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Assemblage Depended Distribution of Sponge Community in Rocky Intertidal Ecosystem

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Abstract: Population ecology and distribution pattern of common intertidal sponges were studied at Veraval coast of Gujarat state, India. The uneven substratum of the studied intertidal zone supports various macrofaunal assemblages like coral assemblage, zoanthid assemblage and *cerethium* assemblage which provides unique habitat for sponges. Sponges were identified using standard identification keys while the quadrate method and various statistical tools like ANOSIM, SIMPER and PCA were used to study the distribution pattern of common sponge species. Amongst the studied sponge species, *Cliona* sp. was distributed abundantly throughout the sampling sites in all vertical zones and assemblages, five sponge species observed in the coral assemblage and eight sponge species observed in both Zoanthid and *Cerethium* assemblages that indicates essential substrate preferability for the spatial distribution of sponges. Inferences shows that diversity, distribution and seasonal existence of sponges were depends on existing assemblages and substratum.

Keywords: Sponge diversity, Population ecology, Assemblages, Intertidal zone, Gujarat

The coastal environments, especially the rocky intertidal zones show higher degree of spatiotemporal variations in comparison to open sea that provides a unique place to study the diversity and distribution patterns of the organisms in particular ecosystem. Zonation patterns of intertidal rocky shores and its organisms have been intensively well studied in the tropical regions of the world (Denny and Wethey 2001, Chapman and Underwood 2016). Among the intertidal organisms, sponges are sessile and considered to be the first and simplest metazoans with great ecological importance as bioeroders (Hooper 2000), filter feeders (Allen 2000) and biofoulers (Periera et al 2002). Marine sponges inhabit from shallow intertidal areas to deep sea, attached to substratum such as rocks, coral, shells, and marine organisms. Physical characteristics of habitats i.e. vertical, inclined, horizontal and overhanging cliff surfaces are considered as prominent responsible factors for the morphology and shape of sponge species (Bell and Barnes 2000). History of spongology of the Indian Ocean is first given by Thomas in 1971and explained the distribution of sponges of Indian Ocean. Today, the phylum Porifera contributed 8517 valid sponge species all over the world according to World Porifera Database (https://www.marinespecies.org/porifera). In India, nearly 486 sponge species were reported by Dendy (1916), Thomas (1984, 1989), Pattanayak (2006), Vinod (2014), Immanuel (2015), Pawar (2017), Lakwall (2018), Pereira (2020) and George (2020). However, distribution patterns of sponges in context of faunal assemblages and habitats have been meagrely studied particularly in west coast of India. Among the states of India, Gujarat has the longest coastline of 1600 km. Various ecological studies carried out from Gujarat coast (Misra and Kundu 2005, Vaghela et al 2010, Gohil et al 2011, Bhadja et al 2014, Poriya and Kundu 2014, Poriya et al 2014, Raval et al 2015, Vakani et al 2016, Chaudhari et al 2016, Beleem et al 2017, Baroliya and Kundu 2022, Jethva et al 2022). These includes intertidal fauna like molluscs, crabs, worms, echinoderms but the ecology of intertidal sponges of is less explored. The studied coast has rich diversity of sponges but few species are dominated and found throughout seasons. The present study aimed to through insight into the distribution patterns of twelve common intertidal sponges based on existing faunal assemblages.

MATERIAL AND METHODS

Study area: The present study was carried out at a rocky intertidal belt of Veraval (20° 53' N, 70° 26' E), west coast of Gujarat, India (Fig. 1). Site was chosen on the basis of their strategic locations, different types of substratum, assemblages and coast characteristics. The intertidal belt has variety of topographical features such like tide-pools of various sizes, puddles, crevices, small channels and flat rocky surface that provides variety of microhabitats. The upper zone ends up with broad elevation and deep crevices formed by heavy wave action of splash zone.

Quadrate monitoring: Distribution and population of sponges were determined with random quadrate method during the lowest tides of every month. For this, quadrats of

50 x 50 cm were laid at approximately regular intervals in a criss-cross direction on the open area of intertidal belt following a transverse direction covering the maximum area.

Percent cover: Visual methods was used to estimate the percent covers of sponge in permanent 50 x 50 cm quadrats on a wave exposed rocky shore at the Veraval coast. Visual estimates were made with the aid of 25 small squares (10 X 10 cm each) marked off within the quadrat frame. Each small square 'filled' by a species was counted as 4 % cover; often this technique required mentally 'grouping' organisms smaller than one full square and then counting the numbers of squares filled (Fig. 2). This method eliminates the need for decision rules such as 'any square >half-filled is counted as filled instead, a square 3/4 filled is simply 3 % cover. Organisms filling < 1/4 square (<l %) were noted as 'rare', and given an arbitrary rating of 0.5-0.7% (Fig. 2). Among the ecological attributes, monthly variation in percent cover of sponges calculated by following formula:

$$\text{Percent-cover} = \frac{\text{Total cover of benthos from all quadrates}}{\text{Total number of quadrate studied}}$$

Data analysis: ANOSIM, SIMPER analysis and PCA analyses were used to test different ecological attributes. Jaccard Similarity Index used to measure similarity between three assemblages and SHE analysis used to determine the relationship between S (species richness), H (Shannon-Wiener diversity index) and E (evenness as measured using Pielou J) in the samples. It is therefore an approach to look at the contribution of species number and equitability to changes in diversity. Data were transformed using the SQRT transformation to normalize a Poisson distribution. All data was calculated with the help of Microsoft Office Excel. For other ecological data PAST 3 (https://past.en.lo4d.com/windows) software used.

RESULTS AND DISCUSSION

Each organism has different types of adaptations strategies to survive in the particular zone and substratum types that creates dominancy of that organisms in particular area and make its own assemblage. Results of the present study depicted that diversity and distribution of sponge species in studied coastline merely depends on existing assemblages and substratum types. Different ecological aspects like diversity of common sponges, its seasonal existence and percent cover, distribution in different assemblages and substratum were analysed and described here to establish distribution pattern of sponges.

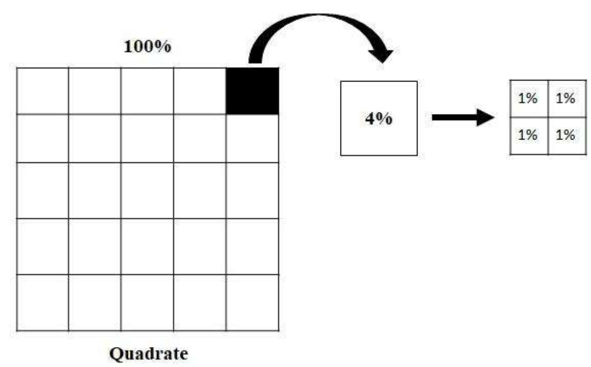

Fig. 2. Schematic diagram showing percent cover analysis of sponge in intertidal zones

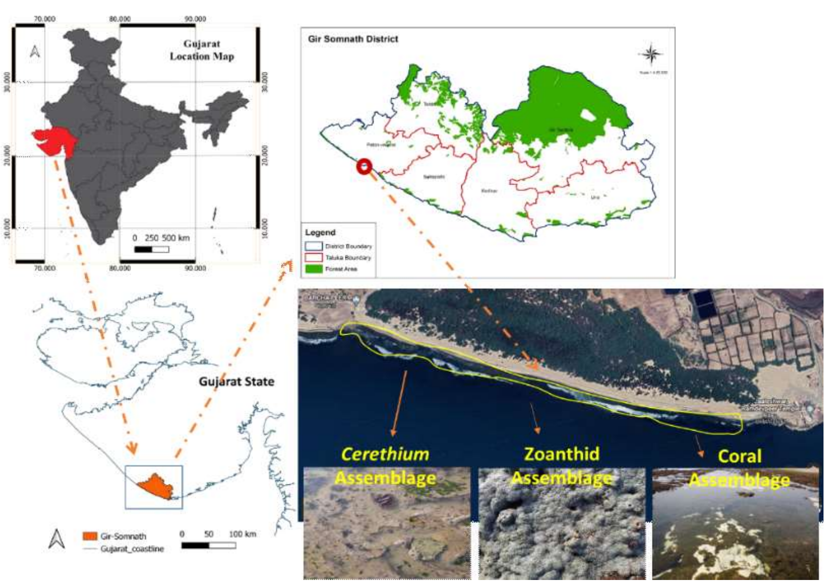

Fig. 1. Study area and assemblages

Faunal assemblages: The entire intertidal zone having different substratum structures and abiotic factors, according to this substratum coral, zoanthid and *cerethium* assemblage were observed during study period where sponge population was present. A total of 12 species of sponges were studied from the selected sites. Sponges were in particular zone (Table 1).

Coral assemblage: The coral assemblage is about 700 m long and has tidal exposure of 60 m, having bare rocky substratum with fewer sharp edges and has a gradient slope. This area identified as coral assemblage as the major biotic portion structured by small to medium sized colonies of different coral species like *Goniopora* Sp., *Porites lutea* and *Porite stephansoni*. Sponges are considered to be important space competitors for corals and other sedentary organisms. There were five sponge species observed in Coral assemblage. Coexistence of sponge and corals in these small to big submerge tidepools indicates benefits for both community for shelter and food, but sometime creates space competition. The upper intertidal zone of this area has big shallow rock pool that expanded up to middle intertidal zones with some algal population of chlorophyceae like *Ulva* sp. By living between the seaweed, sponges get benefited by not getting desiccated.

Zoanthid assemblage: This assemblage is about 700 m long with tidal exposure of about 85 m, having flat substratum with many crevices, few small pools and puddle. The entire intertidal area has large number of small to big, growing and established zoantharian colonies. Total eight sponge species observed in this assemblage. Amongst *Callyspongia (Cladochalina) diffusa* distributed most in this assemblage between the colonies of zoanthids. Good numbers of small pools and puddles, crevices provide variety of microhabitats in this area which nourishing population of sponges. The entire intertidal area of this assemblage has small vertical crevices with sharp edge that makes a good substratum for species like *Haliclona (Reniera) tubifera*, Thus, a different type of habitat then coral assemblage provides more change of settlement to the species like *Callyspongia (Cladochalina) diffusa* and *Haliclona (Reniera) tubifera*.

Cerethium **assemblage**: This one is one of the large assemblages of about 1200 m long with tidal exposure of about 85 m, with few small pools and puddles and many crevices. The area named as *Cerithium* assemblage due to dominant population of gastropods *Cerithium collumna and Cerithium caeruleum*. All the eight studied sponge species observed in this assemblage. However, *Cinachyrella hirsuta* sponge were most common one in this assemblage. Encrusting sponges found growing on the shells of gastropods due to fewest pools and puddles compare to other assemblages. Thus, it indicates that distribution of different sponge species merely depends on substratum or other substratum forming species.

Spatio-temporal distribution pattern of sponges in different intertidal assemblages: The overall percentage distribution of sponges identified from the study area showed highest cover (46.58%) of *Cliona* sp. followed by *Cinachyrella hirsuta* (Fig. 3).

Cliona sp. was the dominant species of studied coast with cover of 46.58% in sponge community Species distributed randomly in all three assemblages and all vertical zones however it mostly recorded in middle zone of all three assemblages. *Cinachyrella hirsuta* contributed 13.18% cover in sponge community of the coast. Species observed in

Table 1. Distribution of the intertidal sponges recorded between the different vertical zones of different assemblages

Species name	Coral assemblage			Zoanthids assemblage			*Cerethium* assemblage		
	U	M	L	U	M	L	U	M	L
Cliona sp.	++	+++	++	++	+++	++	++	++	+++
Cinachyrella hirsuta (Dendy 1889)	+	++	-	+	++	-	+++	++	-
Callyspongia (Cladochalina) diffusa (Ridley 1884)	-	-	-	-	+	++	-	+	++
Halichondria (Halichondria) panicea (Pallas 1766)	-	++	-	-	-	-	-	-	++
Haliclona (Reniera) cinerea (Grant 1826)	-	-	-	-	++	+	-	-	+
Haliclona (Reniera) tubifera (George & Wilson 1919)	-	+	-	-	+	-	-	-	-
Tetilla dactyloidea (Carter 1869)	-	+	-	-	-	-	-	-	-
Plakortis simplex Schulze 1880	-	-	-	-	-	+	-	-	+
Dysidea sp.	-	-	-	-	+	-	-	-	-
Mycale (Zygomycale) parishii (Bowerbank 1875)	-	-	-	-	-	-	-	+	-
Raspailia (Clathriodendron) arbuscula (Lendenfeld 1888)	-	-	-	-	-	+	-	-	-
Clathria (Microciona) sp.	-	-	-	-	-	-	-	-	+

Signs denote: + Rare, ++ Moderate, +++ Abundant, U- Upper littoral zone, M- Middle littoral zone, L-Lower littoral zone)

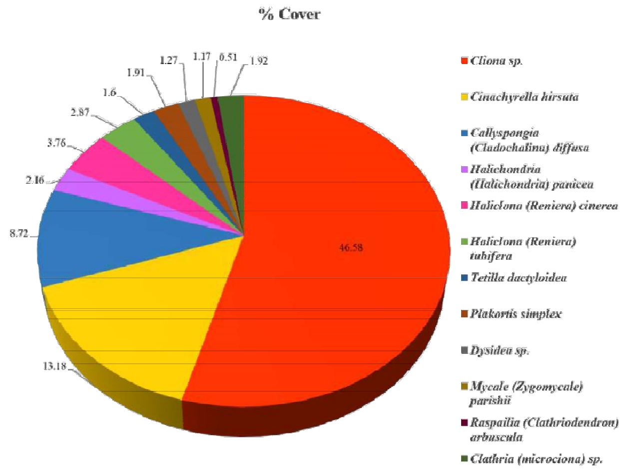

Fig. 3. Percent cover of each species in sponge community of studied coast

all three assemblages in upper and middle vertical zones. Highest abundance of species was in February (17.65% cover) and was abundant in upper zone of *Cerethium* assemblage (Fig. 6). *Callyspongia (Cladochalina) diffusa* distributed in middle and lower littoral zones of zoanthid assemblage and *Cerethium* assemblage while absent in coral assemblage. This was third dominant species of sponge community with highest cover of 10.82% in January in zoanthid assemblage. Abundance of species was increased from September to January (Fig. 5).

Halichondria (Halichondria) panicea typically observed in the middle littoral zone of coral assemblage (Fig. 4) and lower littoral zone of *cerethium* assemblage while absent in zoanthid assemblage. *Haliclona (Reniera) cinerea* distributed mostly in middle to lower littoral zone of the zoanthid assemblage and scarcely scattered in *cerethium*

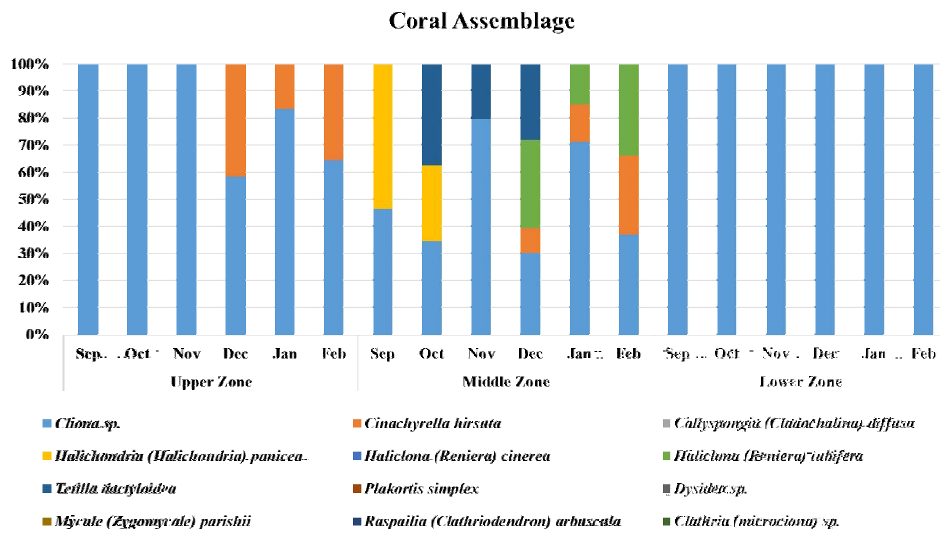

Fig. 4. Distribution of sponge species in coral assemblage

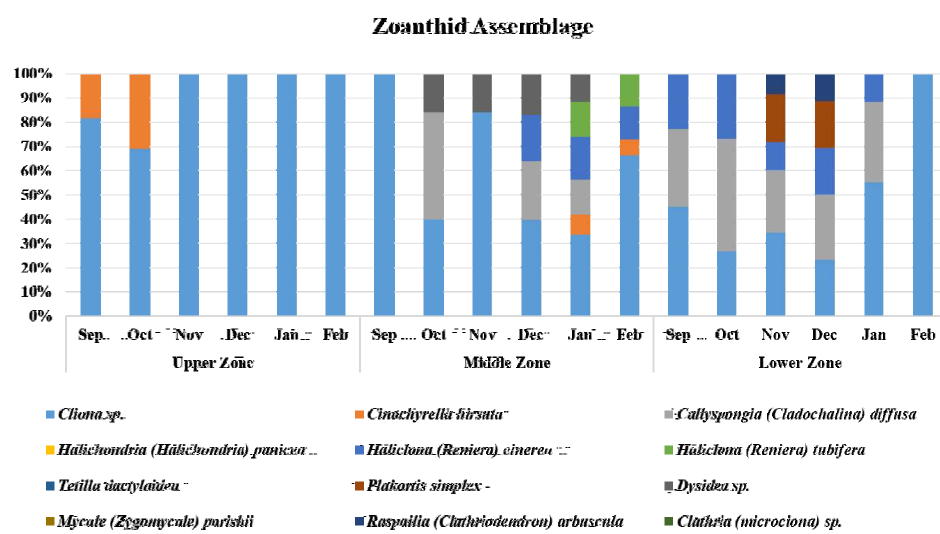

Fig. 5. Distribution of Sponge species in Zoanthid assemblage

assemblage. Increasing trend in abundance of species reported from September to January month. *Haliclona (Reniera) tubifera* was only reported from coral and zoanthid assemblages in the February with 6.30% cover. *Tetilla dactyloidea* was observed only in the coral assemblage with increasing abundance from post monsoon to winter months. *Plakortis simplex,* a boring sponge, was observed only during winter months with highest cover of 4.82% from the lower zone of zoanthid and *cerethium* assemblages. *Dysidea* sp. was observed only in the middle littoral zone of zoanthid assemblage from October to January .*Mycale (Zygomycale) parishii* was observed only in the middle littoral zone of *cerethium* assemblage from October to January month with highest cover of 2.19% in the month of December. *Raspailia (Clathriodendron) arbuscula* was observed only in the lower zone of zoanthid assemblage with the cover of only 0.51% during winter months. *Clathria (microciona)* sp. was observed in the lower zone of *cerethium* assemblage during the winter months with the highest cover of 4.47% in January month.

The percent cover of most sponge species exhibited significant spatial variation in the population attributes. However, no significant variation observed in temporal variation of sponge distribution that may due to the uneven patterns for distribution and growth and preference of different types of microhabitat in different assemblages of studied coast where these species exist.

Relative Distribution of Sponges in Faunal Assemblages

Jaccard similarity index: The Jaccard similarity index varied from 0.14 to 0.30 (Fig. 7). Assemblage wise similarity index indicates that all three assemblages were similar up to some extant in sponge community structure. Highest

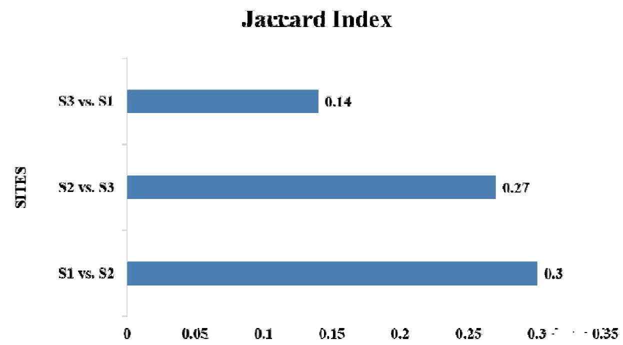

Fig. 7. Comparison of similarity between assemblages for sponge species. (S1- Coral Assemblage, S2- Zoanthid Assemblage, S3-*Cerethium* Assemblage)

Table 2. Temporal and spatial variations of observed sponge species between three micro sites of Veraval

Species of sponge	Temporal	Spatial
Cliona sp.	3.421*	0.539
Cinachyrella hirsuta	0.147	66.157*
Callyspongia (Cladochalina) diffusa	0.503	4.232*
Halichondria (Halichondria) panicea	0.414	1.277
Haliclona (Reniera) cinerea	0.250	14.272*
Haliclona (Reniera) tubifera	1.300	2.016
Tetilla dactyloidea	0.685	3.759*
Plakortis simplex	0.992	1.225
Dysidea sp.	0.488	7.284*
Mycale (Zygomycale) parishii	0.430	8.948*
Raspailia (Clathriodendron) arbuscula	0.802	2.473
Clathria (microciona) sp.	0.620	4.666*

The f-critical value is 3.105875 for temporal variation and 3.68232 for spatial variation and *denotes significance at P < 5 %

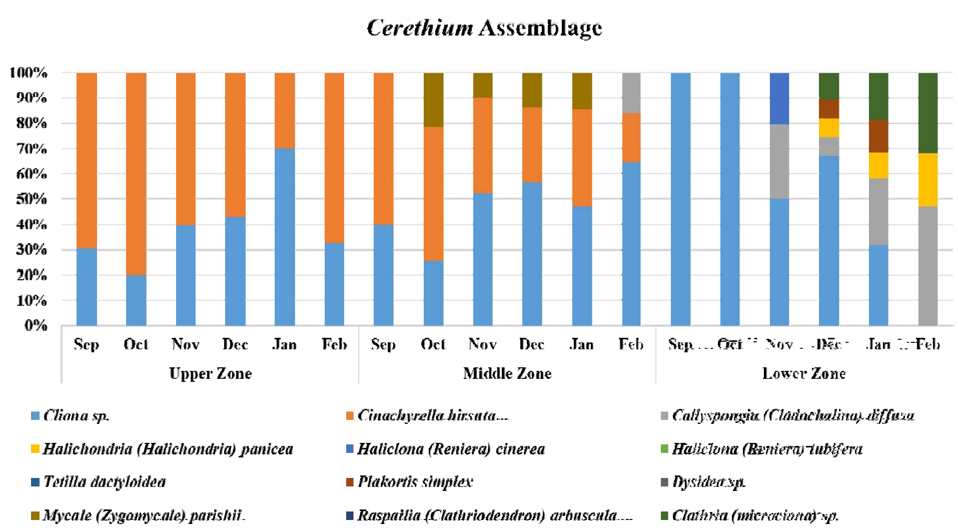

Fig. 6. Distribution of sponge species in *Cerethium* assemblage

similarity was 30% between Coral and Zoanthid assemblages while 27% between Zoanthid and *Cerethium* assemblages, 14% between *Cerethium* assemblage and Coral assemblage. Coral and Zoanthid assemblages were quite similar while lowest similarity was 14% between *Cerethium* and Coral assemblages.

SHE analysis: SHE analysis examines the relationship between species richness, diversity and evenness in the samples (Fig. 8). In the Coral assemblage, analysis showed that, the two diversity indices, the richness (S) and Shannon index (H) have the same increasing gradient while the evenness index (E) has downward gradient. In the Zoanthid assemblage, the richness and Shannon indices have also same pattern as coral assemblage. However, head of both lines starts from 1.3 (ln S) and 0.7 (H) which shows that the range of both indices were greater than Coral assemblage. The minimum evenness was observed in *Cerethium* assemblage. So, it can be determined that the Zoanthid assemblage is the most diverse and favourable for sponges..

SIMPER analysis: ANOSIM analysis showed occurrence of dissimilarity in contribution of sponge species in studied assemblages. It is evaluated by SIMPER analysis that calculates the contribution of each species (%) to the dissimilarity between each two groups. It is calculated from Bray-Curtiss dissimilarity matrix. *Cliona* sp. contributed highest 26.3% dissimilarity between Coral and Zoanthid assemblages, where the overall average dissimilarity is 44.39%. In case of Zoanthid and *Cerethium* assemblages, the overall average dissimilarity is 50.09%, where *Cinachyrella hirsuta* contributed highest 31.89% and lowest contribution 0% is of *Tetilla* dactyloidea. The overall average dissimilarity between *Cerethium* and Coral assemblage is 48.69% where, *Cinachyrella hirsuta* contributed 37.31% while *Raspailia (Clathriodendron) arbuscula and Dysidea* sp. contributed 0% contribution (Table 3).

Principal component analysis (PCA): The 7 principal components (PCs) were contributed to explain 100% of variance among the sites (Fig. 9). The eigen-values associated with each PC. These are often presented as raw values and as proportions of the total variance (which is the sum of all eigen-values). Examining the proportion of variance explained attributed to each PC is useful in determining how much variation that PC is able to 'explain'. Of these, PC 1 (Eigenvalue 5.18) and PC 2 (Eigenvalue 3.71), which together explained 76.91% of the variance. Analysis showed sites and different zones are indicated. This indicates habitat preference of sponge species is also depends on existing assemblage. As few species prefer unique microhabitat in specific assemblage.

The present study reports the distribution and contribution of sponges in the existing intertidal faunal community. Population of sponges significantly not varied

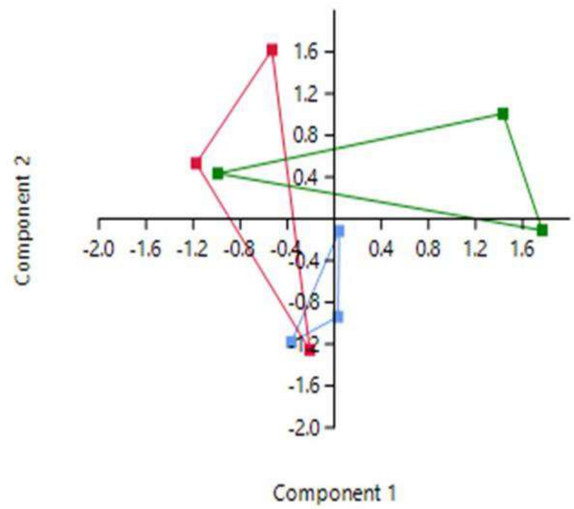

Fig. 9. Principal component analysis (PCA) for species abundance variables. Blue colour indicates the Coral assemblage, red colour indicates the Zoanthid assemblage and green colour indicate the *Cerethium* assemblage. Three point of each site indicates for vertical zonation. Overlapping shows the similarity of sites and distance between two triangle shows dissimilarities between them

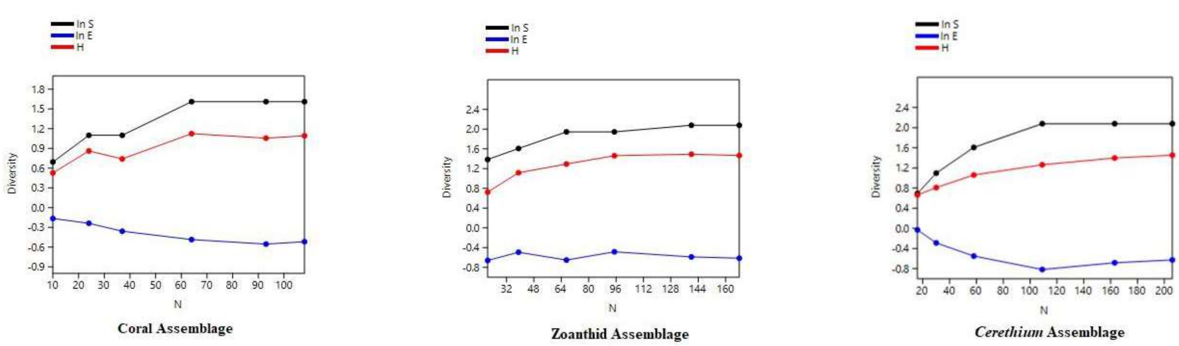

Fig. 8. SHE analysis shows the relationship between species richness, diversity and evenness in the samples

Table 3. Results of SIMPER Analysis between assemblages

Taxon	Average dissimilarity	Contribution (%)	Cumulative (%)	Mean abundance 1	Mean abundance 2
Coral and Zoanthid assemblage					
Cliona sp.	11.67	26.3	26.3	4.29	5.5
Callyspongia (Cladochalina) diffusa	9.552	21.52	47.81	0	1.79
Haliclona (Reniera) cinerea	6.147	13.85	61.66	0	1.18
Cinachyrella hirsuta	3.933	8.861	70.52	0.696	0.325
Haliclona (Reniera) tubifera	3.851	8.675	79.2	0.608	0.35
Tetilla dactyloidea	2.691	6.063	85.26	0.535	0
Dysidea sp.	2.069	4.662	89.92	0	0.424
Plakortis simplex	1.94	4.37	94.29	0	0.35
Halichondria (Halichondria) panicea	1.581	3.562	97.86	0.314	0
Raspailia (Clathriodendron) arbuscula	0.9519	2.144	100	0	0.172
Clathria (microciona) sp.	0	0	100	0	0
Mycale (Zygomycale) parishii	0	0	100	0	0
Zoanthid and *Cerethium* assemblage					
Cinachyrella hirsuta	15.97	31.89	31.89	0.325	3.37
Cliona sp.	9.745	19.46	51.35	5.5	5.73
Callyspongia (Cladochalina) diffusa	7.507	14.99	66.34	1.79	1.12
Haliclona (Reniera) cinerea	4.637	9.257	75.6	1.18	0.0786
Clathria (microciona) sp.	2.969	5.927	81.52	0	0.641
Plakortis simplex	2.008	4.01	85.53	0.35	0.287
Halichondria (Halichondria) panicea	1.872	3.737	89.27	0	0.404
Mycale (Zygomycale) parishii	1.736	3.467	92.74	0	0.39
Dysidea sp.	1.604	3.201	95.94	0.424	0
Haliclona (Reniera) tubifera	1.321	2.637	98.57	0.35	0
Raspailia (Clathriodendron) arbuscula	0.714	1.425	100	0.172	0
Tetilla dactyloidea	0	0	100	0	0
Cerethium and Coral assemblage					
Cinachyrella hirsuta	18.16	37.31	37.31	3.37	0.696
Cliona sp.	9.444	19.4	56.71	5.73	4.29
Callyspongia (Cladochalina) diffusa	5.981	12.29	68.99	1.12	0
Clathria (microciona) sp.	3.458	7.103	76.1	0.641	0
Halichondria (Halichondria) panicea	2.664	5.472	81.57	0.404	0.314
Haliclona (Reniera) tubifera	2.656	5.455	87.02	0	0.608
Tetilla dactyloidea	2.335	4.797	91.82	0	0.535
Mycale (Zygomycale) parishii	2.013	4.134	95.95	0.39	0
Dysidea sp.	1.547	3.177	99.13	0.287	0
Plakortis simplex	0.4237	0.8702	100	0.0786	0
Haliclona (Reniera) cinerea	0	0	100	0	0
Raspailia (Clathriodendron) arbuscula	0	0	100	0	0

between seasons (temporal). Taxonomic similarity-dissimilarity among the different phyla and assemblage structure were studied previously by Poriya and Kundu (2015). The relationship between sponge distribution and assemblages herein demonstrated by various statistical tools that also indicates importance of sponge morphology in assemblage selection (Wulff 2006) and habitat preference that allows the competitive coexistence of species (Montenegro-González and Acosta 2010). Distribution can also be predicted by description or correlations between organisms and habitat components (Kearney 2006).

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CONCLUSION

Sponge communities at studied coast are diverse and this study shows how variation in the sponge distributions dependent on other faunal assemblages. Sponges mostly prefers rock pools, zoanthids bed, underneath of rock, shallow pool, coralline bed, caves-crevices, algal bed. The majority of observed sponges were of encrusting in nature occurring in the cryptic habitats of caves and under surfaces of boulders. Under-surfaces of rocks and caves provides protection from temperature, water current, other extremes and trapping pools helps to reduce evaporation, thus reducing desiccation and salinity ingression. Changes in communities or structure of assemblages can alter the distribution of sponge community, thus sponges can be indicator of coastal ecological studies.

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