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Community Structure of Marine Macrofauna at Diu Coast, Gujarat, India

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ABSTRACT

The marine ecosystem support variety of habitat that consequently supports high species diversity. The present study investigated the diversity of marine macrofauna in the rocky intertidal zone of Diu, Gujarat. Survey was carried out from 4 different sites during April 2022 to March 2023. During the study, all the study sites were surveyed regularly on monthly basis during the lowest low tide period. During the examination, the encountered fauna was carefully observed along the coast using a Quadrat method and visual encounter method and extensive photography was carried out. This study demonstrates 70 species of macrofauna at coastal area of Diu. The highest diversity was observed in the phylum Mollusca (37 species), followed by phylum Arthropoda (16 species), Cnidaria (8 species), Porifera (4 species), Annelida (species 2), Echinodermata (2 species), Platyhelminthes (1 species). This study highlights the importance of protecting the diverse marine habitats in Diu and emphasizes the need for further research on the ecology and conservation of the region's unique marine biodiversity.

Keywords Diversity, Macrofauna, Rocky, Intertidal zone, Diu, Conservation.

INTRODUCTION

Macrofauna are defined as organisms that are large enough to be seen with the naked eye and include species under Porifera, Cnidaria, Annelida, Molluscs, Crustaceans, Echinoderms, and Polychaete worms. Aquatic ecosystems such as oceans, seas, lakes, gulfs and rivers cover approximately 70% of the Earth's surface and consist of maximum inhabitants (Welch and Naczk 1992). Out of these, a total of 18% of the Earth's surface is covered by the coastal zones (Balasubramanian 1999).

The marine ecosystem, mainly the intertidal zone, is one of the most dynamic zones because it is the interface between the sea and terrestrial environment (Balakrishnan and Sivaleela 2022). The animals in this zone are constantly exposed to air and have evolved to cope with environmental pressures (Esenowo and Ugwumba 2010). The rocky intertidal area is divided into four zones by vertical zonation: supratidal, high tidal, middle tidal, and low tidal. The rocky coasts are a type of coastal ecosystem that can

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be found all over the world, forming lengthy stretches of shoreline or patches along the coast (Cruz-Motta *et al*. 2010). This intertidal zone is influenced by factors such as tidal currents, wave action, and seasonal changes. The high wave energy and rocky substrate provide unique microhabitats that support a wide range of species.

Macrofauna - macrobenthos (body size < 1 mm) are organisms that live on or inside the deposit at the bottom of a body of aquatic habitat (Snelgrove, 1998). India is one among 12 mega-biodiverse countries and 25 hotspots of the richest and highly endangered eco-regions of the world. Among the Asian countries, India is perhaps the only one that has a long record of inventories of coastal and marine biodiversity dating back to at least two centuries (David 2013). In terms of marine environment, India has a coastline of about 8000 km adjoining the continental regions and the offshore islands and a very wide range of coastal ecosystems such as estuaries, lagoons, mangroves, backwaters, salt marshes, rocky coasts, sandy stretches and coral reefs (Venkataraman 2003, Venkataraman and Wafar 2005).

Out of this One region that has received increasing attention for its marine biodiversity is Gujarat, located on the western coast of India. The Gujarat coast spans over 1600 km and the coastline of Gujarat is the longest in the Indian states; constituting about 21% of the Indian coast line (Trivedi *et al.* 2015). The Saurashtra coast, which is the Northern part of the Indian coastline, is categorized by its rocky, sandy, and muddy Intertidal zones, harboring rich and diverse flora and fauna (Raval and Ravaliya 2020). Diu is a union territory of India, which is situated on an island in the Arabian Sea in the South-Eastern Gujarat State It is covering an area of 38.8 km^2 (Patale and Tank 2022). The climate condition on this region is extremely warm and humid with an average annual rainfall of 1500 mm (Patale and Tank 2022). Despite its importance, there have been limited studies on the diversity and distribution of macrofauna in this region.

Intertidal marine macrofauna are also important indicators of ecosystem health and can provide insights into the impacts of human activities on the marine environment. They are often used as bioindicators to assess the health of coastal ecosystems, as they are sensitive to changes in water quality, pollution, and habitat destruction. This study will contribute to our understanding of the biodiversity and biogeography of marine macrofauna in this region, as well as provide valuable information for conservation and management efforts.

MATERIALS AND METHODS

Study area

The present investigation was carried out at rocky intertidal area of Diu. Diu is situated slightly off the coast of Kathiawar (Saurashtra), near the part of Gir Somnath. Four different rocky coastal zones of the Diu coast were selected: Site 1-Diu fort area (20°43'1.93"N, 70°59'31.18"E), Site 2- Khukri beach (20°42'13.25"N, 70°58'31.80"E), Site 3- Fudam beach (20°42'22.66"N, 70°57'40.17"E), and Site 4- Nagoa beach (20°42'18.19"N, 70°54'58.26"E). (Fig. 1)

Data collection

This study was conducted from April 2022 to March 2023. The intertidal zone of each site was surveyed regularly, on a monthly basis, and encountered organisms were carefully observed along the coast using the quadrat method and the visual encounter method. Thus, macrofauna under various families were recorded, and a checklist was prepared. All organisms were photographed and identified up to the lowest possible taxonomic level. Identification was done by using identification manuals, reference books, reports, and extensive use of the internet, following the Marine Species Identification Portal website (http://speciesidentification.org), and standard taxonomic keys by Picton (2007), Van Soest *et al*. (2014) for sponges, Apte (2014) for gastropods, Coan and Valentich-Scott (2012) for bivalves, and Beleem *et al.* (2019) for crabs. Scientific names and classification were adopted from the World Register of Marine Species (worms; http://www.marinespecies.org). The complete study was conducted in a non-destructive manner in which organisms were not at all disturbed.

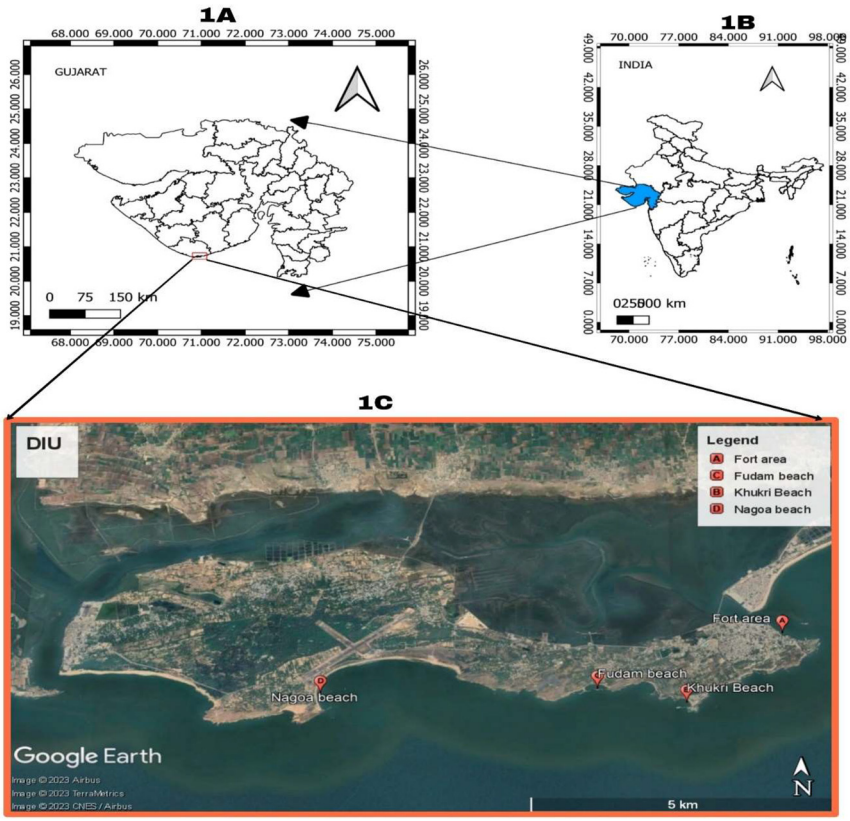


Fig. 1. 1A: Gujarat in Indian (Source: QGIS), 1B: Diu in Gujarat (Source: QGIS), 1C: Study area: Rocky intertidal coasts of Diu. (A) Diu fort, (B) Khukri beach, (C) Fudam beach, (D) Nagoa beach (Map Source: Google earth).

Data analysis

For the analysis of different diversity indices and the corelation of different indices PAST (Ver. 4.03) software tools were used. The species diversity index was calculated using the following formula (Shannon and Wiener 1949): $H=\sum[(pi) \times \ln (pi)]$, pi - proportion of individuals of i-th species in a whole community. Simpson's diversity index (D): $D = \Sigma ni(ni-1) / N(N-1)$ n = the total number of individuals of a species, N = the total number of individuals of all the species. Berger-Parker Dominance Index: Berger -Parker Index= nmax /N, Evenness or equitability (S') was calculated using the (Pielou 1966) formula: J' = H'/ *Jns or H'/log2S.*

RESULTS AND DISCUSSION

The present study reports 70 species of intertidal macrofauna belonging to 64 genera, 52 families, 27 orders, 13 classes, and 7 phyla (Fig. 2). A total of 8812 individuals were observed during the study period. Out of all the species recorded, the highest species richness was observed at the Diu fort area (62 species), followed by Khukri beach (57 species), Nagoa beach (46 species), and Fudam beach (41 species) (Fig. 3). Out of 7 phyla, Phylum Mollusca exhibited the highest contribution with 37 species (28 gastropods, 6 bivalvia, 2 cephalopods, and 1 polyplacophora) and 55% of total diversity. Phylum Arthropoda appeared as the second most dominant group with 16 species with 23% diversity, 8 species of Cnidaria with 11% diversity 4 species of Porifera with 6% diversity, 2 species of Annelida with 3% diversity, 2 species of Echinodermata with 3% diversity, and 1 species of Platyhelminthes with 1% diversity (Fig. 4). The highest species occurrences were found in

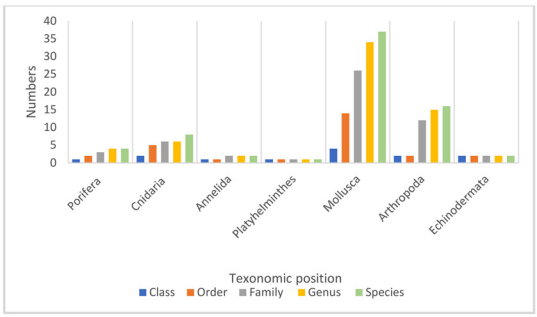


Fig. 2. Taxon wise distribution of macrofauna at Diu.

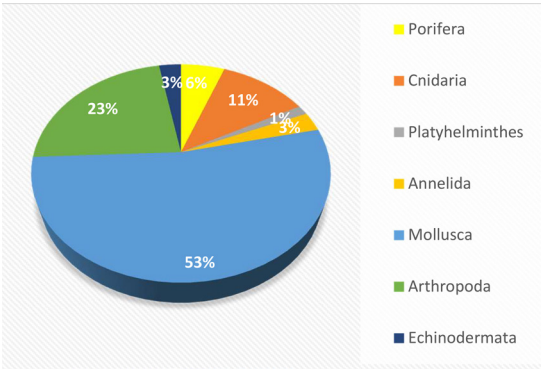


Fig. 4. Phylum wise distribution of macrofauna at Diu.

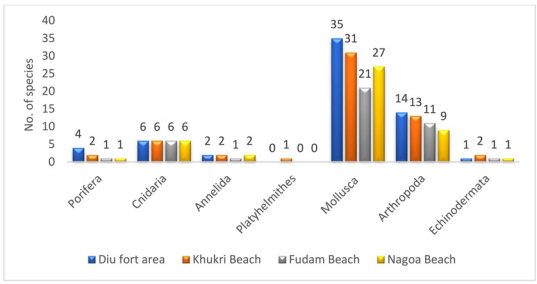


Fig. 3. Site wise distribution of macrofaunal species at Diu.

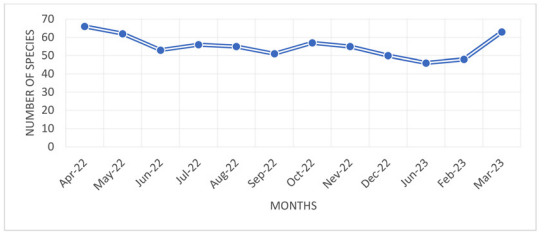


Fig. 5. Month wise species occurrence of macrofauna of Diu.

summer (March, April, and May) (Fig. 5). In Mollusca, *Trochus radialus, Cellena radiata, Astralium semicostatum, Conus miliaris, Nassarius olivaceus, Chiton granoradiatus, Turbo intercoastalis, Thais clavigera,* and *Chicoreus brunneus* are common in the Diu coast. Other common macrofauna are *Haliclona laerulea, Anthoplerura sola, Zoanthus sansibaricus, Neries* sp., *Grapsus albolineatus, Eriphia smithii, Amphibalanus amphitrite,* and *Ophiothrix savignyi* (Table 1). The present study provides a comprehensive checklist of benthic macrofauna along the coast of Diu. The results of the study can be used as a baseline for future research. It will be further helpful to develop a management strategy for the conservation of coastal marine ecosystems.

Diversity indices analysis

In the present study, the Shannon Wiener indices were observed highest in Site 1 (3.404) and lowest in

Table 1. Diversity of macrofauna at coasts of Diu (A) Diu fort area, (B) Khukri beach, (C) Fudam beach and (D) Nagoa beach.

Phylum	Class	Order	Family	Genus	Species	Sites			
						A	B	C	D
Porifera	Demospongiae	Heteroscleromorpha	Chalinidae	Haliclona	*Haliclona caerulea* (Hechtel 1965)	25	14	16	13
				Haliclona	*Haliclona* (*Reniera*) *tubifera* (George and Wilson 1919)	6	0	0	0
		Suberitida	Halichondriidae	Halichondria	*Halichondria (Halichondria) panicea* (Pallas 1766)	15	0	0	3

Table 1. Continued.

Phylum	Class	Order	Family	Genus	Species	Sites			
						A	B	C	D
			Suberitidae	Suberites	*suberites* sp.	15	9	0	0
Cnidaria	Anthozoa	Actiniaria	Actiniidae	Anthopleura	*Anthopleura sola* Pearse and Francis 2000	47	39	48	67
		Scleractinia	Poritidae	Goniopora	*Goniopora pedunculata* Quoy and Gaimard 1833	2	0	0	13
		Zoantharia	Sphenopidae	Palythoa	*Palythoa mutuki* (Haddon and Shackleton 1891)	20	13	28	25
					Palythoa tuberculosa (Esper 1805)	7	5	3	1
			Zoanthidae	Zoanthus	*Zoanthus sansibaricus* Carlgren 1900	7	10	11	5
					Zoanthus sociatus (Ellis 1768)	8	5	23	23
	Hydrozoa	Anthoathecata	Porpitidea	Porpita	*Porpita porpita* (Linnaeus 1758)	57	3	34	4
		Siphonophores	Physalidae	Physalia	*Physalia physalis* (Linnaeus 1758)	2	1	0	0
Annelida	Polychaeta	Phyllodocida	Nereididae	Nereis	*Neris* sp.	46	64	68	74
			phyllocidae	Eulva	*Eulalia viridis* (Linnaeus 1767)	13	18	0	11
Platyhelmin-thes	Trepaxonemata	Polycladida	Pseudocerotidae	Pseudoceros	*Pseudoceros susana*e (Newman and Anderson 1997)	0	0	0	0
Mollusca	Bivalvia	Venerida	Veneridae	Sunetta	*Sunetta donacina* (Gmelin 1791)	10	2	0	9
				Gafrarium	*Gafrarium divaricatum* (Gmelin 1791)	36	23	0	17
				Dosinia	*Dosinia cretacea* (Reeve 1850)	2	0	0	4
		Ostreida	Ostreidae	Ostreidae	*Saccostrea scyphophilla* (Peron and Lesueur 1807)	58	21	51	41
		cardiida	cardiidae	Vasticardium	*Vasticardium flavum* (Linnaeus 1758	4	5	0	0
		Arcida	Arcoidea	Arca	*Arca granosa* (Linnaeus 1758)	0	2	0	0
	Gastropoda	Neogastropoda	Muricidae	Chicoreus	*Chicoreus brunneus* (Link 1807)	38	13	10	34
				Purpura	*Purpura panama* (Röding 1798)	0	1	0	2
					Purpura bufo (Lamarck 1822)	1	0	0	0
				Thais	*Thais clavigera* (Küster 1860)	111	81	97	70
				Murex	*Murex (Murex)* trapa Röding 1798	10	1	0	0
			Olividae	Agaronia	*Agaronia nebulosa* (Lamarck 1822)	3	11	9	9
			Nassariidae	Nassarius	*Nassarius olivaceus* (Bruguière 1789)	94	30	99	53
			Melongenidae	Volegalea	*Volegalea cochlidium* (Linnaeus 1758)	4	0	0	0
			Conidae	Conus	*Conus miliaris* (Hwass in Bruguière 1792)	37	31	29	36

Table 1. Continued.

Phylum	Class	Order	Family	Genus	Species	Sites			
						A	B	C	D
			Pisaniidae	Cantharus	*Cantharus spiralis* (Gray 1839)	32	23	11	22
				Pollia	*Pollia undosa* (Linnaeus 1758)	25	19	0	16
		Littorinimorpha	Rostellariidae	Tibia	*Tibia curta* (GB). Sowerby II, 1842	5	7	0	8
			Cypraeidae	Mauritia	*Mauritia arabica* (Linnaeus 1758)	42	41	32	39
			Bursidae	Dulcerana	*Dulcerana granularis* (Röding 1798)	4	0	15	6
			Cymatiidae	Gyrineum	*Gyrineum natator* (Röding 1798)	9	31	0	29
		Trochida	Turbinidae	Astralium	*Astralium semicostatum* (Kiener 1850)	125	110	92	166
				Lunella	*Lunella coronata* (Gmelin 1791)	140	112	71	76
				Turbo	*Turbo intercostalis* (Menke 1843)	73	72	66	69
			Trochidae	Trochus	*Trochus radiatus* (Gmelin 1791)	117	126	125	158
		*	Nacellidae	Cellana	*Cellana radiata* (Born 1778)	212	221	238	208
		*	Patellidae	Patella	*Patella vulgata* (Linnaeus 1758)	0	0	2	0
		Cycloneritida	Neritidae	Nerita	*Nerita albicilla* (Linnaeus 1758)	31	13	0	0
					Nerita chamaeleon (Linnaeus 1758)	57	36	38	33
					Nerita undata (Linnaeus 1758)	53	47	51	35
		Aplysiida	Aplysiidae	Aplysia	*Aplysia Oculifera* (A. Adams and Reeve 1850)	16	4	6	0
		Systellommatophora	Onchidiidae	Peronia	*Peronia verruculata* (Cuvier 1830)	0	18	6	1
		Caenogastropoda	Potamididae	Telescopium	*Telescopium telescopium* (Linnaeus 1758)	0	3	13	0
			Cerithiidae	Rhinoclavis	*Rhinoclavis sinensis* (Gmelin 1791)	3	1	8	1
	Polyplacophora	Chitonida	Chitonidae	Chiton	*Chiton granoradiatus* (Leloup 1937)	137	182	215	148
	Cephalopoda	Octopoda	Octopodidae	Octopus	*Octopus Vulgaris* (Cuvier 1797)	0	0	0	0
		Myopsida	Loliginidae	Loligo	*Loligo* Lamarck 1798	0	0	0	0
Arthropoda	Malacostraca	Decapoda	Diogenidae	Clibanarius	*Clibanarius nathi* (Chopra and KN Das 1940)	36	35	27	34
					Clibanarius rhabdodactylus (Forest 1953)	31	36	46	55
			Cancridae	Cancer	*Cancer pagurus* (Linnaeus 1758)	5	8	8	8
			Grapsidae	Grapsus	*Grapsus albolineatus* (Latreille in albolineatus 1812)	1	4	8	1
				Metopograpsus	*Metopograpsus thukuhar* (Owen 1839)	2	2	6	0

Table 1. Continued.

Phylum	Class	Order	Family	Genus	Species	Sites			
						A	B	C	D
				Pachygrapsus	*Pachygrapsus crassipes* (Randall 1840)	2	0	7	0
			Portunidae	Portunus	*Portunus pelagicus* (Linnaeus 1758)	0	0	0	0
				Charybdis	*Charybdis (Charybdis) annulata* (Fabricius 1798)	2	1	0	0
			Eriphiidae	Eriphia	*Eriphia smithii* MacLeay 1838	6	1	17	2
			Xanthidae	Leptodius	*Leptodius affinis* (De Haan 1835)	9	14	10	9
			Pilumnidae	Pilumnus	*Pilumnus vespertilio* (Fabricius 1793)	9	0	0	13
			Matutidae	Ashtoret	*Ashtoret lunaris* (Forskål 1775)	0	0	0	0
			Porcellanidae	Petrolisthes	*Petrolisthes boscii* (Audouin 1826)	2	0	0	1
			Penaeidae	Penaeus	*Penaeus indicus* H. Milne Edwards 1837	1	0	0	5
			Palaemonidae	Palaemon	*Palaemon serratus* (Pennant 1777)	2	8	4	40
	Thecostraca	Balanomorpha	Balanidae	Amphibalanus	*Amphibalanus amphitrite* (Darwin 1854)	42	740	584	590
Echinodermata	Ophiuroidea	Ophiacanthida	Ophiocomidae	Ophiocomella	*Ophiothrix savignyi* (Müller and Troschel 1842)	7	17	19	10
	Crinoidea	Crinoidea	Antedonidae	Antedon	*Antedon* sp.	3	3	3	5

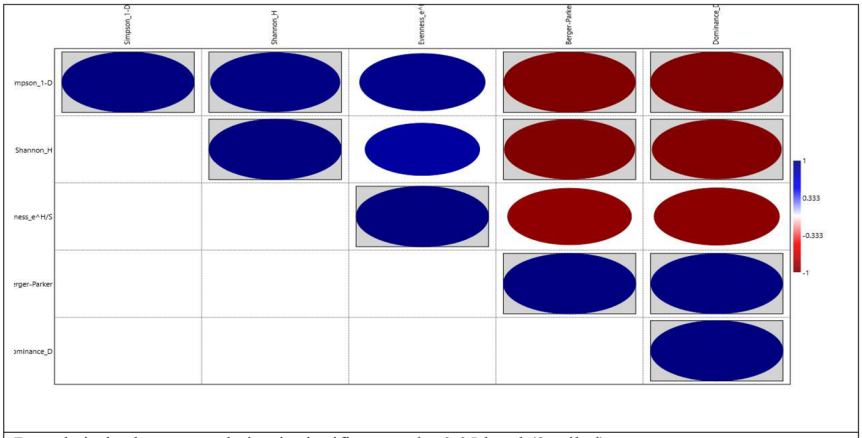
Site 2 (2.817), and dominance was highest in Site 2 (0.1286) and lowest in Site 1 (0.04654) (Table 2). This indicates that the highest diversity was observed at site 1 and the lowest diversity was observed at site 2.

Correlation analysis

The blue circle indicates the positive correlation, the red circle indicates the negative correlation, and the boxed circle indicates the correlation is significant at the 0.05 level (Fig.6). The blue boxed circle indicates a significant positive correlation between Shannon Wiener and Simpson indices at $p < 0.05$, blue boxed circle indicates a significant positive correlation between Dominance and Berger-Parker indices at $p < 0.05$. The red boxed circle indicates a significant negative correlation between Berger-Parker and Shannon Wiener at $p < 0.05$, and the red boxed circle indicates a significant negative correlation between Berger-Parker and Simpson indices at $p < 0.05$. The red boxed circle indicates a significant negative cor-

Table 2.. Diversity indices of different sites (Site 1: Diu fort area, Site 2: Khukri beach, Site 3: Fudam beach and Site 4: Nagoa beach).

	Simpson	Shannon-Wiener	Evenness	Berger-Parker	Dominance
Site 1	0.9535	3.404	0.5014	0.1105	0.04654
Site 2	0.8714	2.817	0.3157	0.3166	0.1286
Site 3	0.8977	2.886	0.4269	0.2591	0.1023
Site 4	0.9034	2.977	0.3925	0.2563	0.09663



Boxed circle shows correlation is significant at the 0.05 level (2-tailed)
The valve displayed in table are the mean Pearson correlation coefficients calculated from triplicate samples collected from selected site

Fig. 6. Correlation of marine macrofauna species diversity indices.

relation between dominance and Shannon Wiener at $p < 0.05$, and the red boxed circle indicates a significant negative correlation between the dominance and Simpson indices at $p < 0.05$.

In this study we found 70 species of intertidal macrofauna (Fig.7). The highest diversity was observed in the phylum Gastropod, followed by phylum Arthropoda, Cnidaria, Porifera, Annelida, Echinodermata, Platyhelminthes (Fig.7). Similar studies were conducted by (Agravat *et al.* 2022). She studied the diversity of intertidal microbenthic flora and fauna, consisting of 21 species of benthic macroflora and 109 species of macrobenthic fauna from the Saurashtra coast. Pandya *et al.* (2021) studied the benthic macrofaunal diversity, consisting of 43 species, viz. Mollusca (21), Crustacea (12), Polychaeta (7), Nemertea (1), and Fishes (2) from the Gulf of Kutch. (Solanki *et al*. 2016) studied the mangrove intertidal macrofauna diversity, consisting of 71 species of marine fauna, 42 species of avian fauna from 31 genera from 12 families, 14 species of Crustacea from 13 genera recorded from 10 families, and 9 species of Molluscs from 8 genera recorded from 7 families from the Gulf of Khambhat. It shows that the rocky intertidal zone of the Saurashtra coast contains more diversity compared to the mangroves and rocky shores of the Gulf of Kutch and Gulf of Khambhat regions of Gujarat. According to Balakrishnan and Sivaleela (2022), a total of 63 species belonging to 58 genera, 39 families, 25 orders, and 6 phyla were identified. Overall, the present study revealed that the rocky intertidal zone of the Diu coast provides suitable habitat and nourishment to the microbenthic diversity. This study emphasises the need for further research on the ecological aspects of the macrobenthic organisms of this region. It will also provide the baseline data to the scientists and policymakers for the conservation of rich diversity consisting of rocky intertidal zones along the Diu coast, Gujarat. Thivakaran and Sawale (2016) studied mangrove macrofaunal diversity and community structure in Mundra and Kharo, Kachchh consisting of 51 species of macrofauna in 44 genera, gastropods and crustaceans dominated the faunal assemblage with 14 and 15 species in 24 genera, and the Shannon diversity index for the entire study period ranged from 1.45 to 2.88 with both the values recorded at Kharo. Diversity values were marginally higher during the winter and summer than the monsoon and post-monsoon (Thivakaran and Sawale 2016). (Raval .2015) studies population ecology of intertidal hermit crab *Diogenes avarus* from a muddy coast of western India, Raval *et al*. (2016) studies shell utilization and size group analysis of two intertidal hermit crabs *Clibanarius infraspinatus* and *Diogenes avarus* From Kathiawar

Fig. 7. Macrofauna found at Rocky Intertidal Coasts of Diu.

Peninsular coast of Gujarat, Kachhiya *et al.* (2017) studies diversity and new records of intertidal hermit crabs of the genus *clibanarius* from Gujarat coast, Agravat *et al.* (2022) studies new distributional record of *Evelineus mcintoshii* Langerhans (1880) from Gujarat, Agravat *et al.* (2022) studies Deciphering the Taxonomy, Phylogeny and Distribution of the Marine Polychaete *Eulalia viridis* Linnaeus (1767) from Saurashtra coast, Gujarat, Hagerty *et al.* in (2020 studied the correlation among gut microbiome alpha

diversity and health-related outcomes of interest, a way of operationalizing the microbiome that yields a numeric value that could be used in common statistical approaches (Hagerty *et al.* 2020).

CONCLUSION

Results of the present study showed that the intertidal region of the Diu coast is fertile and provides a suitable habitat for a diverse and wide range of organisms. The findings of the study also reflect the biological characteristics of the macrofauna in the intertidal and shallow subtidal regions. Gastropods, crabs, and sponges are the dominant taxa recorded during the study. The study determines the correlation between different indices, where the positive correlation was observed in Shannon Wiener and Simpson indices, Dominance and Berger-Parker, and the negative correlation was observed in Berger-parker and Shannon Wiener, Berger-parker and Simpson indices, Dominance and Shannon Wiener, Dominance and Simpson indices. And also, as an initial step towards understanding the macrofaunal community dynamics of the Diu coast, long-term monitoring studies are recommended to evaluate the impacts of human activities on the local marine communities. This study can help identify gaps and the biodiversity of an area, guide conservation efforts, and promote a better understanding of the diverse and important roles that these animals play in marine ecosystems.

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