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Research Article

RESILIENT INTERTIDAL BIODIVERSITY PROFILE OF MAJALI COAST, KARWAR, WEST COAST OF INDIA

***Shivakumar B. Haragi and Ulhas G. Naik**
Department of Studies in Marine Biology, Karnatak University, Post Graduate Centre, Kodibag, Karwar – 581 303 Karnataka, India
**Author for Correspondence*

ABSTRACT
Intertidal biodiversity profile of Majali coast (14^0 53'53 98" N: 74^0 05'45 71" E and 14^0 54'00 46" N: 74^0 05'28 71" E) is very high compared to other coastal lines of the Uttara Kannada district. Exploration and documentation of the biotic community of this coast has not been done so far and is practically little known for its vast assemblage of flora and fauna. Taxa richness of invertebrates was higher, where epibenthic invertebrates were dominated. Total of 130 faunal species (of 82 genera, 59 family and 7 phyla) and macro algae of 26 species (3 class, 11family, 16 genera) were recorded. Majali intertidal shorelines are physically complex with the presence of rocky shore, rocky gravel bed and sandy shore. But, this coast is facing pollution of oil spill threat of tar balls occurrence in colossal quantity during the southwest monsoon season. In this attempt, biotic assemblages were mapped along the Majali shoreline to evaluate biodiversity profile of the different habitat. Tidal amplitude influences the vertical distribution of biotic entities on rocky shore and based on the ecological landscape, it has been demarcated in to the three main zones like upper littoral, mid littoral and lower littoral. Shannon and Simpson's diversity index, Margalef's richness index and Pielou's evenness index indicated different level of ecological state of the shore. Bray-Curtis similarity matrix has shown highest similarity clusters between gravel bed and sandy shore (75.19-88.47). Tar ball were cleared with help of Municipal authority to restore the natural environment., As some developmental activities are going to initiate in this region, this could be another threat in the future for the fragile ecosystem. Intertidal rocky shore have received less attention in the conservation on par with the coral reef despite having higher levels of endemism and being subjected to considerable impacts from coastal development programmes. There is a dire need to declare this natural museum as biodiversity heritage site, through which natural restoration and conservation of the available marine biodiversity along the shore line of Karwar can be taken up immediately.

Key Words: *Marine Biodiversity, Rocky Shore, Sandy Shore and Intertidal Zonation*

INTRODUCTION
As the Majali coastal stretch comprised of sandy and rocky shorelines which are witnessed by variety of rich floral and faunal communities with distinctive morphological characters on par with pelagic/benthic realm of marine ecosystem. This made these shorelines more conspicuous and rich biodiversity profile. The sandy shore lying adjacent to the rocky stretch is full of pebbles, boulders and small rocks submerged in water during high tide water and forms a typical environment for macroflora (macro algae) such as seaweeds and other faunal entities like alphid shrimp, seacucumber, clams etc. On contrary to this, the rocky shore is intricate with crevices, cliffs, pools and other features which has increased the biodiversity by providing secured coverage for variety of organisms and very good bed for seaweeds. In spite of environmental physical stresses like temperature, salinity, solar radiation, desiccation, tide & severe wave action etc besides ecological interaction, the biodiversity is relatively very high here (Ponder *et al*., 2002).

Table 1: Tidal amplitude and Zonation based on the height of the waves Majali. Karwar. West Coast of India

Tide	Amplitude (mtrs)	Zone	Hight (mtrs)
Highest mean high tide	2.20	Spry (rocky shore)	2.0
Highest mean low tide	0.2	Midlittoral (rocky pool and sandy shore)	1.0 to 1.5
Mean tide level	1.4	Lower littoral rocky gravel bed, rocky shore and pool sandy shore	0.8 below
Mean lowest neap tide	-0.13	Lower littoral rocky gravel bed.	-0.2 below

Based on tidal amplitude (Table 1), following zones can be distinguished on rocky shores:
The splash zone, the upper (eulittoral), middle and lower (sublittoral) zones. The substratum is rather stable in condition with the result majority of faunal communities are better adapted with this environment in the lower stretch than the upper stretch of the rocky shore. Each area on the shore has a specific cluster of organism that forms diverse distribution on horizontal bands or zones on the rock. Most of the substrate is stable in this area, based on tidal amplitude following zones can be distinguished on rocky shores: the splash zone, the upper (eulittoral), middle and lower (sublittoral) zones. The present study area of Majali rocky shore also reflects similar distinguishing splash zone which cover during rainstorm and extremely high tides and is moistened by spray of the breaking waves. Because of these severe conditions only a few resistant organisms live here (Table 2). Common animals of this zone are barnacles and periwinkles. The mid shore generally has the greatest species diversity of the intertidal zone. Common habitant of this zone is sponges, hydrozoans, anemones, crabs, isopods, mussels, gastropods, echinoderms and some macro algae. The lower shore is most prolific zone dominated by macro algae (Table 3) and could be the most amazing plants in the sea.

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Porifera 2. Zooanathes 3. Sea cucumber 4. Amphipod 5. Isopod 6. Hermit crab 7. Porcellin crab 8. Alphrid shrimp 9.Brachyuran crabs 10. Barnacles 11. Oyster 12. Clams 13. Mussel 14. Gastropod 15. Star fish 16. Sealily 17. Brittle star 18. Sea cucumber 19. Sea urchin 20. Pisces

India is one among twelve mega–biodiversity countries and 25 hotspots of the richest and highly endangered eco-regions of the world (Mayer N, 2000). The IUCN's Red List of Threatened species for 2009 includes 1,530 marine species of which 80 are threatened with extinction and 31 have a high risk of extinction. Great concern in the rate of new addition to the list of threatened marine species due to intertidal harvest for food, collection for bait, other forms as anthropogenic disturbance include habitat disturbance trampling, pollution and invasions of exotic species (Kingsford *et al* 1991; Underwood 1993). Such impacts compromise the biodiversity values, human-use value and ecosystem functions of intertidal rocky shores. Oil spill and spread out of tar balls have become the regular features in this region for the past several years. The intertidal shore of Majali witnessed oil spill in the month of September 2010 due to the impact of oil carrying ship mishap near Mumbai bay in the month of August 2010. Resultant, big size crude oil balls were driven by wind and currents to this region in colossal quantity. Since 1994 four spills have been reported along the strip of Goa. Grounding of MV Ocean Seraya on the Karwar coast was reported to have affected the beaches of Karnataka and Goa states in 2005 to 2006 (Sivadas *et al*., 2008). So far only threat to marine diversity in this region is oil spills, as debris remains in this vicinity and keeps continuous interaction with the rocky shore species. Karwar is well known for its intertidal region and rocky shore. The objective of this study is to create awareness about the impacts of oil spill on intertidal biodiversity. Prime concern is also to monitor the marine life and also to encourage the use of

rocky shore as educational resource for local school, college and research institutes for its conservation and management. The documentation will be used as baseline data to restrict future shoreline armoring and to declare it as marine biodiversity heritage of this region.

MATERIALS AND METHODS

Intertidal stretch of sandy and rocky shore of Majali coast has showed rich density in flora and fauna which has not explored and documented scientifically so far. Biotic communities of this biotope have showed great diversity pattern with space and time.

Description of the Study Area

Majali coast located in the northern sector of Karwar taluka lying within the grid of 14°53'98" N & 74°05' 71" E and 14° 54'46" & 74 ° 05' 28" E (Figure 1). Long 3km stretch of sandy shore extends north-southerly besides one kilometer stretch of gravel and boulder patches. This is one of the important traditional fishing coasts where fishing can be seen throughout the year. The rocky shore is broad with gentle slope gradient harbour rich floral (seaweeds) and faunal community (gastropod, mussels, oysters, crabs etc).

Climatic and Hydrographic Condition

Since this coast located in the Karwar, the central west coast of India, has experienced typical southwest monsoon (June-September), with torrential rain (>3000mm) and low saline condition. The pre monsoon season (February-May) with extreme temperature and saline profile whereas the post monsoon (October-January) a moderate climatic condition experienced and also period of recolonization of most of the faunal communities. With respect to the climatic condition of this region, many environmental parameters are influenced, establishing the atmospheric temperature range of 28-36°C registering minimum and maximum during December and March respectively. Relative humidity of atmosphere ranged between 70 and 90%.

Analyses of physic-chemical parameters such as temperature, salinity, dissolved oxygen and pH were measured in-situ with hand held DO meter (HACH). Water temperature ranged between 25-30°C, salinity varied between 12.0 (August) and 36.0psu (May) whereas as dissolved oxygen showed range from 4.2 to 5.9ml/l and pH from 6.8 to 8.4.

Biodiversity Profile

In the present study for easy interpretation, three habitats were demarcated as sandy shore, rocky shore with pools and gravel bed respectively (Figure 1 & 2). Habitat survey and biodiversity assessment were made during the low tide period referring the Tidal chart of West coast of India for the period of ten months from August 2010 to May 2011. Every possible practical devices were made use to explore the maximum of niche of flora & fauna to determine their vertical distribution with respect to the rocky substratum (Evans, 1948). Assessment of faunal assemblage at different habitats were made by adopting multivariate analysis using PRIMER-v5 (2001-software) for their species richness, species evenness, Shannon Weiner diversity index and Bray Curtis similarity indices were calculated.

RESULTS AND DISCUSSION

Totally 130 species were recorded during the present study represents phyla like. Porifera, Coelenterata, Annelida, Mollusca, Arthropoda, Echinodermata and Chordata (Table 2). Among flora, three groups of seaweeds were documented namely, green algae (chlorophyceae) comprised by 14 species, brown algae (phaeophyceae) and red algae (rhodophyceae) supported by 11 species each[Table 3]. Green algae was found in maximum density followed by the brown and red algae. But, red algae was found comparatively in higher density in deeper waters whereas other two groups were registered higher density in the inter tidal region of this coast. Highest in faunal community, the dominant species were recorded were molluscs and least density represented by annelid (Table 4 and Figure 2).

Table 2: A check list of intertidal faunal diversity of Majali, Karwar West Coast of India

I. Phylum Porifera
Family: Tetillidae
1. Tetilla dactyloides
Family : Tethyidae
2. Tethys lynerium
II. Phylum : Coelenterate
Family : Veretillidae
3. Cavernularia orientalis
Family : Epizoantidae
4. Epizoanthus elongatum
Family : Actiniidae
5. Bunodosoma goansis
III. Phylum : Annelida
Family : Spionidae
6. Sabellaria sp.
Family : Serpulidae
7. Vemiliopsis glandigerus
IV. Phylum : Arthropoda
Family : Amphipoda
8. Ampelisca sp.
Family : Corphiidae
9. Apocorophium sp.
Family : Caprellidae
10. Caprellidae sp.
Family Isaeidae
11. Cheiriphotis sp.
Family : Hyalide
12. Parhyale sp.
Family : Porcellanidae
13. Petrolisthes boscii
Family : Diogenidae
14. Clibanarius infraspinatus
15. Clibanarius aequabilis
16. Clibanarius arethusa
17. Diogenes affinis
18. Diogenes miles
19. Dardanes setifer
20. Troglopagurus manaarensis
Family : Paguridae
21. Pagurus kulkarnii
Family Xanthidae
22. Atergatis subdentatus
23. Atergatis integerrimus
24. Menippe rumphii
Family : Portunidae
25. Portunus pelagicus
26. Charybdis cruciata
Family : Ocypodidae
27. Ocypode cordimanus
28. *Ocypode ceratophalmus*
Family : Grapsidae
29. Grapsus albolineatus
30. Plagusia depressa tuberculata
Family : Majidae
31. Achaeus lacertosus
32. Schizophrys aspera
Family : Leucosiinae
33. Leucisca squalina
34. Philyra scabriuscula
Family : Calappidae
35. Matuta lunaris
Family : Paenidae
36. *Penaeus sp*. (ornamental)
Family : Idoteidae
37. Synidotea variegata
V. Phylum : Mollusca
Family : Ischnochitonidae
38. Ischnochiton gallensis
Family : Muricidae
39. Drupa tuberculata
40. Murex trapa
41. Thais tissoti
42. Thais bufo
43. Thais carinifera
44. Thais blanfordi

Family : Turritellidae
45. Turritella duplicate
46. Turritella fultoni
Family : Buccinidae
47. Babylonia spirata
Family : Bursidae
48. Bursa spinosa
Family : Patellidae
49. Cellana radiate
50. Cellana rota
51. Cellana nimbus
52. Cellana variabilis
53. *Cellana capensis*
Family : Cerithidae
54. Cerithium morus
55. Cerithium citrinum
56. Cerithium granosum
Family : Fissurellidae
57. Clypidina natata
58. Scutus unguis
59. Diodora lentiginosa
60. *Diodora ticaonica*
Family : Neritidae
61. Nerita albicilla
62. Nerita chameleon
63. Neritina pulchella
64. Neritina oualaniensis
Family : Olividae
65. Oliva ispidula
Falimy : Conidae
66. Conus lividis
Family : Volimidae
67. Hemifersus cochlidium
Family : Littorinidae
68. Littorina subgranosa
69. Littorina undulate
70. Littorina scarba
72. Tectarius malaccanus
Family : Planaxidae
73. Planaxis sulcatus
74. Planaxis similis
Family : Trochidae
75. Trochus radiates
76. Umbonium vestiarium
Family : Cypraeidae
77. Cyprea Arabica
78. Cyprea pallid
Family : Turbinidae
79. Turbo intercostalis
80. Turbo argyrostomus
Family : Potamididae
81. Cerithidae fluviatilis
Family : Calyptraeidae
82. Calyptraea violaceum
83. Calyptraea pellucid
Family : Naticidae
84. Natica tigrina
85. Natica macrochiensis
Family : Strombidae
86. Tibia curta
Family : Cymatiidae
87. Gyrineum natator
Family : Nassidae
88. Bullia livida
89. Bullia granulose
90. Bullia melanoidea
91. Nassa olivacea
Family : Turridae
92. Clavatula tornata
93. Clavatula javana
Family : Dentaliidae
94. Dentalium Octangulatum
Family : Arcidae
95. Arca granosa
96. Arca rhombea
97. Arca pilula
98. Arca gambiensis
Family : Mytilidae
99. Perna viridis
Family : Carditidae
100. Cardita bicolor
101. Cardita variegate
Family : Donacidae
102. Donax scortum
103. Donax lubricus
104. Donax incarnates
Family : Cardiidae
105. Cardium coronatum
Family : Veneridae
106. Gafrarium divaricatum
107. Dosinia prostrate
108. Meretrix meretrix
109. Meretrix casta
110. Sunetta solandri
111. Sunetta donacina
112. Chione costellifera
113. Katelysia marmorata
114. Katelysia opima
115. Paphia malabarica
116. Paphia textile
117. Paphia undulate
Family : Solenidae
118. Solen truncates
119. Solen brevis
120. Siliqua radiata
121. Siliqua albida
VI. Phyum : Echinodermata
Family : Asterinidae
122. Astropecten indica
Family : Ophiactidae
123. Ophiactis sp.
Family : Phyllophoridae
124. Holothura atra
Family : Tropiometridae
125. Tropiometra eucrinus
Family : Temnopleuridae
126. Temnopleurus toreumaticus
VII. Phylum : Chordata
Class Pisces
Family : Gobiidae
127. *Collagobius melanoptera*
Family : Theraponidae
128. *Therapon jarbua*
Family : Arridae
129. Arius arius
Family : Dasyatidae
130. Himantura imbricata
Family : Scaridae
131. *Cetoscarus bicolor*

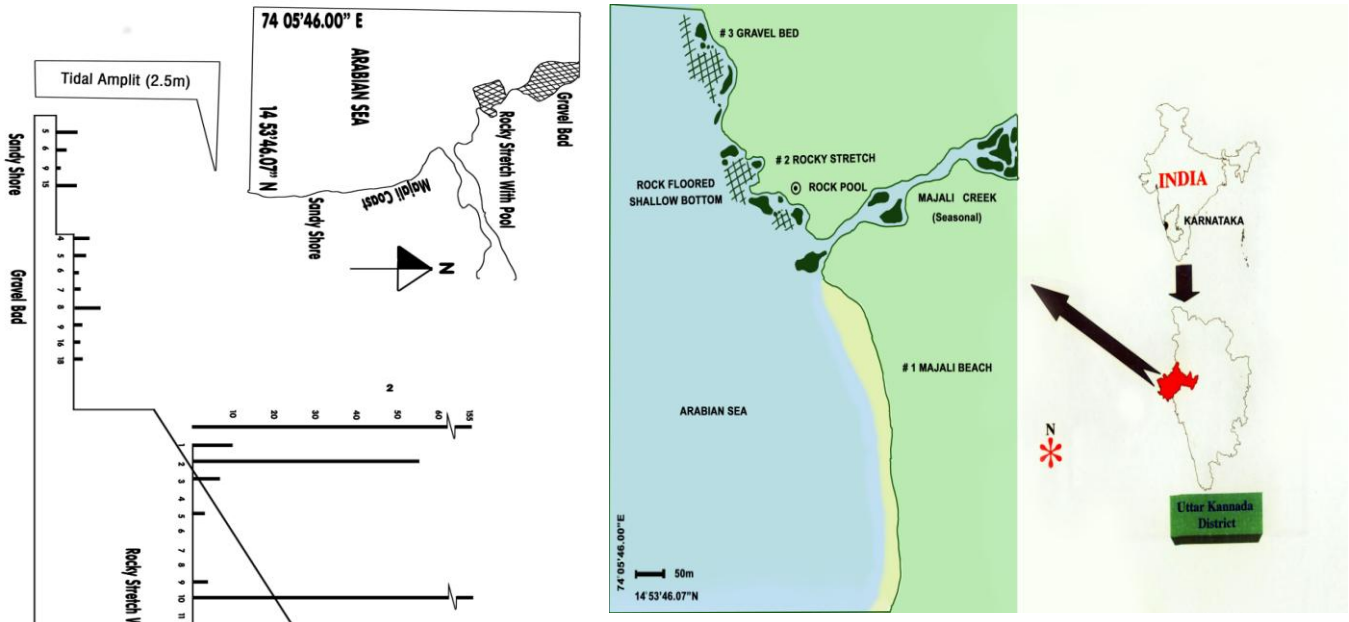

Figure 2: Schematic presentation of Study site and density of floral & faunal communities at Majali coast, Karwar

Figure 1: Location of the study area Majali Rocky Shore Karwar, West Coast of India.

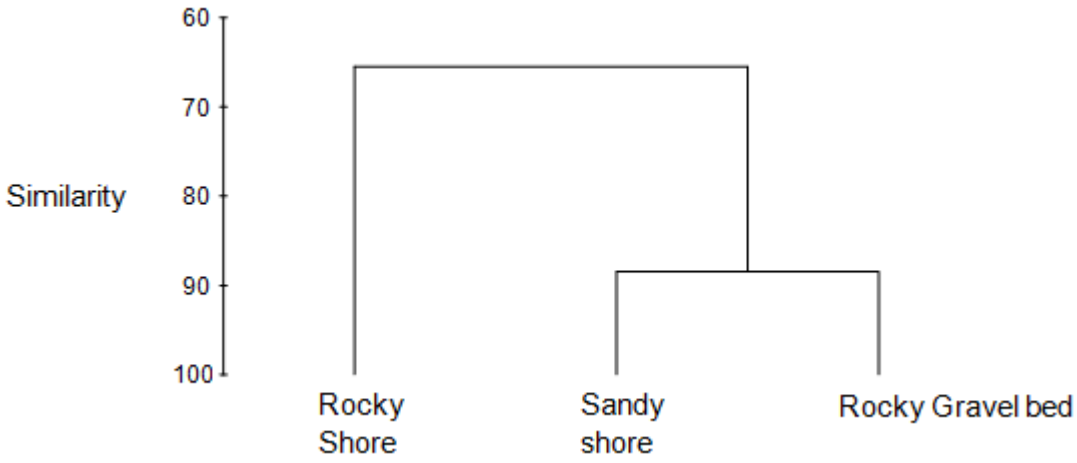

Figure 3: Dendrogram of complete linkage of faunal diversity among three different habitat of inter tidal zone

The Shannon Weiner species diversity (*d*') was more in gravel bed (2.7596) followed by sandy shore (2.2309) and rocky pool (1.9941). However Margalef's index which has good discriminating ability clearly brought out the variation in species richness amongst three habitat. The species richness showed

clear difference upholding the rocky bed and pool with (3.0809) followed by gravel bed (2.4924) and sandy shore (1.7472) (Table 5).

The species diversity of faunal community was estimated based on Margalef species richness (*d*) and Shannon Weiner Index (*H'*). It is surmised from the data that higher species richness was recorded at rocky shore with pool (3.081) and lower at sandy shore region (1.747). Higher richness could be due to the substratum which might have provided a very good shelter for the animals from the desiccation and from the predators. Cliffs and crevices of rocks supports the crabs and mussels for crawl or for attachment including the seaweeds which are highly populated in this area. Moderately higher richness of species was also fond in the gravel bed, which indicates that it can also give better substratum to thrive these animals in this bed.

CHLOROPHYTA (Green algae)

Family : Ulvaceae

1. *Enteromorpha clathrata* 2. *Enteromorpha intestinalis* 3. *Ulva fasciata 4. Ulva lactuca*

Family : Cladophoraceae

5. *Cladophora fascicularis* 6. *Chaetomorpha media* 7. *Chaetomorpha linum*

Family: Caulerpaceae

8. *Caulerpa peltata 9. Caulerpa racemosa 10. Caulerpa scalpelliformis 11. Caulerpa sertuilaroides* 12. *Caulerpa taxifolia*

Family: Codiaceae

13. Codium elongatum

PHAEOPHYTA (Brown algae):

Family: Dictyotaceae

14. Dictyota dichotoma 15. Padina gymnospora 16. Padina tetrastomatica 17. Spatoglossum asperum 18. Stoeachospermum marginatum

Family: Sargassaceae

19. Sargassum cinerium 20. Sargassum ilicifolium 21. Sargassum polycystum

RHODOPHYTA (Red algae):

Family: Rhodomelaceae

22. Laurencia cartilaginea

Family: Grateloupiaceae

24. Grateloupia lithophila

Family: Gracilariaceae

25. Gracillaria corticata

Family: Hypneaceae

26. Hypnea musciformis

The Shannon Weiner diversity index (*H'*) varied between 1.9941 (ropcky shore with pool) and 2.7596 (gravel bed) during the study period. Though the richness of species might be high in the rocky shore pool but was less diverse in species. Here, probably single or two dominant species could have been supported richness but gravel bed has created suitable substratum for diverse population. Similar findings were also found in coastal waters of Karwar (Bhat, 1984, Naik *et al*., 2005 and Ramesh, 2009).

The similarity in species composition among the habitat was in the range of 65.50 to 88.47% (Table 6). The dendrogram (Fig. 3) clearly reveals the sandy shore and gravel bed forming one cluster with maximum of 88.49%. It shows that, these two substratum has created ideal and uniform environmental set

up which has together form an suitable bed for these animals in this rocky shore line. These two habitats got linked at 75.19% with rocky pool. While the observed data reveals that rocky shore with pool had more number of species 14 than in the rocky gravel bed 10, latter sandy shore has 7 number of animal type.

Table 4: Distribution of animal types in the intertidal environment of Majali, Karwar, West Coast of India

Sl. No	Animal type	Total No. of Species	Habitat		
			Sandy shore	Rocky Shore and Pool	Rocky Gravel bed
1	Sponges	2	0	2	0
2	Hydrozoa	1	0	1	0
3	Sae mat	1	0	1	0
4	Sea anemone	1	0	1	0
5	Polychaeta	2	1	1	0
6	Amphipoda	5	0	0	5
7	Isopoda	1	0	0	1
8	Hermit Crab	7	2	0	5
9	Porcelin crab	1	0	0	1
10	Alphid shrimp	1	0	0	1
11	Brachyuran crabs	14	5	6	3
12	Prawn (ornamental)	1	0	1	0
13	Barnacle	1	0	1	0
14	Oysters	2	0	2	0
15	Clams	26	14	0	12
16	Muscles	1	0	1	0
17	Gastropods	55	6	46	7
18	Star fish	1	1	0	0
19	Sea lilly	1	0	0	1
20	Brittle star	1	0	1	0
21	Sea cucumber	1	0	0	1
22	Sea urchin	1	0	1	0
23	Pisces	5	2	3	0

The diversity of the rocky shore increases down the shore. The vertical distribution along the rocky shore is a direct consequence of the amplitude and height of the tide. However, on this tropical beach, these types of shore intergraded so closely towards a line of demarcation which is virtually not possible to draw a conclusion line. A general observation was made during inter-tidal period on zonation of fauna of rocky and sandy shore (Table1). Based on that very few species of invertebrates have been found in the splash zone. Mid shore showed increase in the number of invertebrate species as well floral species diversity. In the littoral or lower shore, the diversity of the marine organism significantly increased. This zone fascinates to explore during the lowest low tide period only.

Table 5: Univariate diversity indices of intertidal fauna recorded in Majali coast, Karwar, West coast of India

Habitat	S	N	d	J'	H'(loge)	Brillouin	Fisher	1-Lambda
Sandy shore	7	31	1.747	0.7947	2.2309	1.2951	2.8163	0.7222
Rocky Shore and Pool	14	68	3.081	0.5238	1.9941	1.1654	5.3458	0.5289
Rocky Gravel bed	10	37	2.492	0.8307	2.7596	1.6068	4.5021	0.8123

Table 6: Bray-Curtis similarity for intertidal fauna recorded in Majali coast, Karwar, West Coast of India

Substratum	Sandy shore	Rocky shore & Pool	Gravel bed
Sandy shore	0	0	0
Rocky shore & Pool	65.50	0	0
Gravel Bed	88.47	75.19	0

In the intertidal habitat, diversity has been recorded abundantly even though the rare specimen observed like Sea Lilly. Sea cucumber (*Holothuria atra) and* Alphids shrimps (in pair) were observed in the gravel bed area. Amphipods and sea weed crabs were associated together with the seaweeds. Sponges were noticed are mainly composed of demosponges. Annelida (Tubicola) species like *Sabellaria* and *Serpula* were abundantly found as colony of sand and calcareous tubes. Only one species of barnacle were documented was *Balanus amphitrite* in middle sub-littroal and splash zone of the rocky shore. Gastropods were abundantly found along with the eggs. *Gafrarium diverticulum* a rocky shore bivalve is recorded and among the two species of mussels, green mussel *Perna viridis* was recorded. Gastropods and crab species were represented dominantly in the rocky and sandy shore throughout the study period. Among Cnidarians, Hydrozoans colonies were abundant on the boulders as well sea anemone was profoundly distributed in the mid sublittoral zone. Sandy shore is well known for starfish collection along with varieties of bivalves which shares lower shore lines and dead, empty shells recovered from upper littoral zone of sandy shore.

West coast is generally marked with rocky shore headlands where as east coast is usually shelving with beaches, lagoons, deltas and marshes. Because of the influence of upwelling associated with southwest monsoon in the west coast of India, resulting in marked disparity in hydrographic conditions, productivity

pattern and qualitative composition of marine resources (Venkataraman, 2005). Marine algae from Indian coast have been fairly well surveyed since several decades. The latest systematic account lists 1153 species with 271 genera (Kaliaperumal, 2004). The most abundantly among them are Rhodophyta 434 species followed by chlorophyta 216 and pheophyta 191 species. In the rocky shore of Majali the dominant algal species recorded is chlorophyta 14 species. In this area there is lot of scopes for the seaweed framing for commercial purposes which can boost fisherman's economic status.

The faunal represent sponges are the group has an evolutionary history of about 570 million years and so far 486 species have been described. In India 28 species (Thomas, 1998) recorded, where as Majali recorded about 2 species. Regarding the Coelenterate in India 212 species of Hydrozoa, 25 species of Scyphozoan and 600 species of Anthozoa have been recorded till now (Annandale, 1916). The phylum Annelida- Polychaeta have received considerable attention from 1909. Central Marine Fisheries Research Institute has listed 200 species, here only two tubicola have been recorded. The dominated species of Arthropods and Molluscs were contributed to this rocky shore particularly brachyurans and gastropods. Other contributors for Arthropods are Porcelain crab, barnacle, amphipods, isopods and alphid shrimps. In India, Echinoderms 765 species were documented by Sastry (1998). Economically Holothuroids are exploited commercially. Sandy shore as a model place to collect sea-stars in this region. At Majali, Echinoderms like Sea urchins and sea cucumbers were abundant and sea lily and brittle star juveniles were too recorded while among chordate. 3 species of Pisces were recorded.

The Marine resources utilization by human increased noticeably in few decades. The major stress on marine ecosystems is natural threats like storms and cyclones. Anthropogenic impacts are cause for concern includes development activity, poaching, pollution from industries and oil refineries etc. Oil pollution is major cause of concern here as it can induce morality and decrease fecundity. Majali witnessed oil pollution in the month of September 2010. The present study did not show any major impact of oil spill on the intertidal biodiversity because of the minor oil spill and immediate removal of debris of oils from this beach with the help of Municipal and Pollution Control Board. However, marine pollution has been identified and immediate mitigating measures need for sustainable management and conservation of intertidal biodiversity and associated fisheries. An awareness programme has been initiated by the scholars and students of the University to conserve and to declare this region as a biological heritage site, so that it could be a live model for natural museum for future generation.

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