Journal of the Persian Gulf
(Marine Science)/Vol. 7/No. 25/ September 2016/14/23-36

Low richness of hermit crabs community (Crustacea: Decapoda: Paguroidea) and high dominance of *Clibanarius signatus* in the intertidal zones of Larak Island, Persian Gulf, Iran

Mohammad Mehdi Zamani Jamshidi[1]; Jafar Seyfabadi[1*]; Alireza Mahvary[2]

1- Department of Marine Biology, Faculty of Marine Sciences, Tarbiat Modares University,P.O. Box 64414-356, Noor, Mazandaran Province, Iran

2- Department of Environment Hormozgan Provincian directorate, Bandar Abbas, Hormozgan Province, Iran

Received: June 2016 *Accepted: September 2016*

Abstract
Hermit crabs community in the intertidal zones of Larak Island were investigated through a seasonal sampling at five stations using random quadrate sampling method. Overall, seven species were identified and *Clibanarius signatus* was the dominant species, which showed high dominance over other species. Using Bray-Curtis cluster analysis for comparing seasonal abundance showed that except spring, other seasons form one cluster. A significant correlation was observed ($P<0.05$) between Simpson dominance index with temperature, dissolved oxygen and total organic matter. This study showed that the Simpson dominance index was high, primarily because of high dominance of *C.signatus* in intertidal zones of Larak Island. The high species dominance and low species richness in hermit crabs community in Larak Island could be because of unsuitable living conditions and lack of habitat diversity, such as muddy shores and mangrove forests.

Key words: *Hermit crab, Intertidal zone, Simpson's index, Magalef's index, Hormuz Strait*

1. Introduction

The importance of recognizing the biological dynamism of the coastal regions has induced many studies about identification and distribution of marine organisms (Mantelatto et al., 2004). Crustacea is a varied subphylum of arthropoda with a wide distribution in various marine habitats; Hermit crabs are a group of crustaceans in the superfamily Paguroidea, 1117 species of which have been identified so far (McLaughlin et al., 2010). Hermit crabs rely on gastropod shells for protecting their unsupported soft ventral parts. The shell acts as a shield against predators, body dehydration and physical stresses (Hazlett, 1981). The presence of diverse habitats are important as prerequisite to form high diversity for these crabs, in which, Rocky and muddy shores are more diverse habitats than sandy

[*] *Email: seyfabadi@modares.ac.ir*

shores in terms of paguroid crustaceans. Habitats with low heterogeneity of substrates, strong waves, high predatory pressure, loss suitable shells, low availability to organic nutrients and presence of organic pollutants form adverse circumstances to fitness of these crabs. These crabs are one of the significant animal populations in intertidal areas (Fransozo and Mantelatto, 1998). Studies on these crabs in terms of their inclusion in aquatic food chain, and among coastal birds, and also their significant role in cleaning the environment have been considered recently. These studies include a wide range of biological and ecological examinations of these animals, including their distribution (Hewitt, 2004; Rahayu, 2004) and its relationship with environmental factors (Imazu and Asakura, 1994; Osaw and Fujita, 2005; Ayres-Peres and Mantelatto, 2008), immigration (Bell, 2009), and ethology (Gherardi, 2006). Such studies have also been extended to the Iranian coasts of the Persian Gulf and Oman Sea (Moradmand and Sari, 2007; Kazmi et al., 2007; Naderloo et al., 2012; Asgari et al., 2012., Seyfabadi et al., 2013 a, b; 2014; 2015., Zamani Jamshidi et al., 2014., Kheirabadi et al., 2017).

Larak Island with an area of about 49 km2, and 38 km of coastline is located in the Hormuz Strait (Sheppard et al., 1992). Although, the systematic examination and ecology of hermit crabs in the Persian Gulf have been considered in recent years, their biodiversity and distribution pattern in Larak Island remains to be determined. Seven species have been confirmed using the existing holotype samples in the Zoological Museum of the Tehran University (ZUTC) (Seyfabadi et al., 2013a).

This is the only work carried out on the distribution patterns and some of ecological indices of these crabs in the isolated Larak Island. The aims of this study were: 1) to investigate the spatial and temporal distribution of hermit crabs, 2) to calculate some of ecological indices for the hermit crabs fauna of Larak Island, 3) to analyse the relationship of these indices with environmental variables and distribution patterns.

2. Materials and Methods

2.1. Study site

Larak Island is located in the Strait of Hormuz in the Persian Gulf (26° 51′ N, 56° 21′E). Five stations in the intertidal zone around the island were selected that covered representatives of all coastal habitats (sandy shores, sandy-rocky shores, coralline stations, residential station). Exact position of each station was recorded using GPS, after the first field survey (Fig.1, Table 1). The intertidal zone was further vertically divided into high, mid and low tidal sections.

Table 1: Location of sampling stations for hermit crabs in Larak Island (Persian Gulf)

Station description	**Longitude (E)**	**Latitude (N)**	**Station name/ (Station number)**
Rocky and sandy shores /Subtidal zone (coral reefs)/ Some covered by algae/ City station	E′22˚ 56	N′ 53˚ 26	Larak city/ (1)
Rocky and sandy shores	E′ 23˚ 56	N′53˚ 26	Larak Quay / (2)
sandy shores/Subtidal zone (coral reefs)	E′ 23˚ 56	N′ 52˚ 26	East coast/ (3)
Sand and gravel shores	E′22˚ 56	N′50˚ 26	Southcoast/ (4)
Sandy shores	E′ 19˚ 56	N′51˚ 26	West coast/ (5)

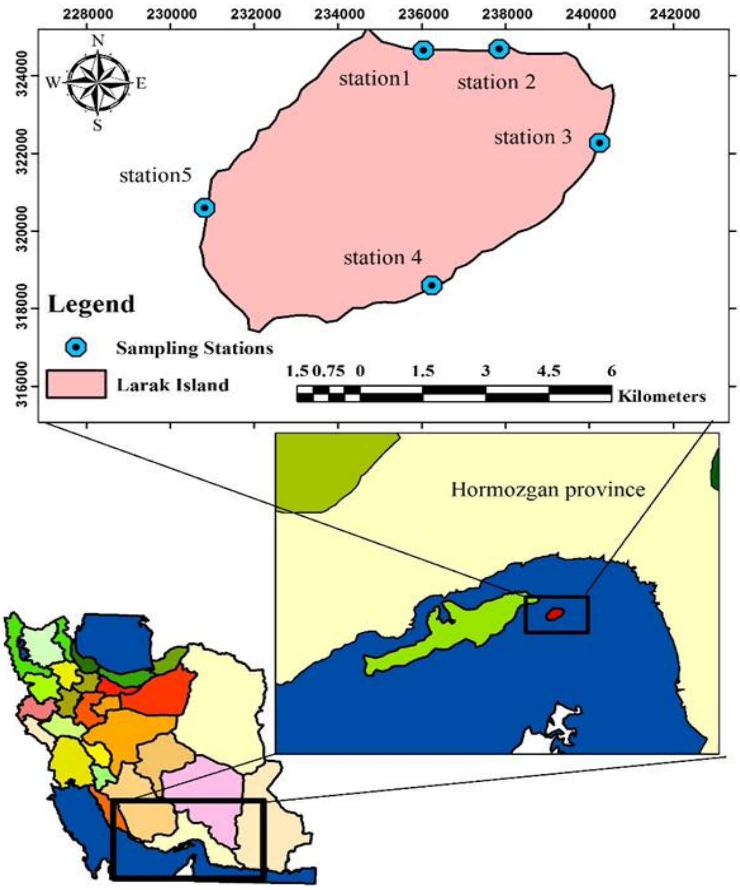

Fig. 1: Five sampling stations in the intertidal coast of Larak Island (Persian Gulf, Iran)

2.2. Sampling

Sampling was performed seasonally in the designated stations and the intertidal divisions from September 2011 to June 2012 (September, December, March and June), using random quadrate sampling. Three transects of 50 meters width perpendicular to the sea horizon were considered for each station, while each transect was divided into three tidal subsections (lower, middle, and upper sections). Considering the tidal time-tables, sampling was adjusted to be performed in the lowest tide with random quadrate (0.5 × 0.5 meter) throwing in each intertidal division (Wang et al., 2009). Each throwing was carried in three replications (totally 27 quadrates in each station). Night sampling was also performed for nocturnal species. The collected samples were labelled with distinction of section and station, and then, transferred to the Research Station of Marine Environment of Hormuz Island. Samples were placed in tap water in order to get the crabs out of their shells. The crab specimens were preserved in 70% ethanol within plastic tubes, labelled with sampling specifications (Echsel and Racek, 1976), and then transferred to the Laboratory of Marine Science Faculty (Tarbiat Modares University).

Total organic matter (TOM) was measured through titration method (Wackley and Black, 1943) by taking about 0.5 kg of sediment samples from two points in each station (Hahn, 1998). The bed slope was measured randomly in three points within each station with 0.01 degree precision by an inclinometer (SUUNTO). Environmental parameters (temperature, salinity and dissolved oxygen) were recorded seasonally in each station, using Horiba-U-10 system.

2.3. Ecological indices analysis

For ecological analysis of the hermit crabs, such indices as Simpson's species dominance and Margalef's species richness were calculated by the use of Excel and PAST softwares (Lamb et al., 2009; Gamito, 2010).

2.4. Simpson's dominance index analysis

$$D = [\Sigma n_i (n_i - 1)] / [(N (N – 1)]$$

2.5. Margalef's richness index analysis

$$I = (S – 1)/ \ln N$$

n= number of specimens in each species; N= total number of specimens; S= number of species.

2.6. Statistical analysis

The normality of data was examined by Kolmogrov-Smirnov test. Spearman correlation coefficient test was applied to exam the relationship between Simpson's species dominance index and environmental variables. All of them were performed by the use of SPSS 17.0 software. Cluster analysis (Bray-Curtis) for the comparison among seasons and stations was calculated using PAST software.

3. Results and Discussion

3.1. Frequency of the hermit crabs

Seven species were identified in total, using the deposited material in the Zoological Museum, University of Tehran (ZUTC) (Seyfabadi et al., 2013a) after examining 803 specimens collected from five stations in the intertidal zones of Larak Island, including *Clibanarius signatus* (775 specimens), *Diogenes avarus* (10 specimens), *Coenobita scaevola* (10 specimens), *Areopaguristes perspicax* (4 specimens), *Dardanus tinctor* (2 specimens), *Diogenes tirmiziae* (1 specimens), and *Dardanus lagopodes* (1 specimens). Results showed the hermit crab, *C. signatus* had high dominance over other species (Fig. 2). Furtheremore, the comparison between the hermit crabs fauna in Larak Island with species reports from other regions showed that all of these species have already been recorded in the Persian Gulf. Also, there is high similarity between its fauna with other Islands in the Strait of Hormuz (Table. 2).

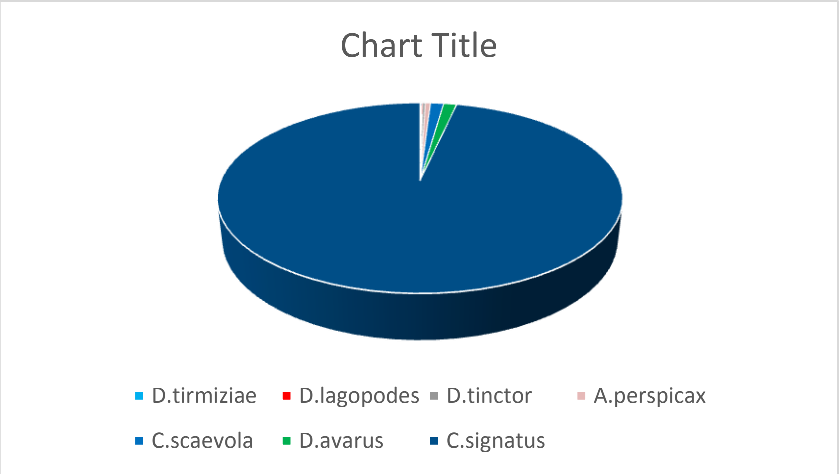

Fig. 2: Frequency of different hermit crabs in the intertidal zones of Larak Island (high dominance of *C.signatus*)

Table 2: The similarity among hermit crabs community in Larak Island with other regions

Species / Studied Area	**Hormuz Island** (Kheirabadi et al., 2017)	**Qeshm Island** (Asgari et al., 2012; Kheirabadi et al., 2016; Kheirabadi, 2017)	**Persian Gulf and Gulf of Oman** (Naderloo et al., 2012)
Clibanarius signatus	●	●	●
Diogenes avarus	●	●	●
Diogenes tirmiziae	●	●	●
Areopaguristes perspicax	●	●	●
Dardanus tinctor		*Dardanus* sp.	
Dardanus lagopodes			
Coenobita scaevola	●	●	●

3.2. Comparing abundance among seasons

Using Bray-Curtis cluster analysis for comparing seasonal abundance showed that except spring, other seasons form one cluster. The comparison of abundance among seasons showed that the most similarity is observed between summer and autumn (similarity =80%) (Fig. 3).

The comparison of abundance among seasons showed that the most similarity is observed between summer and autumn (similarity =80).

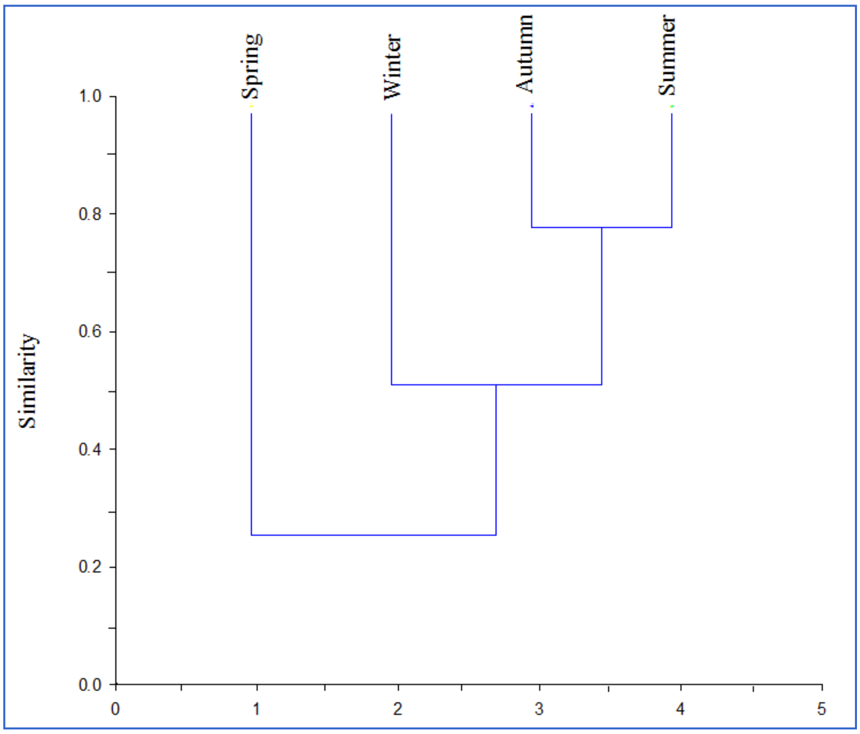

Fig. 3: Cluster analysis (Bray-curtis) for comparison the abundance of the hermit crabs community among seasons.

3.3. Comparing abundance among stations

The comparison of abundance among stations using cluster analysis (Bray-Curtis) showed that the most similarity is between stations 4 and 5 (similarity=95%), but stations 1, 2 and 3 form another cluster (similarity=43%) (Fig 4).

3.4. Environmental variables

All environmental variables for 4 seasons and 5 stations are presented in Tables 3-7.

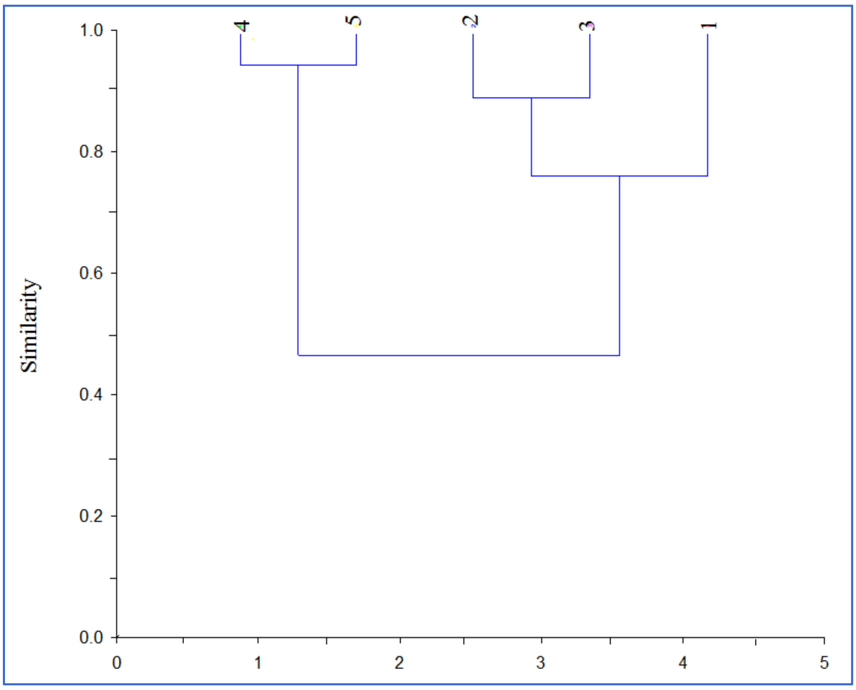

Fig. 4: Cluster analysis (Bray-curtis) for comparison the abundance of the hermit crabs community among stations.

Table 3: Environmental variables in the intertidal zones of Larak Island in summer

Station	Temperature (C)	Salinity (psu)	Dissolved Oxygen (mg/l)	TOM
Station 1	33.15	36.1	5.35	0.0042
Station 2	29.7	36.1	6.22	0.0033
Station 3	32.3	36	5.78	0.0096
Station 4	30.8	35.5	5.9	0.0029
Station 5	31.2	35.6	5.8	0.0027

Table 4: Environmental variables in the intertidal zones of Larak Island in autumn

Station	Temperature (C)	Salinity (psu)	Dissolved Oxygen (mg/l)	TOM
Station 1	22.7	36.6	8.61	0.0058
Station 2	23.5	35.4	8.08	0.0056
Station 3	23.6	36.7	8.04	0.0043
Station 4	21.4	36.8	8.9	0.0039
Station 5	23.1	35	8.58	0.0040

Table 5: Environmental variables in the intertidal zones of Larak Island in winter

Station	Temperature (C)	Salinity (psu)	Dissolved Oxygen (mg/l)	TOM
Station 1	23.4	36.8	8.4	0.0108
Station 2	23.6	35.8	7.95	0.0090
Station 3	22.7	36.9	7.93	0.0092
Station 4	22.2	36.9	8.7	0.0083
Station 5	23.3	35.4	8.38	0.0085

Table 6: Environmental variables in the intertidal zones of Larak Island in spring

Station	Temperature (C)	Salinity (psu)	Dissolved Oxygen (mg/l)	TOM
Station 1	27.7	35.45	6.66	0.0021
Station 2	27.3	35.7	6.74	0.0029
Station 3	28.2	35.3	6.46	0.0048
Station 4	29.4	35.3	6.22	0.0008
Station 5	29.6	35	6.16	0.0009

Table 7: Average of slope for the sampled stations in intertidal zones of Larak Island

Stations	Station 1	Station 2	Station 3	Station 4	Station 5
Slope	3.77	1	5.76	4.55	5.33

3.5. Simpson's index analysis

Simpson's dominance index indicated the highest species dominance was in cold seasons (especially in winter) and the least dominance in warm seasons (especially in spring) (Fig. 5). Station 4 in spring with zero dominance had the least level of dominance during the year. Numeric value for Simpson's dominance index in winter was 1 for all stations. This value was also recorded in some other stations and seasons where only one species was encountered. Spearman correlation coefficient test indicated that Simpson's dominance index had a significant negative correlation with temperature and significant positive correlation with dissolved oxygen and total organic matter (TOM) (Table 8).

3.6. Margalef's index analysis

Margalef's index indicated the highest species richness in spring and the least richness in winter. The station 2 and 5 had the highest and the lowest values of the species richness, respectively. Numeric value for Margalef's richness index was zero in winter for all of stations. This value was also recorded in some other stations and seasons where only one species was encountered (Fig. 6).

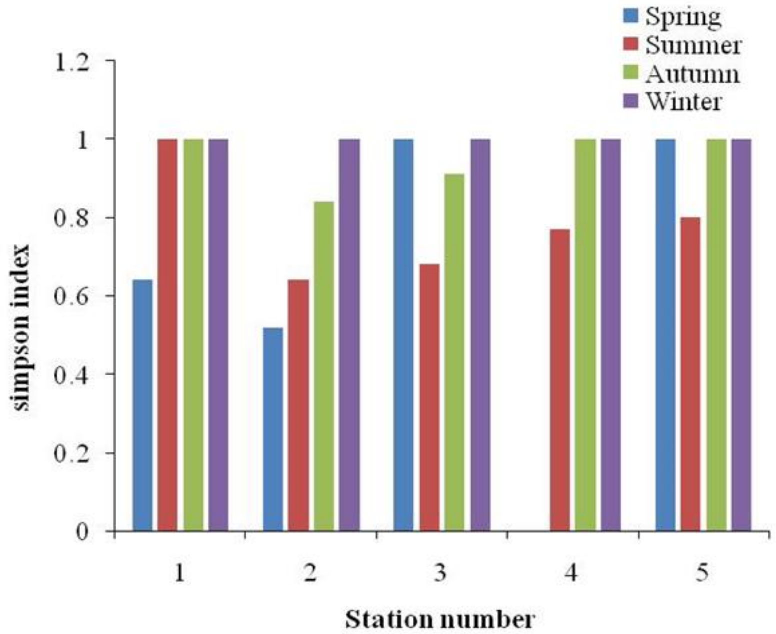

Fig. 5: Simpson's dominance index among various seasons and stations in Larak Island

Table 8: Correlation relationship between Simpson dominance index and environmental variables in intertidal zones of Larak Island ($P < 0.05$)

index	temperature	salinity	DO	TOM	Slope
Simpson	*0.521-	0.217	*0.477	*0.521	0.19

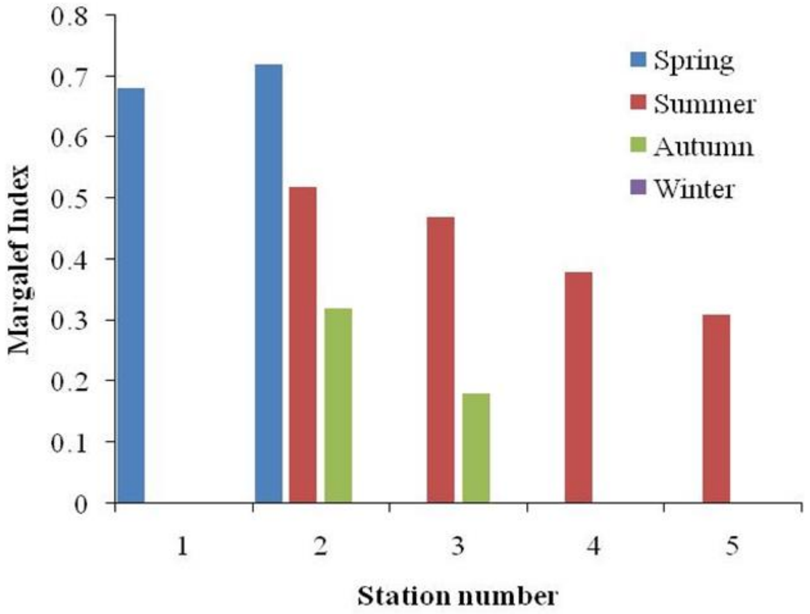

Fig. 6: Margalef's richness index among various seasons and stations in Larak Island

4. Discussion

In environments or conditions with adverse circumstances, the Simpson's value increases (numeric value increases toward 1), which is due to the fact that only a low number of resistant species can endure and the rest either emigrate or die. (Lamb et al., 2009). In the present study, the Simpson's values were high in several cases and the most values were found in winter due to only one species being present (Fig. 5). It may be due to the fact that tidal region of Larak Island in general is not a convenient habitat for hermit crabs, except for the predominant species, namely *C.signatus*, that can endure the inconvenient circumstances. In station 5 Simpson's species dominance index was greater than other stations (Fig. 5) which could be due to the adverse circumstances in this station such as loss of suitable shells (Seyfabadi et al., 2015), strong waves, loss of heterogenity and probably high predatory pressure.

Spearman correlation coefficient showed that species dominance had a significant relationship with temperature, dissolved oxygen and organic material (Table 8). As for the organic matters and its effects on the density, distribution and diversity of macrobenthic communities, including hermit crabs, can be regarded as a source for pollution and nutrient both (Meireles et al., 2006). The sharp increase in the hermit crab dominance in Larak Island may, therefore, be attributed to increased organic materials as source of pollution. Among the hermit crabs, only the dominant species, *C. signatus* tolerated the low temperature in winter primarily because of lower decomposition rate of organic matter which in turn causes large volume biomass compilation pollution (Tables 5 and 8). However, it seems that the main reasons for the high dominance of *C.signatus* are adverse circumstances (including low heterogenity of substrares, strong waves, low organic nutrients and high predatory pressure) and low richness of diverse habitats such as muddy shores and mangrove forests which these habitats are suitable to inhabit several species belong to genus *Diogenes*, as well as *Areopaguristes perspicax* and *Clibanaius signatus*; whereas, the coastlines around Larak Island is totally covered by sandy-rocky shores, which are just suitable to inhabit the hermit crab, *Clibanarius signatus*.

Spearman correlation coefficient showed that species dominance had a significant relationship with temperature, dissolved oxygen and organic material (Table 8). As for the organic matters and its effects on the density, distribution and diversity of macrobenthic communities, including hermit crabs, can be regarded as a source for pollution and nutrient both (Meireles et al., 2006). The sharp increase in the hermit crab dominance in Larak Island may, therefore, be attributed to increased organic materials as source of pollution. Among the hermit crabs, only the dominant species, *C. signatus* tolerated the low temperature in winter primarily because of lower decomposition rate of organic matter which in turn causes large volume biomass compilation pollution (Tables 5 and 8).

However, it seems that the main reasons for the huge dominance of *C.signatus* are adverse circumstances (including low heterogenity of substrares, strong waves, low organic nutrients and high predatory pressure) and low richness of diverse habitats such as muddy shores and mangrove forests which these habitats are suitable to inhabit several species belong to genus *Diogenes*, as well as *Areopaguristes perspicax* and *Clibanaius signatus*; whereas, the coastlines around Larak Island is totally covered by sandy-rocky shores, which are just suitable to inhabit the hermit crab, *Clibanarius signatus*.

Margalef's richness index indicates convenience of habitats for different species by expressing easiest concept of biodiversity, viz. the number of available species in a population. Numeric value of this index can be reduced in adverse environmental conditions (Gamito, 2010). The highest and lowest species richness was found in stations1, and 5, respectively and it was zero in winter due to only being one species in this season (Fig. 6). High species richness in station 2 is likely due to the lack of stress and abundance of gastropods' shells (Seyfabadi et al., 2015), while low species richness in station 5 can be attributed to rarity of gastropods' shells (Seyfabadi et al., 2015), strong waves and loss of heterogeneity. Species richness for hermit crabs community in Larak Island was lower than other investigation in the Strait of Hormuz including Hormuz Island (Kheirabadi et al., 2013) and Qeshm Island (Asgari et al., 2012; Kheirabadi et al., 2016; Kheirabadi, 2017), which is certainly due to lack of some types of intertidal ecosystems such as muddy shores and mangrove forests. Muddy shores and mangrove forests inhabit some hermit crabs including *Diogenes avarus* and *Areopaguristes perspicax* with high abundance.

The comparison of abundance among seasons using cluster analysis (Bray-Curtis) showed that summer, autumn and winter are located in one cluster and spring is located in the another cluster (Fig 3) which is consistent with Meirles et al (2006). Also, it showed that the most similarity is between stations 4 and 5 (similarity=95%), but stations 1, 2 and 3 are located in the another cluster (similarity=43%) (Fig 4), which may be due to loss of suitable shells (Seyfabadi et al., 2015), strong waves and loss of heterogenity in the stations 4 and 5 that cause the less density in these two stations. Abundance was the highest in winter, due to being only one species (Simpson dominance index=1). Statistical analysis via Spearman correlation showed this evidence may be related to low temperature, high amount of TOM and DO. TOM as a source of organic pollution can deter many of hermit crabs species, exception *Clibanarius signatus*. In addition to, this high predominance in winter may be related to the recruitment season of this species.

In this study, we conclude hermit crabs fauna in the intertidal zones of Larak Island in mainly dominated only by one species, *Clibanarius signatus* and predominant species (i.e. *C.signatus*) has high dominance over the other species in intertidal zones of Larak Island. Calculation of dominance by means of Simpson dominance index as the best ecological index for these adverse circumstances showed that intertidal zones of Larak Island is an adverse ecosystem for this superfamily to survive and reproduce. That was due to the fact that a coastline around Larak Island is mainly monotonous compare than other Islands in the Strait of Hormuz such as Hormuz Island and Gheshm Island.

Acknowledgements

The authors express their gratitude to Dr. Alireza Sari, Dr. Reza Naderloo and Mr. Hassan Salehi of the Zoological Museum, University of Tehran (ZUTC) for helping in the confirmation of the identified species. This project was supported by Tarbiat Modares University, Faculty of Marine Science and Marine Environmental Research Station at Hormuz Island.

References

Asgari M, Amini Yekta F, Izadi S. 2012. Dominant intertidal crustacean and gastropod species in Qeshm Island, Iran, Northern Persian Gulf. Marine Biodiversity Records, 1-8.

Ayres-Peres L, Mantelatto F L. 2008. Patterns of distribution of the hermit crab *Loxopagurus loxochelis* (Moreira, 1901) (Decapoda, Diogenidae) in two coastal areas of southern Brazil. Revista de Biología Marina y Oceanografía, 43(2): 399-411.

Bell J. J. 2009. Hitching a ride on a hermit crab home: Movement of gastropod shells inhabited by hermit crabs, Estuarine. Coastal and Shelf Science, 85 (2): 173-178.

Desroy N, Warembourg C, Dewarumez J. M, Dauvin J. C. 2002. Macrobenethic resources of the shallow soft-bottom sediments in the eastern English Channel and southern North Sea. Journal of Marine Science, 60: 120-131.

Echsel H, Racek M. 1976. Biologische Präparation. Translation by: Mollajafari, Kh. And Farhat, M. 1385. Shahid Beheshti University Press, Tehran. 353 P. (In Farsi).

Fransozo A, Mantelatto F. L. 1998. Population structure and reproductive period of the tropical hermit crab *Calcinus tibicen* (Decapoda: Diogenidae) in the region of Ubatuba, São Paulo, Brazil. Journal of Crustacean Biology, 18: 738–745.

Gamito S. 2010. Caution is needed when applying Margalef diversity index. Ecological Indicators, 10: 550-551.

Gherardi F. 2006. Fighting behavior in hermit crabs: the combined effect of resource-holding potential and resource value in *Pagurus longicarpus*. Behavioral Ecology and Sociobiology, 59: 500-510.

Hahn D R. 1998. Hermit crab shell use patterns: response to previous shell experience and to water flow. Journal of Experimental of Marine Biology and Ecology, 228: 35-51.

Hazlett B A. 1981. The Behavioral Ecology of Hermit Crabs. Annual Review of Ecology, Evolution, and Systematics, 12: 1-22.

Hewitt M A. 2004. Crustacea (excluding Cirripedia) of the Dampeir Archipelago, Western Australia. Records of Western Australian Museum Supplement, 66: 169-21.

Imazu M. Asakura A. 1994. Distribution, reproduction and shell utilization patterns in three species of intertidal hermit crabs on a rocky shore on the Pacific coast of Japan. Journal of Experimental Marine Biology and Ecology, 184(1): 41-65.

Kazmi Q B, Siddiqui F A, Kazmi, M A. 2007. Range extension of *Diogenes karwarensis* Nayak and Neelakantan, 1989 and a report on *Dardanus tinctor* Forskal, 1775 (Crustacea: Decapoda: Anomura: Diogenidea) from the Persian Gulf.

Turkish Journal of Zoology, 31:95-98.

Kheirabadi N, Seyfabadi J, Owfi F, Mahvary A. 2013. Diversity, dominance and richness of hermit crabs (Crustacea: spperfamily Paguroidea) in intertidal zones of Hormuz Island. Journal of Fishery and Aquatics (in Persian), 3(1): 9-20.

Kheirabadi N, Stekani S, Darini E, Kheirabadi, R. 2016. Identification and abundance of hermit crabs (Crustacea: Paguroidea) in the southern of Qeshm Island; first record of *Clibanarius virescens* (Krauss, 1843) in the Persian Gulf, ournal of Experimental Zoology (in Persian), 77-86.

Kheirabadi N. 2017. Identification and abundance of shell occupied by hermit crabs in the intertidal zones of southern Qeshm Island, Persian Gulf, Journal of Experimental Zoology (in Persian), 85-96.

Kheirabadi N, Seyfabadi J, Owfi F. 2017. Checklist of hermit crabs (Decapoda: Paguroidea) fauna from the Hormuz Island, Persian Gulf, 13(2): 171-181.

Lamb E. C, Bayne E, Holloway G, Shieck J, Boutin S, Herbes J, Haughland D.L. 2009. Indices for monitoring biodiversity change: Are some more effective than others? Ecological Indicators, 9: 432-444.

Mclaughlin P. A, Komai T, Lemitre R. Rahayu D. L. 2010. Annotated checklist of anomura decapod crustaceans of the world (exclusive of the Kiwaoidea and families Chirostylidae and Galatheidea of the Galatheoidea) part I- Lithodoidea, Lomisoidea and Paguroidea. The Raffles Bulletin of Zoology, 23: 5-107.

Meireles A. L, Terossi M, Biagi R, Mantelatto F. 2006. Spatial and seasonal distribution of the hermit crab Pagurus exilis (Benedict, 1892) (Decapoda: Paguridae) in the southwestern coast of Brazil, Revista de Biologia Marina y Oceanografia, 41(1): 87-95.

Mirbagheri Z. 2010. Density and Distribution of Hermit crabs in the Gulf of Chabahar. M.Sc thesis, Khoramshahr Marine Science and Technology University, Iran, 119 P.

Mantelatto F. L, Martinelli J. M, Fransozo A. 2004.Temporal-spatial distribution of the hermit crab *Loxopagurus loxochelis* (Decapoda, Diogenidae) from Ubatuba Bay, Sao Paulo, Brazil. Revista de Biologia Tropical, 52 (1): 47-55.

Moradmand M, Sari A. 2007. Littoral hermit crabs (Decapoda: Anomura: Paguroidea) from the Gulf of Oman, Iran. Iranian Journal of Animal Biosystematics, 3(1): 25-36.

Naderloo R, Moradmand M, Sari A, Turkay M. 2012. An annotated check list of hermit crabs (Crustacea, Decapoda, Anomura) of the Persian Gulf and the Gulf of Oman with five new records and an identification key to the North Indian Ocean genera. Journal of Zoological Systematics and Evolutionary Research, 88: 63–70.

Osawa M, Fujita Y. 2005. *Clibanarius ambonensis* (Crustacea: Decapoda: Anomura: Diogenidae) from the Ryukyu Islands, south-western Japan. Journal of the Marine Biological Association of the United Kingdom, 2: 1–8.

Rahayu D L, 2004. Hermit crab (Crustacea: Anomura) of the Anamas expedition 2002. The raffles Bulletin of Zoology, 11: 73-78.

Seyfabadi J, Motazedi M, Khodabandeh S, Kheirabadi, N. 2013a. Shell selection behaviour in the land hermit crab, *Coenobita scaevola* (Forskal, 1775) (Decapoda: Coenobitidae) from Larak Island, Persian Gulf, Iran. Zoology in the Middle East, 59 (1): 59–65.

Seyfabadi J, Zamani Jamshidi M. M, Mahvary-Habibabadi A. 2013b. Littoral hermit crabs (Crustacea: Decapoda: Anomura) of Larak Island, Persian Gulf, Iran. Iranian Journal of Animal Biosystematics, 9(2): 99-105.

Seyfabadi J, Kheirabadi N, Owfi F, Mahvary A. 2014. Shell selection behavior and spatial distribution of three species of intertidal hermit crabs from Hormuz Island, Persian Gulf. Zoology in the Middle East, 60 (4): 327–334.

Seyfabadi J, Zamani Jamshidi M. M, Mahvary A Kheirabadi N. 2015. Shell Selection in the Hermit Crab *Clibanarius signatus* Heller, 1861 from the Larak Island in the Persian Gulf. Journal of the Persian Gulf, 6 (19): 21-28.

Sheppard C. R. C, Price A. R. G, Roberts C. M. 1992. Marine ecology of the Arabian region: patterns and processes in extreme tropical environments. Academic Press, London, 336 P.

Wackley H, Black I. A. 1943. An examination of the method for determining soil organic matter and proposed modification of the chromic acid method. Soil science, 37: 29-38.

Wang X, Li X, Li B, Wang H. 2009. Summertime community structure of intertidal macrobenethos in Changdao Archipelago, Shandong Province, China. Oceanology and Limnology, 27: 425-434.

Zamani Jamshidi M.M, Seyfabadi, J, Mahvary, A. 2014. The survey of temporal and spatial distribution of hermit crabs in the intertidal zones of Larak Island (the Strait of Hormuz, Persian Gulf) (in Persian), 19: 113-123.