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Research Article

Identification and distribution of Gastropods in the east coasts of Qeshm Island (the Persian Gulf, Iran)

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Abstract

Gastropods are considered as the main molluscs of rocky shores and often show marked zonation patterns both horizontally and vertically. Biodiversity and distribution of gastropods were investigated at 8 stations on rocky shores of Qeshm Island during the coldest and warmest months January and August, respectively, in 2018. In the present study, 35 gastropod species were identified. The highest frequency of gastropod (550±345) was observed at S2 station (Tula 2) and the lowest one was observed at S8 station (Naz Island) (273±83.70). *Planaxis sulcatus* was found as the dominant species at all stations (%55.76). The results of the 3-way permutational (MANOVA) test showed that the species' structures of the gastropod community are different at various stations and during sampling months. The results of the nMDS test confirmed these differences in the structure and species composition of the gastropod population during two months. The highest diversity (Shannon index: 3.13) and species richness (Margalef index: 4.53) was observed at the S2 station and the lowest diversity (Shannon index: 2.73, Margalef index: 3.03) was observed at the S8station. According to the results of the SIMPER test, the highest percentage of participation in Bray-Curtis dissimilarity between the two months in summer and winter and at different sampling stations in terms of species density was related to *Planaxis sulcatus*. The structure of gastropod population at the studied stations can be influenced by the factor of seasonal changes.

Keywords: Biodiversity, Spatial Distribution, Rocky shores, Qeshm Island, Persian Gulf

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Introduction

More than 70% of the Earth's surface is made up of aquatic ecosystems, whose connections with each other play a major role in the global environmental system. Accordingly, the shores with a production of more than 80% of marine reserves also play a significant role in the formation of this system (Hamzavi *et al.*, 2012).

In this regard, shores and intertidal zones are included in the most important marine ecosystems. These intertidal zones are unique dynamic zones interacting with land, water, atmosphere, and human manipulation (Aghajanpour *et al.*, 2015). These intertidal zones with very valuable ecosystems such as rocky shores are considered as suitable places to many marine species for feeding, spawning, and passing larval stages. In addition, they are resting and feeding places for many birds. Moreover, these are important for supporting biodiversity and the food chain of the sea and coasts due to their high initial production (Fairbridge, 2004). Since these intertidal zones are unique, marine environments constantly exposed to the air, so the organisms living there should be able to be adapted to difficult conditions (Vazirzadeh and Arebi, 2011). These zones reflect the most common sessile species that can survive under difficult conditions and then continue to reproduce (Rahman and Barakati, 2012). These intertidal zones form the most diverse classes of mollusks, so that they have the most global distribution. Gastropod can be found in all marine habitats from deep ocean waters to high intertidal zones (Hickman *et al.*, 2001).

Gastropod communities have a special place in the coastal water food chain and are known as a very important link in both energy dissemination and food renewal in the sea. Sea Gastropod species in the Persian Gulf have very high frequency and diversity; therefore, they are important marine food sources for higher-level consumers (Al-Khayat, 2008). Besides consuming benthic fish, these organisms also play an important role in the feeding cycle of other marine organisms, including birds (Steffans *et al.,* 2006). Due to their presence in the seabed and low mobility, they can act as the best ecological indicators to determine the impact of destructive human activities on the coast (Abbott and Dance, 2000). In fact, due to the direct contact of gastropod with the seabed, including the bed surface and different layers of sediments, any change or anomaly in the bed would have a direct impact on the community of this benthos. Therefore, these organisms can be used as a relative indicator of bed quality in the Persian Gulf and other marine areas (Marsden and Baharuddin, 2015).

Various studies have been conducted on the biological fauna of the gastropod communities on the mud-sandy as well as rocky shores of the Persian Gulf and the Sea of Oman. For example, Ghasemi *et al*. (2011) in their study investigated diversity and frequency of gastropod in two different mangrove habitats. Also presented the first comprehensive list of gastropod identified in the intertidal shores of Bushehr (Kohan *et al.*, 2012).Amini Yekta *et al.* (2012) found that differences in species composition and structure of mollusk due to habitat structure, human disturbances, degree of exposure, substrate instability, and substrate types. Among different shores, rocky shores spaces due to their fixed bed and varied habitats including algae, rock cracks, spaces under rocks and water pools in intertidal zones have a great variety and density of gastropod. It is concluded that Barnacles, Sessile, and Gastropods are the dominant macrophones on rocky shores of Bushehr (Aghajanpour *et al.*, 2015).Furthermore, it reported some factors such as salinity, temperature, sediment, and zoning as the effective factors on the spatial distribution of gastropod population structure in Qeshm (Vahidi *et al.*, 2021). Baseline information, monitoring programs, and experimental trials are required before ecological assessments to provide adequate ecological value from the Iranian rocky shores. Increasing urbanization, recreational activities and expanding the exploitation of beaches represent major anthropogenic disturbances on rocky shores beaches leading to loss of biodiversity as well as good and services. The present research was designed to investigate and compare the key gastropods species within distinctive stations in the rocky shores of Qeshm Island. Given that the available information on the distribution and biodiversity of gastropod on the rocky shores of Qeshm Island is scarce, this study was conducted to provide a complete list of gastropod diversity in this region.

Materials and methods

Study area

The present study was conducted on the rocky shores of Qeshm Island in the north of the Persian Gulf (Fig. 1).

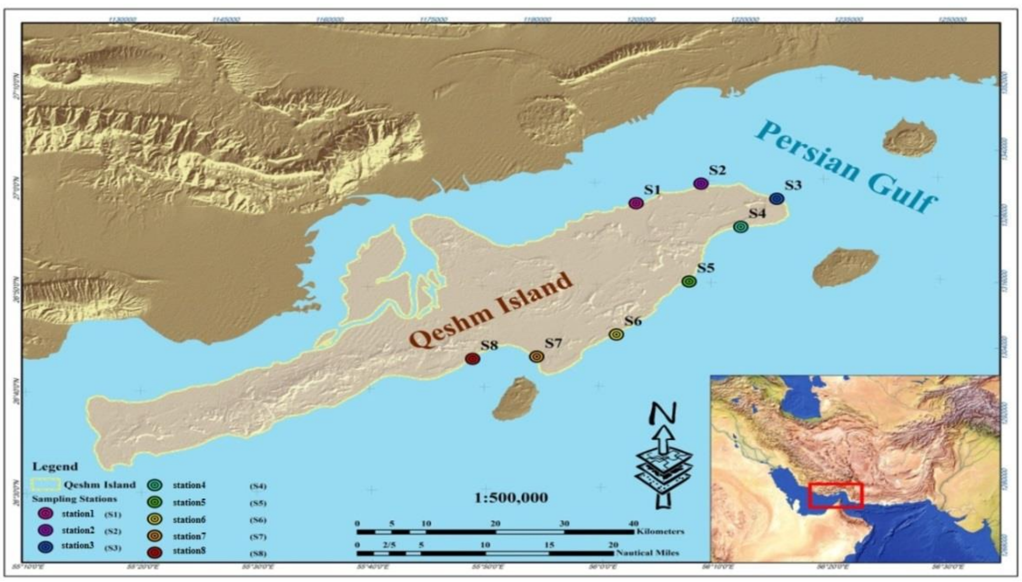

Figure 1: Map of Qeshm Island (Persian Gulf) and location of the sampling stations (Company, S.P.I.C.E., Integrated Coastal Management of Hormozgan (2018)).

Qeshm Island is the largest island in the Persian Gulf, (Company S.P.I.C.E., 2019) located in the northeastern part near the Strait of Hormuz. Table 1 shows the geographical location and specifications of the sampling stations in this study.

Table 1: Geographical location and description of the sampling stations of Qeshm Island (2018)

No.	Station	Local name	Longitude	Latitude	Description
1	Station1 (S1)	Tula 1	56° 4' 36" E	26° 58' 30" N	Rocky-rubble shores with large rubble 20 to 40 cm
2	Station2 (S2)	Tula 2	56° 9' 11" E	26° 59' 58" N	Rocky-rubble shores in the middle and low mud-sandy zones
3	Station3 (S3)	Aftab	56° 16' 16" E	26° 58' 1" N	It has very large tidal zones, a rocky bed with relatively zero degrees slope to the sea, and the main part of its shore is covered with brown algae *Padina*.
4	Station4 (S4)	Defari	56° 13' 15" E	26° 55' 28" N	Uniform rocky shores, and wide and shallow intertidal mid and high poles. The surface of the bed in the zone is covered with green filamentous algae
5	Station5 (S5)	Tango	56° 7' 51" E	26° 50' 9" N	High sandy area and Mid and Low rock zones with a gentle slope of zero degree to the sea
6	Station6 (S6)	Morva rid	56° 2' 40" E	26° 45' 46" N	Rock bed with rocks in different zones of the shore along with the presence of brown algae *Padina* scattered
7	Station7 (S7)	Biotech nology	55° 54' 37" E	26° 42' 50" N	The shore is in the form of limited rocky areas and large rocks, along with mud-sandy zones.
8	Station8 (S8)	Naz Island	55° 49' 7" E	26° 43' 3" N	Rock-bed consisting of small tidal pools in and around them due to the presence of slippery green algae.

Since southern Iran only has two cold and hot seasons (Alijani, 1998; Aghajanpour *et al*., 2015), so gastropods were sampled in the warmest and coldest months of these two seasons (January and August, 2018) during the maximum daily reflow. This period in the study area was selected based on the meteorological parameters of Qeshm synoptic station, in the coldest time of the year (January) and the warmest time of the year (August) (Vahidi *et al.*, 2019). The geographical location of each one of the studied stations was recorded using Hand-Held GPS.

At each station, 1 to 2 transects perpendicular to the seashore were identified, and along with each transect, 3 upper, middle, and lower tidal zones were identified. In each one of intertidal upper, middle, and lower zones, 3 quadrates with the size of 0.5 m by 0.5 m with 3 replicates in each zone were separately thrown (Lee, 2008). Afterward, 9 replicates were performed in each transect.

The samples placed in each quadrat were collected in separate containers, and 4% formalin was then used to fix the obtained samples (APHA, 2017). Thereafter, the samples were transferred to the laboratory and then identified as much as possible at the species level according to Sea Shell of Eastern Arabia (Bosch *et al*., 1995), Sea Shore of Kuwait Persian Gulf (Jones, 1986) and Encyclopedia of Marine Gastropods (Robin, 2008) using an Olympus sz60 stereomicroscope based on systematic parameters and valid identification keys (Bosch *et al.,* 1995).

Statistical analysis

The DIVERSE test was used to calculate frequency, Shannon Biodiversity Index, Margalef Species Richness Index, Pielou's Evenness Index, and Sorensen Index (Clarke *et al.*, 2014). Independent samples t-test was used to find the significant differences in diversity index of gastropods between summer and winter. All data were tested for normality (Shapiro-wilk test) and homogeneity of variances (Leven's Test) before the t-test. The variations of diverse variables between the eight stations were analyzed by one-Way Analysis of Variance (ANOVA).Multiple comparisons were conducted using Tukey's test. In order to investigate the effect of month factors (2 levels January and August), stations (eight levels S1, S2, S3, S4, S5, S6, S7, and S8), and intertidal zones (3 levels High, Mid, and Low) on the species structure and composition of gastropod population, the3-way permutational (MANOVA) test was used with 9999 displacements (Clarke *et al.,*2014). Accordingly, before performing this test, the data square root was obtained. Similarity Bray Curtis similarity index was then used to identify similarity matrix. All the factors were also fixed and crossed. Additionally, Non-metric Multidimensional Scaling (nMDS) test, drawn from Bray Curtis similarity matrices after obtaining the data square root, was used to draw a three-dimensional pattern of both spatial and temporal variations in species' distribution of gastropods (Clarke *et al.*, 2014).Moreover, the SIMPER test was used to compare similarity of the two months of January and August at different sampling stations in terms of the distribution of gastropod species.

The obtained data were analyzed using software SPSS-19.0 and PRIMER (Plymouth Routines in Multivariate Ecological Research v.6).

Results

In the present study, 35 species belonging to 15 gastropod families were identified. Table 2 shows the species identified in Qeshm Island. In addition, it shows the relative frequency (percentage) of gastropod species identified in the study area.

The highest value (55.76%) belonged to the species *Planaxis sulcatus*.

Table 2: Gastropod species identified at the Qeshm Island sampling stations (2018).

Class	Order	Family	Genus	Species	Relative frequency (%)
Gastropod	Trochida	Trochidae	*Trochus*	*Trochus(Infundibulops) firmus* (Philippi, 1850)	24.30
				Trochus(Infundibulops) fultoni (Melvill,1898)	21.10
				Trochus(Infundibulops) scabrosus (Philippi, 1850)	18.10
				Trochus(Infundibulops) erithreus (Brocchi, 1821)	18.50
				Trochus(Infundibulops) sp.	13.10
		Turbinidae	*Lunella*	*Lunellacoronata*(Gmail, 1791)	15.90
	seguenziida	Chilodontaidae	*Euchelus*	*Euchelus asper* (Gmelin, 1791)	10.50
	Cycloneritida	Neritidae	*Nerita*	*Neritalongii* (Recluz, 1814)	9.50
				Nerita textiles (Gmelin, 1814)	11.10
				Nerita albicilla (Linnaeus, 1758)	10.90
				Neritasanguinolenta (Menke,1829)	11.00
	Caenogastropod	Epitoniidae	*Epitonium*	*Epitoniumangulatum* (Say, 1831)	10.70
		Cerithiidae	*Cerithium*	*Cerithiumrueppeli* (Philippi,1848)	8.10
				Cerithiumscabridum (Philippi,1848)	7.90
		Planaxidae	*Planaxis*	*Planaxissulcatus* (Born, 1780)	55.76
	Littorinimorpha	Strombidae	*Strombus*	*Strombuspersicus* (Swainson,1821)	10.60
		Cymatiidae	*Cymatium*	*Cymatium aquatile* (Reeve, 1844)	9.10
				Cymatium caudatum (Gmelin, 1791)	6.20
		Cypraeidae	*Cypreae*	*Cypreaegrayana* (Schilder, 1930)	4.90
				Cypreaelentigo (Roding P.F, 1798)	4.90
				Cypreaeturdus (Lamarck, 1810)	3.40
	Lepetellida	Fissurellidae	*Diodora*	*Diodora listeria* (Dorbigny,1847)	10.20
				Diodora singaporensis (Reeve, 1850)	7.70
	Neogastropod	Muricidae	*Thais*	*Thais savignyi* (Deshayes, 1844)	13.90
				Thais lacera (Born, 1778)	10.10
				Thais tissoti (Petit, 1853)	9.00
				Thais sp.	8.00
			Hexaplex	*Hexaplexkusterianus* (Tapparrone-Canfri, 1875)	11.80
			Cronia	*Croniakonkanensis*(Melvill,1893)	12.40
			Morula	*Morula anaxares* (Kiener, 1836)	9.60
				Morula granulate (Duclos, 1832)	9.50
		Nassariidae	*Nassarius*	*Nassarius(Niotha) jactabundus* (Melvill,1906)	10.00
				Nassarius(Niotha) fissilabris (A.Adams,1852)	11.40
	Systellommatophora	Onchidiidae	*Onchidium*	*Onchidiumperonii* (Cuvier, 1804)	10.00
	Patellogastropod	Naceliidae	*Cellana*	*Cellana(Pattela) rota* (Gmelin, 1791)	9.70

The results of studying the frequency of gastropod at different stations showed thatthe mean density during the year is 429.60 ind. m^{-2}. Notably, the maximum density was observed in winter with a mean of 737 ind. m^{-2}at the S3 station and the minimum density was observed in summer with a mean of 215 ind. m^2 at the S8 station (Fig. 2). Figure 3shows the trend of changes in gastropoddensity (ind. m^{-2})in different studied intertidal zones. The maximum density was observed in intertidal zones at the S3 station (628 ind. m^{-2}) and the minimum density was observed in intertidal zones at the S8 station (243 ind. m^{-2}).

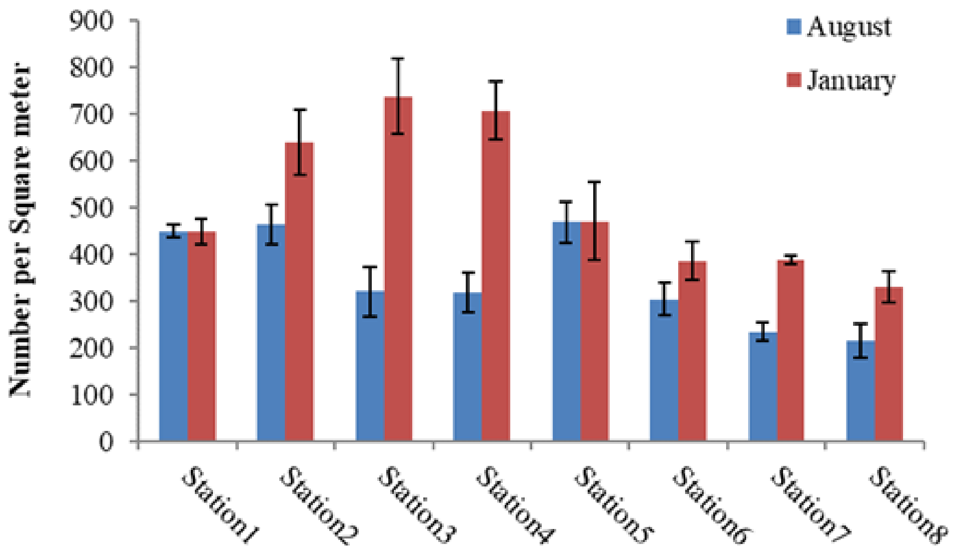

Figure 2: Comparison the Gastropod density (number per square meter) at the Qeshm Island sampling stations in 2 months (2018).

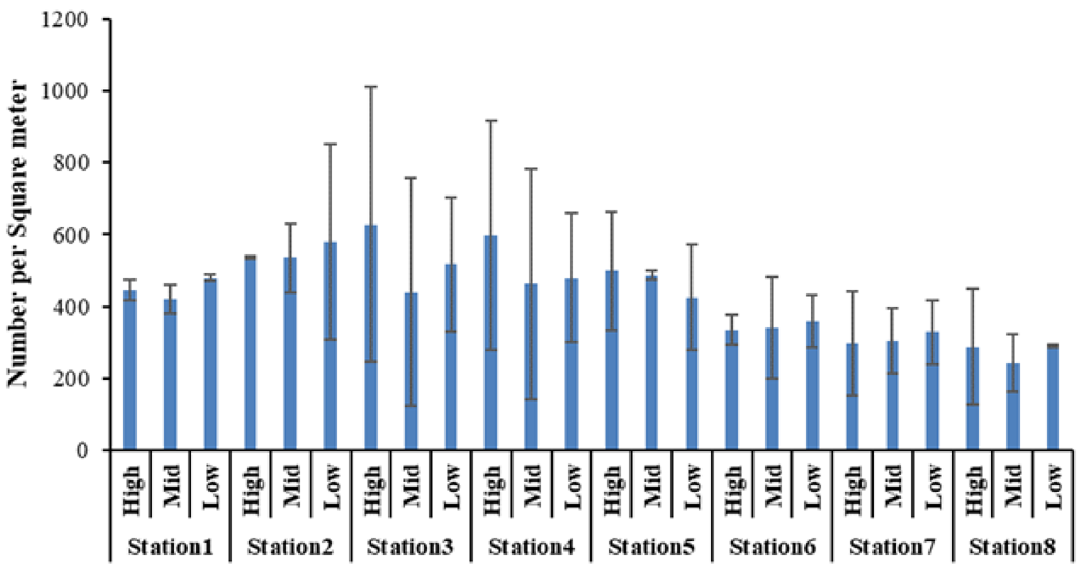

Figure 3: Comparison of the Gastropod density (number per square meter) in different intertidal zones of Qeshm Island (2018).

In this regard, the highest number of gastropod species was observed in intertidal zonesat the station 2 and the lowest one was observed in intertidal zones of the station 8. *Planaxis sulcatus* was found as the dominant species (55.76%) at all stations, but its frequency varied at different stations.

Correspondingly, its highest frequency at the station 5was 73.44%±30.40 and the lowest one was 25.11%±20.90 at the station 8. *Trochus firmus* (24.30%), *Trochus fultoni* (21.01%) and *Trochus erithreus* (18.50%) were in the next ranks, respectively. *Trochus erithreus* and *Trochus fultoni* had the highest frequencies at the station 1(26.05%±4 and 21.50%±59.40, respectively) and *Trochus firmus* had the highest frequency (29.90%±9.60) at the station 7.

The results of three-way permutational ANOVA test (main test) showed that the two months and the stations had effects on the composition of the species of gastropod population ($p<0.05$); however, intertidal zones showed no significant effect on the composition of their species ($p>0.05$).A pairwise test showed a significant difference in species composition between summer and winter as well as a significant difference between S7/S1, S8/S1, S2/S6,S2/S7, S2/S8, S8/S4, and S8/S5 stations. Notably, no significant difference was observed between other zones (Table 3). The results of nMDS test also confirmed the existence of differences in the mean structure and species composition of gastropod population among different months and stations. According to the results of nMDS test, 2d Stress was estimated as 0.05 (Figs. 4 and 5). Stress values below 0.2 indicate separation between groups (Clarke *et al.,* 2014).

Table 3: Results of MANOVA permutational test to investigate significant differences in the structure of Gastropod population during the sampling months at different sampling stations.

Factor	df	MS	Pseudo F	P(perm)	Unique perms
Main test					
Months	1	1091	31.79	*0.001	997
Zone	7	239	6.98	*0.004	998
Intertidal zones	2	35.32	1.02	0.39	-
Pairwise comparisons					
Months			t-value	P(perm)	
January /August			5.6	*0.001	998
zone			t-value	P(perm)	
S1 / S7			9.60	*0.03	957
S1 / S8			4.54	*0.03	964
S2 /S6			4.03	*0.05	958
S2 / S7			4.50	*0.03	957
S2 / S8			5.60	*0.02	957
S8 / S4			4.90	*0.03	976
S8 / S5			10.30	*0.03	959

* A Significant difference at the level of 5%.

According to the results of the SIMPER test, the highest mean Bray-Curtis dissimilarity in terms of species density between summer and winter was recorded as 43.78, with the highest percentage of participation in this dissimilarity belonged to *Planaxis sulcatus* (Table 4). Additionally, the highest mean Bray-Curtis dissimilarity among the studied stations belonging to the two stations of S2 and S8 (48.40). Moreover, the highest percentage of participation in dissimilarity among all stations was related to *Planaxis sulcatus* (Table 5).

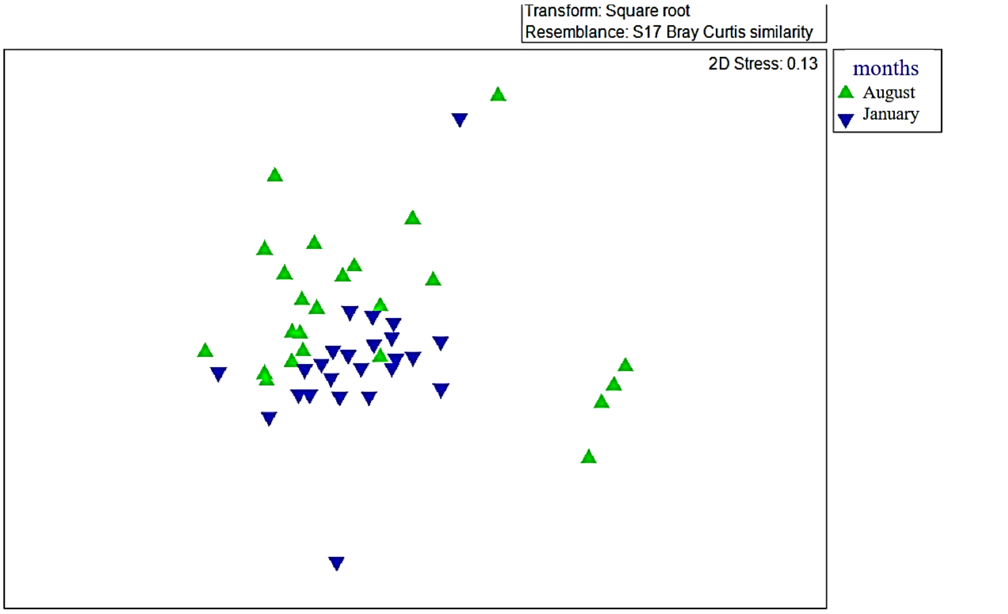

Figure 4: Differences in the frequencies of Gastropod between January and August in Qeshm Island (2018).

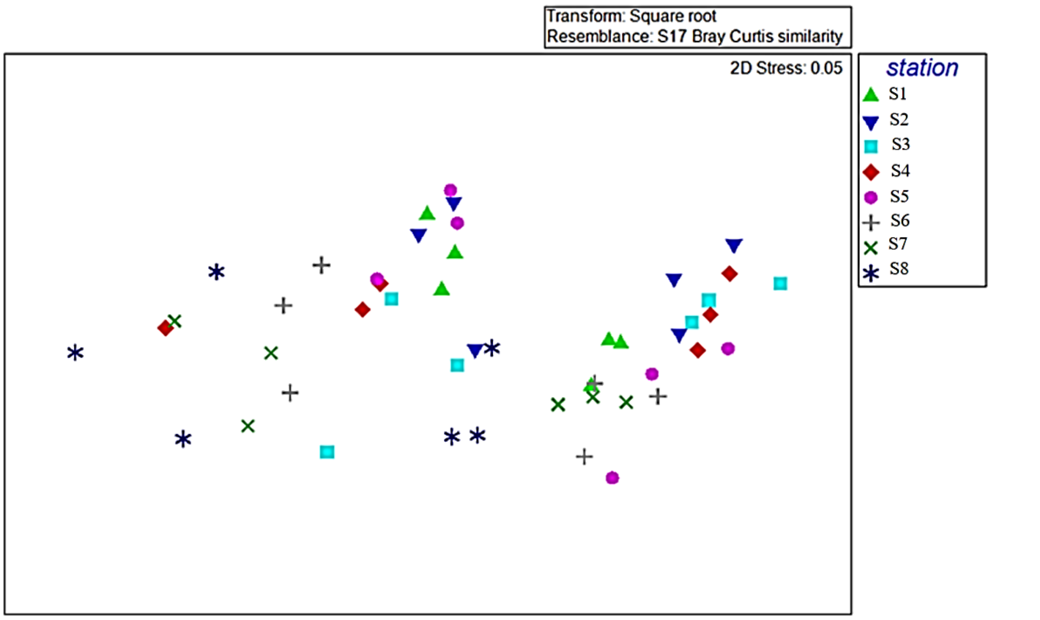

Figure 5: Differences in the frequencies of Gastropod at different sampling stations in Qeshm Island (2018).

The mean dissimilarity between the two months was 43.78%.The effective species during this process were the following: *Planaxis sulcatus*, *Thais savignyi*, *Lunella coronata*, *Thais* sp., *Trochus firmus*, *Nerita textiles*, and *Trochus erithreus*. The mean dissimilarity between the S1 and S7 stations was 44% and the effective species during this process were the following: *Planaxis sulcatus*, *Thais* sp., *Lunella coronata*, *Trochus fultoni*, and *Trochus scabrosus*, respectively.

Table4: Comparison of similarity in summer and winter in terms of the distribution of Gastropod species.

Groups: summer and winter
Mean dissimilarity = 43.78

Species	Group August Av.Abund	Group January Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
P. sulcatus	54.39	57.15	8.39	1.41	19.16	19.46
T.savignyi	9.34	18.47	3.37	1.36	7.71	26.37
L. coronata	11.04	20.93	3.30	1.43	7.54	34.41
*Thais*sp.	8.11	18.12	3.24	1.43	7.40	41.81
T.firmus	18.38	30.23	3.16	1.61	7.21	49.02
N. textiles	6.09	16.26	3.13	1.25	7.14	56.16
T.erithreus	16.01	21.11	3.10	1.32	7.07	63.24

Av. Abund: Average Abundance; Av.Diss: Average Dissimilarity; Diss: Dissimilarity; SD: Standard Deviation; Contrib: Contribution; Cum: Cumulation.

Table 5: Comparison of similarity between different stations in terms of the distribution of Gastropod species.

Groups S1 &S7
Average dissimilarity = 44.00

Species	Group S1 Av.Abund	Group S7 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
P. sulcatus	63.33	48.83	10.67	1.49	24.25	24.25
Thais sp.	21.77	8.06	4.03	1.36	9.17	33.42
L. coronata	24.50	9.06	3.90	1.64	8.86	42.28
T. fiultoni	26.05	18.33	3.62	1.34	8.23	50.51
T. scabrosus	23.43	9.67	3.52	1.28	7.99	58.50

Groups S1 & S8
Average dissimilarity = 45.01

Species	Group S1 Av.Abund	Group S8 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
P. sulcatus	63.33	25.11	12.39	1.22	27.52	27.52
L. coronata	24.50	8.39	4.45	1.58	9.89	37.41
C.konkanensis	18.21	1.06	4.16	1.68	9.25	46.66
Thais sp.	21.77	13.17	4.00	1.26	8.88	55.54

Groups S2 & S6
Average dissimilarity = 39.46

Species	Group S2 Av.Abund	Group S6 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
P. sulcatus	71.97	48.39	5.86	1.60	14.86	14.86
N. sanguinolenta	22.05	2.50	3.94	2.07	9.97	24.83
T. erithreus	17.88	18.05	3.41	1.35	8.64	33.47
T. firmus	29.54	21.10	3.19	1.52	8.09	41.56
N. textiles	14.87	15.39	3.19	1.35	8.08	49.63

Table 5 (continued):

Groups S2& S8
Average dissimilarity = 48.46

Species	Group S2 Av.Abund	Group S8 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
P. sulcatus	71.97	25.11	11.32	1.56	23.35	23.35
L. coronata	23.98	8.39	3.82	1.56	7.88	31.23
N. sanguinolenta	22.05	6.39	3.78	1.63	7.79	39.02
T. savignyi	18.59	3.39	3.63	1.72	7.50	46.52
T. erithreus	17.88	17.44	3.59	1.37	7.41	53.93
H. kusterianus	18.11	10.33	3.45	1.54	7.13	61.06
C. konkanensis	16.21	1.06	3.33	1.53	6.87	67.92
Thais sp.	12.06	13.17	3.06	1.22	6.32	74.25
N.textiles	14.87	4.83	3.04	1.33	6.28	80.52

Groups S2 & S7
Average dissimilarity = 40.42

Species	Group S2 Av.Abund	Group S7 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
P. sulcatus	71.97	48.83	6.44	1.18	15.94	15.94
N. sanguinolenta	22.05	4.72	3.81	1.65	9.43	25.37
L. coronata	23.98	9.06	3.32	1.66	8.22	33.59
T. erithreus	17.88	18.86	3.19	1.44	7.90	41.49
H. kusterianus	18.11	6.33	3.05	1.47	7.55	49.04
T. fiultoni	21.43	18.33	3.04	1.73	7.52	56.56

Groups S5& S8
Average dissimilarity = 43.35

Species	Group S5 Av.Abund	Group S8 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
P. sulcatus	73.44	25.11	11.82	1.35	27.27	27.27
T. savignyi	15.78	3.39	3.46	1.13	7.98	35.25
H. kusterianus	18.28	10.33	3.44	2.22	7.92	43.17
L. coronata	15.61	8.39	3.21	1.26	7.40	50.57
Thais sp.	12.22	13.17	3.13	1.21	7.22	57.79

Groups S4 & S8
Average dissimilarity = 44.85

Species	Group S4 Av.Abund	Group S8 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
P. sulcatus	42.50	25.11	8.20	1.08	18.28	18.28
N. textiles	18.94	4.83	4.02	1.49	8.97	27.26
T. savignyi	18.50	3.39	3.94	1.79	8.79	36.05
L. coronata	20.33	8.39	3.89	1.62	8.67	44.72
T. erithreus	20.16	17.44	3.82	1.16	8.52	53.24
Thais sp.	14.94	13.17	3.35	1.23	7.47	60.71
T. scabrosus	19.00	18.78	3.17	1.36	7.08	67.79

Av. Abund: Average Abundance; Av.Diss: Average Dissimilarity; Diss: Dissimilarity; SD: standard Deviation;Contrib: Contribution; Cum: Cumulation.

The mean dissimilarity between the S1 and S8 stations was 45.01% and the effective species during this process were the following: *Planaxis sulcatus*, *Lunella coronata*,*Cronia konkanensis*, and *Thais*sp..The mean dissimilarity between the S2 and S6stations was 39.46%.During this processthe effective species were the following: *Planaxis sulcatus*, *Nerita sanguinolenta*, *Trochus erithreus*, *Trochus firmus*, and *Nerita textiles* respectively. The mean dissimilarity between the S2 and S8 stations was 48.46% and the effective species during this process were the following: *Planaxis sulcatus*, *Lunella coronata*, *Nerita sanguinolenta*, *Thais savignyi*, *Trochus erithreus*, *Hexaplex kusterianus*, *Cronia konkanensis*, *Thais*sp., *and Nerita textiles*,respectively. The mean dissimilarity between two S2 and S7 stations was 40.42%. During this process the effective species were the following: *Planaxis sulcatus*, *Nerita sanguinolenta*, *Lunella coronata*, *Trochus erithreus*, *Hexaplex kusterianus*, *Cronia konkanensis*, and *Trochus fultoni* respectively.The mean dissimilarity between S5 and S8 stations was 43.35% and the effective species during this process were the following: *Planaxis sulcatus*, *Thais savignyi*, *Lunella coronata*, *Hexaplex kusterianus*, *Lunella coronata*, and *Thais* sp. respectively. The mean dissimilarity between the two S4 and S8 stations was 44.85%. During this process the important species were the following: *Planaxis sulcatus, Nerita textiles, Thais savignyi*, *Lunella coronata*, *Trochus erithreus*, *Thais*sp., and *Trochus scabrosus*, respectively.

The values of Shannon diversity, Margalef richness, Simpson diversity, and Pielou's evenness were recorded for gastropod population at different sampling stations in this study (Table 3). The highest values of Shannon, Margalef, and Simpson were observed at the S2 station (3.13, 4.53, and 0.95, respectively) and the highest Pielou's index (0.95) was observed at the S4 and S8 stations. The lowest Shannon and Margalef were observed at the S8 station (2.73 and 3.03, respectively), the lowest Pielou's index was observed at the S1 station (0.89), and the lowest Simpson was observed at the S7 station (0.92).

The results of t-test showed non-significant differences for Number of taxa (F=0.32, df=46, sig=0.57), Margalf richness (F=0.97, df=46, sig=0.75), Pielou’s evenness (F=3.23, df=46, sig=0.79) and Simpson (F=2.04, df=46, sig=0.15) between months (p>0/05). But the results of t-test showed significant difference for Shannon Wiener diversity (F=5.52, df=46, sig=0.02) between summer and winter ($p<0.05$).The results of one-way ANOVA test showed that sampling stations had significant effects on the number of gastropod species, Shannon, and Margalef, However, theyhad no significant effect on Simpson and Pielou (Table 6).

Structure of gastropod population

Shannon Species Diversity Index

Shannon index values for the species populations during the study are shown in Table 6. The highest Shannon species diversity index (3.13) was recorded at the S2 station and the lowest index (2.73) was recorded at the S8station. The mean index was 2.90.

Table 6: Gastropod community structures at eight stations during studying Qeshm Island (2018).

Station	Gastropod community structural parameters.				
	*Number of taxa	*Margalef richness	Pielou's evenness	*Shannon Wiener diversity	Simpson (1-Lambda')
S1	25.33[ab]	3.99[ab]	0.89	2.89[abc]	0.93
S2	29.50[a]	4.53[a]	0.92	3.13[a]	0.95
S3	24.33[abc]	3.78[abc]	0.93	2.97[abc]	0.93
S4	26.33[ab]	4.13[ab]	0.95	3.12[ab]	0.95
S5	22.83[bcd]	3.55[bc]	0.93	2.90[abc]	0.93
S6	21.50[bcd]	3.52[bc]	0.92	2.82[bc]	0.93
S7	19.83[cd]	3.32[bc]	0.93	2.76[c]	0.92
S8	17.83[d]	3.03[c]	0.95	2.73[c]	0.93

Note: Values are expressed as mean. Different lower case letters in a row show significant differences ($p<0.05$) indicated by Tukey's pairwise significant difference test.
∗shows significantly calculated *p*-value detected by ANOVA.
Shannon Wiener diversity (H), Pielou's evenness (J), Margalef richness (D), and Simpson (1-Lambda').

Margalef species richness index

The values of Margalef species richness index for gastropod populations are shown in Table 6. The highest Margalef species richness index (4.53) was recorded at the S2 station and the lowest index (3.03) was recorded at the S8 station. The mean index was 3.73.

Simpson species diversity index

The values of Simpson species diversity index for gastropod populations during the study are shown in Table 6. The highest Simpson species diversity index (0.95) was observed at the S2 andS4 stations and its lowest value (0.92) was at the S7 station. The mean index was 0.93.

Pielou's species evenness index

The values of Pielou's species evenness index for gastropod populations are shown in Table 6. The lowest Pielou's species evenness index (0.89) was recorded at the S1 station and the highest value (0.95) was recorded at the S4 and S8 stations. The mean index was 0.93.

Discussion

According to the results of the current study, the rocky shores of Qeshm, similar to other shores of the Persian Gulf, have high biological diversity and richness (Amini Yekta *et al.,* 2013).In this study, 35 species of gastropod belonging to 15 families were identified. Al-Khayat reported 99 species of gastropod in Qatar shores and Kohan reported 62 species on the tidal shores of Saudi Arabia (Al-Khayat, 2008; Kohan *et al.,* 2012). In this study, *P. sulcatus* was found as the most dominant one. A similar result was reported in the studies by Asghari *et al.* (2011) and Kohan *et al.* (2012) performed on the rocky shores of the southern Iran, Al-Khayat (2008) in Qatar shores and Leung (2012) on rocky shores of Hong Kong. This species can be found under different environmental conditions in almost all zones of the Persian Gulf (Kohan *et al.,* 2012). *P.sulcatus* accumulates on the sides of large and small rocks, and besides resisting the energy of the bed waves; it performs its nourishing and reproductive activities (Leung, 2012).

Also AminiYekta *et al*. (2013) showed 28 species of gastropod belonging to 15 families in rocky intertidal of the Qeshm Island. In this research, *Cerithium caeruleum* was the most abundant species. The discrepancy between the results of this study and the present study can be attributed to the different of number of stations (Amini Yekta; 2 stations), conditions of selected stations (non- anthropogenic and anthropogenic effects; in the research of Amini Yekta *et al.* (2013) sampling locations were not exposed to any particular anthropogenic pollutant) and number of sampling months (monthly). Also Ghiasnejad *et al.* (2008) identified 29 gastropod species from intertidal zone of Qeshm Island which *P. sulcatus*, *Cerithium caeruleum*, and *Thais savignyi* were the most abundant species.

The highest density was observed in the upper tidal zone at the S3 station (628 ind. m^{-2})and the lowest density was observed in the middle zone of the S8 (243 ind. m^{-2}).

The structure of gastropod community is mostly affected by various factors such as changes in temperature, salinity, increased water evaporation, tidal fluctuations, the hunter-gatherer relationship, and exposure (Samidurai *et al.,* 2012). Various studies conducted in the Persian Gulf showed that high temperatures, followed by high salinity and evaporation, affect macrofauna community structure, including gastropod (Mousavi-Nadushan and Mokhayer, 2017; Vahidi*et al.,* 2019; Azizi *et al.,* 2020).

In the present study, the patterns of spatial and temporal distributions of gastropod were different at different sampling stations. The results of PERMANOVA test showed that the factor of station has a significant effect on the structure of gastropods population. Accordingly, we observed this significant difference between the S7/S1, S8/S1, S2/ S6, S2/S7, S2/S8, S8/S4, and S8/S5 stations (Table 3). On the one hand, the factor of tidal zone did not have a significant effect on the structure of gastropod population. Typically, according to the global pattern of distribution of rock bedrock organisms, the upper zone in terms of density and diversity has a significant difference with the lower zone (Boaventura *et al.,* 2002). It seems that, due to the existence of similar substrates and the effects of human uses in this study, no significant difference was found between the zones at the sampling stations. In this regard, Defeo *et al.* (2009) mentioned the man-made effects (piers, fisheries, and effluents) and effects of natural phenomena (floods and monsoons) causing changes in the distribution pattern of rocky beds (Defeo and McLachlan, 2013). Azizi *et al*. (2020) has reported a similar result on rocky shores of southern Iran. The highest diversity and richness of species were observed at the S2 station and the lowest diversity and richness of species were observed at the S8 station (Table 6). This may be due to the fact that the S2 station is located in a protect zone Compared to other stations that is more difficult to reach by humans, while it is a beautiful tourist Island around which residential zones can be seen. Shannon Species Diversity index is one of the most common and practical indicators in the ecological studies, showing that the numerical value of this index does not depend on the number of samples collected, instead it depends on the value and importance of each species as well as the presence of species in the ecosystem. Shannon Species Diversity index indicates the conditions of environmental stress. By increasing pressure and environmental stresses, species are gradually removed or change their location, under such conditions the numerical value of this index reduces (Magurran, 2004; Haughland, 2009). In the present study, the highest Shannon species diversity index was observed in January at the S2 station. The study results show that this station has desired conditions and stability during performing the study. The distribution of gastropod communities is affected by environmental and local conditions such as hydrological, physical and chemical properties (temperature, salinity, and pH), tidal patterns, sediments, total organic matter, hunting, competition, and human activities (Lee, 2008; Rezende *et al.*, 2014; Sihombing *et al.*, 2017; Vahidi *et al.*, 2021).

Due to the stable bed, the presence of cracks in the rocks, spaces between rock fragments and water pools in intertidal zones have a lower diversity of gastropod compared to mud-sand shores (Meadows and Campell, 1988). In general, it can be said that spatial changes in the structure of gastropod population at the studied stations are affected by various factors such as seasonal changes in temperature, type of bed (rocky and in some mud-sand zones of the S1 and S2 stations), uniformity and hardness of the bed, the presence of tidal pools and micro-habitats (cracks), and tourist and residential zones. The results show diversity and richness of gastropod species in rocky shores of Qeshm to be used for the environmental assessment in future studies. Given that in the present study had been tried, considered stations which were not exposed to any particular anthropogenic activities (S2) and the habitats (like S8) that were laid out to anthropogenic activities (such as tourism, recreational activities and expanding the exploitation of beaches). The result of this paper provides basic information to establish a foundation for future biomonitoring activities in rocky shores of Qeshm Island. The results of this study provided the substantial evidence that regarding the role of distinctive habitats (non-anthropogenic and anthropogenic effects) in the biodiversity and food webs of rocky shores, which can be compared with the findings of the future studies to monitor environmental changes and show the process of improvement or degradation of the system.It is recommended to investigate the effect of environmental factors such as temperature, tourism, residential areas on the structural changes of gastropod population on rocky shores. In addition, it is recommended, protection of the buffer zone that affects them in order to preserve these valuable ecosystems.

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