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Distribution and diversity of intertidal marine faunal species along with Maharashtra and Goa coast, India

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Abstract

The distribution and diversity of intertidal marine faunal specimens were collected from sandy, muddy, mangrove and rocky habitats along the Maharashtra and Goa coasts, India, from June 2016 and December 2018. A total of 63 species belonging to 58 genera, 39 families, 25 orders, and 6 phyla were identified. A maximum of 39 species under the phylum Mollusca, followed by 15 species of arthropods whereas the minimum of only one species was recorded under the phyla Echinodermata and Brachiopoda. Statistical tool PAST (Ver. 1.42) was employed to calculate species diversity (*H'*), richness (*D'*) and evenness (*J'*). The diversity of macrofaunal groups is highly disturbed due to anthropogenic activities, but they still support rich intertidal biodiversity, which needs immediate attention for protection and conservation.

Keywords: Coastal Environment, Diversity, Goa, Macrofaunal Assemblage, Maharashtra

Introduction

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. The two most important physical factors that influence the life and activities of organisms in the intertidal zone are the existence of waves and the duration of exposure to sunlight. The Indian Coast is constantly threatened by effluent discharges from cities and industrial downs. This gives rise to immense environmental problems leading to the deterioration of water quality and the reduction of flora and fauna (Datta, *et al.,* 2010; Gohil and Kundu, 2012; Pavithran and Nandan, 2014). Because of their accessibility, intertidal habitats are highly explored in comparison with other habitats (Vaghela, *et al.,* 2010). This coastline is known for its rich marine life, especially the intertidal biota in its extended intertidal and subtidal areas (Shukla and Misra, 1977). The rocky intertidal zone is among the most physically harsh environments on earth. Marine invertebrates and algae living in this habitat are alternately pounded by waves and exposed to thermal extremes during low tide periods (Crowe et al., 2000; Denny and Wethey, 2001; Lakwal et al., 2018) Denny and Wethey, 2001; Lakwal, et al., 2018). Wave, wind action, grain size and tide amplitude are the most significant factors in their physical categorization (Nybakken, 1993). Maharashtra's coast is characterized by pockets of beaches flanked by rocky cliffs of Deccan basalt, estuaries and patches of mangroves. Maharashtra state has about 720 km of indented coastline, which is marked by the presence of major estuaries and narrow creeks. It comprises the coastal districts of Thane, Raigad, Greater Bombay, Palghar, Ratnagiri and Sindhudurg. The shoreline is generally straight. The purpose of this study is to compile a list of intertidal marine faunal species found along the Maharashtra and Goa coasts.

Materials and Methods

Study Sites

This study was conducted along with Maharashtra and Goa, representing the coastal environments of the west coast of India and investigated the distribution and

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Table 1. Collections location of intertidal fauna along Maharashtra and Goa

S. No.	Study sites	District	State	Coordinates		Habitats
				Latitude (N)	Longitude (E)	
01.	Aare Ware Beach	Ratnagiri	Maharashtra	17°131.66	073°275.67	Sandy
02.	Bhatye Beach	Ratnagiri	Maharashtra	16°580.80	073°173.02	Sandy
03.	Chivala Beach	Sindhudurg	Maharashtra	16°034.69	073°273.98	Sandy
04.	Devbaag Beach	Sindhudurg	Maharashtra	16°000.64	073°292.07	Sandy
05.	Devgad Beach	Ratnagiri	Maharashtra	16°223.18	073°221.39	Sandy with mudflats and mangroves
06.	Ganpatipule Beach	Ratnagiri	Maharashtra	17°064.65	073°163.88	Sandy and mangroves
07.	Kalbadevi Beach	Ratnagiri	Maharashtra	17°032.07	073°171.56	Rocky shore
08.	Kunkeshwar Beach	Ratnagiri	Maharashtra	16°356.05	073°393.34	Sandy
09.	Malvan Beach	Sindhudurg	Maharashtra	16°031.80	073°275.06	Sandy
10.	Rock Garden Beach	Sindhudurg	Maharashtra	16°033.88	073°272.37	Rocky shore
11.	Tarkarli Beach	Sindhudurg	Maharashtra	16°041.43	073°284.21	Sandy and rocky
12.	Vetye Beach	Ratnagiri	Maharashtra	16°411.82	073°194.47	Sandy
13.	Anjuna Beach	North Goa	Goa	15°164.11	073°544.63	Sandy and rocky
14.	Arambol Beach	North Goa	Goa	15°411.39	073°421.44	Sandy
15.	Baga Beach	North Goa	Goa	15°334.24	073°445.37	Sandy
16.	Bogmalo Beach	Vasco da Gama	Goa	15°221.52	073°495.55	Sandy
17.	Colva Beach	South Goa	Goa	15°164.11	073°544.63	Sandy
18.	Mandarin Beach	Goa	Goa	15°621.52	073°426.01	Sandy
19.	Mandrem Beach	North Goa	Goa	15°393.99	073°424.46	Sandy
20.	Morgim Beach	North Goa	Goa	15°373.10	073°434.70	Nesting and hatching habitat of the Olive ridley sea turtle
21.	Vagator Beach	Goa	Goa	15°360.31	073°440.02	Sandy and rocky

diversity of marine faunal species (Table 1 and Figure 1).

Sample Collection

Samples were collected using the handpicking method during low tide. After collection, they were preserved in 10% neutralized formalin. Representative samples were taken in a Petri dish and carefully examined under a binocular microscope with strong incident illumination. The animal groups were sorted, counted and preserved for specific determination. The collected marine faunal communities were identified by adopting standard methods as described by Mollusca [Menon, *et al.* (1951); Apte (1988); Subba Rao (1991); Dance (2002)], Amphipoda [Barnard (1972); Myers (1985)], Fish [Fish and Fish (2011)], Crustaceans [Trilles (1979); Pillai (1985); Aneesh (2014) and Aneesh, *et al.* (2016)].

Estimation of Diversity and Distribution

Different biodiversity statistical software tools were used to determine the diversity indices, richness, and evenness using PAST (Ver. 1.42). The species diversity index was calculated using the following formula (Shannon and Wiener, 1949): $H' = -\sum pi \ln p_i$, where p_i is the proportion of individuals of each species belonging to the i^{th} species of the total number of individuals. Species richness (D') was calculated using the formula given by (Simpson, 1949): $D' = 1 - C$; $C = \sum pi^2$; $pi = ni/N$. Evenness or equitability (S')

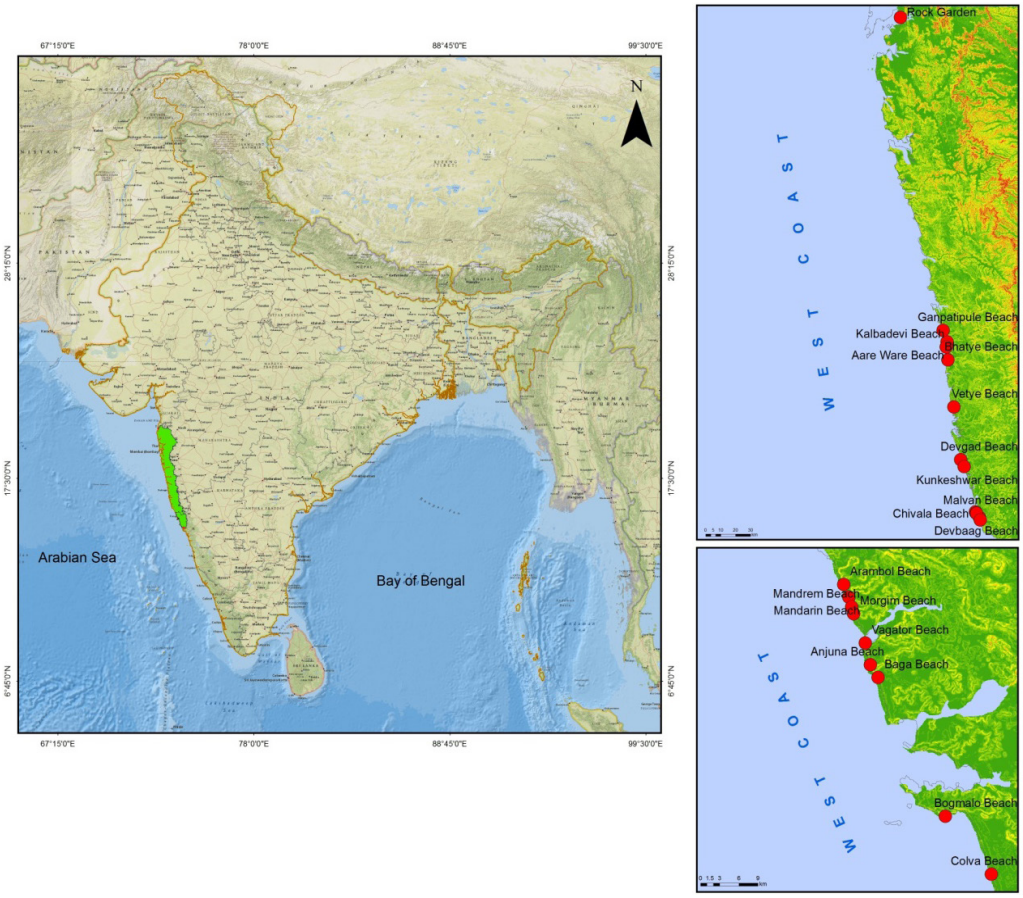

Figure 1. Map showing sampling locations along the Maharashtra and Goa.

was calculated using the (Pielou, 1966) formula: $J' = H'/Jns$ or $H'/\log_2 S$.

Results

A total of 457 intertidal marine faunal specimens belonging to 63 species, 58 genera, 39 families, 25 orders, and six phyla were collected from 22 intertidal coastal environments. Diversity indices, richness, and evenness were calculated. Table 2 contains a list of recorded taxa and their respective intertidal coastal marine faunal species, as well as their habitats. In the present study, the diversity index (H') varied from 1.8749 to 0.3437. The minimum species diversity (0.3437) was recorded on the Baga Beach and the maximum level (1.8749) was observed on the Malvan (Figure 2). The species richness index (D') varied from 0.000 to 2.345. The minimum species richness (0.000) was observed at Arambol Beach, and the maximum (2.345) was noted at Vetye Beach (Figure 3). The species evenness index (J') varied from 0.000 to 2.018. The minimum species evenness (0.000) was observed on Arambol Beach, and the maximum (2.018) was recorded on Vetye Beach (Figure 4). The dominant species in the intertidal marine habitat were Arthropoda (18%), Brachiopoda (0%), Chordata (1%), Cnidaria (10%), Echinodermata (1%), and Mollusca (70%). The maximum number of species collected belongs to Arthropoda (18%), followed by Mollusca (70%) (Figure 5). The plot revealed that the grouping recognized in the cluster was evident. The stress value, which overlies the

Table 2. Distribution of intertidal fauna along Maharashtra and Goa

S. No.	Species	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	Total
	Phylum ARTHROPODA																						
	Class MALACOSTRACA Latreille, 1802																						
	Order ISOPODA Latreille, 1817																						
	Family CYMOTHOIDAE Wägele, 1989				*																		
01.	*Anilocra leptosome* Bleeker, 1857																						**01**
02.	*Catoessa boscii* (Bleeker, 1857)				*											*							**42**
03.	*Norileca indica* (H. Milne Edwards 1840)														*								**08**
	Order DECAPODA Latreille, 1802																						
	Family OCYPODIDAE Rafinesque, 1815																						
04.	*Austruca lactea* (De Haan, 1835)																		*				**01**
	Family PORTUNIDAE Rafinesque, 1815																						
05.	*Goniosupradens erythrodactylus* (Lamarck, 1818)																					*	**01**
	Family OZIIDAE Dana, 1851																						
06.	*Epixanthus frontalis* (H. Milne Edwards, 1834)												*										**01**
07.	*Ozius tuberculosus* H. Milne Edwards, 1834																		*				**01**
	Family GRAPSIDAE Macleay, 1838																						
08.	*Geograpsus stormi* de Man, 1895		*																				**01**
09.	*Grapsus albolineatus* Latreille in Milbert, 1812														*				*				**03**
	Family MATUTIDAE De Haan, 1835																						
10.	*Matuta victor* (Fabricius, 1781)										*									*			**01**
	Family VARUNIDAE H. Milne-Edwards, 1853																						
11.	*Metaplax longipes* Stimpson, 1858											*											**01**
	Family PORTUNIDAE Rafinesque, 1815																						
12.	*Portunus sanguinolentus* (Herbst, 1783)								*														**01**
13.	*Thalamita prymna* (Herbst, 1803)		*																				**01**
	Family LEUCOSIIDAE Samouelle, 1819																						
14.	*Seulocia rhomboidalis* (De Haan, 1841)									*		*						*		*	*		**14**
	Class THECOSTRACA Gruvel, 1905																						
	Order SCALPELLOMORPHA Buckeridge & Newman, 2006																						
15.	Family LEPADIDAE Darwin, 1852						*																**05**
	Lepas (Anatifa) anatifera Linnaeus, 1758																						
	Phylum BRACHIOPODA Duméril, 1805																		*				
	Class LINGULATA Gorjansky & Popov, 1985																						
	Order LINGULIDA Waagen, 1885																						
	Family LINGULIDAE Menke, 1828																						
16.	*Lingula anatina* Lamarck, 1801																						**01**
	Phylum CHORDATA																						
	Class ACTINOPTERYGII																						
	Order PLEURONECTIFORMES																						
	Family PARALICHTHYIDAE Regan, 1910																						
17.	*Pseudorhombus triocellatus* (Bloch & Schneider 1801)								*														**01**
	Family Soleidae Bonaparte, 1833																						
18.	*Solea ovata* Richardson, 1846								*														**01**
	Order TETRAODONTIFORMES Berg , 1940																						
	Family TRIACANTHIDAE Bleeker, 1859																						
19.	*Triacanthus biaculeatus* (Bloch, 1786)																			*			**02**
	Class REPTILIA Laurenti, 1768																						
	Order TESTUDINA Klein, 1760																						
	Family CHELONIDAE Oppel, 1811																						
20.	*Chelonia mydas* (Linnaeus, 1758)										*												**01**
	Phylum CNIDARIA																						
	Class HYDROZOA Owen, 1843																						
	Order LEPTOTHECATA Cornelius, 1992																						
	Family AEQUOREIDAE Eschscholtz, 1829																						
21.	*Aequorea forskalea* Péron & Lesueur, 1810			*																			**04**
	Order ANTHOATHECATA Cornelius, 1992																						
	Family PORPITIDAE Goldfuss, 1818																						
22.	*Porpita porpita* (Linnaeus, 1758)											*											**03**

	Family PORPITIDAE Goldfuss, 1818																					
23.	*Velella velella* (Linnaeus, 1758)						*															**15**
	Phylum ECHINODERMATA																					
	Class ASTEROIDEA de Blainville, 1830																					
	Order PAXILLOSIDA Perrier, 1884																					
	Family ASTROPECTINIDAE Gray, 1840																					
24.	*Astropecten indicus* Döderlein, 1888								*													**04**
	Phylum MOLLUSCA																					
	Class GASTROPODA Cuvier, 1795																					
	Order NEOGASTROPODA Wenz, 1938																					
	Family OLIVIDAE Latreille, 1825																					
25.	*Agaronia propatula* (Conrad, 1849)									*												**06**
	Family BABYLONIIDAE Kuroda, Habe&Oyama, 1971																					
26.	*Babylonia spirata* (Linnaeus, 1758)				*											*						**04**
	Family NASSARIIDAE Iredale, 1916 (1835)																					
27.	*Nassarius stolatus* (Gmelin, 1791)								*													**15**
	Family CLAVATULIDAE Gray, 1853																					
28.	*Turricula javana* (Linnaeus, 1767)																				*	**04**
	Order CAENOGASTROPODA																					
	Family POTAMIDIDAE H. Adams & A. Adams, 1854																				*	**04**
29.	*Cerithidea obtusa* (Lamarck, 1822)																					
	Family PLANAXIDAE Gray, 1850																					
30.	*Planaxis sulcatus* (Born, 1778)															*						**01**
	Family TURRITELLIDAE Lovén, 1847																					
31.	*Turritella attenuate* Reeve, 1849					*	*					*	*			*			*		*	**57**
32.	*Turritella duplicate* (Linnaeus, 1758)								*							*						**04**
	Order LITTORINIMORPHA Golikov & Starobogatov, 1975																					
33.	Family NATICIDAE Guilding, 1834											*										**01**
	Tanea picta (Récluz, 1844)																					
34.	*Notocochlis tigrina* (Röding, 1798)						*															**08**
	Family ROSTELLARIIDAE Gabb, 1868																					
35.	*Tibia curta* (G. B. Sowerby II, 1842)																				*	**04**
	Order CYCLONERITIDA																					
	Family NERITIDAE Rafinesque, 1815																					
36.	*Nerita undata* Linnaeus, 1758											*										**05**
	Order LEPETELLIDA Moskalev, 1971																					
	Family FISSURELLIDAE J. Fleming, 1822																					**01**
37.	*Scutus unguis* (Linnaeus, 1758)																				*	
	Order SIPHONARIIDA																					
	Family SIPHONARIIDAE Gray, 1827																					
38.	*Siphonaria laciniosa* (Linnaeus, 1758)	*								*										*	*	**05**
	Order TROCHIDA																					
	Family TROCHIDAE Rafinesque, 1815																					
39.	*Umbonium vestiarium* (Linnaeus, 1758)																					**18**
	Class BIVALVIA Linnaeus, 1758																					
	Order ARCIDA Stoliczka, 1871																					
	Family ARCIDAE Lamarck, 1809																					
40.	*Anadara pilula* (Linnaeus, 1758)									*												**03**
41.	*Anadara secticostata* (Reeve, 1844)									*												**01**
42.	*Tegillarca rhombea* (Born, 1778)																				*	**04**
	Family GLYCYMERIDIDAE Dall, 1908 (1847)																					
43.	*Tucetona sibogae* Matsukuma, 1982				*																	**01**
	Order MYTILIDA Férussac, 1822																					
	Family MYTILIDAE Rafinesque, 1815																					
44.	*Brachidontes pharaonis* (P. Fischer, 1870)															*						**01**
45.	*Perna viridis* (Linnaeus, 1758)			*	*								*		*		*					**14**
	Order VENERIDA Gray, 1854																					
	Family VENERIDAE Rafinesque, 1815																					
46.	*Callista erycina* (Linnaeus, 1758)						*				*											**02**
47.	*Dosinia exoleta* (Linnaeus, 1758)										*											**02**
48.	*Gafrarium pectinatum* (Linnaeus, 1758)	*								*							*					**07**
49.	*Marcia opima* (Gmelin, 1791)					*	*								*							**23**

50.	*Meretrix meretrix* (Linnaeus, 1758)													*				*		*	**21**
51.	*Paratapes textilis* (Gmelin, 1791)								*												**01**
52.	*Sunetta solanderii* (Gray, 1825)			*																	**01**
53.	*Sunetta scripta* (Linnaeus, 1758)					*			*		*		*				*		*		**46**
	Family MESODESMATIDAE Gray, 1840																				
54.	*Coecella horsfieldii* Gray, 1853																			*	**03**
55.	*Crassostrea cuttackensis* (Newton & Smith, 1912)																			*	**06**
56.	*Dendostrea folium* (Linnaeus, 1758)																			*	**01**
57.	*Saccostrea cucullata* (Born, 1778)																			*	**07**
	Order CARDIIDA Ferussac, 1822																				
	Family DONACIDAE J. Fleming, 1828																				
58.	*Donax cuneatus* Linnaeus, 1758						*		*		*			*	*	*			*		**25**
59.	*Donax scortum* (Linnaeus, 1758)												*								**01**
	Family PSAMMOBIIDAE J. Fleming, 1828																				**01**
60.	*Hiatula diphos* (Linnaeus, 1771)																			*	
	Order OSTREIDA Férussac, 1822																				
	Family OSTREIDAE Rafinesque, 1815																				
61.	*Magallana bilineata* (Röding, 1798)													*							**01**
	Order PECTINIDA Gray, 1854																				
	Family PLACUNIDAE Rafinesque, 1815																				
62.	*Placuna placenta* (Linnaeus, 1758)									*											**04**
	Order ADAPEDONTA Cossmann & Peyrot, 1909																				
	Family SOLENIDAE Lamarck, 1809																				
63.	*Solen ceylonensis* Leach, 1814						*		*												**07**
																					434

01. Aare Ware; 02. Anjuna; 03. Arambol; 04. Baga; 05. Bhatye; 06. Bogmello; 07. Chivala; 08. Colva; 09. Devbaag; 10. Devgad; 11. Ganpatipule; 12. Kalbadevi; 13. Kunkeshwar; 14. Malvan; 15.

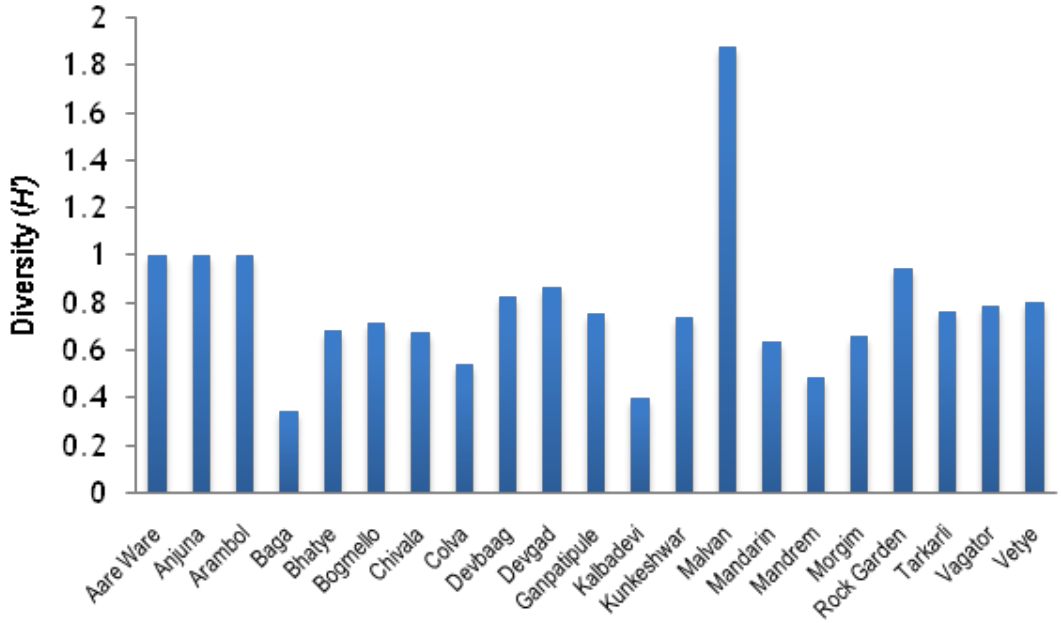

Figure 2. Shannon – Wiener (*H'*) diversity indices of intertidal marine faunal communities from different stations of Maharashtra and Goa.

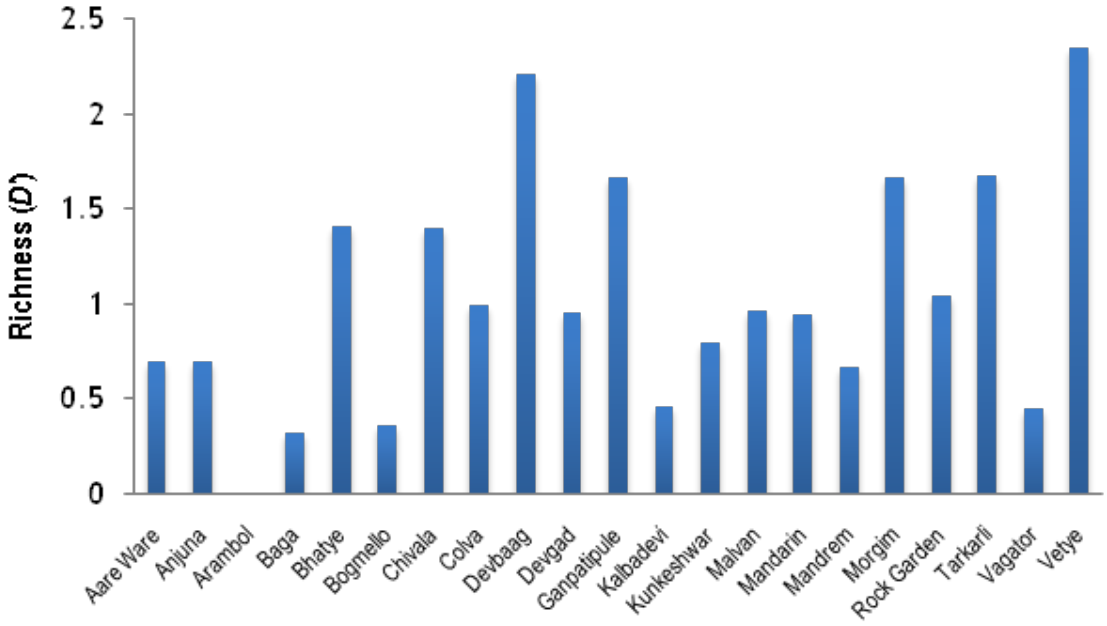

Figure 3. Simpson (*D'*) richness indices of intertidal marine faunal communities from different stations of Maharashtra and Goa.

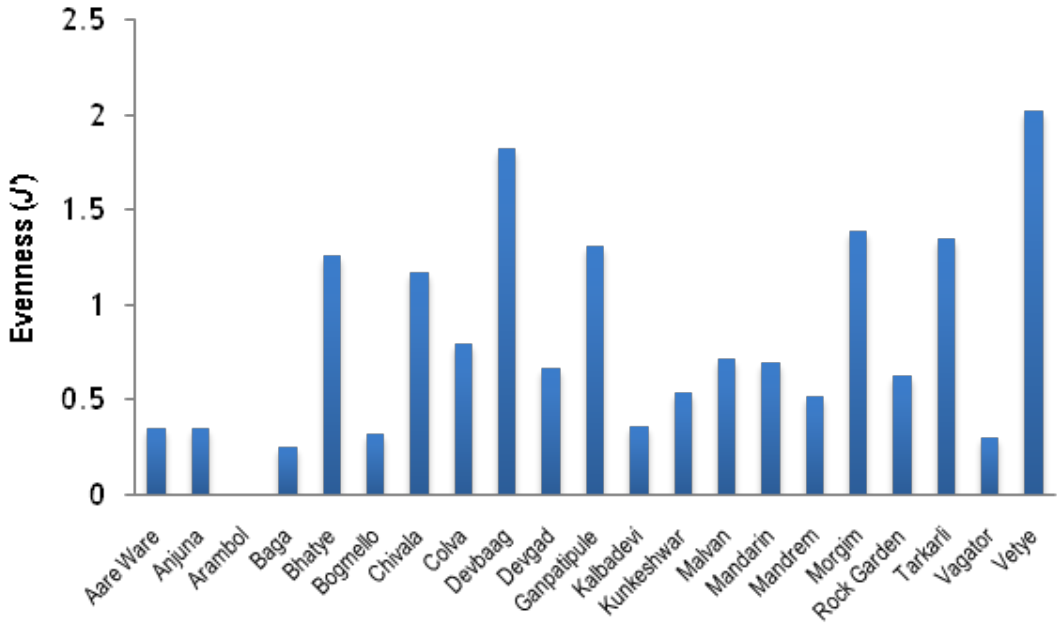

Figure 4. Pielou's evenness (*J'*) indices of intertidal marine faunal communities from different stations of Maharashtra and Goa.

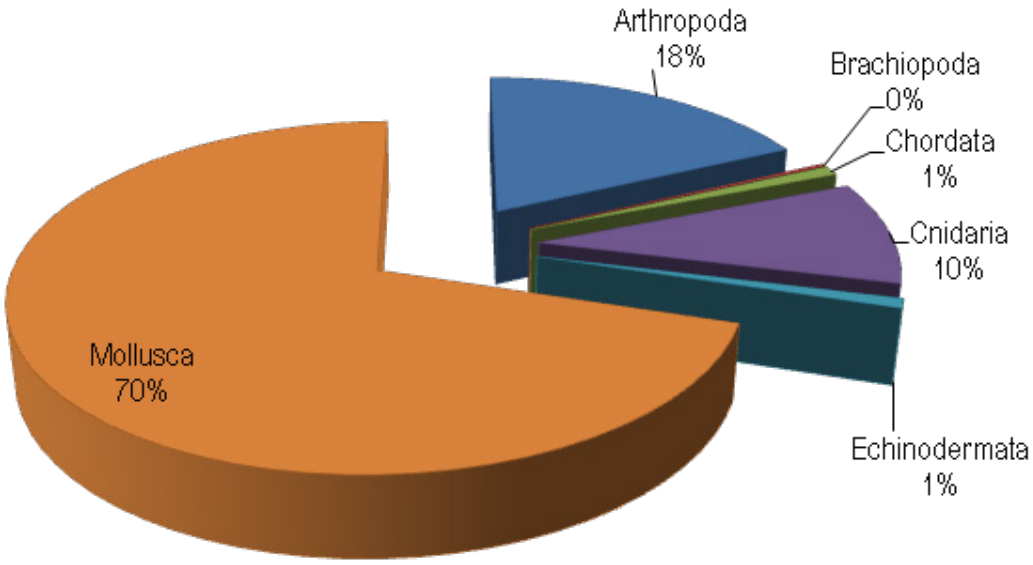

Figure 5. Relative proportion of species composition in the major phyla of intertidal marine faunal diversity.

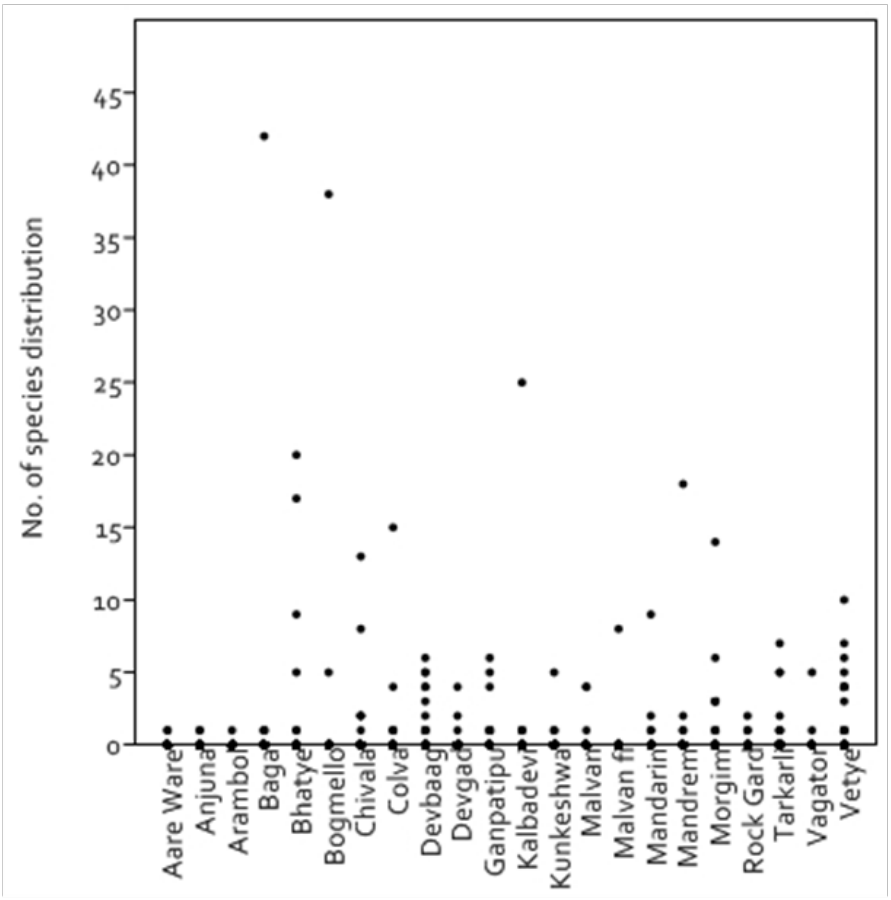

Figure 6. Distribution of intertidal marine faunal species from different coastal sites along Maharashtra and Goa.

top-right corner of the plot, is also very minimal (0.01), signalling a good ordination pattern of species in twenty-one sites (Figure 6).

Discussion

Studies on the distribution and diversity of intertidal marine faunal species along the Maharashtra and Goa coasts, India, were carried out between June 2016 and December 2018. The orders concerning the number of individuals in the different habitats were as follows: Arthropoda (18%), Brachiopoda (0%), Chordata (1%), Cnidaria (10%), Echinodermata (1%), and Mollusca (70%). Phylum Porifera appeared as the second most dominant group, contributing 12 species with 15% diversity, Coelenterates comprised 10 species with 12% diversity and Arthropods contributed 10 species with 12% diversity, Echinodermata had 3 species with 4% and lastly, Annelids had 2 species with 2% diversity of the total diversity (Lakwal, *et al.,* 2018). Shannon's diversity index, by contrast, estimated the unsampled as well as the sampled portion of the community (Magurran, 2004). The diversity was calculated, and a minimum (0.3437) value was found on Baga Beach. Vetye Beach has higher species richness (2.345) and evenness (2.018). Generally, in a healthy environment, the Margalef richness index is higher, in the range of 2.5-3.5 (Khan, *et al.,* 2004). The species richness index ranged from 0.000 to 2.345 from different sites in the current study, indicating the rich diversity of these coasts. In the present study, a marked variation in diversity indices was observed among the sites. A study by Kolhe and Mogalekar (2017) recorded a total of 24 species of decapod crustaceans under three infra orders, seven families and 13 genera from the coastal waters of Ratnagiri in Maharashtra. In the present study, 15 species belonging to Isopoda (03 species), Decapoda (11 species) and Scalpellomorpha (01 species) are reported. Gastropods and bivalves are generally benthic organisms, and they are regularly used as bioindicators for aquatic health. This study is consistent with a similar study that was conducted at the intertidal zone of the Ratnagiri coast in Maharashtra, where 127 species of gastropods were observed and identified (Kurhe, 2014). In the present investigation, 39 species of mollusca were identified belonging to 14 orders, 23 families and 35 genera were identified and reported from different intertidal habitats along with Maharashtra and Goa. A community becomes more dissimilar as the stress increases, and therefore species diversity decreases with decreasing water quality. Hence, communities dominated by relatively few species would indicate environmental stress (Plafkin, *et al.,* 1989).

It was also suggested that the specific seaweed association of molluscs plays a considerable role in their abundance and distribution in the intertidal zone (Newell, 1976; Purchon, 1968; John, *et al.,*1992; Misra and Kundu, 2005; Vaghela *et al.,* 2010). A similar study was carried out at some of the localities in Raigad district, Maharashtra, on the west coast of India (Khade and Mane, 2012). Similar studies in Gujarat by Bhadja (2010) reported 60 species of intertidal macro-invertebrates from the rocky intertidal belt, including 35 species of molluscs, followed by coelenterates (17 species), arthropods (15 species), annelids (08 species), Porifera (06 species) and Echinodermata (06 species). Another study by Poriya and Kundu (2014) recorded a total of 82 invertebrate species from Gujrat, including four species of Porifera, 20 species of coelenterates, five species of Annelida, 11 species of Arthropoda, 40 species of Mollusca and three species of Echinodermata. In the present study, *Astropecten indicus* was reported from Colva Beach, and in addition, the data provided in this intertidal fauna checklist will serve as a baseline that can be used in the future to monitor natural and anthropogenic changes along the Maharashtra and Goa coasts of India. More research will aid in the discovery of new species or genera of intertidal marine fauna from various coastal environments. Therefore, the data presented in this paper can be taken as baseline data for the management of the intertidal habitat of Maharashtra and Goa in the near future. Biodiversity is one of the vital cornerstones of sustainable development and represents the biological wealth of a country. The globe is currently facing its greatest-ever biodiversity crisis. The intertidal marine fauna group's diversity in the prevalence of different habitats provides a broad opportunity for investigation to promote exploration of the possibility of eco-biological value and their conservation.

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