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Seasonal occurrence and abundance of molluscan fauna at rocky area of Ras Juddi, Makran coast – northern Arabian Sea

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Abstract: Molluscan species diversity and abundance were investigated using quadrat and random sampling methods on the rocky shore of Ras Juddi (25°13'25" N, 63°30'15" E), Pasni, along the Makran coast, from December 2021 to October 2022. A total of 69 molluscan species belonging to 38 families were recorded during the study. The identified species comprised 46 Gastropoda (57%), 15 Bivalvia (41%), 4 Polyplacophora (1%), 3 Cephalopoda (1%), and 1 Scaphopoda (≤1%), representing the first comprehensive report on the intertidal zone of Ras Juddi, Makran coast. The highest number of individuals was observed during the Inter-Monsoonal month of April (n=282), followed by the North-East Monsoon (December and January) (n=262) and the Inter-Monsoon period in October (n=242). The lowest abundance was recorded during the South-West Monsoon in August (n=102). Among the identified species, *Barbatia obliquata* (n=219), *Anachis terpsichore* (n=144), and *Perna viridis* (n=90) exhibited the highest abundance. A specimen of chiton (Polyplacophora) belonging to the genus *Leptoplax* sp. was collected, which is potentially a new record for Pakistan and will be confirmed through further detailed taxonomic investigation. This research presents the first comprehensive report on the diversity and abundance of molluscan species in the studied area.

1. Introduction

Ras Juddi, situated along the Makran coast in the Northern Arabian Sea, is characterized by a rocky cliff extending into the sea via a platform or rocky ledge. Rocky shores constitute a significant component of coastal zones, encompassing a physical continuum from the edge of the continental shelf to the intertidal and nearshore regions. These environments provide unique habitats for a diverse array of specialized fauna. This zone comprises a heterogeneous mosaic of habitats, including near-shore terrestrial, intertidal, benthic, and pelagic realms. Organisms inhabiting these dynamic areas are subjected to daily and seasonal fluctuations in environmental parameters, necessitating tolerance mechanisms against extreme variations in temperature, salinity, moisture, and wave action (Padisák, J., Naselli-Flores, 2021; Nasri *et al*., 2021 & 2024; Lund-Hansen *et al*., 2024). Despite these challenging conditions, resilient organisms such as algae, lichens, barnacles, and molluscs flourish in these habitats, demonstrating remarkable resilience and adaptability (Moyse and Nelson-Smith, 1963).

Mollusca represents the second largest phylum within the animal kingdom, following Arthropoda, with an estimated 50,000 to 55,000 currently recognized valid marine species (MolluscaBase eds. 2024). Molluscs exhibit exceptional diversity, particularly in tropical and temperate regions, but are distributed across all latitudes. They also display a remarkable range in size, from nearly microscopic species to the largest of all invertebrates, the giant squid. This phylum represents a morphologically diverse group of marine fauna, exhibiting significant variations in body structure and habitat preferences within marine ecosystems (Biju Kumar and Ravinesh, 2015). These organisms are characterized by their soft bodies, typically enclosed within a single, calcareous shell that varies considerably in size, shape, and coloration. Molluscs play crucial ecological roles in coastal food webs, functioning as consumers of algae, decomposers of detritus (Marshall *et al*., 2013; Smith, 2013), and serving as a food source for various organisms, notably as veliger larvae and recently settled juveniles. Furthermore, molluscan species constitute a significant component of global fisheries and contribute substantially to national economies (Ingole *et al*., 2002; Ríos-Jara *et al*., 2004; Shahabudhin *et al*., 2010).

The molluscan diversity of Pakistan is notably high, comprising a total of 1149 species (Kazmi *et al*., 2018), including 713 Gastropoda, 349 Bivalvia, 62 Cephalopoda, 16 Scaphopoda, and 9 Polyplacophora species. The molluscan fauna along the Sindh and Balochistan coasts of Pakistan has been the subject of extensive research (Woodword, 1856; Ranjha, 1960; Ashraf, 1969; Khan and Dastagir, 1971, 1972; Khan *et al*., 1973; Ahmed, 1977; Ahmed *et al*., 1982; Tirmizi and Zehra, 1982, 1984; Burney and Barkati, 1995; Kazmi, 1995; Ahmed and Hameed, 1999; Nasreen *et al*., 2000; Rahman and Barkati, 2012; Afsar *et al*., 2012; Ghani *et al*., 2017, 2018, 2019; Ali *et al*., 2019). However, the sampling site of Ras Juddi has not been previously explored, resulting in a lack of published records regarding its intertidal molluscan diversity. Therefore, the present study aims to provide the first data on the seasonal abundance, diversity, and distribution of macrobenthicmolluscs at Ras Juddi (Pasni) along the Makran coast, Balochistan.

2. Methodology

2.1 Study area

The study was conducted in rocky intertidal area at Ras Juddi (25°13'25" N, 63°30'15" E) (**Figure 1**), which is sandy cum rocky shore with a tidal exposure of about 1000 meters long and approximately 500 meters wide at 0.0 m low tide. The exposed rocky ledge is subjected to intense wave actions of the Arabian Sea. The habitat structure is highly potential with enormous biodiversity. The intertidal zone of Ras Juddi is mainly rocky with few sandy patches. The habitat structure mainly comprises rocky bed platforms (ridges) including beds of *Perna viridis*, rocky boulders, crevices and tide pools. Since the pools are natural ones, the shape and size are not precisely the same.

2.2 Sample collection and processing

Samples were collected during each survey from December-2021 to October-2022 through qualitative and quantitative sampling methods, performing the Transect-quadrat method and Random sampling to ensure maximum coverage of faunal types of the rocky intertidal community on a seasonal basis: North-East Monsoon (December and January), Inter Monsoon (April), South-West Monsoon (August), and Inter Monsoon (October). The rocky ledge was partitioned into three zones: high tidal zone (HTZ), mid-tidal zone (MTZ), and low tidal zone (LTZ). The physico-chemical parameters including air temperature (ºC), water temperature (ºC), pH, and salinity (‰) were measured in situ. Samples were randomly collected by parallel and perpendicular monitoring from low, mid, and high

tidal zones ensuring different habitats such as irregular boulders, turnable rocks, rock pools, and platforms. For the quantitative sampling, both parallel and perpendicular transects were adopted through quadrats of 1m × 1m at 30 feet apart each were alternatively placed at the three tidal zones. The samples were photographed and preserved in 5% Formaldehyde, tagged with date and location and after shifting in 70% Alcohol deposited in the Museum Repository of MRC & RC at University of Karachi. Specimens were examined morphologically and studied under microscope based on conchological features with the help of field guides and monographs (Day, 1969; Roper *et al*., 1984; Bosch *et al*., 1995; Kazmi *et al*., 2018; Vadher *et al*., 2020). Statistical analysis of macrobenthic faunal community structure was calculated by Shannon – Wiener (1949) diversity index, the Pielou's Evenness Index (J') (Pielou, 1966) and Margalef' s index (Margalef, 1951).

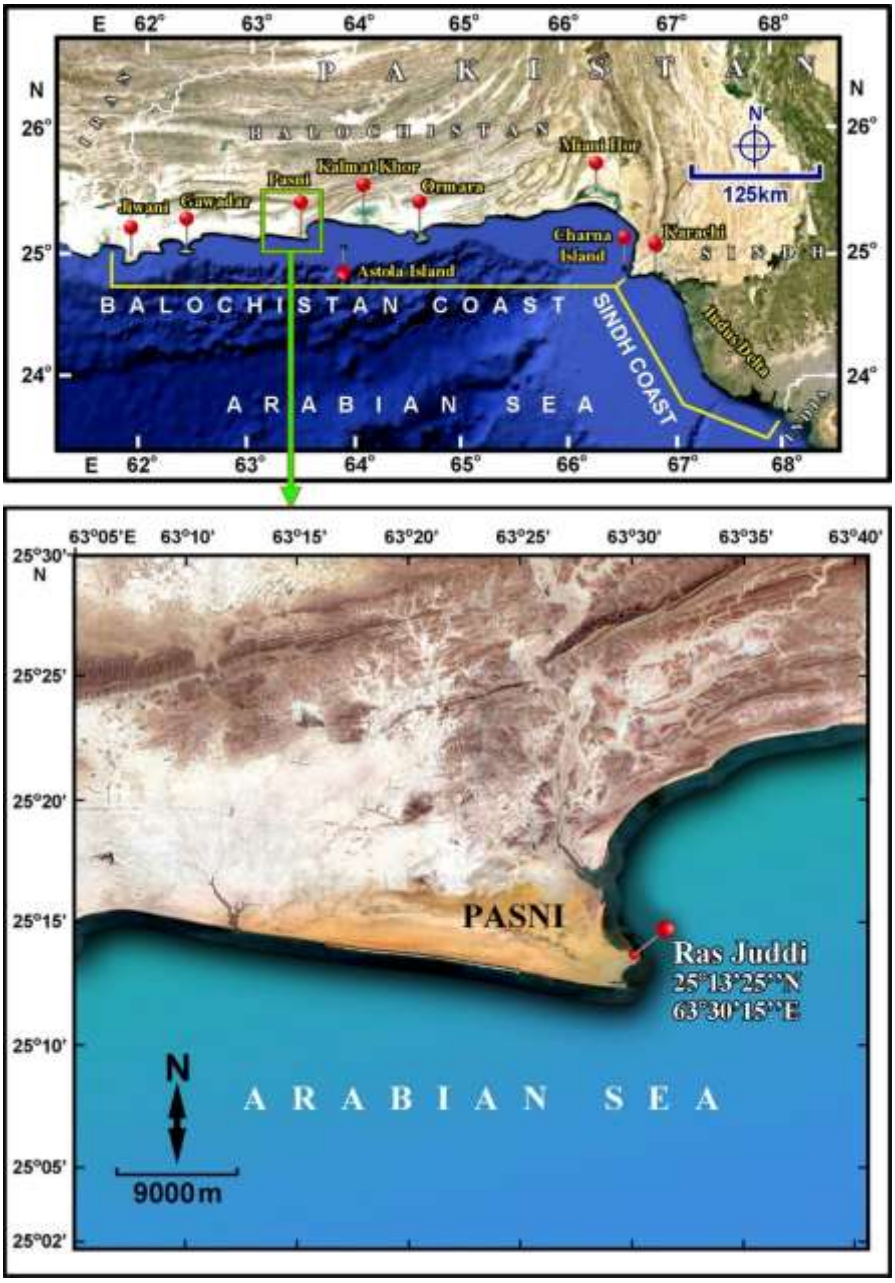

Figure 1. Map showing study area of Ras Juddi (25°13'25" N, 63°30'15" E), Pasni, Makran coast.

3. Results and Discussion

Physicochemical parameters measured at Ras Juddi, Pasni along the Makran coast from December 2021 to October 2022 (**Figure 2**) showed the following ranges: air temperature (26-29 °C), water temperature (25-30 °C), salinity (37 ‰), and pH (8.0-8.2).

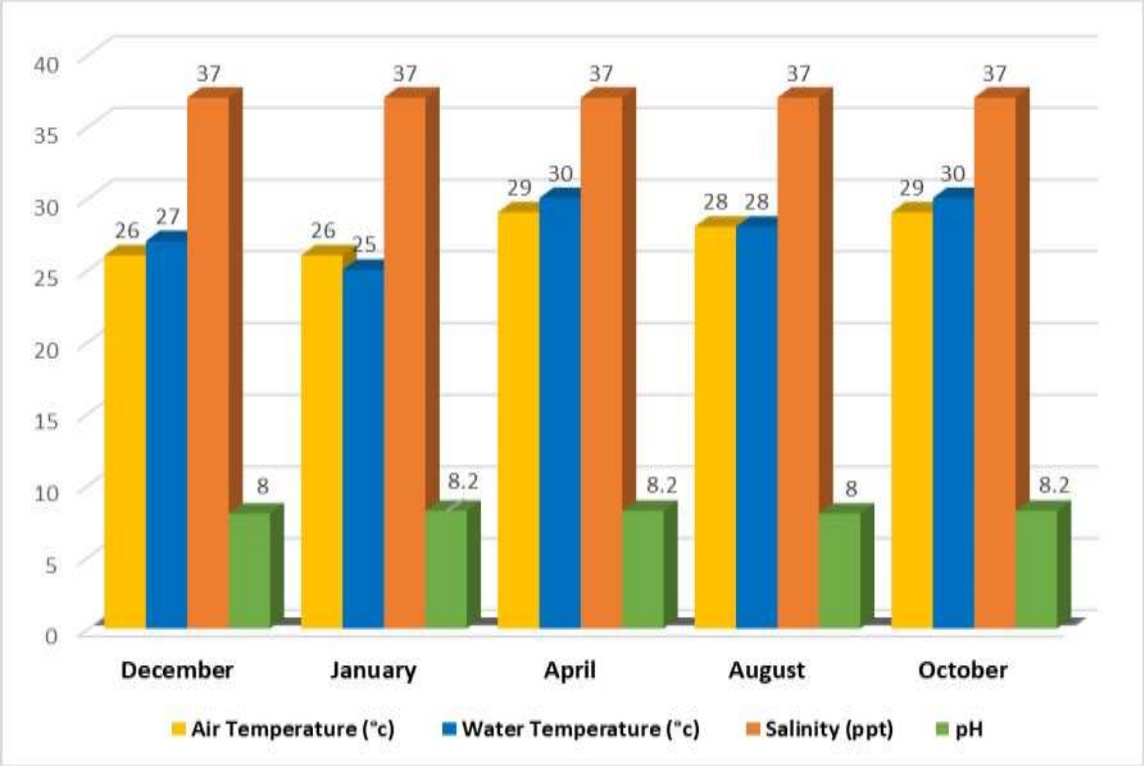

Figure 2. Monthly variation in the physico-chemical parameters recorded through seasons during December 2021- October 2022 at Ras Juddi, Makran coast

A total of 888 macrobenthic molluscan specimens were recorded using the quadrat method across the study period, encompassing the North-East Monsoon (December and January), Inter-Monsoon (April), South-West Monsoon (August), and Inter-Monsoon (October) seasons. The highest number of individuals was observed during the Inter-Monsoon period in April (n=282), followed by the North-East Monsoon (December and January) (n=262) and the Inter-Monsoon period in October (n=242). The lowest number of individuals was recorded during the South-West Monsoon in August (n=102). The molluscan specimens were classified as Gastropoda (57%), Bivalvia (41%), Polyplacophora (1%), Cephalopoda (1%), and Scaphopoda (≤1%) (**Figure 3**). A total of 69 molluscan species belonging to 38 families were identified at Ras Juddi through quadrat and random sampling. Of these, 60 species within 34 families were recorded using the quadrat method. Gastropoda was the most dominant class, comprising 41 species and exhibiting the highest abundance during the North-East Monsoon (December-January). Common gastropod species included *Anachis terpsichore*, *Lunella coronata*, *Euchelus asper*, *Semiricinula tissoti*, *Turbo intercostalis*, *Naria turdus*, *Nassarius deshayesianus*, and *Nerita albicilla*, which were predominantly found in the mid and low tidal zones. Shell-less gastropods such as the nudibranchs *Elysia grandifolia*, *Dendrodoris* sp., and *Doriopsisilla* sp. were observed in the low tide zone, while *Cellana karachiensis*, *Siphonaria belcheri*, and *Lunella coronata* were uniformly distributed across the high tide zone. Bivalvia was the second most abundant class, with 12 species, particularly during the Inter-Monsoon seasons (April and October). Common bivalve species in the study area included *Barbatia obliquata*, *Perna viridis*, *Irus irus*, and *Circenita callipyga*.

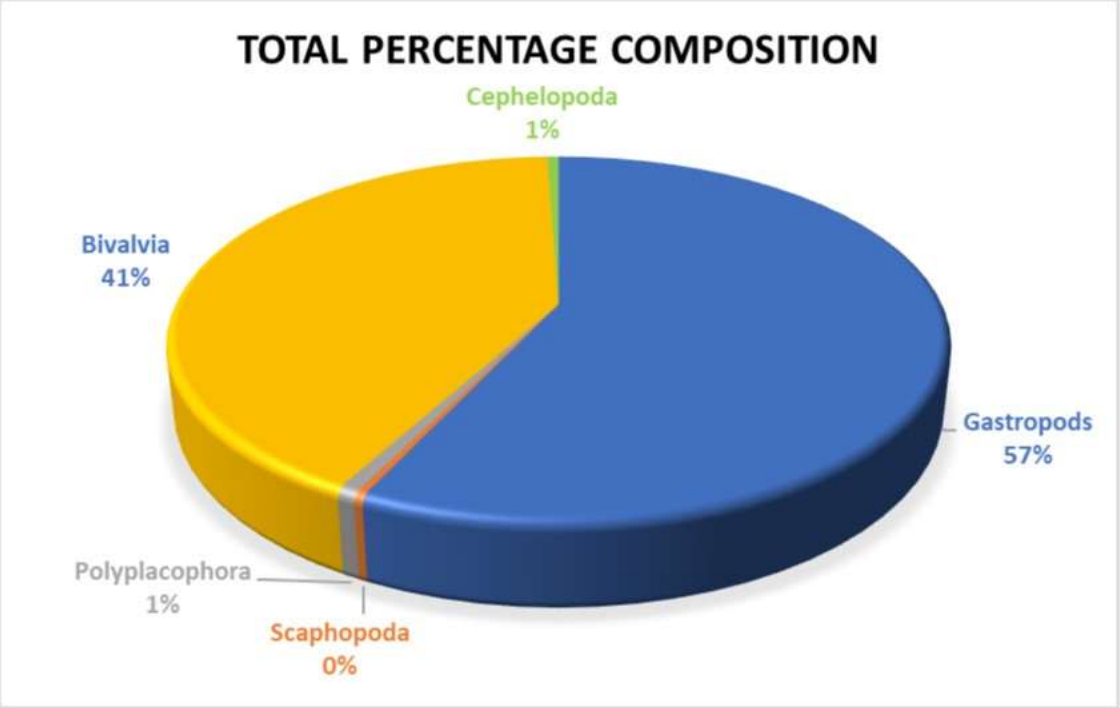

Figure 3. Total percentage composition (%) of Phylum Mollusca through seasons during December 2021 – October 2022 at Ras Juddi, Makran coast

Class Polyplacophora was represented by three chiton species: *Rhyssoplax peregrina*, *Acanthochitona* sp., and *Ischnochiton winckworthi*. Cephalopoda was represented by *Octopus vulgaris*, *Octopus cyanea*, and egg masses of *Loligo* sp., primarily found in the mid and low tidal zones. Only a single species of Scaphopoda, *Dentalium octangulatum*, was recorded. The highest overall abundance during the study period was observed in *Barbatia obliquata* (n=219), *Anachis terpsichore* (n=144), and *Perna viridis* (n=90).

Random sampling yielded an additional nine species: *Lyncina carneola*, *Drupella rugosa*, *Tylothais savignyi*, *Babylonia spirata*, *Glossodoris* sp., *Leptoplax* sp. (potentially a new record for Pakistan), *Diplodonta* sp., *Chama* sp., and *Standella pellucida*. Thus, a total of 69 molluscan species belonging to 38 families were identified from the intertidal zone of Ras Juddi, Makran coast, representing the first such comprehensive report for this area (**Table 1**). The distribution across classes was Gastropoda (46 species), Bivalvia (15 species), Polyplacophora (4 species), Cephalopoda (3 species), and Scaphopoda (1 species).

Table 1. The taxonomic classification of rocky shore fauna through seasons during December 2021- October 2022 at Ras Juddi, Makran coast

Phylum	Class	Family	Species
		Nacellidae	*Cellana karachiensis*
		Neritidae	*Nerita albicilla*
		Fissurellidae	*Diodora funiculata*
			Diodora ruppellii
			Diodora singaporensis
			Umbonium vestiarium

Mollusca	**Gastropoda**	Trochidae	*Trochus* sp.
			Clanculus scabrosus
			Clanculus tonnerrei
			Monodonta nebulosa
		Turbinidae	*Turbo intercostalis*
			Lunella coronata
		Chilodontaidae	*Granata sulcifera*
			Euchelus asper
		Cerithiidae	*Cerithium zonatum*
			Cerithium sp.
		Zebinidae	*Stosicia annulata*
		Calyptraeidae	*Crucibulum* sp.
		Cypraeidae	*Lyncina carneola*
			Purpuradusta gracilis
			Naria turdus
		Naticidae	*Natica pulicaris*
			Neverita didyma
		Bursidae	*Bufonaria echinata*
		Cymatiidae	*Gyrineum natator*
		Muricidae	*Indothais lacera*
			Indothais sacellum
			Purpura bufo
			Tenguella granulata
			Drupella rugosa
			Tylothais savignyi
			Semiricinula tissoti
		Babyloniidae	*Babylonia spirata*
		Nassariidae	*Nassarius deshayesianus*
			Bullia othaeitensis
		Columbellidae	*Anachis fauroti*
			Anachis terpsichore
			Mitrella blanda
		Conidae	*Conus coronatus*
		Clavatulidae	*Turricula tornata fulminata*
		Siphonariidae	*Siphonaria belcheri*
		Plakobranchidae	*Elysia grandifolia*

	Chromodorididae	*Glossodoris* sp.
	Dendrodoridae	*Dendrodoris* sp.
		Doriopsilla miniata
		Doriopsilla sp.
Scaphopoda	Dentaliidae	*Dentalium octangulatum*
Polyplacophora	Chitonidae	*Rhyssoplax peregrina*
	Acanthochitonidae	*Acanthochitona* sp.
		Leptoplax sp.
	Ischnochitonidae	*Ischnochiton winckworthi*
Bivalvia	Mytilidae	*Perna viridis*
		Perna perna
	Arcidae	*Barbatia obliquata*
		Barbatia sp.
	Limidae	*Limaria* sp.
	Ungulinidae	*Diplodonta* sp.
	Chamidae	*Chama* sp.
	Mactridae	*Mactra lilacea*
		Standella pellucida
	Veneridae	*Irus irus*
		Gafrarium divericatum
		Circenita callipyga
		Circe scripta
	Semelidae	*Semele* sp.
	Pholadidae	*Pholas dactylus*
Cephalopoda	Octopodidae	*Octopus vulgaris*
		Octopus cyanea
	Loliginidae	*Loligo* sp.

Seasonal variations in molluscan fauna diversity indices were calculated from December 2021 to October 2022 (**Figure 4**). The highest Shannon-Wiener diversity index (H'= 0.77) was observed during the Inter-Monsoon period in October, and the lowest (H'= 0.58) during the North-East Monsoon (January-December). The highest Margalef's Species Richness Index (d= 0.72) was recorded during the Inter-Monsoon period in October, while the lowest (d= 0.43) was measured during the South-West Monsoon (August). The highest Pielou's Evenness Index (J'= 0.65) was calculated during the South-West Monsoon (August), and the lowest (J'= 0.41) during the North-East Monsoon (January-December).

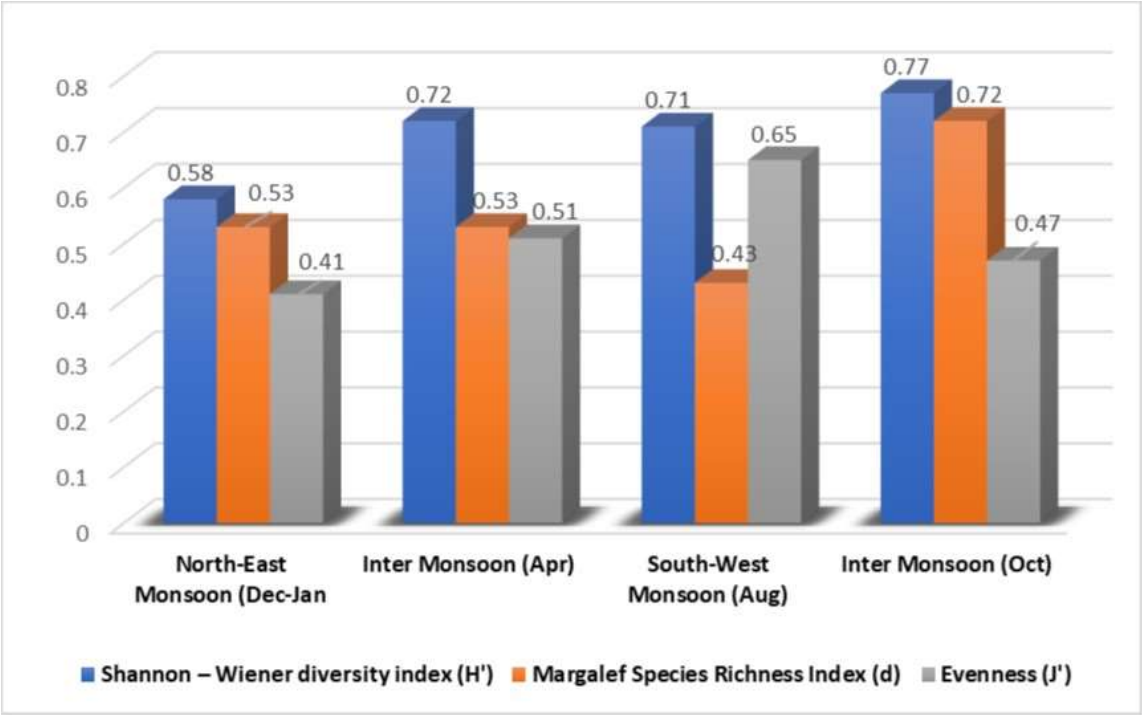

Figure 4. Seasonal variations in Shannon – Wiener diversity index (H'), Margalef Species Richness Index (d) and Evenness (J') through seasons during December 2021 - October 2022 at Ras Juddi, Makran coast

The pictures of the species obtained in our study are presented in **Figures5-8.** The present study conducted a comprehensive assessment of the macrobenthic molluscan communities inhabiting the rocky intertidal zone of Ras Juddi, Pasni, along the Makran coast. This investigation represents the first detailed analysis of species-level composition, abundance, diversity, and dominance within this specific area. Employing quadrat and random sampling methodologies, this research establishes a fundamental baseline for future research endeavors and resource management initiatives in the region. Previous studies on the faunal assemblages of Pakistan's rocky shores have identified Mollusca, Arthropoda, and Annelida as major contributors to the intertidal fauna (Ahmed *et al*., 1982; Burney and Barkati, 1995). Globally, Mollusca and Arthropoda are also recognized as dominant macroinvertebrate groups in many coastal ecosystems (Dwivedi *et al*., 1973; Evink, 1975). Specifically discussing the rocky shore communities of Pakistan, Ahmed (1997) noted the dominance of gastropods and decapods.

The patterns of species distribution in relation to zonation within intertidal rocky shore communities have been extensively studied by marine biologists (Stephenson and Stephenson, 1949, 1972; Lewis, 1964). Studies conducted along various shores in Pakistan have indicated that mid-tidal zones are typically the most productive in terms of total species and individual numbers (Burney and Barkati, 1995; Ahmed and Hameed, 1999; Nasreen *et al*., 2000). In contrast to some of these findings, the distribution and abundance of macrobenthic molluscs at Ras Juddi, Makran coast, were found to be prominently high in both the low and mid-tidal zones, while the high tidal zone exhibited lower abundance and distribution, with species such as *Cellana karachiensis*, *Siphonaria* sp., and *Lunella coronata* showing uniform coverage. Littler (1980) also documented variations in the distribution and abundance of organisms across three tidal zones at ten different sites within the Southern California Bight. Similarly, Li*et al*. (1993) reported the highest vertical distribution of species within the mid-tidal zones in Daya Bay, China. RahmanandBarkati (2012)observed a decline in species count with

increasing tidal height on Karachi's rocky shores (Buleji, Nathiagali, Manora, and Cape Monze), where the mid-tidal zone had the highest average number of individual molluscs, except for Nathiagali, which showed the highest numbers in the low-tidal zone.KhanamandSaher (2018) also reported a richer faunal diversity in the lower intertidal zone compared to the middle and high intertidal zones, with molluscs being the dominant phylum among the six represented.

Figure 5. Gastropoda: **A,** *Cellana karachiensis*; **B,** *Nerita albicilla*; **C,** *Diodora ruppellii*; **D,** *Diodora singaporensis*; **E,** *Umbonium vestiarium*; **F,** *Clanculus scabrosus*; **G,** *Lunella coronata*; **H,** *Turbo intercostalis*; **I,** *Euchelus asper*.

Figure 6. Gastropoda: **A,** *Cerithium zonatum*; **B,** *Crucibulum sp*; **C,** *Naria Turdus* with egg mass; **D,** *Gyrineum natator*; **E,** *Purpura bufo*; **F,** Colony of *Semiricinula tissoti*; **G,** *Bullia othaeitensis*; **H,** *Conus coronatus*; **I,** *Siphonaria belcheri.*

The documented number of molluscan species along the Balochistan coast is considerably lower than that reported for the Sindh coast. The present study identified a total of 69 molluscan species belonging to 38 families from the intertidal zone of Ras Juddi, Makran coast, representing the first such comprehensive record for this location. In comparison, Ahmed *et al*. (1982) reported a total of 53 molluscan species from various locations including East and West Bay of Gawader, Dasht Hor, and Jiwani. Their work also provided detailed insights into the distribution and abundance of the green

mussel species, *Perna viridis*, along the Sindh and Balochistan coasts, indicating a higher abundance in Balochistan. Consistent with this, the intertidal zone of Ras Juddi was dominated by *Barbatia obliquata*, followed by *Perna viridis* among the 15 bivalve species identified, with Perna viridis forming extensive beds.

Figure 7. Gastropoda: **A,** *Elysia grandifolia*; **B,** *Dendrodoris sp.*; **C,** *Doriopsilla miniata*; Polyplacophora: **D,** *Rhyssoplax peregrina*; **E,** *Acanthochitona sp.*; **F,** *Ischnochiton winckworthi*; Bivalvia**: G-H,** Bed of *Perna viridis*.

Figure 8. Bivalvia**: A,** *Perna perna*; **B,** *Barbatia obliquata*; **C,** *Limaria sp.*; **D,** *Irus irus*; **E,** *Gafrarium divericatum*; **F,** *Circenita callipyga*; **G,** *Pholas dactylus*; Cephalopoda**: H,** *Octopus vulgaris*; **I,** *Octopus sp.* egg mass.

Tirmizi and Zehra (1984) documented approximately 23 molluscan species from Pasni, 12 from Astola Island, and 11 from Gadani. Ghani *et al*. (2017) identified 34 molluscan species from Bandri beach, Jiwani, with *Umbonium vesterium* being the most dominant. A comprehensive checklist by Ghani *et al*. (2018) listed 98 molluscan species from Bandri Beach, with Muricidae being the most speciose family (12 species), followed by Ostreidae (6 species). Rahman and Barkati (2012) found gastropod molluscs to be the most prominent fauna on four rocky beaches of Karachi coast, with no significant variations in species diversity, richness, and evenness. Rahmawati *et al*. (2021) observed

20 molluscan species at Nglambor Beach, Indonesia, with Thais hippocastanum being the most abundant in the upper and lower intertidal zones, and *T. tissoti* in the middle zone. They also noted the aggregation behaviour of Muricidae species in rock crevices for water retention and humidity maintenance during dry seasons and low tides, a phenomenon observed in *Semiricinulatissoti* during the present study, where Muricidae was the most diverse gastropod family (7 species).

Class Polyplacophora was represented by three chiton species (*Rhyssoplax peregrina*, *Acanthochitona* sp., *Ischnochiton winckworthi*), consistent with previous records (Kaas, 1954; Kazmi and Khan, 2014). The collection of *Leptoplax* sp. through random sampling potentially represents a new record for Ras Juddi, requiring further taxonomic investigation for confirmation. *Dentalium octangulatum* was the sole scaphopod species recorded, also observed at Bandari beach, Jiwani coast (Ghani *et al*., 2019). Class Cephalopoda was represented by *Octopus vulgaris*, *Octopus cyanea*, and egg masses of *Loligo* sp.

A primary focus of this study was to survey underexplored coastal areas of Pakistan bordering the northern Arabian Sea and to develop an inventory of benthic fauna, a crucial step under the Convention on Biological Diversity. Pakistan, as a signatory to various international environmental conventions and treaties (including the Paris Agreement, CBD, CITES, RAMSAR Convention, Kyoto Protocol, UNCLOS, Basel Convention, and Stockholm Convention), has committed to protecting its marine and coastal biodiversity. While past initiatives by Pakistan to protect these ecosystems are commendable, ongoing and emerging threats necessitate increased and timely attention from governmental bodies, the private sector, and the public (Daily Times, 2018). Pakistan's commitment to Sustainable Development Goal 14, which focuses on the conservation and sustainable use of oceans, seas, and marine resources, requires actions that ensure the continued health of these environments through necessary regulatory frameworks, upgraded monitoring institutions, and active participation in international efforts to achieve SDGs via agreed protocols.

Conclusion

The lack of comprehensive historical data on the seasonal and spatial abundance of Mollusca along the Makran coast underscores the significance of this study as an initial step towards fulfilling Pakistan's commitments to international treaties. This research contributes valuable knowledge regarding the species richness and diversity of Gastropoda, Scaphopoda, Polyplacophora, Bivalvia, and Cephalopoda along the Makran coast of Pakistan bordering the Northern Arabian Sea. The findings provide invaluable insights into molluscan assemblages and offer a preliminary understanding of their natural habitats in this previously unexplored region. The data and baseline information obtained from this research serve as a crucial foundation for future exploration and conservation efforts along the Makran coast.

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Compliance with Ethical Standards: This article does not contain any studies involving human subjects.

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