BOLETIM DO INSTITUTO DE PESCA
Scientific Article

The habitat preference and benthic assemblage structure of gastropods at notorious place of Buleji, coast of Sindh, Pakistan: New records and insights

Urooj Fatima[1]*, Fatima Hayat Shaheen Zafar[1], Sher Khan Panhwar[2]

[1]Federal Urdu University of Arts, Science and Technology – Faculty of Science, Department of Zoology – Karachi, Pakistan.
[2]University of Karachi – Center of Excellence in Marine Biology – Karachi, Pakistan.
*Corresponding author: fatimaurooj127@gmail.com

ABSTRACT

Earlier studies on faunal diversity of Buleji was conducted to examine gastropod assortment in the intertidal area, but none has been conducted in relation to the abiotic factors aimed to ascertain habitat change and intertidal migration of snails. For this purpose, gastropods diversity data from March 2021 to February 2022 (bimonthly) and previous gastropods biodiversity data which conducted over last three decade were gathered. A total of 38 gastropod species were recorded during the study with 10 species being documented first time in Buleji. The low tidal zone was found to be most populated zone with species like *Lunella coronata*, and *Planaxis sulcatus,* while the high tidal zone was abundantly populated by *Lunella coronata*, *Monodonta* cf. *nebulosa*, *Nodilittorina natalensis*, and *P. sulcatus*. Canonical correspondence analysis revealed that some species were highly vulnerable to the abiotic factors such as *Babylonia* sp., *Clypeomorus sp.*, *Conus* sp., *Monodonta* sp., *Nerita*-sp., *Nodilittorina*, *Thais* sp., and *Planaxis* sp. is very sensitive to the sea surface temperature, total dissolve substances, salinity, conductivity and atmospheric temperature, whereas *Astraea* sp., *Chiton* sp., *Clypeomorus* sp., *Lunella* sp., *Nerita* sp. and *Turbo* sp. showed affirmative relationship with dissolved oxygen. As consequences, some species shifted their habitat from one tidal zone to another zone, while some others stayed or some disappeared completely when compared them from previous data of Buleji.

Keywords: Abiotic factors; Buleji; Gastropods; Biodiversity; Intertidal zone.

Preferência de hábitat e estrutura da comunidade bentônica de gastrópodes num local notório da costa de Sindh, Paquistão: Novos registros e descobertas

RESUMO

Estudos anteriores sobre a diversidade da fauna de Buleji foram conduzidos para examinar a variedade de gastrópodes na zona intertidal, mas nenhum foi realizado em relação aos fatores abióticos com o objetivo de determinar a mudança de habitat e a migração intertidal dos caracóis. Para este efeito, foram recolhidos dados de diversidade de gastrópodes de março de 2021 a fevereiro de 2022 (bimestralmente) e dados anteriores de biodiversidade de gastrópodes recolhidos ao longo das últimas três décadas. Um total de 38 espécies de gastrópodes foram registadas durante o estudo, sendo que 10 espécies foram documentadas pela primeira vez em Buleji. A zona de maré baixa foi considerada a mais populosa, com espécies como *Lunella coronata* e *Planaxis sulcatus,* enquanto a zona de maré alta foi abundantemente povoada por *Lunella coronata, Monodonta* cf. nebulosa, *Nodilittorina natalensis* e *P. sulcatus*. A análise de correspondência canónica revelou que algumas espécies eram altamente vulneráveis a fatores abióticos, como *Babylonia* sp., *Clypeomorus* sp., *Conus* sp., *Monodonta* sp., *Nerita* sp., *Nodilittorina* sp., *Thais* sp. e P*lanaxis* sp., que são muito sensíveis à temperatura da superfície do mar, ao total de substâncias dissolvidas, à salinidade, à condutividade e à temperatura atmosférica. Por outro lado, algumas espécies, como a *Astraea* sp., *Chiton* sp., *Clypeomorus* sp., *Lunella* sp., *Nerita* sp. e *Turbo* sp., apresentaram uma correlação positiva com o oxigénio dissolvido. Como consequência, algumas espécies migraram de uma zona de maré para outra, enquanto outras permaneceram nos seus habitats originais e algumas desapareceram por completo, quando comparadas com os dados anteriores de Buleji.

Palavras-chave: Fatores abióticos; Buleji; Gastrópodes; Biodiversidade; Zona intertidal.

Received: December 30, 2024 | **Approved:** April 7, 2026
Section editor: Luis Felipe Duarte

INTRODUCTION

Buleji is a renowned coastal area where large number of visitors reach every day for sea sightseeing and sport fishing. Texturally, it is made up of solid rocks and sand in cradle. Settlement of diverse shell in the intertidal area is the real beauty of this place (Zafar, 2013). The intertidal zone is an area with interchanging periods of submersion and exposure due to tidal cycles, generating a highly stressful habitat where only well-adapted organisms can flourish (Baloch, 2025). Due to effortless access and fascinating rocky structure, it catches attention of visitors. It is now assessable that this current situation of the area expresses significant disturbance of coastal ecosystem.

The rocky texture has great variety of macrofauna such as limpets, snails, squids, oysters, octopus, crabs, etc. and provide them shelter and food. The most noticeable macrofauna of the Buleji rocky shore are gastropods. In aquatic food-chain, gastropods are the primary consumers. Benthic organisms play a vibrant role in ecosystem by recycling nutrients, decomposing organic matter, and encouraging food webs (Kachhi et al. 2024; Kashani et al., 2025). They are sessile and used as a source of food, besides their shells being used for decoration, pearl industry, and other purposes (Monolisha & Edward, 2015; Wosu, 2003). Gastropods are considered as good environmental and water-quality indicators (Alhejoj et al., 2017). Due to their filter feeding nature, they are very sensitive to the habitat, specially to water quality or environment, because they detect and shift their habitat from one place to another or gradually disappear in case of pollution or human made activities.

Moreover, development of huts has been steadily increasing in Buleji. Environmental change is a fact of life and can lead species evolution or species extinction (Kennedy et al., 2002). Abundance and diversity rely on habitat structure and physical factors (Satyam & Thiruchitrambalam, 2018). The community structure and composition of intertidal benthic organisms depend on the highest high tide and the lowest low tide. Rocky shores organisms encounter extreme physiochemical conditions during tidal changes from upper to lower intertidal zones (Baharuddin et al., 2018).

Gastropods are well adapted to survive fluctuating conditions (Marshall et al., 2013). They have hard exoskeleton which is made up of calcium carbonate and a protective operculum through which they can tolerate extreme condition including temperature over 50°C (Knox, 2001; Xu et al., 2018). These fluctuations in environmental variables such as temperature, salinity, dissolved oxygen, and CO_2 concentration can strongly affect the diversity and distribution of gastropod communities (Llovel & Terray, 2016; Wittmann & Pörtner, 2013). Marine coasts and seas are considered critical habitat for biodiversity (Kang et al., 2021).

The ecology of benthic communities has been an interesting topic for researchers for decades (Underwood, 2000). The rocky shores of Buleji, Pacha, Paradise Point, Cape mounts, and Manora, especially along the Sindh coast, have been studied extensively. However, due to its effortless access and colorful aquatic life, Buleji attracts local researchers. Afser (2009), Ahmed & Hameed (1999), Bano (2009), Khan & Dastagir (1971), Moazzam & Rizvi (1983), Rehman & Barkati (2010), Shamim (2001), Tirmizi & Zehra (1982), Zafar (2013), and Zehra & Parveen (1991) have studied seasonal variations of intertidal macro-organisms' population structure (Barkati & Burney, 1995; Nasreen et al., 2000; Rehman & Barkati, 2012). Some other information is available on the identification, distribution, and zonation of macrofauna of the coast of Pakistan (Ahmed, 1977; Haq et al., 1978; Khan & Dastagir, 1971). While Qari (1985), Qari & Qasim (1988), Saifullah (1973), and Shameel & Tanaka (1992) have dealt with the ecology and distribution of seaweeds on the rocky shore of Buleji, Barkati and Burney (1995) studied the species composition and biomass of marine animal's communities of rocky ledge of Buleji. However, there is still no research related to the impacts of physicochemical parameters on the biodiversity of benthic marine fauna of tidal areas, except few about the effects of pollution on marine biodiversity along these shores (Rehman & Barkati, 2004). The present study is important, because it provides a more complete understanding of the impacts of abiotic factors which influence gastropods diversity and benthic assemblage structure of Buleji.

MATERIALS AND METHODS

Study area and timeline

Buleji (rocky cum sandy) shore is situated between the Hawks Bay and Paradise point (Fig. 1). Exposed area of Buleji is arbitrarily divided into three zones thinking on tidal height: low tidal zone (LTZ), mid tidal zone (MTZ), and high tidal zone (HTZ). The MTZ and HTZ inhabit boulders of various sizes scattered predominantly. The MTZ also occupies the highest number of gastropods. The present study is based on regular visits (bi-monthly) of the intertidal area of Buleji from March 2021 to February 2022.

Sampling strategy

The intertidal zone of the shore is measured vertically with a 200-m rope from LTZ to HTZ. Horizontally, it measures 100 m at the LTZ. Each zone vertically measured 66.6 m. Random sampling through quadrate (1 m^2) method was made due to the rocky texture or large-size boulders. Five replications were applied at the distance of 20 m horizontally, where random approach

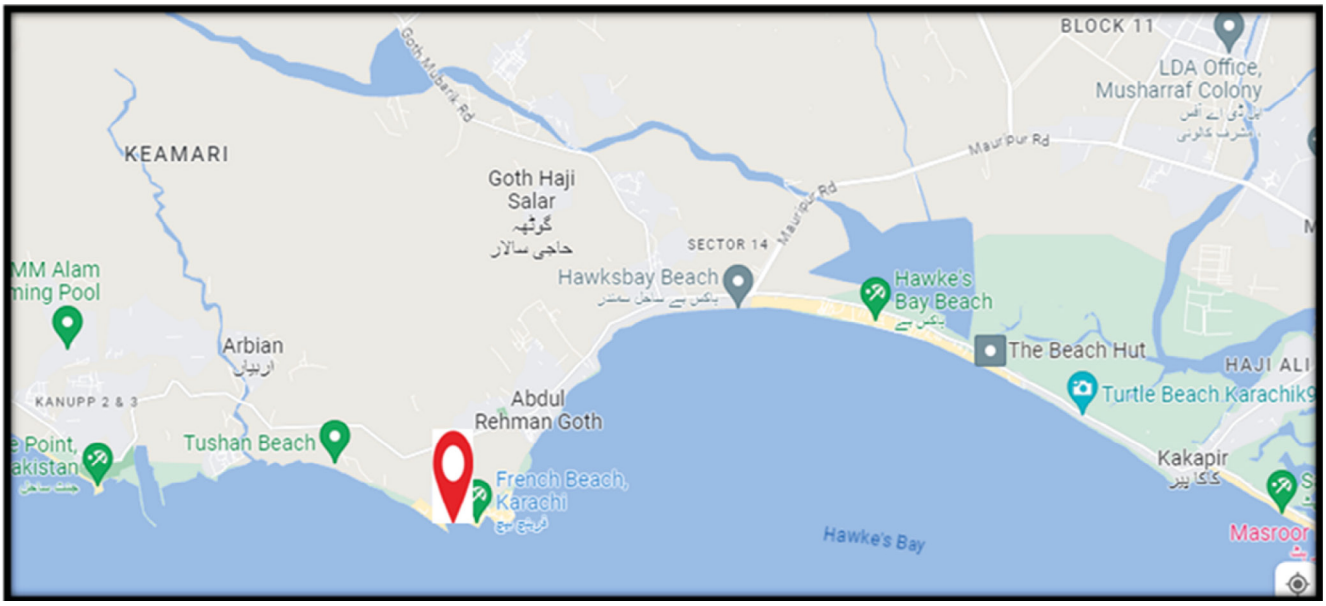


Figure 1. Location map red mark indicates Buleji/French beach.

of collection was adopted. In this way, five spots were made at each zone. The species habitat observation and counting were performed on the spot. Each species sample was placed in zipper lock bags, labelled, and taken to the laboratory for identification.

Species identification

Each individual gastropod species collected was identified (Fig. 2) by using national or international published literatures, such as Bosch et al. (1995), and Kazmi et al. (2018).



Figure 2. Check list of 38 gastropod species inhabiting intertidal area encountered in this study.

Environmental and water quality parameters

The physicochemical parameters, including tidal level, atmospheric temperature (°C), water temperature (°C), dissolved oxygen (ppm), conductivity, total dissolved substances (TDS), pH level, and salinity (ppt), was recorded during each visit using online water quality tester (HL4, Hydro lab, United States of America).

Historical (time series) data was collected from the published scientific literatures on Buleji.

Statistical analysis

Statistical analysis was performed with Excel sheets by using the formulas of biodiversity indices such as Shannon-Wiener's index, Simpson's index, richness, evenness, dominance, and canonical correspondence analysis.

Gastropod biodiversity indices

Ecologically, biodiversity can be defined as a degree of variation within or among the species that lives in a particular area. Diversity index is a quantitative measurement of how many different types of species live in an area. These indices are the statistical representation of biodiversity in different aspects, such as richness, evenness, dominance, Shannon's and Simpson's indices, which are widely used to measure ecological biodiversity.

Canonical correspondence analysis

A relationship between the physio-chemical parameters and gastropods abundance and distribution was calculated by using the multivariate approach of canonical correspondence analysis (CCA).

RESULTS

Two types of data, including one-year sampling and three-decade historical biodiversity data of the same site, were used to underline the current situation of intertidal gastropods assemblage (Table 1). In addition, impacts of physicochemical parameters on the fragile coastal communities of gastropods were observed, although this study was done to describe decadal variation in gastropods diversity in relation to previous data.

Table 1. Current (2021–2022) and historical (1991–2020) gastropods diversity of intertidal area of the rocky shore of Buleji, Karachi, Pakistan.

Species	n/%	Current zone	Author	Year	n/%	Previous zone
Astralium semicostatum	61/0.57	LTZ	Ahmed & Hameed	1999	Not mentioned	MTZ
Babylonia spirata	2/0.01	HTZ	Afser	2009	109	Not mentioned
Cellana karachiensis	138/1.30	LTZ	Barkati & Burney as *C. radiata*	1991	486	Not mentioned
			Ahmed & Hameed	1999	Not mentioned	Not mentioned
			Zafar	2013	1,909	HTZ
			Atta et al.	2013	64	MTZ and HTZ
Chiton sp.	10/0.12	MTZ	Barkati & Burney	1991	Not mentioned	Not mentioned
Cerithium caeruleum	519/4.91	MTZ	Ayub	2013	350	MTZ
Cerithium scabridum	8/0.07	MTZ	Ayub	2013	374	MTZ
Clypeomorus bifasciata persicus	227/2.14	MTZ	Ahmed & Hameed	1999	Not mentioned	MTZ
			Rehman & Barkati	2004	Not mentioned	MTZ
			Ayub	2013	261	MTZ
Conus coronatus	5/0.06	LTZ	Kazmi et al.	2018	Not mentioned	MTZ

Continue...

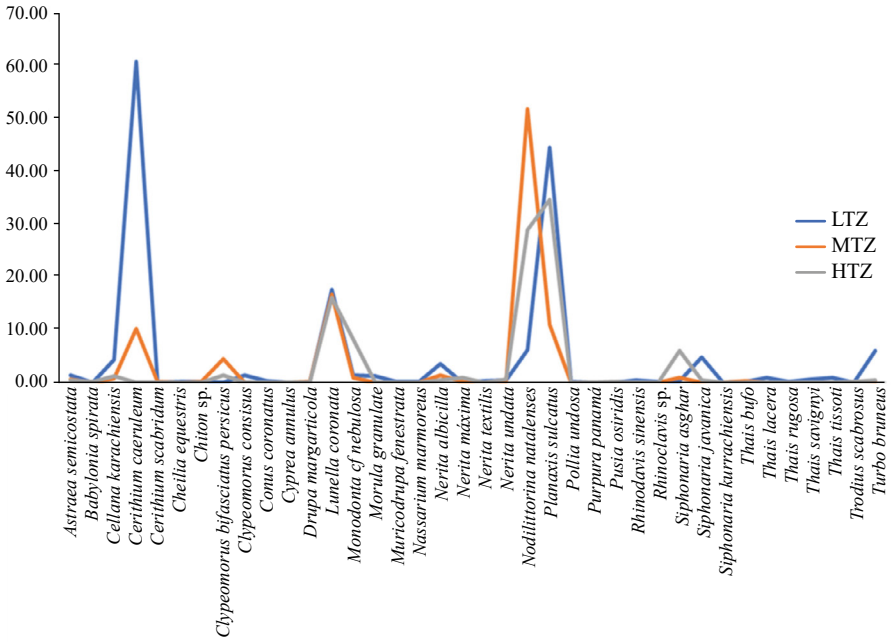
Continuation.

Species	n/%	Current zone	Author	Year	n/%	Previous zone
Drupa margariticola	6/0.07	MTZ	Ahmed & Hameed	1999	Not mentioned	MTZ
Lunella coronata	1380/16.77	MTZ	Barkati & Burney	1991	Not mentioned	Not mentioned
			Ahmed & Hameed	1999	Not mentioned	Not mentioned
			Rehman & Barkati	2004	Not mentioned	MTZ and HTZ
			Afser	2009	956	HTZ
Monodonta cf. *nebulosa*	204/2.48	HTZ	Kazmi et al.	2018	Not mentioned	Subtidal zone
Morula granulata	18/0.3	LTZ	Barkati & Burney	1991	132	Not mentioned
			Rehman & Barkati	2012	0.97%	Not mentioned
			Afser	2009	47	LTZ
Nassarius marmoreus	1/0.01	LTZ	Kazmi et al.	2018	Not mentioned	Not mentioned
Nerita albicilla	139/1.69	LTZ	Ahmed & Hameed	1999	Not mentioned	HTZ
			Rehman & Barkati	2004	Not mentioned	MTZ and HTZ
			Rehman & Barkati	2012	2.26	Not mentioned
Nerita textilis	7/0.09	LTZ	Kazmi et al.	2018	Not mentioned	Not mentioned
Nerita undata	34/0.41	MTZ	Kazmi et al.	2018	Not mentioned	Not mentioned
Planaxis sulcatus	1,982/24.09	LTZ	Ahmed & Hameed	1999	Not mentioned	HTZ
			Rehman & Barkati	2004	Not mentioned	HTZ
			Rehman & Barkati	2012	13.25	Not mentioned
Pollia undosa	3/0.04	LTZ	Rehman & Barkati	2012	0.03	Not mentioned
Purpura panama	1/0.01	MTZ	Rehman & Barkati	2004	Not mentioned	LTZ
			Afser	2009	93	Not mentioned
Rhinoclavis sinensis	12/0.11	LTZ	Rehman & Barkati	2004	Not mentioned	LTZ
			Rehman & Barkati	2012	0.35	Not mentioned
			Ayub	2013	41	MTZ
Siphonaria asghar	142/1.73	HTZ	Bano	2009	447	Not mentioned
Thais bufo	11/0.13	MTZ	Afser	2009	55	LTZ
Thais lacera	17/0.21	LTZ	Afser	2009	1,035	Not mentioned
Thais rugosa	2/0.02	LTZ	Rehman & Barkati	2004	Not mentioned	LTZ
Thais savignyi	13/0.16	LTZ	Afser	2009	Not mentioned	Not mentioned
Thais tissoti	17/0.21	LTZ	Afser	2009	8	MTZ
Turbo bruneus	141/1.71	LTZ	Kazmi et al.	2018	Not mentioned	Not mentioned

LTZ: low tidal zone; MTZ: mid tidal zone; HTZ: high tidal zone.

Gastropods species inventory

Gastropods are the dominant group of macrofauna inhabiting in the intertidal zone of Buleji. In Buleji, 8,228 gastropod individuals were found throughout the entire study period, which consisted of nine orders, 17 families, and 25 genera. Most abundant gastropods species of Buleji were *Cerithium caeruleum*, *Lunella coronata*, *Nodilittorina natalensis*, and *Planaxis sulcatus*, which were observed during the entire study period (Fig. 3). This study also reported for first time 10 species of gastropods from the coast of Buleji (Table 2). However, 78 species of gastropods which were reported earlier could not be seen during the present study, probably because of the sampling procedure, lack of information about the exact location, the shore's vertical/horizontal profile, or their completely disappearance.



LTZ: lower tidal zone; MTZ: mid tidal zone; HTZ: high tidal zone.

Figure 3. An overall percentages composition of gastropods encountered in intertidal (lower, mid and upper) area of Buleji.

Table 2. Gastropods species first time reported during the whole study (Mar 2021–Feb 2022) from the rocky shore of Buleji, Karachi, Pakistan.

Species	Number of specimens	Intertidal zone
Cheilia equestris (Linnaeus, 1758)	1	LTZ
Clypeomorus concisus (Hombron & Jacquinot, 1848)	27	LTZ
Cypraea annulus (Linnaeus, 1758)	1	MTZ
Muricodrupa fenestrata (Blainville, 1832)	1	LTZ
Nerita maxima (J. F. Gmelin, 1791)	21	HTZ
Nodilittorina natalensis (R. A. Philippi, 1847)	81	LTZ/MTZ/HTZ
Pusia osiridis (Issel, 1869)	2	MTZ
Rhinoclavis sp. (Cossmann, 1889)	3	LTZ
Siphonaria javanica (Lamark, 1819)	105	LTZ
Siphonaria kurracheensis (Reeve, 1856)	2	MTZ

LTZ: low tidal zone; MTZ: mid tidal zone; HTZ: high tidal zone.

Percentage composition of gastropod diversity

During the study, at the LTZ, *P. sulcatus* showed the highest percentage (44.5%) and *Cheilia equestris*, *Thais bufo*, and *Muricodrupa fenestrata* showed the lowest percentage (0.05%) (Fig. 4). On the MTZ, *N. natalensis* showed the highest percentage (51.7%), while *C. annulus*, *Thais savignyi*, *Purpura panama*, and *Pusia osiridis* showed the lowest percentage (0.02%) (Fig. 5). On the HTZ, one more time *P. sulcatus* and *N. natalensis* showed the highest percentage (34.7 and 28.9%), and *P. osiridis* showed the lowest percentage (0.02%) (Fig. 6).

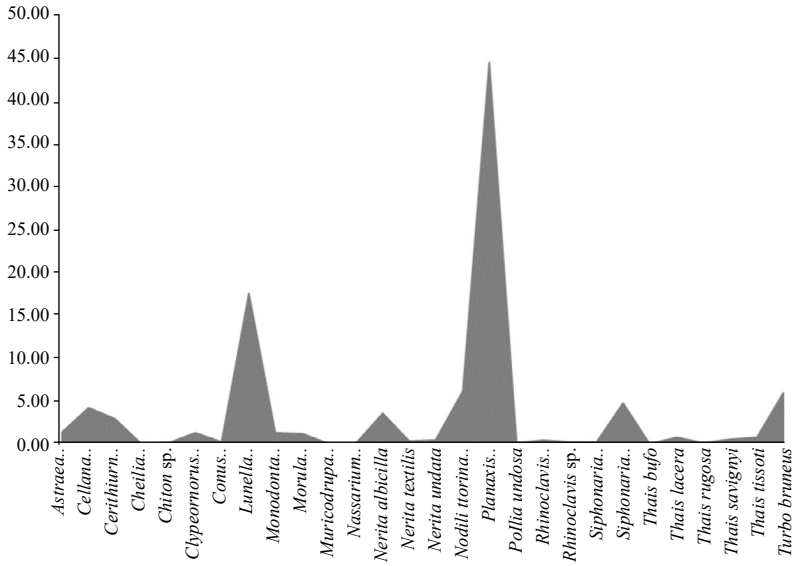


Figure 4. Segregated species diversity of gastropods inhabiting at lower tidal zone.

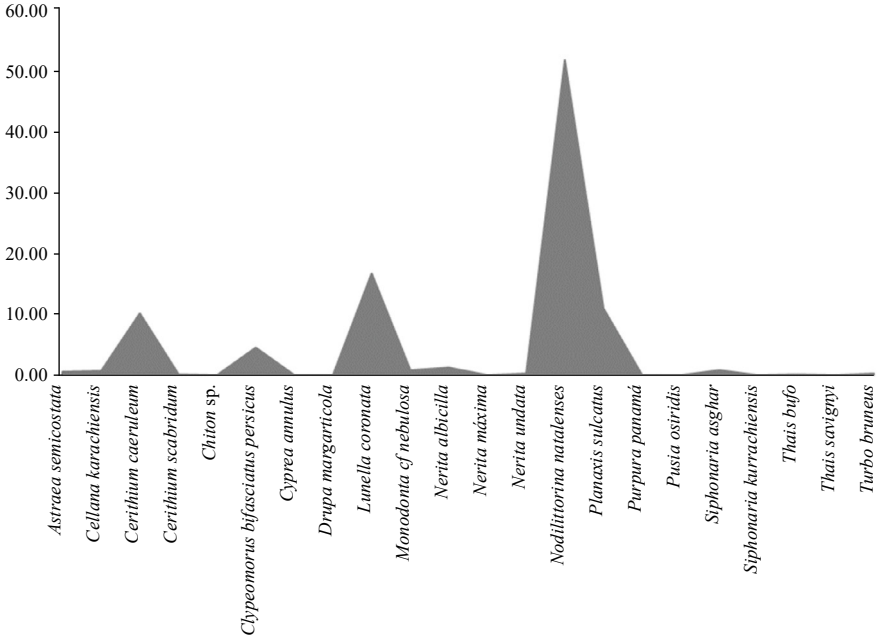


Figure 5. Segregated species diversity of gastropods inhabiting at mid tidal zone.

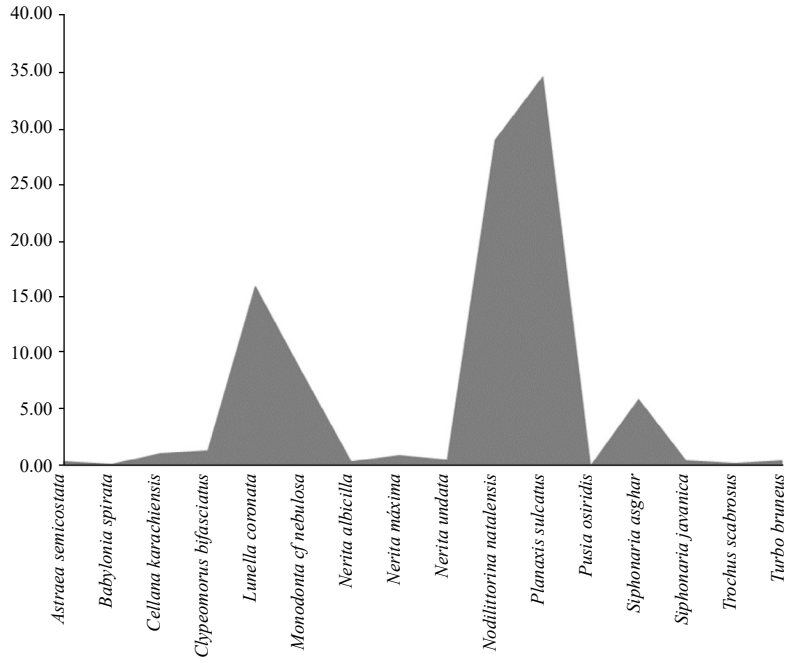


Figure 6. Segregated species diversity of gastropods inhabiting at high tidal zone.

The percent composition of different species indicates that many gastropod species were rare, for instance *Babylonia spirata* (0.02%), *Cheilea equestris* (0.01%), *Chiton* sp. (0.1%), *Cerithium scabridum* (0.1%), *Conus coronatus* (0.06%), *Cypraea annulus* (0.01%), *Drupa margariticola* (0.07%), *Thais rugosa* (0.02%), *M. fenestrata* (0.01%), *Nassarius marmoreus* (0.01%), *Nerita textilis* (0.09%), *Pollia undosa* (0.04%), *P. panama* (0.01%), *P. osiridis* (0.02%), *Rhinoclavis sinensis* (0.11%), *Rhinoclavis* sp. (0.04%), *Siphonaria kurracheensis* (0.02%), and *Trochus scabrosus* (0.04%).

Statistical analysis

A comparative and detailed account of indices revealed that diversity was the highest in the month of March 2021 and the lowest in May 2021, according to the Shannon's index (Table 3).

Table 3. Bimonthly variations in dominance, Simpson, Shannon (H′), evenness, and richness*.

Diversity indices	Mar 2021	May 2021	July 2021	Oct 2021	Dec 2021	Feb 2022
Dominance	0.175	0.800	0.234	0.466	0.440	0.206
Simpson	0.825	0.200	0.765	0.534	0.560	0.794
Shannon	2.074	0.539	1.882	1.149	1.125	2.039
Evenness	1.000	0.260	0.907	0.554	0.542	0.983
Richness	2.730	1.480	2.354	1.523	1.794	2.580

*H′ < 1: low species diversity; 1 < H′ ≤ 3: medium species diversity; H ′> 3: higher species diversity.

The maximum Simpson's index was observed in March 2021, and the minimum was noted in the month of May 2021 (Table 3).

The maximum evenness index value was noted in March 2021, while the minimum value was observed in the month of May 2021 (Table 3).

The maximum value of richness index was noted in the month of March 2021, and the minimum in May 2021 (Table 3).

The maximum dominance value was noted in May 2021, and the minimum in the month of March 2021 (Table 3).

Canonical correspondence analysis

Diversity data of gastropods in different seasons were used to gauge impact of environmental relationship such as atmospheric temperature (°C), sea surface temperature (°C), salinity (‰), conductivity (m), pH, dissolved oxygen (mg/L), and TDS (mg/L), and to develop CCA (Fig. 7). Overall variability 69.20 and 28.49 were calculated from I and II CCA components. For better understand, biplot was divided into four groups that define positive and negative relationship with environmental variables. Species name and their abbreviations are given in Table 4. For instance, group I defines negative relationship of sea surface temperature, TDS, salinity, and conductivity; they are the factors that impact the distribution and abundance of h, i, l, p, t, and v. Group II defines positive relationship of a, d, g, o, r, s, and aa with dissolved oxygen. Group III merely embraces b, k, u, and w that linked with atmospheric temperature. Nevertheless, group IV include c, e, f, j, m, n, q, y, and z, defining the least interaction with the environmental variables recorded in this discourse.

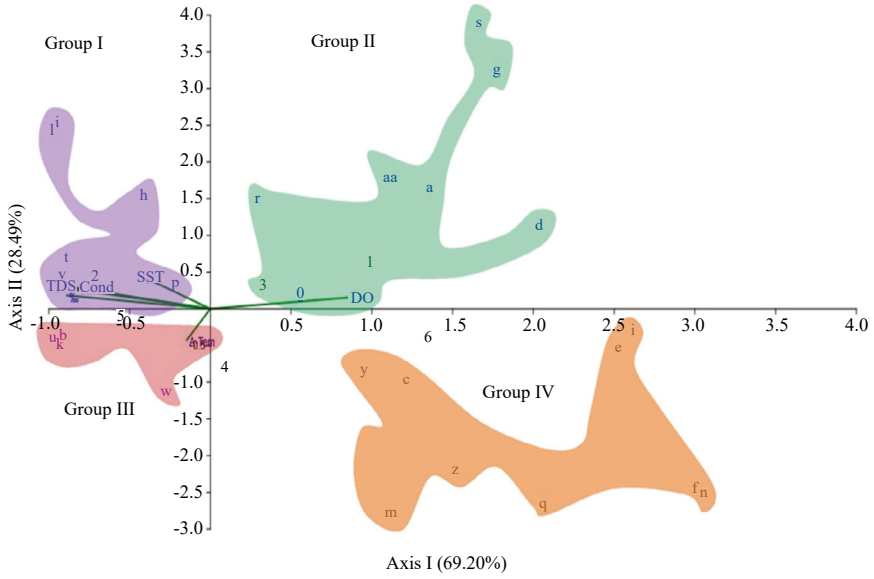


Figure 7. Biplot of canonical correspondence analysis applied to the gastropod diversity in relation to the environmental variables.

Table 4. Gastropods species that applied on biplot chart of canonical correspondence analysis to check the impact of physio-chemical parameters.

Species	Abbreviation
Astrea semicostatum	a
Babylonia spirata	b
Cellana karachiensis	c
Chiton sp.	d
Cerithium caeruleum	e
Cerithium scabridum	f
Clypeomorus bifaciatus persicus	g
Clypeomorus concisus	h
Conus coronatus	i
Drupa margariticola	j
Thais bufo	k
Thais lacera	l
Thais savignyi	m
Thais tissoti	n
Lunella coronata	o
Monodonta cf. *nebulosa*	p
Morula granulata	q
Nerita albicilla	r
Nerita maxima	s
Nerita undata	t
Nerita textilis	u
Nodilittorina natalensis	v
Planaxis sulcatus	w
Rhinoclavis sinensis	x
Siphonaria asghar	y
Siphonaria javanica	Z
Turbo bruneus	Aa

Water quality parameters

The seasonal variations in atmospheric and water temperature, salinity, pH, dissolved oxygen, conductivity, and TDS of the Buleji are detailed in (Fig. 8). The atmospheric temperature varied from 22 (in December) to 38°C (in October), with yearly average of 28.5°C. Sea water temperature varied from 22.3 (in February) to 33.3°C (in May), with yearly average of 27.4°C. The salinity ranged from 34.1 (in March 2021 and February 2022) to 34.8‰ (in December), with yearly average value of 34.4‰. The pH was 7, and this value was the same in all visits. The dissolved oxygen ranged from 5.5 (in December) to 7.1 (in February), with yearly average of 7. Conductivity measured from 51.1 (in February) to 52.8 (in December), with yearly average of 52.2; and TDS measured from 33.1 (in February) to 33.8 (in December), with yearly average 33.4.

Habitat change with reference to the three decadal data of gastropods diversity

Symbolic description with reference to the habitat and gastropod species collected in this study is given in Table 5.

DISCUSSION

One year of the present study and three-decade time series biodiversity data have answered several questions pertinent to the conservation and management of an important notorious place (Buleji). Despite numerous attempts by researchers to assess the intertidal area and understand habitat degradation, the underlying issues affecting passive-moving organisms remain

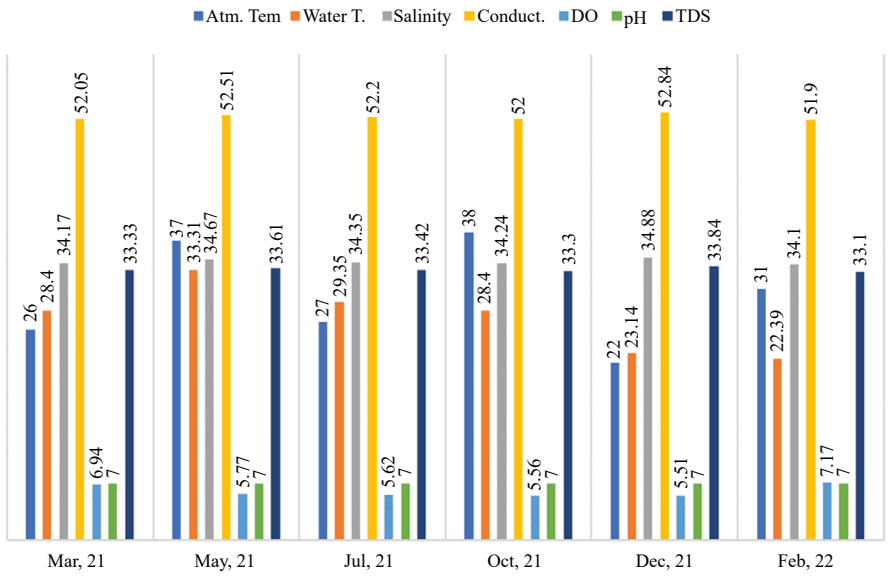


Figure 8. Summary of water quality parameters: sea surface temperature (SST), air temperature (AT), salinity, pH, dissolve oxygen (DO), and conductivity recorded during study period.

Table 5. Percentages of gastropods species and their symbols showing habitat zones.

Species	%	Category indicated with this symbol
astraea semicostatum	0.74	*
Babylonia spirata	0.02	>
Cellana karachiensis	1.68	±
Cerithium caeruleum	6.31	<
Cerithium scabridum	0.10	>
Chiton sp.	0.12	>
Clypeomorus bifasciatus persicus	2.76	>
Conus coronatus	0.06	*
Drupa margariticola	0.07	!
Lunella coronata	16.77	<
Monodonta cf. *nebulosa*	2.48	*
Morula granulata	0.30	>
Nassarius marmoreus	0.012	←
Nerita albicilla	1.69	±
Nerita textilis	0.09	←
Nerita undata	0.41	←
Planaxis sulcatus	24.09	≠
Pollia undosa	0.04	>
Purpura panama	0.01	±
Rhinoclavis sinensis	0.11	>
Siphonaria asghar	1.73	>
Thais bufo	0.13	>
Thais lacera	0.21	>
Thais rugosa	0.02	>
Thais savignyi	0.16	←
Thais tissoti	0.21	≠
Trochus scabrosus	0.04	←
Turbo bruneus	1.71	←

*Change in species' habitat; >: no change in species' habitat, but population reduced; ±: species' habitat changed, but population reduced; <: no change in species' habitat, but population increased; no change in species' habitat; ←: reported earlier but not mentioned their exact habitat zone; ≠: species' habitat changed, but population increased.

unclear. Our analysis revealed micro- and macro-level changes impacting gastropod diversity. This data will inform managers to develop effective conservation strategies and protect Karachi's ecological integrity.

The diversity, ecology, biology, and benthic assemblage structure of Buleji remained under focus of various researchers (Afser, 2009; Ahmed & Hameed, 1999; Ayub, 2013; Bano, 2009; Barkati & Burney, 1991, 1995; Nazim et al., 2015; Rehman & Barkati, 2004, 2010, 2012; Zafar, 2013). In the past tradition, biodiversity assessment was merely conducted hence the present study was designed to gauge changes over three decades in gastropod diversity and examine macro-changes in benthic communities' structure of entire tidal area of Buleji using recent and historical biodiversity data.

Gastropods were the well-dominated macroinvertebrates at the shore of Buleji. The ledge was arbitrarily divided into three zones—the LTZ, MTZ, and HTZ, respectively. The distribution of organisms depends upon the tidal height because some species can survive in low exposure period while others need longer exposure time. The present study shows that MTZ mostly dominated by large number of gastropods species rather than LTZ and HTZ. Some species were found most abundant all over the study, including *L. coronata*, *N. natalensis*, and *P. sulcatus*. Barkati and Burney (1995) reported *Cerithium morus*, *Crithidia* sp., *Nodilittorina picta*, *Nerita albicilla*, *P. sulcatus*, and *Turbo coronatus* (*L. coronata*) as thr most abundant species from Buleji. Some species were found in very low numbers throughout the study. Ten gastropod species have been documented for the first time in this study, but these species were reported earlier or there is a lack of information about their exact location and description. However, 78 species of gastropods could not be seen during the present study (2021–2022), maybe due to sampling procedure, or location (vertical/horizontal profile of Buleji).

Physicochemical parameters play an important role in an aquatic ecosystem. Benthic communities also interact with them. Variation in biomass may be associated with environmental factors (Ahmed & Hameed, 1999). Abundance and diversity rely on habitat structure and physical factors (Satyam & Thiruchitrambalam, 2018). Gastropods are sessile, very sensitive to their environment, filter feeding organisms and are considered a good water quality indicator (Alhejoj et al., 2017). They have a hard exoskeleton which is made up of calcium carbonate and a protective operculum through which they can tolerate extreme condition, including high temperature (Knox, 2001; Xu et al., 2018), if any change occurs in the environment, or they may alter or change their habitat. Environmental factors directly correlate with distribution, variations in abundance, reproduction, and mortality of macroinvertebrate (Bacci & Sella, 1970). During the present study, variations among the species of gastropods have also been observed. Marine biodiversity and richness patterns of fish and invertebrate species are very interconnected with environmental factors on the shores (Macpherson, 2002).

In the present study, abundance of gastropods diversity has been observed in the months of May and December 2021, when conductivity, salinity, and TDS were high. Atmospheric temperature and water temperature were high in May. A smaller number of individuals were observed in July 2021, due to seasonal fluctuations in water because of the monsoon season. Fluctuations in environmental variables such as temperature, salinity, pH, dissolved oxygen, and CO_2 concentration can strongly affect the diversity and distribution of gastropods communities (Wittmann & Pörtner, 2013). Differences in environmental conditions can cause difference in species' richness (Kacchi et al., 2024). Low species' richness was observed in the month of October when the highest atmospheric temperature was recorded. It indicates that few species can tolerate high temperature, and those were present that time. All those species that were not found in this month but that were found in the other five visits showed that they do not survive in extreme hot conditions, and that maybe they have changed their habitat. Macroinvertebrates which inhabit the LTZ face extreme physiological stress due to very short time, and those species which inhabit the MTZ and HTZ often face more thermal stress than those of LTZ (Sokolova et al., 2000).

In Buleji, the maximum numbers of individuals were noted in the MTZ and LTZ, because of the occurrence of magnificent population of *N. natalensis*. The two highest peaks of juveniles of small-size snail *N. natalensis* were observed in May and December.

In the present study, out of the total of 38 species of gastropods recorded, 10 species were recorded for the first time, due to their attachment fashion gastropods mainly found in rocks and stagnant structures (Ahmed, 1977). Buleji remained under focus of various researchers on multiple aspects, such as Barkati & Burney (1991), who studied species composition and biomass of rocky shore of Buleji. They concluded that high production of biomass showed that MTZ produced maximum biomass and, that time, crustacean had first rank in number of individuals, while molluscan had the second rank, in the months of May and August. Barkati & Burney (1995) reported that the MTZ of the rocky shore of Buleji harbored the greatest number of gastropods during the most part of the year. Ahmed and Hameed (1999) collected 43 gastropods species and observed the highest values of species richness in the month of August from the same beach.

Subsequently, Rehman & Barkati (2004) studied the development of abundance biomass curve in relation to pollution and disturbances in mollusks communities and collected 15 species of gastropods from Buleji. Zafar (2013) studied the population of *Cellana karachiensis* from two different locations—Paradise Point and Buleji. In Buleji, 1,909 species were observed in the whole study, mostly present in HTZ and MTZ, whereas in this study the highest number of *C. karachiensis* was found in the LTZ of Buleji.

The present study showed the highest number of individuals in the month of December 2021 and the lowest in July 2021, while the highest richness of gastropods species was recorded in March 2021. The richness was particularly low in May and October 2021, whereas Barkati & Burney (1991) observed the lowest and the highest diversity in May and February 1991, respectively. Similarly, Ahmed & Hameed (1999) noticed at the rocky ledge of Buleji the highest value of diversity richness from June to August and the lowest in November to March.

Environmental variables play crucial role in the governance, structure, and functions of an ecosystem. The relationship between environmental factors and gastropods diversity was analyzed by CCA. For better understanding, CCA was grouped in four parts. Group I showed negative impact of sea surface temperature, SST, salinity, and conductivity on some gastropod species including *C. coronatus*. Due to the negative impact of such parameters, these species moved from the MTZ to LTZ. Kazmi et al. (2018) found these species mainly on the MTZ, but in the present study they were found on LTZ. According to Kazmi et al. (2018), *Monodonta cf nebulosa* shifted habitat from the LTZ/sub-tidal zone to HTZ, whereas in the present study they were collected at the HTZ. However, some species showed resistance and did not change habitat despite receiving negative impacts and consequently reduced population.

Group II defined positive impact of dissolved oxygen on *Astraea semicostata*. Because of that, they changed habitat from the MTZ to LTZ. Earlier, these species were collected from the MTZ (Ahmed & Hameed, 1999). So far, these species were extensively scattered in the entire intertidal area whereas pooled at the LTZ. Due to its wide tolerance level, *L. coronata* did not change its habitat, with significant increase in population. Ahmed and Hameed (1999) reported these species without distinguishing zone, whereas Afser (2009) reported them from the HTZ and collected 956 individuals of these species. Rehman and Barkati (2004) collected these species from the MTZ and HTZ. Rehman and Bakati (2004) reported 13.34% of these species, almost the same as the present study (13%). Similarly, *N. albicilla* showed no change in habitat, but its population reduced. *Turbo bruneus* was reported in earlier studies without defining zones (Kazmi et al., 2018), and in the present study it was found at the LTZ and HTZ.

Group III reflected some negative impact of atmospheric temperature on some gastropod's species such as *B. spirata*. Afser (2009) collected 109 individuals of these species, but he did not define the exact zone where they were found, whereas in the present study they were collected from the HTZ. Due to the change in the atmospheric temperature, their population will reduce or will disappear in future. Barkati & Burney (1991) collected only five individuals of *T. bufo*, but the authors did not mention their exact location. Ahmed & Hameed (1999) also reported these species from Buleji without defining zones. Afser (2009) collected 55 individuals, but in the present study the species collected from the MTZ suffered a reduction. Another species of this group, *P. sulcatus*, did not change its habitat, but its population has increased. According to Barkati & Burney (1991), 1,442 individuals were collected. Ahmed & Hameed (1999) also reported this species at the HTZ, as well as Rehman & Bakati (2004), but in the present study they were scattered from the entire intertidal area, and they were massively scattered at the LTZ, while *N. textilis* was reported in previous studies. Kazmi et al. (2018) reported this species without defining its zones or diversity.

The last group, the group IV, showed no impact on some gastropod's species, including *C. karachiensis*. They changed their habitat from the HTZ to MTZ and then to the LTZ, and their population reduced. Barkati & Burney (1991) reported 486 individuals of these species but did not define the exact location. Zafar (2013) reported the total of 1,909 number of samples at the HTZ. Similarly, Atta et al. (2013) reported these species from both the HTZ (57) and MTZ (seven), while in the present study they were found at the entire intertidal area but mostly at the LTZ. Similarly, *Thais tissoti* changed its habitat, but its population increased. According to Afser (2009), they were found on the MTZ, and only eight individuals were recorded, while in the present study they were collected at the LTZ. *Drupa margariticola* showed no change in its habitat. Ahmed and Hameed (1999) reported *Drupa* sp. at the MTZ, and the present study found them at the same zone. *Cerithium caeruleum* showed no change in habitat, but its population increased. Ayub (2013) recorded these species at the MTZ, and 350 individuals were collected from Buleji. The present study collected them at the same zone. Some species of this group such as *C. scabridum*, *Morula granulata*, and *Siphonaria asghar*

showed no change in their habitat, but their population reduced. Maybe there are other factors that have influenced their diversity, *i.e.*, non-availability of food, predation, etc. Ayub (2013) recorded 374 individuals of *C. scabridum*. Similarly, Barkati & Burney (1991) recorded 132 individuals of *M. granulata*, and Afser (2009) 47, whereas in the present study they were reduced. *Thais savignyi* was reported earlier (Afser, 2009), but its habitat is missing in the intertidal zone.

CONCLUSION

Based on one-year intertidal gastropod diversity data and time series (three decades), biodiversity data proved that periodic changes in diversity of Buleji, Karachi, Pakistan, have not only happened due to the visitors or anthropogenic activities; abiotic factors have shaken its intertidal assemblage structure. In this study, 38 gastropod species were taxonomically identified. Among them, 10 were documented for the first time in Buleji. However, these species were recorded earlier in other locations along the coastal belt of Pakistan.

The assemblage structure of intertidal area was divided in three horizontal zones: low, mid, and high. Regarding the categorization of the gastropods, the LTZ was mainly populated with *L. coronata*, and *P. sulcatus*, whereas *C. caeruleum*, *L. coronata*, *N. natalensis*, and *P. sulcatus* were found at the MTZ, and *L. coronata*, *M. cf nebulosa*, *N. natalensis*, and *P. sulcatus* were abundantly scattered at the HTZ.

Both Shannon-Weiner's and Simpson's diversity indices calculated the highest value in the month of March 2021 and the lowest one in May 2021. Comparing current and historical biodiversity data, many species shifted their habitat from one zone to another. This might have imposed impacts on abiotic factors.

CCA proved that some species were highly sensitive to the abiotic factors such as *B. spirata*, *C. concisus*, *C. coronatus*, *M.* cf. *nebulosa*, *N. undata*, *N. natalensis*, *T. bufo*, *T. lacera*, and *N. textilis*. *P. sulcatus* is highly sensitive to the sea surface temperature, TDS, salinity, conductivity, and atmospheric temperature, whereas *A. semicostata*, *Chiton* sp., *Clypeomorus bifasciatus persicus*, *L. coronata*, *N. albicilla*, *N. maxima*, and *T. bruneus* showed affirmative relationship with dissolved oxygen. As consequences, some species shifted their habitat from one tidal zone to another zone, while some others stayed or disappeared completely when compared data found in this study with previous data of Buleji.

CONFLICT OF INTEREST

Nothing to declare.

DATA AVAILABILITY STATEMENT

All data sets were generated or analyzed in the current study.

AUTHORS' CONTRIBUTION

Conceptualization: Zafar FHS; **Formal Analysis:** Fatima U; **Investigation:** Fatima U; **Resources:** Zafar FHS; **Supervision:** Zafar FHS, Panhwar SK; **Validation:** Zafar FHS, Panhwar SK; **Data curation:** Fatima U; **Writing – original draft:** Fatima U; **Writing – review & editing:** Zafar FHS, Panhwar SK; **Final approval:** Fatima U.

FUNDING

Not applicable

DECLARATION ON THE USE OF ARTIFICIAL INTELLIGENCE TOOLS

Artificial intelligence was not adopted at any stage of this research.

ACKNOWLEDGMENTS

The Director of the Center of Excellence in Marine Biology is greatly acknowledged for the support, laboratory space, and guidance throughout study and stay in the center.

REFERENCES

Afser, N. (2009). Study of some Imposex Gastropods species from the polluted marine waters along the coast of Karachi [PhD thesis, University of Karachi].

Ahmed, M. (1977). An assessment of the magnitude of coastal pollution in Pakistan through a survey of its marine fauna and fisheries. *Thalassia Yugoslavica*, 13, 395-412.

Ahmed, M., & Hameed, S. (1999). Species diversity and biomass of marine animal communities of Buleji rocky ledge, Karachi, Pakistan. *Pakistan Journal of Zoology*, *31*(1), 81-91.

Alhejoj, I., Bandel, K., & Salameh, E. M. (2017). Aquatic mollusks: Occurrence, identification and their use as bio indicator of environmental conditions (Salinity, trace elements and pollution parameters) in Jordan. In *Water Resources in Arid Areas*.

Atta, M. H., Mujahid, A., & Chugtai, F. (2013). Distribution, abundance and population density of *Cellana radiata* and *Acemea* sp. on the rocky coast of Buleji, Karachi Pakistan. Centre of Excellence in Marine Biology, University of Karachi. *International Journal of Biology Research*, 1(2), 155-159.

Ayub, S. (2013). Population dynamics of cerithium (Gastropoda: Cerithioidea: Cerithiodae) species on exposed and protected shore of Buleji, Karachi. Centre of Excellence in Marine Biology, University of Karachi.

Bacci, G., & Sella, G. (1970). Correlations between characters and environmental conditions in *Patella coerulea* group. *Pubblicazioni della Stazione Zoologica di Napoli*, 38, 1-24.

Baharuddin, N., Basri, N. B., & Syawal, N. H. (2018). Marine gastropods (Gastropods: Mollusca) diversity and distribution on intertidal rocky shores of Terengganu, Peninsular Malaysia. *AACL Bioflux*, 11(4), 1144-1154.

Baloch, A. (2025). Occurrence, abundance, and diversity of intertidal gastropods at rocky shore of Mubarak Village. *Pakistan Journal of Marine Sciences*, 34(2), 107-116.

Bano, A. (2009). Distribution, abundance and reproductive biology of Siphonarid Limpets (*Gastropoda pulmonata*) occurring on the two rocky shores of Karachi. *Journal of Zoology*, 23(1), 35-38.

Barkati, S., & Burney, S. M. (1991). *Biomass and species composition of a littoral rocky shore of the Karachi Coast*. National scientific and Research Development Board Research Project. Annual Report. University of Karachi.

Barkati, S., & Burney, S. M. (1995). Benthic dynamics of a rocky beach macro-invertebrates. II Cyclical changes in biomass in various tidal heights at Buleji, Karachi (Arabian Sea). *Marine Research*, 4, 63-76.

Bosch, D. T., Dance, S. P., Moolenbeek, R. G., & Oliver, P. G. (1995). *Seashells of Eastern Arabia*. Motivate Publishing.

Haq, S. M., Moazzam, M., & Rizvi, S. H. N. (1978). Studies on marine fouling organisms from Karachi coast. I. Preliminary studies on the intertidal distribution and ecology of fouling organisms at Paradise Point. *Pakistan Journal of Zoology*, 10, 103-115.

Kachhi, K. K., Akhter, N., Panhwar, S. K., & Kashani, I. (2024). Escalating trends of Hydrogen Sulphide (H2S) and its role in structuring Pakistan coastal zones barren. *Pollution*, 10(1), 256-264. https://doi.org/10.22059/poll.2023.364144.2036

Kang, B., Pecl, G. T., Lin, L., Sun, P., Zhang, P., Li, Y., Zhao, L., Peng, X., Yan, Y., Shen, C., & Niu, W. (2021). Climate change impacts on China's marine ecosystems. *Reviews in Fish Biology and Fisheries*, 31, 599-629. https://doi.org/10.1007/s11160-021-09668-6

Kashani, I., Mohammad, A. A., Hameed, A., Jan, A., Ahmed N., & Kachhi, K. K. (2025). Climate change and anthropogenic impacts threats to the northern Arabian Sea rocky shore communities. *Sarhad Journal of Agriculture*, 41(1), 134-141. https://doi.org/10.17582/journal.sja/2025/41.1.134.141

Kazmi, Q. B., Khan, M. M., & Sultana, S. (2018). *Marine Molluscan fauna of the Pakistan coastal waters*. Marine Reference Collection and Resources Centre, University of Karachi.

Kennedy, S., Twilling, R. R., Kleypas, J. A., Cowan, J. H., & Hare, S. R. (2002). *Coastal and marine ecosystem and global climate change: potential effects on U.S. resources*. PEW Center on Global Climate Change.

Khan, M. D., & Dastagir, S. G. (1971). *On the Mollusca: Gastropod fauna of Pakistan*. Records Zoological Survey of Pakistan.

Knox, G. A. (2001). *The ecology of seashores*. Taylor & Francis Inc.

Llovel, W., & Terray, L. (2016). Observed southern upper-ocean warming over 2005–2014. *Environmental Research Letters*, 11(12), 124023. https://doi.org/10.1088/1748-9326/11/12/124023

Macpherson, E. (2002). Large scale species-richness gradients in the Atlantic Ocean. *Proceedings of the Royal Society of London Series B*, 269(1501), 1715-1720. https://doi.org/10.1098/rspb.2002.2091

Marshall, D. J., Baharuddin, N., & McQuaid, C. D. (2013). Behavior moderate's climate warming vulnerability in high-rocky-shore snails: interactions of habitat use, energy consumption and environmental temperature. *Marine Biology*, 160(9), 2525-2530. https://doi.org/10.1007/s00227-013-2245-1

Moazzam, M., & Rizvi, N. (1983). Settlement of oyster larvae in Pakistani waters and its possible implication for setting up oyster culture. Proceedings: Symposium. *Coastal Aquaculture*, 2, 467-474.

Monolisha, S., & Edward, P. J. K. (2015). Biodiversity of marine mollusk from selected location Andhra Pardesh Coast, South Eastern India. *Indian Journal of Geo-Marine Sciences*, 44(6).

Nasreen, H., Ahmed, M., & Hameed, S. (2000). Seasonal variation in biomass of marine macro-invertebrates occurring on the exposed rocky ledge of Manora Island, Karachi, Pakistan. *Pakistan Journal of Zoology*, 32(4), 343-350.

Nazim, K., Ahmed, M., & Khan, M. U. (2015). Population distribution of mollusks in mangrove forests, Pakistan. *FUUAST Journal of Biology*, 5(1), 37-41. https://doi.org/10.64793/fuuastjb.v5i1.131

Qari, R. (1985). *Seasonal variation in biomass and biochemical composition of some edible seaweeds from the Karachi coast* [M. Phil. Thesis, Centre of Excellence in Marine Biology, University of Karachi].

Qari, R., & Qasim, R. (1988). Seasonal changes in the standing crop of intertidal seaweeds from the Karachi coast. Marine Science of the Arabian Sea. In M. F. Thompson & N. M. Tirmizi (eds.), *Proceedings of Marine Science of the Arabian Sea* (pp. 449-456). American Institutes of Biological Sciences.

Rehman, S., & Barkati, S. (2004). Development of abundance-biomass curves indicating pollution and disturbance in molluscan communities on four beaches near Karachi, Pakistan. *Pakistan Journal of Zoology*, 36(2), 111-123.

Rehman, S., & Barkati, S. (2010). Diversity of benthic macromolluscs on four rocky shores of Karachi coast, Pakistan. *International Journal of Biology and Biotechnology*, 7(1-2), 111-120.

Rehman, S., & Barkati, S. (2012). Spatial and temporal variations in the species composition and abundance of benthic molluscs along 4 rocky shores of Karachi. *Turkish Journal of Zoology*, 36(3), 291-306. https://doi.org/10.3906/zoo-1004-26

Saifullah, S. M. (1973). A preliminary survey of the standing crop of seaweeds from the Karachi coast. *Botanica Marina*, 16(3), 139-144. https://doi.org/10.1515/botm.1973.16.3.139

Satyam, K., & Thiruchitrambalam, G. (2018). Habitat ecology and diversity of rocky shore fauna. In C. Sivaperuman, A. Velmurugan, A. K. Singh & I. Jaisankar (eds.), *Biodiversity and climate change adaptation in tropical islands* (pp. 187-215). Academic Press. https://doi.org/10.1016/B978-0-12-813064-3.00007-7

Shameel, M., & Tanaka. J. (1992). A preliminary checklist of marine algae from the coast and inshore waters of Pakistan. Cryptogamic Fauna of Pakistan. *National Museum of Nature and Science*, 1, 64.

Shamim, S. (2001). Studies on distribution and reproduction ecology of *Onchiodium verruculatum* (Cuvier) (Mollusca: Gastropoda: Pulmonata) [M.Phil. thesis, CEMB University of Karachi].

Sokolova, I. M., Granovitch, A. I., Berger, V. J. A., & Johannesson, K. (2000). Intraspecific physiological variability of the gastropod *Littorina saxatilis* related to the vertical shore gradient in the White and North Seas. *Marine Biology*, 137(2), 297-308. https://doi.org/10.1007/s002270000343

Tirmizi, N. M., & Zehra, I. (1982). *Illustrated key to families of Pakistani marine mollusks*. Pakistan Science Foundation.

Underwood, A. J. (2000). Environmental ecology of rocky intertidal habitats: What are we learning? *Journal of Experimental Marine Biology and Ecology*, 250(1-2), 51-76. https://doi.org/10.1016/S0022-0981(00)00179-9

Xu, X., Wu, J., Yang, Y., Zhu, R., & Yan, S. (2018). Operculum of a water snail is a hydrodynamic lubrication sheet. *Journal of Bionic Engineering*, 15(3), 471-480. https://doi.org/10.1007/s42235-018-0038-4

Wittmann, A. C., & Pörtner, H. O. (2013). Sensitivities of extant animal taxa to ocean acidification. *Nature Climate Change*, 3(11), 995-1001. https://doi.org/10.1038/nclimate1982

Wosu, L. O. (2003). *Commercial snail farming in West-Africa: A guide*. Ap Express Publishers.

Zafar, F. H. S. (2013). *Population dynamics and some biological aspects of the true limpets (Gastropods: Prosbranchia: Patellidae) occurring on the two rocky shores of Karachi, Pakistan* [Ph.D. Thesis, Department of Zoology, University of Karachi].

Zehra, I., & Parveen, R. (1991). Studies on the breeding season, egg capsule and early larval development of *Thellostyla albicilla* (Linne, 1758) from Karachi Coast, Pakistan. *Journal of Zoology*, 23(1), 35-38.