Chapter

Assemblage of Gastropods in the Rocky Intertidal Zone of Asry Beach, Kingdom of Bahrain

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Abstract

The macrofaunal components find its habitat in all areas of the marine ecosystem. Specifically, gastropods are considered the most common inhabitants of the intertidal zone with wide range of distribution in the rocky intertidal biota. A 3-year study on gastropod assemblage in Asry Beach, Kingdom of Bahrain was conducted from 2016 to 2018 which determines diversity and evenness of the rocky intertidal species. Taxonomic identification showed 31 species which belong to 25 genera and 16 families. The total annual population of gastropod assemblage does not vary significantly at $p < 0.05$ using analysis of variance (ANOVA). Shannon-Wiener species diversity index (H′) revealed high species diversity (H′ = 4.19) in the *Family Muricidae*; moderate (H′ = 2.04–3.29) among the species of the *Family Pyramidellidae*, *Cerithiidae*, *Oliveliidae*, *Calliostomatidae*, *Turbinidae*, *Trochidae*, *Buccinidae*, *Velutinidae* and *Margeliidae*; and low (H′ = 1.04–1.11) among the species of the *Family Batillariidae*, *Borsoniidae*, *Cerethiopsidae*, *Epitoniidae*, *Volutidae* and *Columbellidae*. Pielou's evenness index show that most of the species have complete evenness (J' = 1.0–3.81). The varying annual mean temperature exert no effect on the total assemblage of gastropods (r = −0.0231). Tolerant species include *C. selectum*, *L. attenuatum* and *Turbonilla* sp. 1. The rocky intertidal pool is typically diverse although exposed to varying environmental occurrences.

Keywords: gastropod assemblage, rocky intertidal, tolerant species, Shannon-Wiener index, Pielou's evenness index

1. Introduction

The marine ecosystem is ecologically rich in terms of community of organisms which comprise the wide coastal area extending to a vast oceanic environment. The intertidal habitat had been the focus of many studies for ecological interactions which has an impact on diverse assemblage of macroflora and macrofauna. The rocky shore as an intertidal area is found at the shoreline between low and high tides and predominantly composed of solid rocks. Macrofaunal community tends to survive despite fluctuating daily diurnal tidal patterns and intense temperature [1]. This zone is considered highly productive with varying levels of biodiversity and dynamic due to diversity of both macrofauna and macroflora [2–4]. The wet rocky shore promotes enormous algal growth which serves as the feeding ground for the many macrofaunal community, specifically the gastropods thus promoting more diversity [5]. The rocky intertidal as a community is influenced by competitive

processes primarily competition for space. The so called competitive dominance is manifested through the use of space. Community organization depends on consumer-prey interaction, physical disturbances as factors and competition for space [6]. Gastropods are the largest and the most diverse faunal group in *Phylum Mollusca*. The gastropods are known to have a wide range of distribution. They can live in a variety of habitats and are adapted to varying environmental conditions as affected by daily fluctuating tidal patterns and duration of exposure to sunlit which determine diurnal temperatures. These one-shelled marine invertebrates considered as economically important are the major inhabitants of the intertidal marine ecosystem. Marine gastropod species are varied and abundant as an important source of food for higher consumers and contribute to coastal food chains [7, 8]. Mollusks in the rocky shore are highly important in maintaining dynamics in the shore and ecological balance in beaches in addition to their key role in the trophic chains and nutrient recirculation [9]. Further, gastropods have important role in structuring the intertidal assemblages and regulating the intertidal communities since they can respond to variation in microhabitats in a vertical gradient and change their behavior in response to environmental occurrences [10]. Gastropod assemblage is influenced by the characteristic substrate which the majority of the shores are rocks. Characteristically, gastropods show variation in sizes, color and other phenotypic diversity [11]. Gastropods are motile however they are comparatively slow in locomotion which prevents them from moving into and out of the intertidal zone over a relatively short period of tidal range [12]. Hence these molluscan descendants have low migration potential which determines habitat stability in the rocky intertidal zone.

Studies on gastropod assemblage and diversity were conducted in various intertidal habitats of the marine ecosystem. A biodiversity study of gastropod in the intertidal zone of fine sand and coral reef was conducted in January 2017 in Sombu Beach, Wakatobi, Indonesia using quadrant plot method. Ten transects along the beach were established composed of four plots. There were 40 plots used as sources of data for analysis. The diversity of gastropod community was determined using Shannon-Wiener index [H′], evenness index (E) and dominance index (D). Results showed 13 species of gastropods which belong to three genera since the variety of substrate is low which has an impact on food resource and habitat of the identified gastropods [13]. A baseline study was conducted between November 2016 and February 2017 on marine gastropods diversity and distribution in two intertidal rocky shores of Terengganu, Peninsular Malaysia. The intertidal area was categorized and divided into three zones: upper, middle and lower. A 40 m length transect composed of six 1 m^2 quadrats was laid at random perpendicular to shore. Results revealed a total of five subclasses of gastropods which belong to nine families and 28 species from upper to lower intertidal zones. Diversity indices based on the results of Shannon-Wiener index (H) and Pielou's evenness index (J') were compared with reference to the identified zones [14]. In another study, a spatial distribution of macroinvertebrates on intertidal rocky shores was conducted in Gorgona Island, Colombia of the Tropical Eastern Pacific. Qualitative data were determined using rapid ecological assessments while quadrat method for quantitative data. Species richness, abundance and diversity were determined using Shannon-Wiener H′ and Pielou J' for evenness. Results of the study revealed 121 species of macroinvertebrates. Mollusks were the most abundant in terms of species and individual count. Researchers concluded that environmental stressor, heterogeneity and stability are limiting factors on the spatial distribution of macroinvertebrates species in this particular area of intertidal rocky shores [15]. A biodiversity study of gastropoda was conducted in the coastal waters of Ambon Island, Indonesia to determine the correlation between the physico-chemical factors and the diversity of coastal waters

gastropods. The physical and chemical factors included temperature, salinity, pH and dissolved oxygen (DO). Results showed a total of 65 species in the two established research stations which belong to 48 genera, 19 families and 7 orders. The station-to station averages of the physico-chemical parameters were also determined. Results further show a very high diversity in both stations. Correlation analysis revealed a significant positive correlation between the physical and chemical factors (temperature, salinity, pH and DO) and the diversity of gastropods in the coastal waters of Ambon Island, Indonesia [16].

The Kingdom of Bahrain is endowed with a marine biota as habitat of all life forms. A number of public beach is found in Bahrain however Dry Dock Beach or commonly called Asry Beach in Hidd, Muharraq is of great interest. The beach as it is known to the people is part of the dry dock shipyard in the area. As a public beach, the area is often threatened by unaccountable wastes which may also affect the macrocomponents of the marine ecosystem. Hence continuous monitoring of the macroinvertebrates specifically the gastropods in the intertidal ecosystem is being undertaken since 2011 [17]. The intertidal ecosystem in Asry Beach is predominantly rocky and sandy. The shoreline is characteristically wide during ebb tide while very narrow during the spring tide. The rocky substrate extreme variation in temperature may exert drastic effect on the gastropod community. Hence, this study was conducted to determine the current status of the assemblage of gastropod population in the rocky intertidal zone of Asry Beach from January 2106 to January 2018. Specifically to identify and classify taxonomically the species of gastropod assemblage from the sampled quadrates; find out significant differences in the annual species assemblage of gastropods; calculate diversity using Shannon-Wiener (H′) diversity index; find out species evenness using Pielou's evenness index; and relate the effect of the aerial temperature on the total species assemblage of gastropods.

2. Research methods

2.1 Study site

The study area is located in the northeastern part of Dry Dock Beach commonly known as Asry Beach in Hidd, Muharraq having geographic coordinates of 26.1957°N and 50.6623°E. The total area of the intertidal zone is 206.30 m stretch where people usually perform beach activities during low tide. Part of the area is a 73.05 m stretch which composed the rocky intertidal biota (**Figure 1**). Both macrofauna and macroflora assemblages abound in the area in spite of the various human activities and other natural environmental occurrences.

2.2 Sampling, identification and field collection

This particular research was undertaken from January 2016 to January 2018 in a small parcel of the rocky environment of Dry Dock Beach commonly called Asry Beach in Muharraq, Kingdom of Bahrain. Sampling was done every month during the low tide between 7:00 and 1:00 pm. Belt transect method [12–14] was utilized for the quantitative assessment of gastropods in the rocky shore. A-50 m belt transect made of 0.45 mm clear nylon beading wire and 12 mm corrugated round steel bar post was established parallel to the elevated rocky shoreline during the low tide. The transect line was divided into 25 1 m^2 quadratic plots [13, 14] made of size 18 twisted nylon cord Bead Smith Super-Lon (S-Lon) on both sides for a total of 50 quadrates. The area where the transect line was laid represented the rocky intertidal ecosystem of the 73.05 m stretch. Random sampling [14] was conducted

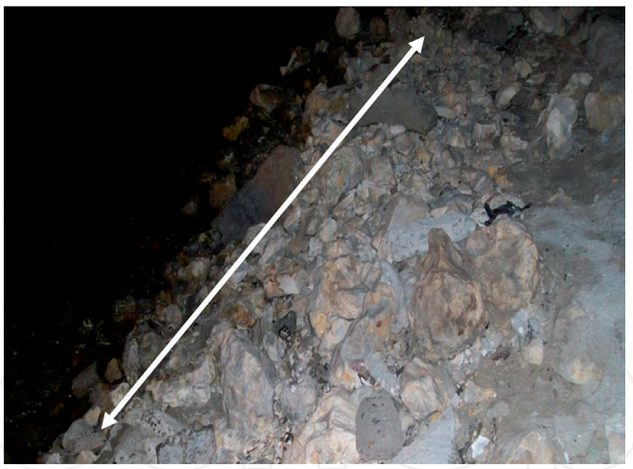

Figure 1.
Part of the 73.05 m stretch of the rocky shore during low tide (↔).

simultaneously for a total 25 sampled plots. Both live gastropod species and empty shells within the sampled quadrates including those in rock crevices were identified *in situ*. Aerial temperature was taken at the same time every sampling month using non-mercury thermometer.

Unidentified gastropod species and shells were photo-documented and collected. Specimens were placed in labeled transparent plastic bags. While in the field, the collected samples of live specimen were stored in an ice bucket to prevent desiccation. Collected samples were brought in the BioLab for identification to the lowest possible taxonomic level based on morphological characteristics using references in gastropods taxonomic identification [18–20]. The species names were also verified in a database [14] for marine species of gastropods [21]. Using taxonomic classification, identified gastropods were categorized into three hierarchy or categories namely: (1) *family*, (2) *genus*, and (3) *species*. Some live specimens in their natural habitat were photo-documented using Nikon D7000 camera. Collected specimens and shells were measured end-to-end from the longest point of axis for the length using Vernier caliper with ±0.01 mm accuracy and likewise photographed in the laboratory.

2.3 Data analysis

2.3.1 Determination of species diversity

Diversity of gastropod species was calculated using Shannon-Wiener Index (H′) with the formula: [13–15].

$$H' = -\sum_{i=}^{s} p_i \log p_i \quad (1)$$

where H′ = value of Shannon-Wiener diversity index; P_i = proportion of the ith species; $\log_e$ = natural logarithm of p_i; s = number of species in the community or species richness.

Using Shannon-Wiener diversity index (H′), species of gastropod in the assemblage is classified based on the following category: low (H′ < 2); moderate (2 < H′ < 4); and high (H′ > 4).

Species evenness index was determined using Pielou's evenness index with the formula:

$$J' = H'/H' max \quad (2)$$

where H′ = Shannon-Wiener diversity index; H_{max} = natural logarithm of species richness.

Species ranges from zero to one; zero means no evenness and one means complete evenness.

2.3.2 Statistical analysis

One-way analysis of variance (ANOVA) was used to find out significant differences in the total species assemblage. Correlation analysis using Pearson correlation coefficient *r* determined if the aerial temperature significantly affected the total annual species assemblage of gastropods.

3. Results and discussion

3.1 Study site

The characteristic substrate of the study site in Asry Beach is shown in **Figure 2**. It is an obligate, slightly elevated rocky platform which is often exposed to alternating tide sequences resulting to its periodic submergence and emergence. As part of the public beach, however people prefer the sandy part and spend their leisure time in water for swimming. Hence this area remains undisturbed which promotes massive growth of algae that provides nutrients and venue for ecological and intra-inter-specific interactions [5] among the faunal community of organisms. Based on observation and results of the study on the entire intertidal ecosystem [17] human factor is considerably not a limiting factor for the gastropod assemblage to be abundant in the area. This is in contrast to some research findings that human activities may intensify the exploitation of gastropod species for commercial purposes [11, 14]. Hence the rocky platform of the intertidal zone in this particular area serves as the habitation of the many life forms enduring the harsh environmental condition [1].

3.2 Sampling, identification and field collection

A total of 16 families composed of 25 genera and 31 species were identified in the rocky shore of Asry Beach from January 2016 to January 2018. The taxonomic

Figure 2.
Cut view of the sampling site showing the rocky habitat (A) during low tide with massive algal growth (B).

identification, classification and total population of individual gastropod species in the sampled quadrates are presented in **Table 1**. Of the 16 families, *Family Muricidae* has four species which belong to four genera, *Nucella*, *Ocenebra*, *Ocinebrina* and *Scabrotrophon* while *Family Cerithiidae* [8] and *Oliveliidae* [7] has three species each. *Calliostoma selectum* of the *Family Calliostomatidae* has the most

Identified gastropods/Taxonomic hierarchy		**Year**			**Total**
Family	**Species**	2016	2017	2018	
Volutidae	*Arctomelon tenrsii*, Dall, 1872	3	3	6	**12**
Columbellidae	*Astyris aurantiaca*, Dall, 1871	1	2	1	**4**
Batillariidae	*Batillaria attramentaria*, Sowerby, 1855	3	3	3	**9**
Cerithiidae	*Bittium vancoverense*, Dall & Bartsch, 1910	4	4	7	**15**
	Lirobittium attenuatum, Carpenter, 1864	156	148	167	**471**
	Stylidium eschrichtii, Middendroft, 1849	10	17	21	**48**
Oliveliidae	*Callianax baetica*, Carpenter, 1864	5	7	9	**21**
	Callianax obiplicata, Sowerby, 1825	5	7	6	**18**
	Callianax pycna, S. S. Berry, 1925	2	3	7	**12**
Calliostomatidae	*Calliostoma selectum*, Dillwyn, 1817	1025	1221	1231	**3481**
	Calliostoma variegatum, Carpenter, 1864	54	68	81	**203**
Cerethiopsidae	*Cerithiopsis* sp.	63	71	77	**211**
Pyramidellidae	*Evalea tenuisculpta*, Carpenter, 1864	37	42	53	**132**
	Turbonilla sp. 1	68	77	81	**226**
	Turbonilla sp. 2	5	7	6	**18**
Turbinidae	*Homalopoma baculum*, Carpenter, 1864	28	38	42	**109**
	Homalopoma luridum, Dall, 1885	58	62	67	**187**
Buccidae	*Lirabuccinum odirum*, Reeve, 1846	6	8	11	**25**
	Volutharpa ampullarea, Middendroft, 1848	2	5	5	**12**
Trochidae	*Lirularia olirulata*, Carpenter, 1864	52	60	67	**179**
	Lirularia succinata, Carpenter, 1864	3	5	8	**16**
Velutinidae	*Marsenia thrombica*, Dall, 1871	9	15	9	**33**
	Velutina velutina, O. F. Muller, 1776	2	5	3	**10**
Muricidae	*Nucella lamellosa*, Gmelin, 1791	3	3	5	**11**
	Ocenebra inornata, Recluz, 1851	2	2	3	**7**
	Ocinebrina atropupurea, Carpenter, 1864	1	4	5	**10**
	Scabrotrophon maltzani, Kobett & Kuster, 1878	1	1	1	**3**
Epitoniidae	*Opalia borealis*, Kepe, 1881	7	10	13	**30**
Margeliidae	*Oepota olividensis*, Carpenter, 1864	1	1	3	**5**
	Oenopota tabulate, Carpenter, 1864	6	8	8	**22**
Borsoniidae	*Ophiodermelta cacellata*, Carpenter, 1864	1	1	1	**3**
Total		**1624**	**1908**	**2011**	5543
Total *Family*	**16**				
Total *Genus*	**25**				
Total *Species*	**31**				

Table 1.
Gastropod assemblage in the sampled quadrates using belt transect method.

number of the gastropods in the rocky intertidal zone having a total of 3841 followed by *Lirobittium attenuatum* of the *Family Cerithiidae* with 471, *Turbonilla* sp. 1 of the *Family Pyramidellidae* [7] with 226, *Cerithiopsis* sp., 211 of the *Family Cerethiopsidae*, and *Calliostoma variegatum*, 203 which is also from *Family Calliostomatidae*. Over-all, the highest number of total species was recorded in 2018 with 2011, a total of 1908 in 2017 while 1624 in 2016. In a 3-year study, a total of 5543 individual species were identified inhabiting the small parcel of the rocky shore of Asry Beach. Samples of gastropods in their natural habitat are shown in **Figure 3**, which include *Turbonilla* sp. (A) of the *Family Pyramidellidae*, *Lirularia olirulata* (B) of the *Family Trochidae*, and a group of *Cerithiopsis* sp. (C) of the *Family Cerethiopsidae* in association with algal community. Various studies on gastropod assemblage showed diversity of gastropods in the intertidal habitats [13–16] similar in this study with the use of diversity indices. However, the types of substrate vary from fine sand coral reef flats [13] and rocky shore beaches [9], including intertidal rocky shores [14, 15] and generally the intertidal zone of mixed substrate [6, 11]. Results of gastropod diversity study in Sombu Beach, Wakatobi, Indonesia showed 13 species of classes of gastropods covering only a month of study however using more transects [13] while a 3 year study of monthly sampling but using only one transect with 31 identified species. Generally, the type of substrate and the length of time for data gathering vary, although both conducted researches utilized the same sampling method. Composition of molluscs was compared in two communities of rocky shore beaches exposed to human activities. Results showed greater abundance and evenness in the site with less human activities [9] which is comparatively different from the claim that human factor considerably exerts no effect on diversity of gastropods in Asry Beach based on the results of monitoring studies [17]. Likewise, the researches being compared used diversity indices in quantitative analysis of data. Some similar researches covered wider spatial distribution of intertidal gastropods [1, 11, 14] although this research covered only a smaller scale on obligate rocky platform. Identified gastropods were taxonomically classified [13, 14] to the lowest level and specific count of species was determined.

3.3 Data analysis

3.3.1 Measure of diversity

Species diversity and evenness are presented in **Table 3**. Results of the Shannon-Wiener diversity index (H′) and Pielou's evenness index (J') show that species diversity is high (H′ > 4) in the *Family Muricidae* with computed H′ value of 4.19. Evenness is complete (J' = 1) where J' value is 3.81. High species diversity of this group indicates the most number of species (four species) and evenly distributed in the sampled plots of the study site compared to other gastropod families. Generally, the muricids are commonly found in rocky habitat hence these are called rock snails. They are carnivores and predators of sessile animals [18, 19]. Identified gastropod assemblage can adapt to varying environmental conditions such as fluctuation in temperature due to intense solar radiation [1, 6] biotic and abiotic factors [11], substrate condition [10] and wave actions [1, 13]], physical and chemical factors such as temperature [1, 6], salinity, pH and dissolved oxygen (DO) [16] and increase human activities [9, 11]. Specifically in this particular research, aerial temperature was considered as a factor since transect with sampled plots were laid on the elevated rocky habitat (**Figure 1**). Recorded monthly aerial temperature from January 2016 to January 2018 was correlated with the population of gastropod species assemblage (**Table 1**). In some related gastropod diversity studies, temperature in general [16] was considered as limiting factor instead of aerial temperature.

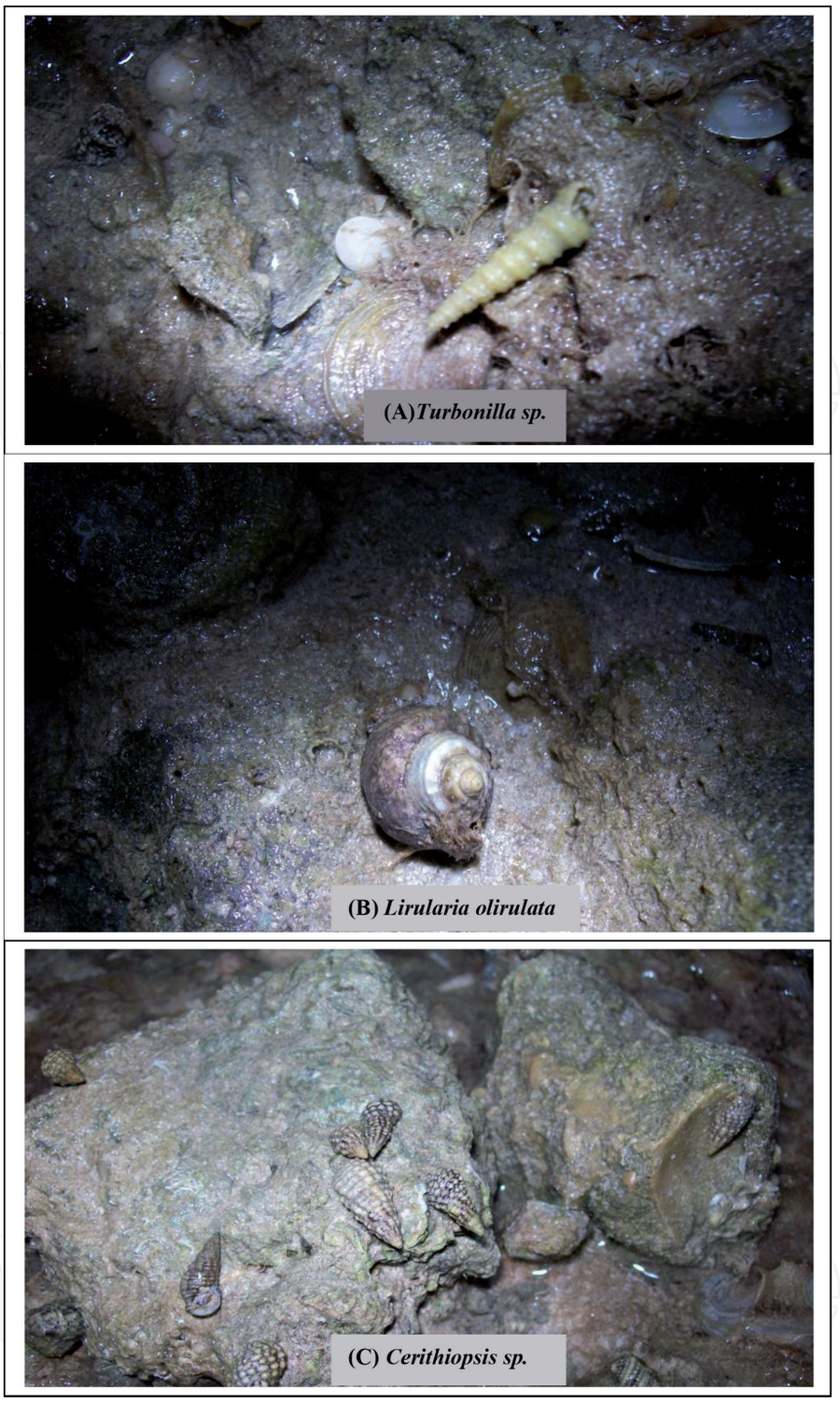

Figure 3.
Samples of gastropods in their natural habitat during the lowest low tide.

In sampling locations partly submerged in water as in tidal pool [6, 12] coral reef habitat [13] and the littoral zone [14], water temperature was considered a moderating variable. Generally, the various habitats determined the species of gastropods [7] which directly or indirectly affected by the dynamics of the environmental temperatures. The distribution of organisms is non-homogeneous in the intertidal zone which changes based on the biotic and abiotic factors [12]. Species diversity is moderate ($2 < H' < 4$) among the *Family Pyramidellidae* ($H' = 3.29$; $J' = 2.99$); *Family Cerithiidae* ($H' = 3.22$; $J' = 2.92$); *Family Oliveliidae* ($H' = 3.12$; $J' = 2.84$); *Family Calliostomatidae* and *Turbinidae* ($H' = 2.19$; $J' = 1.99$) including species

of *Family Trochidae*, *Buccidae*, *Velutinidae*, and *Margeliidae* having two to three species. Other species in the *Family Batillariidae*, *Borsoniidae*, *Cerethiopsidae*, *Epitoniidae*, *Volutidae* and *Columbellidae* have low diversity (H′ < 2). Of the 31 species (**Table 1**), three gastropod species have no evenness, *O. borealis* of the *Family Epitoniidae* (J' = 0.97) *A. ternsii* which belong to *Family Volutidae* and *A. aurantiaca of the Family Columbellidae* (J' = 0.95). Over-all, diversity in the rocky habitat of Asry Beach is moderate with the weighted mean of H′ = 2.06 however evenly distributed (J' = 1.88) (**Table 2**). Results imply that the resources specifically food [5] in the sampled rocky habitat supports the assemblage of gastropod species thus maintaining ecological balance in beaches [9].

Identified gastropods/Taxonomic classification		**Shannon-Wiener (H′)**	**Species evenness (J')**
Family	***Species***		
Volutidae	*Arctomelon ternsii*, Dall, 1872	1.04	0.95
Columbellidae	*Astyris aurantiaca*, Dall, 1871	1.04	0.95
Batillariidae	*Batillaria attramentaria* Sowerby, 1855	1.11	1.01
Cerithiidae	*Bittium vancoverense*, Dall & Bartsch, 1910*Lirobittium attenuatum*, Carpenter, 1864*Stylidium eschrichtii*, Middendroft, 1849	3.22	2.92
Oliveliidae	*Callianax baetica*, Carpenter, 1864*Callianax obiplicata*, Sowerby, 1825*Callianax pycna*, S. S. Berry, 1925	3.13	2.84
Calliostomatidae	*Calliostoma selectum*, Dillwyn, 1817*Calliostoma variegatum*, Carpenter, 1864	2.19	1.99
Cerethiopsidae	*Cerithiopsis* sp.	1.10	1.0
Pyramidellidae	*Evalea tenuisculpta*, Carpenter, 1864*Turbonilla* sp. 1*Turbonilla* sp. 2	3.29	2.99
Turbinidae	*Homalopoma baculum*, Carpenter, 1864*Homalopoma luridum*, Dall, 1885	2.19	1.99
Buccidae	*Lirabuccinum odirum*, Reeve, 1846*Volutharpa ampullarea*, Middendroft, 1848	2.10	1.91
Trochidae	*Lirularia olirulata*, Carpenter, 1864*Lirularia succinata*, Carpenter, 1864	2.12	1.93
Velutinidae	*Marsenia thrombica*, Dall, 1871*Velutina velutina*, O. F. Muller, 1776	2.08	1.89
Muricidae	*Nucella lamellosa*, Gmelin, 1791*Ocenebra inornata*, Recluz, 1851*Ocinebrina atropupurea*, Carpenter, 1864*Scabrotrophon maltzani*, Kobett & Kuster, 1878	4.19	3.81
Epitoniidae	*Opalia borealis*, Kepe, 1881	1.07	0.97
Margeliidae	*Oepota olividensis*, Carpenter, 1864*Oenopota tabulate*, Carpenter, 1864	2.04	1.85
Borsoniidae	*Ophiodermelta cacellata*, Carpenter, 1864	1.11	1.01
Weighted Mean		2.06	1.88

Table 2.
Result of Shannon-Wiener diversity index (H') and Pielou's species evenness (J').

3.3.2 Statistical analysis on the annual species assemblage

Although the total annual assemblage is high (**Table 1**) statistical analysis using one-way analysis of variance (ANOVA) revealed insignificant differences in the total annual population of gastropod species (**Table 3**). Results imply stability of gastropod species assemblage due to availability of food resources to support community structure [9]. Wet rocky biota promotes massive algal growth which serves as feeding ground for gastropod species [5]. Individual gastropod species only compete for space [6], be it on the rock surface or crevices. Although gastropods are motile, they tend to move slowly thus preventing them from moving in and out of the intertidal ecosystem as a consequence of short period of tidal change [12]. These attributes explain the stability of gastropod assemblage in this particular biota.

3.3.3 Effect of aerial temperature on the total assemblage of gastropods

Gastropods are adapted to various environmental factors [6, 13], including changes in diurnal temperature [1, 7, 8, 15]. Tolerant species are identified based on the highest annual individual species count and total count (**Table 1**). Top

Source	SS	df	MS	*F*-value	*p*-value
Between treatments	2653.5699	2	1326.7849	0.03052	.96995^{ns}
Within treatments	3912380.7097	90	43470.8968		
Total	3915034.2796	92			

ns = means not significant at p < 0.05.

Table 3.
Result of analysis of variance (ANOVA).

Month	Mean annual aerial temperature (in °C)			
	Year			Mean
	2016	2017	2018	
January	18	19	18	**18.33**
February	19	17	20	**18.67**
March	23	21	25	**23**
April	26	28	27	**27**
May	32	33	32	**32.33**
June	34	35	36	**35**
July	36	37	36	**36.33**
August	36	37	36	**36.33**
September	34	35	35	**34.67**
October	29	31	31	**30.33**
November	25	26	25	**25.33**
December	21	20	18	**19.67**
Mean	**27.75**	**28.25**	**28.25**	**28.08**

Table 4.
Summary of mean aerial temperature (in °C), January 2016–January 2018.

Variables	Sum	Mean	SS	n	r	*p*-value[ns]
Aerial temperature (°C)	333.99	27.832	508.163	12	−0.0231	.943438
Total species of gastropod assemblage	5543	461.917	11776022.917			

ns, not significant @ p < .05.

Table 5.
Result of Pearson r coefficient of correlation.

tolerant species include *C. selectum* with increasing annual population of 1025 in 2016, 1221 in 2017, and 2231 in 2018 (total of 3481); *L. attenuatum* (2016 = 156; 2017 = 148; and 2018 = 167; total = 471); *Turbonilla* sp. 1 (2016 = 68; 2017 = 71; and 2018 = 81; total of 226). Results imply that these species have higher level of tolerance to temperature changes. The mean temperatures vary annually. In 2016, the mean monthly temperature ranged from 18 to 36°C; 17 to 37°C in 2017; and 18 to 36°C in 2018. Hence, the mean temperature in **Table 4** shows fluctuating monthly temperatures with annual mean temperature of 27.75°C in 2016 and 28.25°C in 2017 and 2018.

Statistically, result of Pearson r coefficient of correlation in **Table 5** shows a negative correlation (r = −0.0231). It means that temperature changes exert no effect on the total count of gastropod assemblage. The *p*-value of .943438 means not significant at $p < .05$. The identified assemblage of gastropods in the rocky zone of Asry Beach constitutes a stable community structure which means that aerial temperature has insignificant effect (*p*-value = .943438, not significant at $p < .05$) on the population of gastropods although the rocky habitat is exposed to diurnal sun lit. In some related studies however [16], correlation analysis revealed a significant positive correlation between the physical factors such as temperature, salinity, pH and DO in diversity of gastropods in the coastal waters of Ambon Island, Indonesia. Temperature as a factor in the related study refers to water temperature considering the type of substrate where the gastropods were sampled. Hence different from the emergent rocky habitat where the gastropods abound on rock surfaces and crevices (**Figure 2**).

4. Conclusions

Asry Beach in the Kingdom of Bahrain is typically an intertidal ecosystem characterized by both sandy and rocky substrate. As a public beach, visitors and other beach goers prefer the sandy portion rather than the rocky part. The rocky zone remains undisturbed where macroflora/fauna community contributes in the coastal food chain and in other ecological interactions. The emergent wet rock surfaces and crevices promote massive algal growth which serves as the feeding ground for many macrofaunal communities. Marine gastropods as natural inhabitants in the rocky biota are tolerable to changes in aerial temperature, thus maintains the dynamics in the rocky shores and ecological balance in beaches. The over-all status of diversity and individual species distribution determine the impact of both the biotic and abiotic factors on gastropod assemblage. Periodic biodiversity assessment and monitoring are initiatives for the protection, preservation and conservation of the natural habitat of gastropods.

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References

[1] Dave TH, Chudasama BG. Survey and diversity of intertidal mollusks along the coast of Veraval (Gujarat), Arabian Sea. International Journal of Science, Environment and Technology. 2018;**7**:353-360

[2] Vaghela A, Bhadja P, Kundu R. Diversity and distribution of intertidal mollusca at Saurashtra coast of Arabian Sea, India. Global Journal of Bio-Science and Biotechnology. 2013;**2**:154-158

[3] Lakwal VR, Kharate DS, Mokashe SS. Intertidal macrofaunal invertebrates diversity from Ratnagiri coast, (MS) India of Arabian Sea. International Journal for Research in Applied Science and Engineering Technology. 2018;**6**:1630-1638

[4] Donnarumma L, Sadulli R, Appolloni L, Sanchez-Lizazo JL, Russo GP. Assessment of structural and functional diversity of mollusk assemblages within vermetid bioconstructions. Diversity. 2018;**10**:96. DOI: 10.3390/d10030096

[5] Jeeva C, Mohan PM, Dil Baseer Sabith KK, Ubare VV, Murugananthar M, Kumari RK. Distribution of gastropods in the intertidal environment of south, middle and north Andaman Islands, India. Open Journal of Marine Science. 2018;**8**:173-195. DOI: 10.4236/ojms.81009

[6] Sullivan H. The effect of gastropod diversity and density on macroalgae diversity in the Massachusetts rocky intertidal. Journal of Marine Ecology. 2015;**1**:19-26

[7] Kohan A, Badbardast Z, Shokri M. The gastropods fauna along the Bushehr Province intertidal zone of the Persian Gulf. Journal of the Persian Gulf. 2012;**3**:33-42

[8] Siti-Balkhis AB, Yaman IC, Siti-Hasmah I, Khalil MZ, Muhammad-Shukri MY, Zulfigar Y, et al. A survey of the marine intertidal macrogastropoda in the northern straits of Malaca. ASM Science Journal. 2015;**8**(2):159-164

[9] Martinez E, Sanchez J, Alba A, Vazquez AA. Changes in structure and composition of two communities of rocky shores mollusks exposed to different human impact in playa Jibacoa, Cuba. Journal of Ecosystem & Ecography. 2015;**5**:1-6. DOI: 10.4172/2157-7625.1000162

[10] Pandey V, Thiruchitrambalam G, Satyam K. Habitat heterogeneity determines structural properties of intertidal gastropod assemblages in a pristine tropical island ecosystem. Indian Journal of Geo Marine Sciences. 2018;**47**:846-853

[11] Kurhe AR, Rodriguez MA, Suryawanshi GD. Vertical distribution and diversity of gastropods mollusks from intertidal habitats of the Ratnagiri coast Maharashtra, India. International Research Journal of Natural and Applied Sciences. 2014;**1**:1-13

[12] Pandey M, Desai AY, Mathew KL. Quantitative abundance of key intertidal gastropods at port Okha reef Gujarat. International Journal of Fisheries and Aquatic Studies. 2017;**5**:188-192

[13] Rahmayanti F, Nazira FK, Dewi AK, Tranggono YA. Biodiversity of gastropod in the Sombo Beach, Wakatobi, Indonesia. In: IOP Conference Series; 2018. DOI: 10.1088/1755-1315

[14] Baharuddin N, Basri NB, Syawal NH. Marine gastropods (Gastropoda; Mollusca) diversity and distribution on intertidal rocky shores of Terengganu, peninsular Malaysia. AACL Bioflux. 2018;**11**:1144-1154

[15] Londono-Cruz E, Lopez de Mesa-Agudelo LA, Arias-Galvez F, Herrera-Paz DL, Prado A, Cuellar LM, et al. Distribution of macroinvertebrates on intertidal rocky shores in Gorgona Island, Colombia (tropical eastern Pacific). Journal of Tropical Biology. 2014;**62**:189-198

[16] Rumahlatu D, Leiwakabessy F. Biodiversity of gastropods in the coastal waters of Ambon Island, Indonesia. AACL Bioflux. 2017;**10**:1-12

[17] Lumeran BT. Gastropods in the intertidal zone of Asry Beach, Kingdom of Bahrain. International Advanced Research Journal in Science, Engineering and Technology. 2015;**2**:93-97. DOI: 10.17148/IARJSET.2015.2720

[18] Harbo RM. A Field Guide to Seashells and Shellfish of the Pacific Northwest. Canada: Harbour Publishing Company Limited; 2009. 22 pp

[19] Robin A. Encyclopedia of Marine Gastropods. Germany: ConchBooks, IKAN Interwasser-Archi; 2008. 480 pp

[20] Shell Catalogue [Internet]. 2019. Available from: www.gastropods.com/taxon_pages/TN_Family-shtml

[21] World Register of Marine Species-Gastropods (WoRMS) [Internet]. 2019. Available from: www.marinespecies.org/