

## Substrate deposit effect on the characteristic of an intertidal macroalgal community

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Present study consists the effect of substrate deposit (silt, clay, sand, gravel and shards of shells) on the characteristic of an intertidal rocky shore macroalgae. Macroalgal assemblage was segregated from substrate deposit in two stages. Substrate deposit was subsequently quantified. Silt and sand-shell combine were the major constituent of the substrate deposit. Subsequent results showed that the characteristic of the intertidal macroalgal assemblages are influenced both positively and negatively. Species richness was high in a station with high clay substrate deposit. Substrate deposit as a whole, thus, has a functional role and has an influencing role which can cause a characteristic change on the macroalgal diversity of intertidal rocky shore ecosystem.

[**Keywords:** Intertidal, Macroalgae, substrate deposit, diversity]

### Introduction

Intertidal rocky shore ecosystem forms the interphase between marine and terrestrial ecosystem, and supports a wide array of organisms. Dominant primary producers of this ecosystem are the macroalgae which constitute an important component of a coastal and marine ecosystem, and they are considered as one of the most productive on earth<sup>1</sup>. Macroalgae also have the ability to remove toxic compounds from the water<sup>2</sup> and useful as an indicator of climate change<sup>3,4</sup>. Like other plant communities, intertidal macroalgal communities are dynamic in terms of structure and function<sup>5</sup>. Macroalgal community also serves as a host providing feeding, breeding and nursery ground to a variety of marine animal community. Diversity, distribution and abundance of macroalgae are known to be influenced by both physical and biological factors<sup>6,7</sup>. Substrate deposit similarly influences the structure and composition of macroalgal assemblages. Although the effect of sedimentation is believed to play an important factor in the life cycle of rocky shore organisms especially, the intertidal macroalgae, relatively few reports on such effects are available<sup>8,9,10,11,12</sup>.

The term 'substrate deposit', as used in the present paper is broad and includes a range of material like silt, clay, sand, gravel and shards of shells which are found deposited on the hard substratum along with the assemblage of macroalgae. Increased sediment deposition in coastal areas through various forms of human activities has been recognized as a major threat to marine biodiversity<sup>13, 11</sup>. The process of substrate deposition is largely dependent on the

hydrodynamics of the immediate environment. Although other factors like nutrient concentration in the water column, temperature, etc. will have a role; it is assumed that the substrate deposits can have a role in defining the characteristic of the macroalgal assemblage. It is believed there is a functional relationship between substrate deposit and the intertidal rocky shore macroalgal community and, it defines macroalgal assemblages either in positive or negative manner. On the basis of this, a simple experiment was performed and the paper describes the subsequent result of the interactive relationship between substrate deposit and the macroalgae.

### Materials and Methods

To test the hypothesis, a random sampling from 18 different stations was done by quadrat method (measuring 0.25 square meter) along the intertidal rocky shores of Anjuna (15°48'00" N 74°20'13" E) and Vagator beach (15°35'53"N 73°44'41"E) Goa, India (Fig. 1). The 18 sampled stations were code named and presented as QA1, QA2, QA3, QAP1, QAP2, QAP3, QAS1, QAS2, QAS3, QV1, QV2, QV3, QVP1, QVP2, QVP3, QVS1, QVS2 and QVS3, where code series QA represent samples of Anjuna site and code series QV represent samples Vagator site respectively. Macroalgal assemblages present within the quadrat were removed gently with the help of a scraper along with the substrate deposit present therein. Samples, both macroalgae and substrate deposit, were brought to the laboratory in a sealed polythene bag. Samples were sorted and processed in the laboratory.

Sorting of macroalgae and substrate deposit was done in two stages. First, the macroalgae was separated from the sediment by

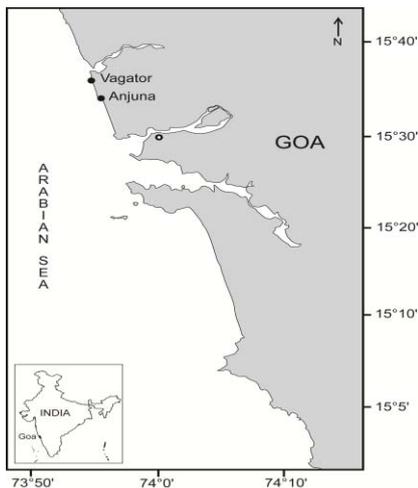


Fig. 1 -- Map of sampling site

using 500 micron mesh sieves. This was done by running water over it. Water and the substrate deposit that passed through a 500 micron mesh were collected in another sieve 63 micron mesh and the water was retained in an enamel plated tray. In the second stage, the substrate deposit retained in 63 micron mesh and the water collected in an enamel plated tray was used for analysing the composition of substrate deposit. Percentage composition of substrate deposit (sand, clay and silt) analysis was done through standard titration method and pipette analysis respectively<sup>14,15</sup>. In addition to these three constituents of substrate deposit, a great amount of gastropod/bivalve shell shards were also present, which were retained with the macroalgae. These were sorted and separated manually from the macroalgae. For a better clarity on the percentage of shell shard content within a quadrat, dry weight of shell shard was taken separately. However, for the purpose of statistical analysis, sand and shell shards were considered as one component. Accordingly, the ordination diagram of canonical correspondence analysis (CCA) was plotted. Identification of macroalgae was done with the help of available taxonomic identification keys and literatures<sup>16,17,18,19,20,21</sup>.

Univariate and multivariate analyses of data were performed using the PRIMER version 6 (Plymouth Routines in Multivariate Ecological Research) package<sup>22</sup> (Clarke and Warwick 1994). The following indices were determined:

Margalef's species richness ( $d$ ), Pielou's evenness ( $J'$ ), Shannon-Wiener diversity ( $H'$ ) and Simpson's Diversity Index ( $1-\lambda$ ). Bray-Curtis similarity index was constructed based on macroalgal abundance after square root transformation. Multivariate statistical analysis of Canonical Correspondence Analyses (CCA) was used to determine the interactive relationship between the substrate deposit and the diversity of macroalgal assemblage<sup>23</sup>. The CCA result was plotted using biplot scaling.

### Results

Analysis showed a variable concentration of substrate deposit from all the different stations (Fig. 2). Substrate deposit of silt and sand-shell was the major constituent in all the stations. The clay substrate deposit was present in negligible amount except in station QA2, it was ca 7.96 %.

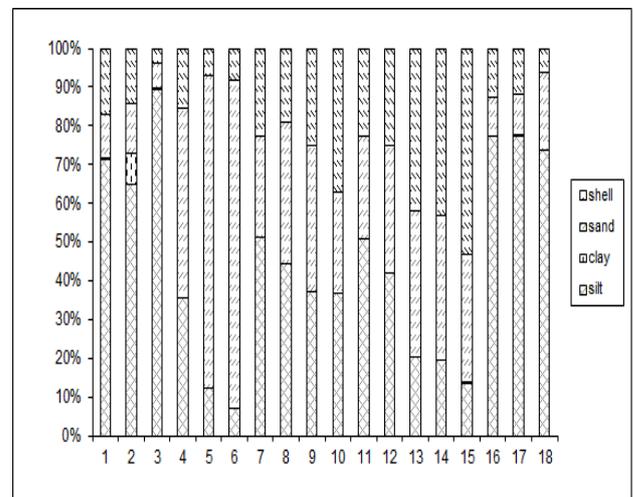


Fig. 2 -- Substrate deposit composition (%). The numbers indicate the sampling station code viz: 1-QA1, 2-QA2, 3-QA3, 4-QAP1, 5-QAP2, 6-QAP3, 7-QAS1, 8-QAS2, 9-QAS3, 10-QV1, 11-QV2, 12-QV3, 13-QVP1, 14-QVP2, 15-QVP3, 16-QVS1, 17-QVS2 AND 18-QVS3.

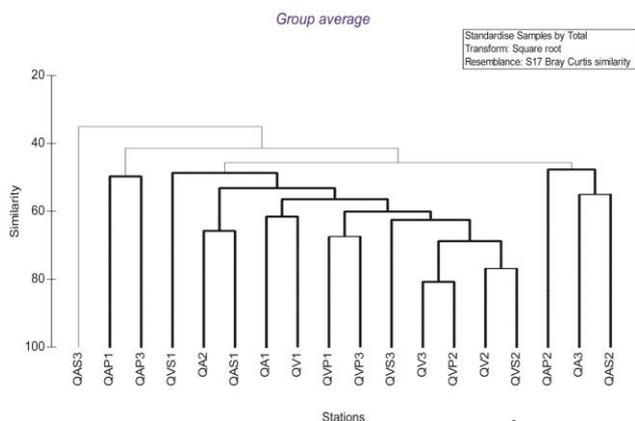
The species richness in the present study was high in station QA2 and Margalef species richness index and Shannon-Weiner diversity index respectively (Table 1) showed the same. This was followed by station QA3 in terms of diversity index. Station QAP3 and QVS1 scored the lowest in all measures of diversity index. These stations were represented by only eight (8) species each. The result of ANOVA, however, showed the macroalgal diversity between different stations are not statistically significant ( $p>0.05$ ).

The cluster analysis and SIMPROF revealed that there are four groups of cluster

(Fig. 3). Dendrogram of Bray-Curtis similarity showed that station QVS1, QA2, QAS1, QA1, QV1, QVP1, QVP3, QVS3, QV3, QAP2, QV2 and QVS2 formed the major cluster. While station QAP2, QA3 and QAS2; QAP1 and QAP3; and QAS3 formed the other three clusters.

**Table 1** -- Diversity Index of macroalgal diversity. Number of species (*S*), number of specimens (*N*), Margalef species richness (*d*), Pielou's evenness (*J*), Shannon index (*H'*) and Simpson's Diversity Index (*1-λ*).

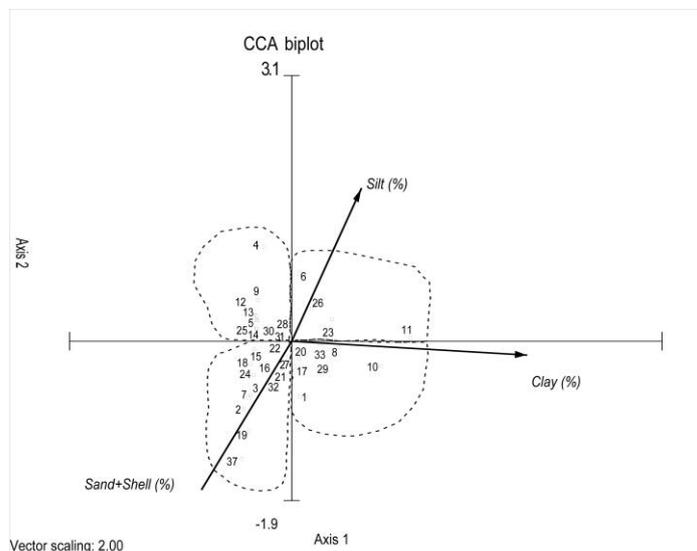
Station	S	N	d	<i>J</i>	<i>H'</i> (loge)	<i>1-λ</i>
QA1	16	155	4.1	0.98	2.72	0.96
QA2	18	200	4.6	0.98	2.82	0.96
QA3	17	97	4.4	0.98	2.79	0.96
QAP1	14	85	3.8	0.94	2.47	0.93
QAP2	13	87	3.6	0.92	2.35	0.91
QAP3	8	78	2.2	0.92	1.9	0.87
QAS1	17	118	4.5	0.95	2.69	0.95
QAS2	17	159	4.5	0.94	2.66	0.94
QAS3	17	141	4.5	0.94	2.66	0.94
QV1	17	140	4.5	0.95	2.71	0.95
QV2	14	81	3.7	0.98	2.59	0.94
QV3	12	63	3.2	0.97	2.42	0.93
QVP1	14	75	3.7	0.96	2.55	0.94
QVP2	9	37	2.4	0.95	2.09	0.89
QVP3	16	152	4.1	0.97	2.69	0.95
QVS1	8	79	2.2	0.94	1.95	0.87
QVS2	17	130	4.5	0.95	2.68	0.94
QVS3	15	171	3.9	0.09	2.57	0.94



**Fig. 3** -- Cluster analysis and similarity profile (SIMPROF) of macroalgal community of different stations

The distributional pattern of macroalgal assemblage in relation to substrate deposit is shown in a canonical correspondence analysis (CCA) ordination diagram (Fig. 4, Table 2). Result indicated a relationship between the substrate deposit and the macroalgal assemblages.

Macroalgal species like *Enteromorpha compressa*, *Centroceras clavulatum*, *Hypnea valentiae*, *Caulerpa sertularioides*, *Cladophora fascicularis* *Gelidium micropterum* and *Padina tetrastromatica* preferred clay substrate deposit. Interactive influence of clay substrate deposit was not recorded in *Ceramium fastigiatum*, *Polysiphonia* sp and *Gymnogongrus* sp. Species of *Gracilaria foliefera* and *Gracilaria arcuata* showed a preference for silt. A number of macroalgal species like *Enteromorpha* sp., *Caulerpa racemosa*, *Gelidium pusillum*, *Acanthophora spicifera*, *Bryopsis hypnoides*, *Gracilaria corticata* *Sargassum cinereum*, *Gelidiopsis variabilis*, *Rhodymenia australis*, *Stoechospermum marginatum* were found to inhabit which had a high content of sand-shell deposit. CCA result also showed that there are number of species like *Cheilosporum spectabile*, *Amphiroa fragillissima*, *Cladophora bombayensis*, *Hypnea spinella*, *Sphacelaria furcigera*, *Ulva* sp, *Chaetomorpha antennina*, *Chaetomorpha media* and *Sargasum cinctum* which remain unaffected by the substrate deposit constituent of the habitat.



**Fig. 4** -- Interactive relationship of the substrate deposit and macroalgal species. The numbers in the figure indicate the name of species as represented in Table 2.

## Discussion

The substrate deposit is known to cause significant impact on the rocky shore community in several ways, but assessing their role in the intertidal community structure is difficult<sup>12</sup>. And subtle variation was observed in the characteristic of macroalgal assemblages during field study with the change in texture and composition of substrate deposit profile. It can also cause several adverse effects on benthic organisms<sup>24</sup> including macroalgae, and early life history of many algae<sup>25</sup>. Besides this, fine sediments can interfere with settlement, growth and photosynthetic activity of an organism; also the effect of sediment may be extremely complex with varied outcome for the organism's assemblages<sup>11</sup>.

In terms of diversity and richness, station QA2 had high diversity index in the present study

Table 2: Macroalgal species code of CCA biplot

Name of Species	Code
<i>Enteromorpha compressa</i> (L.) Nees.	1
<i>Enteromorpha</i> sp	2
<i>Bryopsis hypnoides</i> Lamouroux	3
<i>Chaetomorpha antennina</i> (Bory de Saint-Vincent) Kützing	4
<i>Chaetomorpha media</i> (C. Agardh) Kützing	5
<i>Chaetomorpha linum</i> (O.F. Muller) Kützing	6
<i>Caulerpa racemosa</i> var. <i>peltata</i> Lamouroux	7
<i>Caulerpa sertularioides</i> (S.G.Gmelin) M.A. Howe	8
<i>Cladophora bombayensis</i> Borgesen	9
<i>Cladophora fascicularis</i> (Mertens ex C. Agardh) Kützing	10
<i>Struvea anastomosans</i> (Harvey) Picc et. Grum ex. Piccone Borgesen	11
<i>ulva</i> sp.	12
<i>Sphacelaria furcigera</i> Kuetz.	13
<i>Sargassum cinctum</i> J Agardh	14
<i>Sargassum linearifolium</i> (Turner) C Agardh	15
<i>Sargassum cinerium</i> J. Agardh	16
<i>Padina tetrastromatica</i> Hauck	17
<i>Dictyota ciliolata</i> Sonder ex Kützing	18
<i>Stoechospermum marginatum</i> (C. Agardh) Kützing	19
<i>Gelidium micropterum</i> Kützing	20
<i>Gelidium pusillum</i> (Stackhouse) Le Jolis	21
<i>Gelidiopsis variabilis</i> (Greville ex. J Agardh) F Schmitz	22
<i>Gracilaria arcuata</i> Zanard	23
<i>Gracilaria corticata</i> (J. Agardh) J. Agardh	24
<i>Gracilaria dura</i> (C. Agardh) C. Agardh	25
<i>Gracilaria foliefera</i> (Forsskal) Borgesen	26
<i>Gracilaria textori</i> (Suringar) De toni	27
<i>Hypnea spinella</i> (C. Agardh) Kützing	28

<i>Hypnea valentiae</i> (Turner) Montagne	29
<i>Amphiroa fragilissima</i> (L.) Lamouroux	30
<i>Cheiloporum spectabile</i> Harr. ex Grunow	31
<i>Acanthophora specifera</i> (Vahl) Borgesen	32
<i>Centroceras clavulatum</i> (C. Agardh) Montagne	33
<i>Ceramium fastigiatum</i> Roth.	34
<i>Polysiphonia</i> sp.	35
<i>Gymnogongrus</i> sp.	36
<i>Rhodomenia australis</i> Sonder	37

followed by station QA3. Station QA2 was relatively calm in relation to other stations and this might possibly be the reason of high clay content. Incidentally, this station had the highest number of species in terms of species diversity. This result may indicate the influencing role of the substrate deposit have on the macroalgal diversity.

The CCA generated ordination axes visualizes not only a pattern of variation in the community, but the characteristics of species distribution along the environmental variables<sup>26</sup>. Diversity and distribution of macroalgae in relation to the effect of substrate deposit is indicated by the CCA biplot ordination in this paper. A study on the role of finer sediments in the formation and maintenance of turfing algal assemblages<sup>27</sup> found that in a shallow sub-tidal lagoon at the Galapagos Islands, crustose coralline algae colonized new surfaces early in succession when sediments were experimentally removed from rocks. The green alga *Chaetomorpha antennina* have a strong crustose holdfast and found growing firmly attached to the hard substratum in a region exposed to wave. There is less possibility of substrate deposit getting accumulated in such condition. Although these characters are more of an adaptive feature, it indicates the negative influence of a substrate deposit. Similarly, *Sargassum cinctum* occur in a region exposed to wave action, the CCA result showed they are negatively influenced by substrate deposit. In the present study, even though *Amphiroa fragilissima* was collected amidst a deposit of sand-shell combine in all the stations, the CCA result indicated otherwise that substrate deposit has a negative influence. In other words, this species is tolerant to sand stress. Abundance of intertidal species, an opportunistic macroalgal species like

*Chaetomorpha linum*, *Cladophora columbina*, *Ulva lobata* and *Ulva intestinalis* in southern California was related to sand stress<sup>8</sup> and disturbance tolerant (*Mazzaella* and *Gymnogongrus* species) in Cape Peninsula, South Africa<sup>28</sup>. *Ulva flexuosa* is known to survive dark stress and regenerate on return to ambient condition<sup>29</sup>. Fluctuation of sand levels similarly was recorded to affect the composition, abundance and distribution of intertidal species in New Hampshire<sup>30</sup>. Abundance of *Gelidium corneum* and *Mesophyllum lichenoides* along the eastern Basque coast were negatively influenced by sediments, while *Halopityx incurvus* and *Chondracanthus acicularis* were highly abundant in areas of high sediments cover and this was attributed to the sediment gradient<sup>31</sup>.

The macroalgal species *Spacelaria furcigera* occurs mostly as an epiphyte and the CCA result showed it is not influenced by the substrate deposit. Green algal species *Struvea anastromosans*, however, have a preference to both or a mixture of clay and silt. Presence of *Ulva* species in the ordination group of sand-shell combine may possibly be due to the fact that the zoospores were settled and attached on the sand grains and the shards of gastropod/bivalve shells. The hard substratum of quartzite was shown to be a suitable substratum for macroalgal growth<sup>5</sup>.

Present study showed that species richness was high in a station which had high clay substrate deposit along with other substrate deposit component. Although in most of the observation by earlier worker elucidated only negative effect of substrate deposit on the macroalgal assemblages, this study shows otherwise. It shows substrate deposit as a whole acts as a functional unit and have an influencing role which can cause a characteristic change on the macroalgal diversity of intertidal rocky shore ecosystem.

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