Research Article

Climate Change, and Anthropogenic Impacts Threats to The Northern Arabian Sea Rocky Shore Communities

Imtiaz Kashani[1]*, Asadullah Ali Mohammad[2], Abdul Hameed[1], Ali Jan[3], Nazeer Ahmed[4] and Kishwar Kumar Kachhi[1]

[1]Centre of Excellence in Marine Biology, University of Karachi, Karachi – 75270, Pakistan; [2]Fisheries and Coastal Development Department, Government of Balochistan, Pakistan; [3]National Institute of Oceanography, Pakistan; [4]Agriculture Research Institute, Pakistan Agriculture Research Council-82601, Turbat, Pakistan.

Abstract | This study delves into the fascinating world of intertidal life, comparing the biodiversity and abundance of two distinct rocky shores along the Sindh and Balochistan coasts in the northern Arabian Sea. Climate change and anthropogenic driver ultimately effect on benthic community which play a key role in functioning the ecosystem. Our findings unveil a hidden gem: Sunehri Beach, boasting higher species richness despite facing greater tidal influences. Mollusks, particularly gastropods, thriving in these rocky havens. The number of individuals per unit area of intertidal fauna was higher at Mubarak Village, which was dominated by mollusks and arthropods. Mollusks were consistently more abundant than other species. *Balanus balanus* is the common species found on both sides with the highest abundance, but population abundance and health significantly varied from one site to another. A Simpson's Diversity Index of 0.075 suggests that Mubarak Village has a higher level of species richness than Sunehri Beach (0.133). This indicates that there was more abundance of the species at this location. The Shannon diversity index in Mubarak Village is 2.87 and 2.27 in Sunahri Beach which indicates the diversity is significantly greater in Mubarak Village. The study further highlights the crucial role of structural complexity in sustaining biodiversity and abundance of the benthic communities. They indicate that the significance of structural connectivity between habitats that influenced by the global environmental context. Our results advocate management strategies that prioritize the preservation of habitat complexity and consider the entire spectrum of habitats within tropical seascapes. By understanding these unique ecosystems, we can pave the way for sustainable coastal management and conservation of the diverse communities that call them home.

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***Correspondence** | Imtiaz Kashani, Centre of Excellence in Marine Biology, University of Karachi, Karachi–75270, Pakistan; **Email:** imtiazkashani@gmail.com
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Introduction

Benthic coastal zone has great ecological importance in marine ecosystems. It exhibits a sessile or sluggish nature for common species. Periodically, low tides expose intertidal habitats and change the scenario to aerial conditions. The unique characteristics of physical and biological slopes make these habitats ideal for the marine community. High tide zone organisms are exposed to air for a longer time than low tide zone organisms. This means that high tide zone organisms tolerate different salinities, extreme temperatures, risk of desiccation, changes in respiration (if gills dry out), and variation in food availability. These benthic communities play a dynamic role in ecosystems by recycling nutrients, breaking down organic matter, and supporting food webs. Complex habitats affect abundance and species composition (Moustaka *et al*., 2024). Species richness and biodiversity have a significant impact in the functioning of and potential for changes in communities (Scrosati *et al*., 2011). The tropical regions exhibit higher biodiversity than temperate regions, with biodiversity increasing towards the tropics and declining towards polar regions (Antonin, 2023). Climate change and human activities significantly impact benthic communities, which are crucial for ecosystem health (Saeedi *et al*., 2022). Human activities and climate change are transforming the structure and interconnections of habitats that many animals depend on (Hughes *et al*., 2018; Gissi *et al*., 2021). However, comprehensive data regarding species distribution and abundance remain limited. Benthic communities are crucial biogeochemical cycling sites and play a key role in biological niche. The alterations have far-reaching effects on ecosystems and the feedback they provide to the climate system (Pineda-Metz, 2020). Notably, Ghani *et al*. (2019) did explore intertidal biodiversity in Pakistan, but their work solely addressed species richness. Understanding the population dynamics of intertidal organisms in these regions have far-reaching implications for conservation and sustainable coastal management. Changes in the diversity, abundance, and composition of fish assemblages can impact the delivery of crucial ecological processes across (Harborne *et al*., 2017: Moustaka *et al*., 2024). With rising concerns about global biodiversity loss (Pimm, 2008) and increasing vulnerability of marine ecosystems to anthropogenic impacts and climate change, such research can offer essential data to guide policy decisions and foster effective conservation strategies. Thus, this research aimed to observe species composition and abundance across tidal heights different stations along the coasts of Pakistan in the northern Arabian Sea, providing valuable data to guide policy decisions and foster effective conservation strategies.

Materials and Methods

Sampling sites

Two rocky ridges, Mubarak Village and Sunehri Beach, were surveyed along the coasts of Sindh and Balochistan in the northern Arabian Sea. Mubarak Village is a small village situated at 24°50'19.6"N 66°39'24.1"E. The beach of Mubarak Village here faces the open Arabian Sea and is composed of a rocky stratum, studded with small boulders, cobbles and pebbles. In some places, rocky shelters form cave-like structures that protect organisms from predators. In contrast, Sunehri Beach is located at 24°52'54.3"N 66°41'41.7"E. This beach is situated just before Mubarak Village (Figure 1). It is a sandy cum rocky beach studded with large boulders, cobbles, and pebbles, and is also known for its oyster beds.

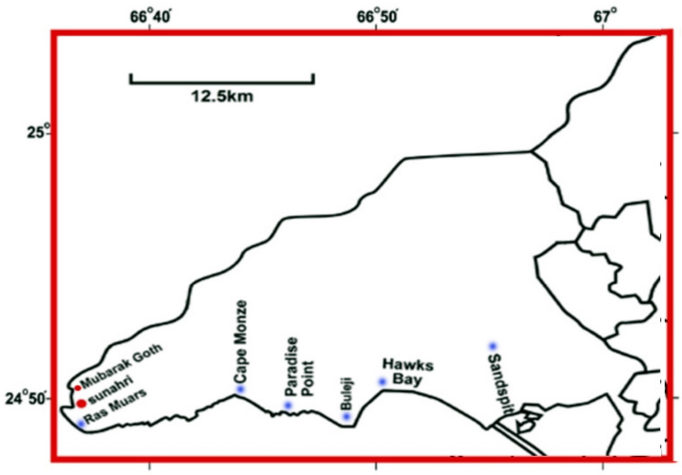

Figure 1: *Two distinct rocky shores of in the northern Arabian Sea, as indicated by the red dots in the map.*

Table 1: *Oceanographic parameters from observed locations.*

Parameters	Mubarak village	Sunahri beach
Air temperature	26 °C	27.5 °C
Water temperature	23 °C	26 °C
Do	4.9 ppm	4.6 ppm
pH	8.0	8.3
Salinity	35 %	37 %
Tidal level	0.2 m	0.2 m

Sampling and laboratory techniques

The study was conducted on September 7, 2022. The physical parameters including date, time, tide level, air and water temperatures, pH level, salinity and DO were documented at both sites (Table 1). Random specimens were collected during low tide in the intertidal zones. After relaxation, the specimens were preserved in neutralized 5-10% formaldehyde and then shifted to 70% ethyl alcohol before being taken to the CEMB laboratory for taxonomic and microscopic studies.

Because of the typography of the shore, variable substratum, and limited sampling time during low tide, the beach was randomly divided into three zones based on tidal height (high tide zone, mid tide zone, and low tide zone). Quadrate samples (50 × 50 cm) were randomly placed over the area parallel to the shoreline. Two replicate samples were obtained from both sites. All samples were transferred to the laboratory and preserved in 5-10% formaldehyde for further analysis. The collected samples were washed and prepared for taxonomical study by using Subba and Dey (2000) taxonomic literature.

Calculating biodiversity index

Calculating biodiversity indices can help us to understand the diversity and richness of species in a given area. There are several biodiversity indices used in ecological studies, and we used Simpson's Diversity Index (also known as Simpson's index of diversity) for species richness. The Shannon diversity index was used to calculate the diversity within a given community. These indices provide a single numerical value that reflects the complexity of the species composition of a community. The formulae for both the procedures are as follows:

Simpson's diversity index (D) is as follows:

$$D = \Sigma(pi^2)$$

Where; Σ is represents the sum of the calculations for all species. pi is the proportion of individuals of each species.

The Shannon diversity index (H') was calculated as follows:

$$H' = -\Sigma\,(pi * ln(pi))$$

Where: H' = Shannon diversity index, Σ = Summation symbol, pi = Proportion of individuals belonging to the species (relative abundance of each species), and ln = Natural logarithm.

Results and Discussion

Mubarak village

A total of 26 species were identified, out of which 14 were mollusks, including seven gastropods, six bivalves, and one species of Aplacophora. Arthropods comprise nine species, including one species of barnacles, six species of crabs, and two species of shrimp. Only one species was found in Echinodermata (Table 2). Chordates have only been seen in Mubarak village, with an abundance of 1.4 %. The most abundant species was *Balanus balanus* (18.1 %), followed by Peronia verruculata and Turbo brunneus (8.3 %). The average number of species decreased with increasing tidal heights.

Table 2: *Species abundance and dominance patterns of intertidal communities in two diverse coasts.*

Phylum	Species	Mubarak village (abundance/ biomass)	Sunehri Beach (abundance/ biomass)
Arthropoda	*Balanus balanus*	18.1 %	27.3 %
	Pagurus fabricus	1.4 %	11.2 %
	Thalamita prymna	2.8 %	0.7 %
	Leptodius exaratus	1.4 %	-
	Petrolisthes leptocheles	0.7 %	-
	Charybdis cruciata	3.5 %	-
	Atergatus	6.3 %	-
	Penaeus	3.5 %	-
	Elphius	0.7 %	-
Echinodermata	*Holothuria cinerascens*	1.4 %	3.5 %
Chordata	*Boleophthalmus dussumieri*	0.7 %	-
	Abudefduf bangalensis	0.7 %	-
Mollusca	*Indothais lacera*	4.9 %	3.5 %
	Asteracmea maraisi	6.3 %	5.8 %
	Gastrana	3.5 %	5.8 %
	Staphylaea staphylaea	0.7 %	-
	Nerita textilis	6.9 %	7.7 %
	Turbo brunneus	8.3 %	9.1 %
	Telecopium telescopium	1.4 %	13.3 %
	Mancinella siro	2.8 %	3.5 %
	Marcia recens	4.2 %	5.6 %
	Cellana radiata	5.6 %	3.5 %
	Chiton	4.9 %	-
	Circe	0.7 %	-
	Peronia verruculata	8. 3%	-
	Pecten pecten	0.7 %	-

Biodiversity index

A Simpson's diversity index of 0.075 suggests that Mubarak Village has a higher level of species richness than Sunehri Beach. This indicates that there was more abundance of the species at this location. The presence of fewer species contributes to a higher abundance index, even if they are not equally diverse. Although, the area is impacted by climate change i.e. Environmental disturbances, habitat loss, and other factors but besides these obstacles it is the most importantly noticed the higher level of species occur in the region.

The Shannon diversity index in Mubarak Village was 2.87, which indicates that the diversity was greater. In the case of H' = 2.87, the community has relatively high species diversity compared to Sunehri Beach communities with lower H' values.

Sunehri beach

Overall, 13 species were trapped at the location. Among them, nine species were mollusks comprised of five gastropods spp. and bivalves four spp. Three species of arthropods were identified: Barnacles (one spp.), crabs (two spp.), and Echinodermata (1 species) (Table 2). The most abundant species was *Balanus Balanus,* but their abundance was 4.9 % higher than that of Mubarak village. Albeit *Telecopium telescopium* and *Pagurus fabricus* are the following abundance species at 13.3 % and 11.2 %, respectively.

Biodiversity index

Simpson's diversity index of 0.133 suggests that Sunehri Beach has a lower level of species richness. This value signifies that there is some lower diversity present at Sunehri Beach, although it is relatively moderate (Table 3). This location may have a few dominant species that are highly abundant, with relatively fewer other species present. Sunehri Beach might have a few dominant species that are relatively abundant. Compared to Mubarak Village, the area is severely effected by oil-boats and plastic bags that significantly reduce or effect the overall biodiversity.

The Shannon diversity index at this location is 2.27. The Shannon diversity index suggests a reasonable level of diversity, but it is lower than the value of Location 1 (2.87) (Table 3). This indicates that the community in this location might have fewer species or that some species are more dominant than others.

When the two study sites (Mubarak Village and Sunehri Beach) were compared, variation was observed in the number of species present at each site (Figure 2). Aplacophora was not found at Sunehri Beach, the reason could be the high sensitivity of the organism and non-suitable environmental conditions. However, *Patelloida maraisi*, *Nerita textilis*, *Turbo brunneus*, and *Thais mancinella* were distributed equally on both sides. Only one species of Echinodermata was recorded at both study sites. Despite chordates not being found on Sunehri Beach, two species were spotted in Mubarak village. The highest abundant species found in both locations were Balanus balanus followed by *Turbo brunneus* and *Patelloida maraisi* (Figure 3). However, significant changes in each location were driven by a combination of anthropogenic activities and varying tidal heights.

Table 3: *Abundance-weighted biodiversity indices (Simpson's and Shannon) for individual species at two intertidal sites.*

Species	Mubarak village (Simpson's diversity index value pi)	Sunehri beach (Simpson's diversity index value pi)
Indothais lacera	0.0024	0.0012
Asteracmea maraisi	0.0039	0.0031
Gastrana	0.0012	0.0031
Staphylaea staphylaea	0.0000	-
Nerita textilis	0.0048	0.0059
Turbo brunneus	0.0069	0.0083
Telecopium telescopium	0.0002	0.0177
Mancinella siro	0.0008	0.0012
Marcia recens	0.0017	0.0031
Cellana radiata	0.0031	0.0012
Chiton	0.0024	-
Circe	0.0000	-
Peronia verruculata	0.0069	-
Pecten pecten	0.0000	0.0744
Balanus balanus	0.0326	0.0125
Pagurus fabricus	0.0002	0.0000
Thalamita prymna	0.0008	-
Leptodius exaratus	0.0002	-
Petrolisthes leptocheles	0.0000	-
Charybdis cruciata	0.0012	-
Atergatus	0.0039	-
Penaeus	0.0012	-
Elphius	0.0000	0.0012
Holothuria cinerascens	0.0002	-
Boleophthalmus dussumieri	0.0000	-
Abudefduf bangalensis	0.0000	-
Simpson's diversity index (richness/abundant)	0.075	0.133
Shannon diversity index		
SDI (H)	2.87	2.27
Evenness	0.881	0.885
Richness (number of species)	26	13
Average population size	5.54	11
Total number of individuals	144	143

Figure 2: *Dominant species in the intertidal zone of Mubarak village.*

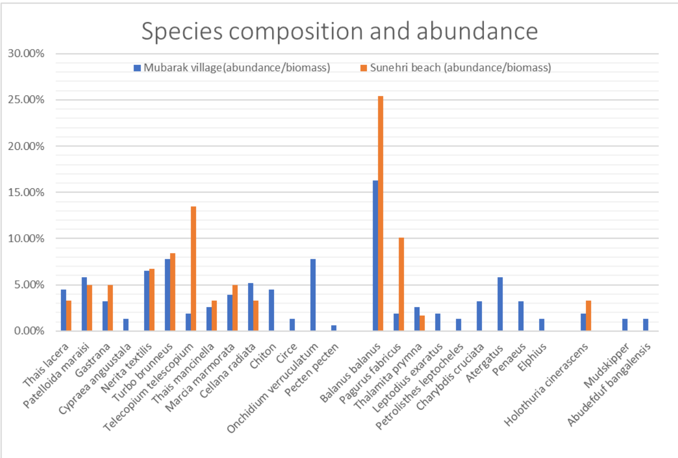

Figure 3: *Comparing habitat-specific differences in species abundance and biomass between Mubarak Village and Sunehri Beach.*

Our findings raise concerns about potential threats to the studied communities. The observed differences in diversity and composition suggest potential impacts of environmental disturbances and anthropogenic activities that severely effect benthic communities. Factors like habitat loss, pollution, and unsustainable resources extraction could contribute to species loss and dominance of hardier species like *Balanus balanus*. Mollusca were the most commonly found phylum on plastic beach litter (Cesarini *et al*., 2022).

The Sindh and Balochistan coasts, situated in southeastern and southwestern Pakistan, respectively, extend along the Arabian Sea. These coastal regions possess distinct geological, hydrological, and environmental attributes, owing to their geographical locations, ocean currents, and local climate patterns. Investigating intertidal organisms in these areas through comparative study can yield valuable insights into the influence of geographical factors on biodiversity patterns and community structure. In the study, a total of 39 species were collected from two different sites and the most common species were from gastropods. The abundance of gastropods on both sites indicates that the substratum, rocky shore, and cave-like structures are beneficial for protection and growth. As a result, mollusks seem to dominate the intertidal zone of both study sites, although the number of species varied. Following Mollusks, the second most dominant species belonged to phylum Arthropoda which also differs in biodiversity and richness. Echinoderms were the least dominant. Besides the abiotic factor, the main difference was observed between each location was topography and substratum which may be one of cause for benthic community dynamics.

Topography plays a crucial role, creating distinct ecological niches for species. Moreover, topography influences rainfall, air mass movement, wave action nutrients distribution reproduction and shelter. Ecosystem diversity shapes responses to climate change, prompting species to migrate to higher elevations or latitudes in search of suitable climatic conditions (Rubenstein *et al*., 2023). The result of fauna richness and diversity is mainly caused by topography, climate change and anthropogenic activities because we observed that the topography of Mubarak Village consists of steepness and curves which make small lagoons or wetlands that provide breeding grounds and shelters from upper predators. Similar observations were founded by Ott (2020) who conceived that topography or substrate structure is the main driver in the variations in fauna richness. The variation in the abundance of species may be due to their tolerance ability. Species were more prone to desiccation i.e., organisms were hardly found and if found, they were under rocks or crevices. Species which can tolerate harsh environmental conditions by developing hard body covering seem to dominate in the intertidal zone (Villaespesa *et al*., 2023). Abundance and diversity depend on habitat structure and physical factors (Satyam and Thiruchitrambalam, 2018). The difference in species richness can be due to differences in environmental conditions (Kachhi *et al*., 2024). In addition, the biodiversity of marine organisms is affected by climate change, habitat-forming, coralline algae, and associated fauna (Ragazzola *et al*., 2021; Kelaher *et al*., 2022; Kachhi *et al*., 2022). Biodiversity loss associated with climate change, invasive species, and land-use intensification profoundly impacts terrestrial ecosystems and phenotypic alteration in the species (Allan *et al*., 2015; Kashani and Panhwar, 2023). Elevation in the temperature may affects diverse animal communities. Precipitation and temperature are reliable indicators of fauna biodiversity patterns (Antonelli *et al*., 2018). Rising sea levels and high tides have severely impacted the littoral zone, which is constantly washed and swept by strong waves. This dynamic environment leads to temporal and spatial diversity across all marine habitats. On the rocky shore, algal and mollusks growth is higher than scum or sandy shore (Worm and Karez, 2002). The tides are generally larger in Mubarak village than in Sunari Beach because of topography and geographical position and this may lead to affect species richness and biodiversity especially free-swimming organisms. The drifting of sediments and algae development can vigorously affect underlying fauna (Urra *et al*., 2013). Subsequently, implementing effective conservation strategies is crucial to preserving the ecological integrity and biodiversity of these vulnerable coastal ecosystems. Understanding the ecological roles and interactions of these dominant species is crucial for comprehending ecosystem dynamics and potential impacts of disturbances. This might involve establishing protected areas, implementing stricter regulations on coastal development and activities, and raising public awareness about the importance of these communities.

Overall mollusks were abundant in both sites, though species composition is differing. Some rocky shore habitats are insecure due to physical disturbance and anthropogenic activities. Consequently, these impacts eventually effect on species biodiversity and richness dimensions. Human population, tourism, walking over and climate change seriously affect intertidal fauna which resulted in decreasing the abundant diversity of the rocky shore community.

Conclusions and Recommendations

The comparative analysis of intertidal organisms in Sindh and Balochistan underscores the delicate balance between natural forces and human influence shaping coastal ecosystems. While geographical factors like substratum create diverse habitats, anthropogenic activities have significantly altered the biodiversity and composition of these communities. The prevalence of resilient species like *Balanus balanus* signals a shift towards less diverse and more tolerant ecosystems. Given the global biodiversity crisis and the increasing threats to marine environments, understanding the dynamics of intertidal organisms in the northern Arabian Sea is paramount. By investigating species diversity, abundance, and their interactions, we can develop effective conservation strategies. Establishing protected areas, enforcing stricter regulations, and raising public awareness are essential steps to safeguard these valuable ecosystems.

Ultimately, the future of our coastal regions hinges on our ability to balance human needs with the preservation of biodiversity. Conserving and restoring wetlands, mangroves, and seagrass beds can provide natural buffers against climate change impacts. Ensuring that fishing practices are sustainable can help maintain healthy benthic communities and prevent overfishing. Continued research and monitoring of benthic communities can help us better understand their responses to climate change and develop effective conservation strategies.

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Novelty Statement

A comparative study of ecological parameters, geographical location, fauna biodiversity, and abundance between two diverse rocky coastal habitats in Sindh and Balochistan, considering the impact of climate change and anthropogenic pressures.

Author's Contribution

Imtiaz Kashani: Conducted the research work and prepared the manuscript for publication.
Asadullah Ali Mohammad: Helped in experimental setup and finalize the manuscript writing.
Ali Jan: Provide technical assessment and Support in laboratory work.
Abdul Hameed and Kishwar Kumar Kachhi: Evaluated and revised the final version of the manuscript.
Nazeer Ahmed: Help in data analysis and methodological assessment.

Conflict of interest
The authors have declared no conflict of interest.

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