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Research Article

Patterns of mollusks (Bivalvia and Gastropoda) distribution in three different zones of Harra Biosphere Reserve, the Persian Gulf, Iran

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Abstract

The diversity and spatial distribution of mollusks and their relationships between physico-chemical parameters of the water (temperature, dissolved oxygen, salinity and pH) and sediments texture (sand, silt-clay and TOM) in three different mangrove zones (deltaic mangrove, island mangrove and coastal mangrove) of Harra Biosphere Reserve were studied during two sampling seasons (August 2014 and January 2015). A total of 9 transect (27 stations) perpendicular to the coastline was selected to cover all over the study area. Counts of mollusks (bivalvia and gastropoda) with three replicate sediment samples were recorded from each zone and station. In this study, 32 different species of mollusk including 8 bivalves and 24 gastropods have been found and listed. Deltaic mangrove zone had more total abundance (636±342 ind m^{-2}) than all the other mangrove zones sampled and dominated by white clam (*Dosinia alta*) and snails (*Cerithidea cingulata* and *Asseminea* sp). Results from the two-way crossed ANOSIM showed that molluscan species composition (bivalvia and gastropoda) differed among various seasons and mangrove zones. Results from benthic samples illustrated that deltaic zone had the highest diversity (Shannon Wiener diversity: 1.45) and coastal zone had the lowest values (1.03) among these three zones. In conclusion, sediments texture, temperature, salinity and pH were the main physico-chemical factors determining dispersion of molluscan faunal communities in the study area. This result implied that the different mangrove types had different effects on the molluscan communities (bivalvia and gastropoda) at Harra Biosphere Reserve.

Keywords: Mollusc, Assemblage structure, Mangrove habitats, Spatial-temporal pattern

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Introduction

Mangroves are various types of trees and shrubs that are found at the intertidal zone in the tropical and subtropical regions where they grow up in conditions marked by high salinity, high temperature, increased evaporation, different degrees of tidal amplitudes and muddy anaerobic sediments (Nagelkerken *et al*., 2008; Kathiresan and Bingham, 2001). Despite the physical and biological vulnerability of these coastal areas, they support the rich biodiversity and facilitate feeding, generative, shelter and nursery grounds for a large number of marine and terrestrial living organisms (Sydenham and Thomas, 2003; Kathiresan and Rajendran, 2005). Mangrove ecosystems are also significant to people for different reasons, such as fisheries, culture, forestation, protection against coastline erosion and other local subsistence usages (Kathiresan and Bingham, 2001; Doydee *et al*., 2010)

The mangrove habitats maintain the different and exquisite communities of benthic organisms that range in size from the minute bacteria to larger (0.5< mm size) invertebrates termed as macrobenthos (Roberts, 2006). Benthic living beings include an important element that affects the fertility of the habitat to a greater extent (Thilagavathi *et al*., 2013). Benthos contributes in the processes of nutrient cycling, which in turn promotes primary productivity (Samidurai *et al*., 2012). Molluscan communities are one of the most important dominant groups of benthic macrofaunain the mangrove zones and have many effects on the structure and function of mangrove systems (Nagelkerken *et al.,* 2008). They have been distinguished as a major connector in the transfer of organic material from mangrove habitats to the third trophic level (Kieckbusch *et al.*, 2004; Persic *et al.*, 2004; Alfaro, 2006). Also diversity and abundance of mollusks have been utilized as a bioindicator of ecosystem health and mangrove forest management (Bryan *et al*., 1983; Amin *et al*., 2009). The distribution of mollusks species in mangrove ecosystem can be influenced by different environmental factors such as salinity, dissolved oxygen, pH, and sediments texture, which has many effects on the function of macrobenthic assemblages (Barroso and Matthews-Cascon, 2009; Rezende *et al*., 2014). In intertidal communities, the zonation of mollusks can be consequence as a physiological stress gradient because of environmental circumstances such as tidal changes, grain size, the forest zoning and exposure duration (Dittmann, 2000; Tanaka and Maia, 2006).

Although there is a wealth of knowledge on the importance of mangrove forests on a global scale (Netto and Gallucci, 2003; Saravnakumar *et al*., 2007), there are a few specific quantitative data on the diversity and density of mollusks in mangroves (Jiang and Li, 1995; Printrakoon *et al*., 2008). However, some researchers have indicated differences in molluscan community assemblages in relation to the function of mangrove distribution. For example a study carried out by Rodigues *et al*. (2016) revealed that the mollusk composition patterns were different between the two mangrove creeks at the Amazon Coast of Brazil. Samidurai *et al.* (2012) reported that diversity of molluscan communities in riverine mangrove is much higher than the developing and island mangroves because of hydrographical condition, nutrients, and grain size. Ya-Fang *et al.* (2012) also have found distinctive molluscan community composition within three different types of wetlands such as mangrove arbor, emergent vegetation and seaweed as mangrove habitats had the highest number of molluscan taxa. They have also reported that differences in molluscan assemblages through these three study areas have been correlated with environmental parameters. Zakaria and Nawaz Rajpar (2015), detected that the pristine condition of habitat (*i.e.,* no disturbance) and complicated structure of vegetation are the main driving force that influence the dispersal and diversity of crustacean and mollusk.

Some studies in Iranian mangrove environments have been performed to study molluscan community which excludes our study area (Ghasemi *et al*., 2011; Safahieh *et al*., 2012; Aghajanpour *et al*., 2015). Aghajanpour *et al*. (2015) have found mobile gastropods are as the dominant macrofauna related with intertidal mangrove trees. Moreover, comparative investigations between two mangrove habitats of Iran have shed light the differences in benthic (only gastropods) density associated with the different kinds of mangrove ecosystems (Ghasemi *et al*., 2011). Soleimanirad *et al*. (2011) have been investigated the population ecology of macrofauna in Gabrik mangrove creek. The results illustrated that bivalves were the densest group of macrofauna that rose from mouth to the end of creek. Kamrani *et al*. (2012) also have described that the development of small bridges influenced the density and distribution of macrofauna into Basatin mangrove creek. Danehkar (2001) also has investigated the interaction of *Avicennia marina* trees and gastropoda fauna in mangrove forest of Qeshm and Khamir regions. Fundamental information, observing programs, and experimental trials are required before ecological assessment to provide ecological value of the Iranian's mangroves. Specific goals were (1) to investigate the abundance, diversity and composition structure of molluscs in various mangrove zone (islands, coastal and deltaic mangrove), (2) to analyze relationships between community structure and different environmental conditions, and (3) to establish a foundation for future biomonitoring activities in Harra Biosphere Reserve. It is a first step for assessing the relative significance of habitats with different structures and complication in Iranian mangrove ecosystems.

Materials and methods

The study site

The present study was performed at the Harra Biosphere Reserve (Laft-Khamir mangrove forest) with 85686 hectares (36°40' to 37° and 55°21' to 55°52' E)

(Fig. 1) in the northern parts of Persian Gulf. Ramsar convention has announced this region as an international wetland and called it Khouran Straits (Harrington, 1976).

It includes the largest mangrove species of *A. marina* in the Persian Gulf coastlines and, therefore, it would propose a center of biodiversity in Iran. Mangroves are scattered throughout the study area in a different of habitats. There is a separate mangrove zonation pattern (i.e., deltaic mangrove, island mangrove and costal mangrove) in the Harra Biosphere Reserve based on the hydrological conditions (Vahidi *et al*., 2019). Deltaic mangrove zone (2163ha) is joined to the Persian Gulf open waters from one side and Mehran River delta from another side. It is a dynamic area of mixed-water flow and salinity. Island mangrove zone is linked to the Persian Gulf from all ~~sides~~ around. It has the most spatial spreading in the study area (3425ha). Coastal mangrove zone (2035ha) is connected to the Persian Gulf from one direction and also limited by coast.

The tidal regime of study area is semi-diurnal; with a minimum and maximum tidal range of 0.3 m and 4.6 m, respectively. The differences in mangrove zones and high biodiversity turn region a great place to study macro- benthic community composition throughout various gradients.

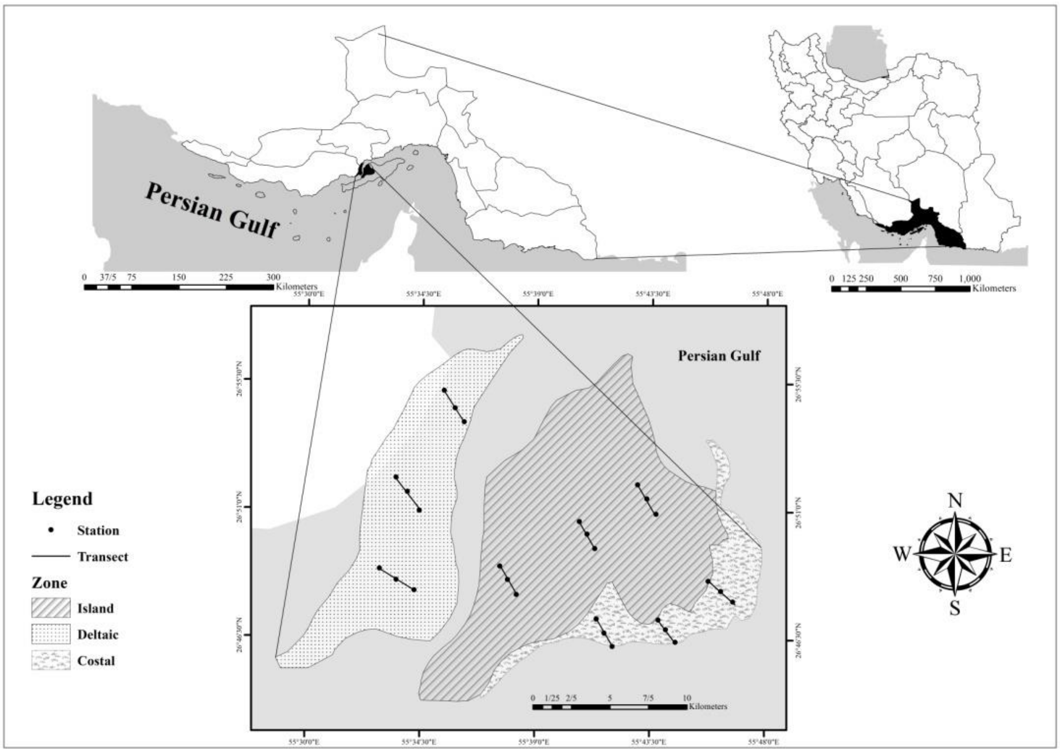

Figure 1: Map of the sampling sites at Harra Biosphere Reserve, northern Persian Gulf. Transect lines are shown within three zones across different habitats.

Field sampling

As the southern part of Iran has two natural seasons (cold and warm seasons) (Alijani, 1998), sampling was done at the climax of every natural season {as defined by climatological parameters, e.g., the warmest (August 2014) and the coldest (January 2015) months of the year} at the time of high tide at the sampling areas during the study period. The sampling was done during midday. Within each mangrove zone (deltaic, island and coastal), three transect lines were located perpendicular to the coastline. Then three stations have determined in each transect (Totally 27 stations in 3 mangrove zones). Geographic situations of each station and time of sampling were registered by hand-held GPS. Ekman Bottom Grab (225 cm^2) was applied to collate sediment samples for sediment grain size and in faunal analysis. Three replicate sediment samples were removed from each zone and station during each sampling season for grain size analysis and to measure total organic material. Particle size measurement of sediment has gained by mechanical sieving or with a Horiba LA-950 laser particle size analyzer (LA-950, Horiba). Analysis of total organic matter (TOM) was done out by burning sediment in oven at 450 °C for 5 h (Neria and Hopner, 1994). Measurements of water temperature, dissolved oxygen, salinity and pH were registered at each of the 27 sampling stations to recognize relative differences among stations during each sampling season (APHA, 2005).

Mollusks were sampled in August of 2014 and January 2015. Three replicate sediments were collected for mollusks (macrofauna: only bivalvia and gastropoda) within each zone at each station. All samples have been separated through a 0.5 mm mesh. Then the species were fixed by 10% formalin. After transferring the samples to the lab, species were colored by rose Bengal (1 g L^{-1}) (Mistri et al., 2002). Counts of all mollusks were registered, following species identification to the lowest probable taxonomic level using accessible reference texts. Typically, the lowest taxonomic level was species (Smythe, 1982; SubbaRao *et al*., 1992; Bosch *et al*., 1995; Hosseinzadeh *et al*., 2001). The species were identified by Olympus sz60 stereomicroscope.

Data analysis

Mollusks species collated from the sediments were identified and listed. biodiversity measures such as Shannon Wiener diversity (H), Pielou’sspecies evenness (J) and Margalef species richness (D) were calculated separately for each mangrove zone. The variation of environmental variables such as water temperature, salinity, pH, dissolved oxygen, sediments texture (i.e., sand%, silt-clay% and TOM%) and diversity Indices between the three mangrove zones were analyzed using one-way ANOVA and Tukey's post hoc test.

Global and pair-wise analysis of similarities (two-way ANOSIM) on the basis of Bray–Curtis similarity matrix were calculated applying fourth-root transformed abundances of mollusks to investigate the differences in the species composition between mangrove zones (Clarke and Gorley, 2006). Principal Components Analysis (PCA) was utilizing to find relationships between variation in spatial patterns of the most abundant taxa and environmental factors (Leps and Smilauer, 2003). Statistical package (SPSS-19.0), software of PRIMER (Ploymouth Routines In Multivariate Ecological Research v. 6) and CANOCO programme (v. 5.0) were used for statistical analyses.

Results

Environmental parameters

In the Harra Biosphere Reserve, spatial differences of physical factors throughout the study period resembled, showing the properly-mixed nature of this marine ecosystem. Water temperature ranged from 22.3 to 24.1°C in winter and 32 to 37.8 °C in summer. Salinity and dissolved oxygen measurements ranged from 34ppt to 47 ppt and 5 to 9.2 mg L^{-1} respectively. The value of pH was measured from 8.2 to 8.7 during study period (Table 1). A brief description of the one-way ANOVA and variation of the physicochemical factors among the 3 mangrove zones is determined in Table 1. Based on the results only pH showed significant difference (p<0.05) between the deltaic and coastal zones.

Table 1: Summary of the physicochemical parameters of water between the 3 mangrove zones (deltaic, island and coastal) in the Harra Biosphere Reserve .

Physicochemical parameters	Deltaic zone	Island zone	Coastal zone
Temperature (°C)	29.17 ± 6.59^{a} (22.5-37.3)	29.47 ± 6.96^{a} (22-37.8)	28.34 ± 5.57^{a} (22.4-34.7)
Dissolved oxygen (mg L^{-1})	7.53 ± 1.03^{a} (6.1-8.7)	7.68 ± 0.90^{a} (6.2-8.8)	7.31 ± 1.54^{a} (5-9.2)
pH^{*}	8.53 ± 0.07^{a} (8.4-8.7)	8.49 ± 0.08^{ab} (8.3-8.6)	8.43 ± 0.10^{b} (8.2-8.6)
Salinity (ppt)	40.5 ± 4.52^{a} (34-47)	39.88 ± 4.83^{a} (35-47)	39.88 ± 3.23^{a} (36-46)

Note: Values are mean±SE, range in parenthesis. Different lower case letters in a row define significant differences (p<0.05) indicated by Tukey's pairwise significant difference test.
∗shows significantly counted P value found by ANOVA.

Organic content was the highest in coastal, while deltaic zone has the least. The sediments texture in terms of sand (%), silt-clay (%) were 2.89-70.68 and 29.32- 97.11, respectively (Table2). Silt-clay was most abundant in the coastal zone, while sand was dominant in deltaic zone. One-way ANOVA resulted in non-significant differences among zones (p>0.05) for all sediment characteristics.

Table 2: Mean (±SE) values for sediment characteristics (grain size, and TOM) within three mangrove zones (deltaic, island and coastal) in the Hara Biosphere Reserve.

Sediment texture	Coastal zone	Island zone	Deltaic zone
Total organic matter (%)	5.11±0.85 (2.26-9.43)	4.9±0.1 (1.65-7.05)	3.93±0.07 (1.65-5.65)
Silt-clay (%)	77.35±11.22 (82.8-96.36)	71.47±15.86 (29.32-95-77)	70.06±19.06 (41.47-97.11)
Sand (%)	22.64 ±11.22 (3.64-63.99)	28.52 ±15.86 (4.23-70.68)	29.93±19.06 (2.89-53.58)

Community structure

The mollusk assemblage in Harra Biosphere Reserve was found to be rich in species, with a total of 32 species distributed among 23 families recorded in the pilot and surveys (Table 3). Gastropods are dominated in the mollusk fauna (24 species) and contributed numerically up to 61% of the population. Bivalves consist of 8 species and contributing 39% of the mollusk population (Fig. 2a). The percentage composition of mollusk was calculated for each mangrove zone and presented in figures 2b-2d. According to the figures 2b-2d the most variation in percentage composition of mollusk was observed for baivalvia between three mangrove zones.

Table 3: Mollusk species recorded during the study experimental.

Faunal group	Family	Species	Deltaic	Island	Coastal
Bivalvia	Corbulidae	*Corbulamodesta*	*	-	-
	Arcidae		*	*	*
	Ostreoidae	*Saccostreacucullata*	*	*	*
	Tellinidae	*Eurytellinanatalensis*	*	*	-
		Serratinacapsoides	*	-	-
	Trapeziidae	*Trapezium sublaevigatum*	*	-	-
	Veneridae	*Phapiacor*	*	*	*
		Dosiniaalta	*	*	*
Gastropoda	Liotiidae	*Cyclostremaocrinium*	*	-	-
		Cyclostremasupremum	*	-	-
	Columbellidae	*Mitrellablanda*	*	-	-
		Mitrellamisera	*	*	-
		Anachismisera	*	*	-
	Assimineidae	*Assemineabedomeana*	*	*	*
		Assemineasp.	*	*	*
	Potamididae	*Terebaliapalustris*	*	*	*
		Telescopiumtelescopium	*	*	-
		Cerithideacingulata	*	*	*
	Stenothyra	*Stenothyraarabica*	*	-	*
	Calliostomatidae	*Calliostoma*sp.	-	*	-
	Trochidae	*Umboniumvestiarium*	*	*	-
	Babyloniidae	*Babyioniaspirata*	*	*	*
	Halosphaeriaceae	*Turitella*sp.	*	*	-
	Pyramidellida	*Turbonillalinjaica*	*	-	-
	Cerithiidae	*Cerithiumcerithium*	*	-	-
	Iravadiidae	*Lucidinelladensilabrum*	*	*	-
		Iravadiaquadrasi	*	-	*
	Epitoniidae	*Epitoniumpallasii*	*	*	-
	Littorinidae	*Littorariaintermedia*	*	*	*
	Amphibolidae	*Salinatorfragilis*	*	-	-
	Terebridae	*Terebra*sp.	*	*	-
	Onchidiidae	*Onchidiumtigrinum*	-	*	-

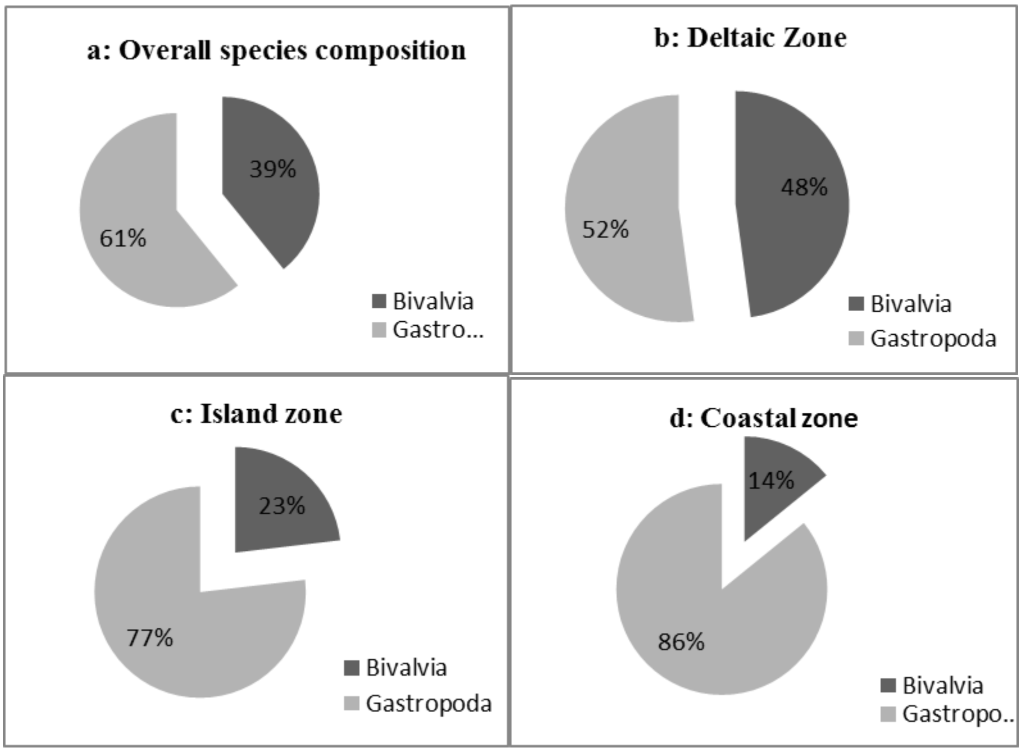

Figure 2: Percentage composition of mollusks in different mangrove zones.

Results from the mollusks samples collected within each of two sampling seasons (August 2014 and January 2015) show a generally consistent pattern (Fig. 3). Deltaic zone tended to have the highest total number (±) of individuals (622.8±146.8 ind m^{-2}) and total taxa (8± taxa m^{-2}) among all the locations sampled, followed by island zone, while coastal zone always had the lowest number (±) of individuals (121.1± ind m^{-2}) and taxa (3± taxa m^{-2}) throughout the sampling period. The snails, *Cerithidea cingulata* and *Asseminea* sp were present throughout zones and stations, but their abundance varied among habitats (Delta: 135.5±177.6 and 132.3±193.7 ind m^{-2}, respectively; Island: 59.9±93.5 and 63.8±55.8 ind m^{-2}, respectively; Coastal: 41±85.5 and 17.2±45.9 ind m^{-2}, respectively). White clam (*Dosinia alta*) generally was most common in delta (241.8±360.3 ind m^{-2}), while giant mangrove whelk (*Terebralia palustris*) were observed in higher abundances (±) in island (64.6±43.7 ind m^{-2}) zone. Also the snail *Littoraria intermedia* was most abundant (±) in coastal (17±8.4 ind m^{-2}) zone.

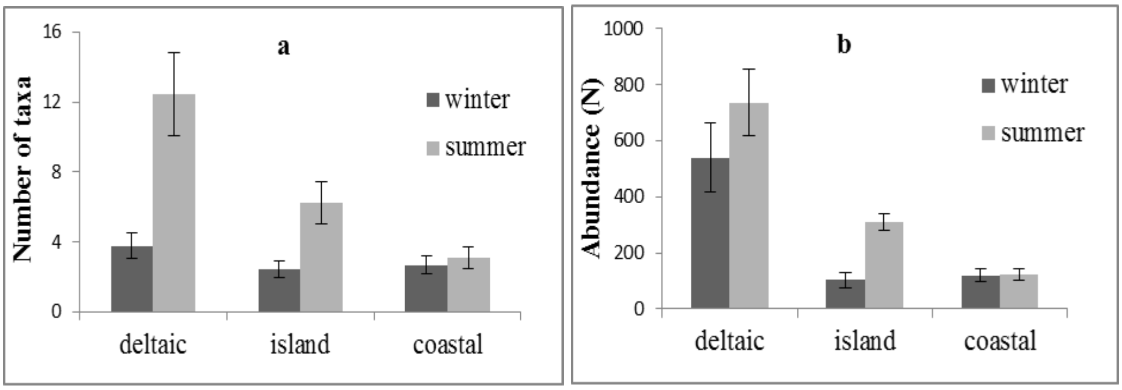

Figure 3: (a) Number of mollusk taxa and (b) total abundance (±) within three mangrove zones between two different season seasons (winter and summer) at Harra Biosphere Reserve.

The species diversity (H), evenness component (J′) and species richness (D) of the molluscan community composition were different in three mangrove zones (Table 3). Margalef's species richness index (D) and the Shannon diversity index (H') of the 3 mangrove zone were in the order of deltaic > island > coastal, and Pielou's evenness (J') was in the order of coastal>island>deltaic (Table 4).

Table 4: Molluscan community structures within three mangrove zones at Harra Biosphere Reserve.

mangrove zone	Molluscan community structural parameters				
	*Number of taxa	*Total abundance (ind m^{-2})	*D	J	*H
Deltaic	9[a]	637.1[a]	1.15[a]	0.74[a]	1.45[a]
Island	5[b]	207.1[b]	0.68[ab]	0.85[a]	1.21[ab]
Coastal	3[b]	121.0[b]	0.52[b]	0.89a	1.03[a]

Note. Values are mean. Different lower case letters in a row find significant differences (p<0.05) indicated by Tukey's pairwise significant difference test.
∗showes significantly calculated *P*value detected by ANOVA.
Shannon Wiener diversity (H), Pielou's evenness (J), Margalf richness (D).

The results of two-way crossed ANOSIM tests based on similarity matrices, showed significant differences in species composition of bivalvia among different seasons (ANOSIM Global R: 0.143, *p* value: 0.001) and mangrove zones (ANOSIM Global R: 0.09, *P* value: 0.01). Moreover, the pairwise tests detected significant differences in bivalves species composition between deltaic/island zones and deltaic/coastal zones (Table 5). Likewise, the results of two-way crossed ANOSIM indicated significant differences in gastropods species composition among different seasons (ANOSIM Global R: 0.06, *P* value: 0.04) and mangrove zones (ANOSIM Global R: 0.12, *P* value: 0.01). Significant pairwise differences were just seen between deltaic and coastal zones (Table 5).

Table 5: Results of two-way crossed ANOSIM testing the differences in mollusks (bivalvia and gastropoda) composition among different mangrove zones at Hara Biosphere Reserve.

Mangrove zone	**Bivalvia**	
	Pairwise *R*	***p* value**
Deltaic. Island	0.246*	0.01
Deltaic. Coastal	0.229*	0.02
Coastal. Island	-0/021 ns	0.64
Mangrove zone	Gastropoda	
	Pairwise *R*	*P* value
Deltaic. Island	0.088 ns	0.08
Deltaic. Coastal	0.122*	0.01
Coastal. Island	-0.013ns	51.1

ns nonsignificant, $p>0.05$
*$p<0.05$

Principal Component Analysis (PCA) carried out with the 13 most abundant taxa and the six environmental factors. The first two axis of the PCA ordination explained 99.13% of the variance in species–environment relationships. The results also indicated that the Eigen values for axes 1, 2, 3 and 4 were 0.948, 0.042, 0.005 and 0.002 respectively, and the percentage of total variance explained measured for PCA was 30%.

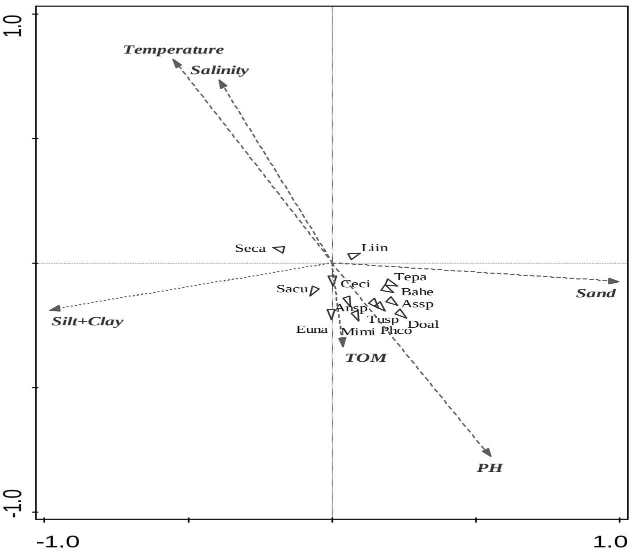

Figure 4: PCA ordination diagram exhibiting the position of the most abundant taxa in relation to environmental variables that has best explain for their distribution among sites. Dashed arrows are the environmental vectors representing temperature, salinity, TOM, silt-clay and sand, the empty arrows are the mollusk species. Arrows pointing in similar relative direction are correlated, and longer arrows indicate increasing values.

Key to taxa: Seca: *Serratina capsoides*, Sacu: *Saccostrea cucullata*, Bahe:*Barbatia helblingii*, Doal: *Dosinia alta*, Phco: *Phapia cor*, Euna: *Eurytell inanatalensis*, Tepa: *Terebalia palustris*, Assp: *Asseminea sp* ,Ansp: *Anachis misera*, Ceci: *Cerithidea cingulata*, Mimi: *Mitrella misera* Tusp: *Turitella* sp ,Liin: *Littoraria intermedia*.

Sand, silt-clay, temperature and salinity with longer arrows were the main environmental elements chosen by CANOCO (Fig. 5). The observation of the PCA plot detected that *D. alta, Asseminea* sp, *P. cor, Turitella* sp *and M. misera* were correlated with the lower temperature, salinity and pH (Fig. 5). Also *T. palustris* has found in habitats with the highest percentages of sand, while *L. intermedia* was detected in habitats with the lowest percentages of silt-clay.

Discussion

Numerous studies have been illustrated the high biodiversity and ecological importance of mangrove ecosystems throughout the world. In spite of the understanding of ecological, economic, and social importance of the Iranian mangrove forest (Vahidi *et al*., 2019; Dehghani *et al*., 2010) knowing little about the ecology and patterns of mollusk distribution in the Harra Biosphere Reserve. Therefore the present study has been designed focusing on some aspects of the ecology of these macrobenthic fauna and showed that they exhibited a distinct variation in relation to the different mangrove types.

Overall, the results of this study have indicated a detectable temporal and spatial distribution pattern of molluscan communities. The benthic mollusk community structure seems to be controlled by the physico-chemical and hydrobiological characteristics of the environment (Samidurai *et al*., 2012). Intertidal mollusks at the study area have been influenced by arduous environmental conditions like high temperature, salinity fluctuations, increased evaporation and tidal ranges. Within this study, 32 species of Mollusca (gastropods and bivalves) belonging to 23 families were recorded in the Harra Biosphere Reserve. The mollusks were dominated by the bivalve, *D. alta* and the gastropod, *Asseminea* sp strongly peaked during cold season. Mud whelk, *C. cingulata* and the mangrove snail, *Terebalia pal ustris* have been found to be promoted in the warm season. Other Iranian studies have been reported the presence of snails, *C. cingulata, Ethalia* sp, *Hydrobia* sp (abundant species), the bivalve, *Paphia galus* and *Barbatia helblingii* within mangrove habitats (Ghasemi *et al*., 2011; Safahieh *et al*., 2012; Aghajanpour *et al*., 2015).

Results from the faunal composition analyses show that the spatial variability was significant between 3 mangrove zones (Table 5). These distinct differences proved that, while some species of gastropods have been found throughout all mangrove zones (i.e., *C. cingulata* and *Asseminea* sp.), most species of mollusks have tendency special dispersal strategy. In fact it seems that the differences between the deltaic zone and other mangrove zones were mainly because of bivalve species. Kabir *et al*. (2014) have found out that bivalves were often supposed to be limited to a narrow seaward zone, because of limitation of feeding and the settlement of larvae. In current study, it was probably due to the relationship between mollusks and the sediments texture. For example in deltaic zone *D.*

alta, positively correlated with sand (r=0.50; *p*<0.05). Van Gils *et al*. (2012) reported that *Dosinia* is a suspension feeding bivalve, which prefers mangrove habitat type, where it applies its short siphons to feed on suspended materials. However, bivalves are clearly not capable of tolerating long periods of exposure to air and tidal fluctuations of salinity (Kabir *et al*., 2014). In fact the various mangrove habitats have different effects on distribution and behavioral adaptation of benthic macrofaunal species (Samidurai *et al*., 2012; Thilagavathi *et al*., 2013).

Typically, it has been illustrated that complex habitats structure, such as sea grasses and mangroves support higher diversities of macrofaunal species in comparison with to non-vegetated habitats (Premavani *et al*., 2014). To detect the diversity and distribution of mollusk species, macrofunal community indices were calculated and results were discussed. In this study the average value of Shannon–Weiner index was 1.24 for mollusks species. These moderate level of diversity values indicated mollusks community is under stress due to natural and/or anthropogenic factors. We detected that deltaic zone has the highest abundant, richness and diversity of mollusk among the three zones of Harra Biosphere Reserve (Table 4). This may be due to the fact that the deltaic zone is less negatively affected by anthropogenic impacts on the environment compared to the other zones. In addition, Danehkar (2007) has been observed the highest percentage canopy cover of mangrove trees occurring in deltaic zone of Harra Biosphere Reserve. Mohit and Appadoo (2009) have found that the diversity of macrobenthos was found to be associated with the mangrove canopy cover. It has been observed that the diversity of organisms from the phyla arthropoda and mollusca will increase in denser (>75% cover) mangrove communities. Biodiversity is necessary to assess ecosystem health because it affects key ecological processes (MaradanaTarakeswara and Aniel Kumar, 2016). In the present study, snails of the families Potamidae and Assimineidae were the most abundant mollusks in the mangrove forest. According to Macintosh *et al*. (2002) some families of gastropoda (e.g. Potamididae) could be used as indicators of ecological change as part of a long term environmental monitoring programe in mangrove ecosystems.

In muddy intertidal habitats, there are detected complicated relationship between environmental variables of sediment and the benthos that live in and on it (Samidurai *et al*., 2012; Dissanayake and Chandrasekara, 2014). These are expected to be reflected in powerful interaction between benthic organism and particular properties of the sediments (Compton *et al*., 2013), although some studies has detected these relationships to be rather weak (Chapman and Tolhurst, 2007). The result of PCA showed that sediment particle size (sand and silt-clay) with longer arrows was more significant factor than to others and also temperature, salinity and pH play an effective role in the distribution of some mollusk species (e.g. *D. alta, Asseminea* sp, *P. cor, Turitella* sp and *M. misera*) in their natural habitats. In fact the effect of high temperature and high salinity is more on distribution of species in comparison with other parameters such as TOM in the Persian Gulf (Mokhayer *et al.*, 2017). This might be a reason which explains the effect of Tom in PCA plot is rarely shown in the present study. Danehkar (2001) also showed that gastropods species number had a significant correlation with the mangrove tree trunk diameter, height of aerial roots and sediment pH in mangrove forest of the Qeshm and Khamir. Kamrani *et al*. (2012) have detected that pH is the main factor incharg of fluctuation in benthic macrofaunal composition in Basatin mangrove creeks**.** Libres (2015) found species distribution of macrofaunal communities are affected by the sediment types, temperature, and salinity in mangrove ecosystems of eastern Bohol. Generally, mollusks organisms in soft sediments have severely patchy dispersals (Kuk-Dzul and Díaz-Castañeda, 2016). At some other studies, variation in diversity or densities of these organisms have been correlated with observed environmental factors such as the inundation duration (Defeo and McLachlan, 2005), density of mangrove and sea grass plants (Lindegarth and Hoskin, 2001), or the sediment features (Kumar and Khan, 2013).

In conclusion, we contend that spatial variability in community structure of mollusca could be largely as a result of differences in sediment texture, temperature, salinity and mangrove zonation. The result of this study provides substantial evidence ~~that~~ those distinctive habitats influences differently to the biodiversity of mangrove stands, which can be compared with future studies to monitor environmental changes, and show the process of improvement or degradation of the system over.

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