of Oman Sea. Certain parameters such as salinity, water temperature, dissolved oxygen and pH were considerably influencing over macrobenthic density. No great variation was exhibited in the sediment composition. The role of community

interaction could not be ruled out completely regarding the lower values of macrobenthic density. In the future, more study should be carried out regarding the physico-chemical status along with macrobenthos in the Iranian Coasts of Oman Sea in general and macrobenthic Bivalves in particular to assess demersal fishery and to evaluate natural and anthropogenic stress.

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