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# Diversity profile of variegated seaweeds along Arabian sea, west coast of India

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**Abstract**

Karwar coast is rich in macro marine algal distribution showing varied distribution and abundance with respect to temporal parameters of the biotope situated along Arabian Sea, West coast of India. The present investigation reported 40 species of seaweeds from the study stations, of which 14 species belongs to Chlorophyta, 10 species to Phaeophyta and 16 species belonged to Rhodophyta on fortnightly basis from Jan 2018-Jan 2019. The performed statistical analysis showed Station Majali showed richer diversity when compared to Station Muduga with few similar species in common. The species diversity indices were calculated to compare the species abundance among varied seasons. Great magnitude of variation was noticed in the distribution and abundance of seaweeds spatio-temporally, similarities were compared using Clustering technique. The highest percentage similarity of about 0.55% was observed at Muduga than Majali; nearly 0.27%. The present study aims at comparisons of seasonal variations in seaweeds assemblages among two sites, calculating the diversity indices and an update of the checklist of seaweeds of Karwar coast.

**Key words :** marine algae, distribution, diversity profile, clustering.

The rocky coast provides a phenomenal spacers for distribution, growth and attachment of seaweeds. Marine macro algae commonly known as seaweeds constitute economically as modulated occupant in living resources of ocean, playing extreme crucial role in coastal marine biodiversity[11,27]. Marine macro algae are gigantic, complexed differentiated thallus conglomeration of photosynthetic algae inhabiting diversely mostly holdfast to rocky substratum, stones and pebbles or attached to sand particles[25,28,30], which are grouped as Chlorophyta, Phaeophyta and Rhodophyta based on pigmentation and cell differentiation[13,15]. Seaweeds congeries formed along with sea grasses aid in primary production, nutrient recycling and prime most chain in food cycle supporting and fluctuating the number of assemblages of associated species[3,13,16]. The rocky coast provides a phenomenal spacer for distribution, growth and attachment of seaweeds acclimatized to harsh environmental

parameters like temperature, salinity, solar radiation, desiccation, tidal ebb and flow and wave action[9,20]. The catastrophic environmental parameters rainfall, salinity, nutrients and light intensity variation during seasons lead to succession of intertidal marine macro algae. The structure and composition of macro algae assemblages fluctuating with time and space from Persian Gulf region were studied by Chapman & Underwood[6], John *et al.*,[12] & Sangil *et al.*,[29]. Many other researchers from East and West coast of India studied the seasonal composition and diversity of marine macro algae recorded the updated checklist of the algae. The seaweed diversity of four districts of Tamil Nadu was surveyed by Kumar who[15] recorded 53 species including 21 Chlorophyta, 15 Phaeophyta and 17 Rhodophyta.

Seasonal variations of seaweeds with relation to environmental and hydrological parameters was studied by Rao *et al.*,[24] at three different sites of Bhimili coast for a period of one year recorded 39 marine algal species and Cheena *et al.*,[7] recorded a total of 72 species of seaweeds from the coastal zone of Port Okha coast, Gujarat belonging to 26 families and 46 genera. Preliminary survey on distribution of brown seaweeds with reference diversity indices of brown seaweeds revealed 21 species of brown algae from three locations in Gulf of Mannar, Tamil Nadu by Rani *et al.*,[23].

Species composition, dominance, its diversity, distribution varies or alters along with space and time hence an updated report is necessary to record the ebb and flow to the succession. Status of seaweeds can be measured by mapping the distribution and diversity of seaweed flora of any particular area, regulating the entry of invasive harmful species, monitoring extinct and endangered species. Further the seaweeds updated list aid in the environment impact assessments, preservation and predict the ecological responses such as climate modulation and sea pollution which is monitored by addition or deletion of individual species to the succession. Hence, the present study was conducted to have an updated list of seaweeds of Karwar bay which emphasise on the temporal variation of seaweeds diversity and richness during the period of 2018 to 2019.

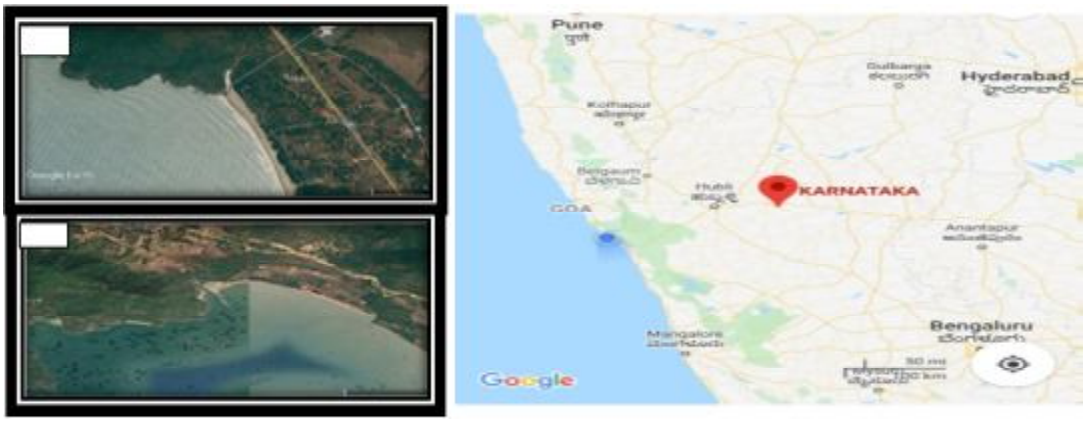



Fig.1: A map showing the study site Majali Beach and Muduga Beaches, Karnataka, West coast of India

*Description of the study area :*

Majali is a village in Karwar Taluk in Uttara Kannada, located 12 km towards North from district headquarters, Karwar. The rocky intertidal region of Majali beach with Lat $14^0$ 53' 54.42" N and Long $74^o$05' 45.65"E fortified with sandy as well as rocky shoreline submerged and exposed rocks which harbours rich macro algae. Muduga Beach with Lat$14^o$ 44' 44.47"N and Long$74^o$13'39.48"E is rich with mangrove plantations having nutritive soil. The main sampling area consists of huge boulders generally rough in nature.

*Sampling procedures:*

The rocky intertidal zone was visited fortnightly to record the species in all three seasons namely pre-Monsoon (Feb-May), South-West Monsoon (Jun-Sep) and post-Monsoon represented in (Tables-1 & 2) during study period from Jan 2018 to Jan 2019, with reference to Karwar Tidal Chart for respective year. Seaweeds were handpicked from Intertidal region using random sampling technique (1*1 $m^2$ quadrant) and brought to Laboratory after carefully washing and packaging in polythene bags. Sampling procedures and analysis of seaweeds were performed with reference to Beligirianga[4]. For authentication of the sample taxonomic identification keys were referred, described by Beligirianga,[4] Wells *et al*.,[33]. Samples were preserved in buffered formalin (4%). Occurrence of seaweeds are categorized as abundant (+++), less abundant (++), sparsely abundant (+) and absent (-) based on visible observation made at sampling site. Abundance of seaweeds (No/$m^2$) were represented by Ecological diversity indices and dominance represented by pie chart in percentage.

*Statistical analysis :*

*Ecological indices :*

Ecological diversity indices were computed to know the richness and diverse nature in species population by examining the S-(Species Richness); $H'$- (Shannon Weiner's Diversity Index); E - (Species Evenness) using the PAST Software package-4.03, statistical package by Clarke and Warwick[8].

*Clustering :*

The similarity of groups was found out with the help of cluster analysis. Clustering by[9], was used for representation of dendrogram using Bray-Curtis Similarity for identifying the seasonal variation in species assemblages. In cluster graph of dendrogram, the samples were plotted with X-axis and the similarity level (Bray-Curtis Similarity) was represented at Y-axis. The coefficient was calculated by the following formula:

$$d_{jk} = \frac{\Sigma|x_{ji} - x_{ki}|}{\Sigma|x_{ji} + x_{ki}|}$$

Here $x_{ji}$ indicated the data of column of i and j where i is the species and j is the sample and $\Sigma$ indicated the matrix overall rows, k represent the absolute value of the sample.

*Comparison of diversity using statistical analysis-Diversity curves :*

The collected data of seaweeds diversity including number of species were

analysed with the software PAST 4.03 package. The abundance of species was plotted on Y-axis which inferred as diversity and the diversity index (Shannon, alpha=1 and Simpson's, alpha=2) was plotted on the X-axis which is based on alpha value. Thus, the diversity curve of species was drawn.

The two study stations were well diversified with three congregate groups of Marine macro algae belonging to families Chlorophyceae, Phaeophyceae and Rhodophyceae. Annotated checklists of species of two stations are compiled and presented in (Tables-1 & 2).

In total, 40 species of seaweeds were collected from both the study stations, of which 14 species belongs to Chlorophyta, 10 species to Phaeophyta and 16 species belonged to Rhodophyta. The study recorded dominance of green algal species to brown algal species.

*Seasonal observations on Seaweeds at station 1* Majali *and Station 2* Muduga *:*

The seasonal diversity of Majali revealed that species dominance was almost near range during post -Monsoon; it recorded 32 seaweed species and 29 species during pre-Monsoon. In post-Monsoon, species under Rhodophyta were 13 followed by Chlorophyta was 11 and 8 under Phaeophyta. During post-Monsoon, the species dominance was the highest with 13 under Rhodophyta, followed by Chlorophyta. During pre-Monsoon, 29 seaweeds were found; of which, 9 species belong to Chlorophyta and 14 species belong to Rhodophyta and 6 species of Phaeophyta. In Monsoon season, seaweed diversity and dominance were very less compared other seasons, a total of 18 species recorded; under which 9 belonged to Chlorophyta, 3 to Phaeophyta and 6 to Rhodophyta (Fig. 2). At station 1 Majali, good species dominance was noticed among all the three groups of marine algae.

The seasonal diversity of Muduga revealed that species dominance was almost unequal during post-Monsoon and pre-Monsoon, in other words, highest dominance was noticed in pre-Monsoon followed by post-Monsoon. Only one species was represented under Rhodophyta among all the seasons. In post-Monsoon, species under Chlorophyceae and Phaeophyceae were almost equal to three, during pre-Monsoon, 11 seaweeds were found, of which, 5 species belong to Chlorophyta and 1 species belong to Rhodophyta and 5 species of Phaeophyta. In Monsoon season, seaweed diversity and dominance was very less compared other seasons, a total of 5 species recorded, under which1 belonged to Rhodophyta and Chlorophyta, 3 to Phaeophyta (Fig. 3). At station 2 Muduga, scanty species dominance was noticed among all the three groups of marine algae.

It was observed from the survey that the dominant species among green algae from both stations were *Ulva intestinalis* and *Ulva lactuca* (Chlorophyta). The lowest dominance was recorded among species *Cladophora vagabunda* (Chlorophyta). Among Phaeophyceae, the dominant species were *Sargassum ilicifolium* and *Sargassum tenerrimum*, whereas in Rhodophyceae it was *Gelidium pusillum*. At station 1 Majali, a total of 40 species were recorded among which Chlorophyta comprised of 2 families and 14 species, Phaeophyta comprised of 3 families and 10 species and Rhodophyta comprised of 10 families and 16 species (Table-1). At station

Table-1. Occurrence, Abundance and Monthly distribution of Seaweeds at Study Station1, Majali, Karwar Coast.

| Table 1: | | | Monthly Observations at Majali Beach | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | | Marine Macro algae (Scientific names) | 2018 | | | | | | | | | | | | 2019 |
| Sl.No. | | Family | POM | PREM | | | | MON | | | | POM | | | |
| | | | J | F | M | A | M | J | J | A | S | O | N | D | J |
| **Chlorophyta** | | | | | | | | | | | | | | | |
| | | *Ulva intestinalis* | - | - | + | - | - | ++ | - | - | ++ | - | +++ | - | - |
| | | *Ulva clathrata* | - | - | +++ | - | - | +++ | - | - | — | - | - | - | - |
| 1 | **Ulvaceae** | *Ulva lactuca* | ++ | - | - | - | - | ++ | - | - | + | +++ | - | - | ++ |
| | | *Ulva compressa* | - | - | + | - | - | ++ | - | - | - | - | + | + | + |
| | | *Ulva flexuosa* | + | - | - | - | — | - | | - | + | - | + | - | - |
| | | *Ulva prolifera* | - | + | + | - | - | + | - | - | - | + | ++ | + | - |
| | | *Ulva rigida* | + | - | - | - | - | - | - | - | - | - | - | - | - |
| | | *Chaetomorpha* | - | ++ | + | + | - | - | - | - | - | + | + | + | + |
| | | *antennina* | | | | | | | | | | | | | |
| | | *Chaetomorpha linum* | - | ++ | ++ | - | - | - | - | - | - | - | - | - | - |
| 2 | **Cladophoraceae** | *Cladophora* | - | + | - | - | - | - | - | - | - | - | + | - | - |
| | | *vagabunda* | | | | | | | | | | | | | |
| | | *Cladophora rupestris* | - | - | + | ++ | - | - | - | + | ++ | - | - | - | - |
| | | *Cladophora sericea* | + | +++ | + | + | ++ | - | - | + | + | ++ | +++ | ++ | + |
| | | *Rhizoclonium ramosum* | - | - | - | - | - | ++ | - | - | - | + | ++ | - | ++ |
| | | *Rhizoclonium* | - | - | - | - | - | ++ | - | - | - | + | ++ | - | ++ |
| | | *tortuosum* | | | | | | | | | | | | | |
| **Phaeophyta** | | | | | | | | | | | | | | | |
| 3 | **Dictyotaceae** | *Dictyota dichotoma* | - | - | + | ++ | - | - | - | - | - | + | + | - | - |
| | | *Padina tetrastromatica* | - | - | + | + | + | - | - | - | - | - | - | - | - |
| | | *Spatoglossum asperum* | - | - | + | + | - | - | - | - | - | - | - | - | - |
| | | *Stoechospermum* | | | | | | | | | | | | | |
| | | *polypodiodes* | - | - | - | - | - | - | - | - | - | + | + | - | - |
| 4 | **Sargassaceae** | *Sargassum cinereum* | - | - | - | - | - | - | - | - | - | + | + | - | - |
| | | *Sargassum swartzii* | - | - | + | + | + | + | + | - | - | - | - | - | + |
| | | *Sargassum ilicifolium* | - | - | + | + | + | + | + | - | - | + | + | + | - |
| | | *Sargasssum polycystum* | - | - | - | - | - | - | - | - | - | + | - | + | + |
| | | *Sargassum tenerrimum* | - | - | - | + | + | + | + | - | - | + | + | - | + |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | **Sphacelariaceae** | *Sphacelaria tribuloides* | - | - | - | - | - | - | - | - | - | + | + | - | - |
| **Rhodophyta** | | | | | | | | | | | | | | | |
| 6 | **Rhodomelaceae** | *Acanthophora muscoides* | + | ++ | - | - | - | - | - | - | - | + | - | - | - |
| | | *Acanthophora specifera* | + | ++ | + | + | - | - | - | - | - | + | + | - | - |
| 7 | **Ceramiaceae** | *Ceramium ciliatum* | - | - | - | - | - | - | - | - | - | - | - | + | +++ |
| | | *Centroceras clavulatum* | - | - | - | - | - | - | - | - | - | - | - | + | +++ |
| 8 | **Gelidiaceae** | *Gelidium pusillum* | - | - | + | - | - | - | - | - | - | ++ | ++ | + | + |
| 9 | **Gelidiellaceae** | *Gelidiella acerosa* | + | + | + | + | + | + | - | - | - | - | - | + | + |
| 10 | **Lithophyllaceae** | *Amphiroa fragilissima* | - | - | + | - | - | - | - | - | - | - | - | - | - |
| 11 | **Corallinaceae** | *Jania spectabilis* | - | - | ++ | - | - | - | - | -- | - | - | - | - | - |
| 12 | **Halymeniaceae** | *Grateloupia lithophila* | - | - | + | ++ | ++ | - | - | - | - | - | + | - | - |
| 13 | **Gracilariaceae** | *Gracilaria corticata* | - | - | - | - | - | + | - | - | - | ++ | + | - | ++ |
| | | *Gracilaria folifera* | ++ | ++ | + | + | - | - | - | - | - | + | + | - | - |
| | | *Gracilaria gracilis* | + | ++ | + | + | - | - | - | - | + | + | + | - | - |
| 14 | **Cystocloniaceae** | *Hypnea valentiae* | - | ++ | ++ | - | - | - | - | + | ++ | + | + | - | - |
| | | *Hypnea pseudomusciformis* | - | - | ++ | - | - | - | - | - | - | - | + | ++ | + |
| | | *Hypnea musciformis* | - | - | + | - | - | - | - | - | - | - | + | + | + |
| 15 | **Lomentariaceae** | *Ceratodictyon intricatum* | - | - | +++ | ++ | - | + | - | + | +++ | - | - | - | - |

+ represents present; - represents absent; PREM-pre-Monsoon; MON-Monsoon; POM-post-Monsoon in the above Table-1 .

2 Muduga a total of 11species were recorded among which Chlorophyta comprised of 2 families and 5 species, Phaeophyta comprised of 2 families and 5 species and Rhodophyta comprised of 1 families and 1 species (Table-2).

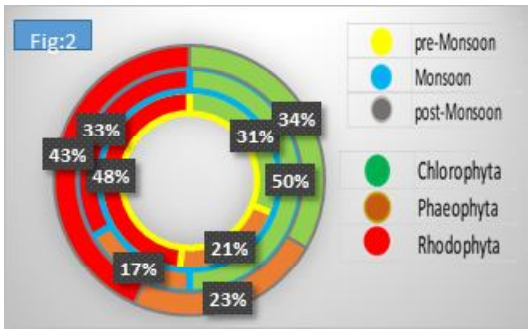
The present study observations (Tables-1 & 2) revealed that marine macro algae groups regeneration with regard to dominance of green algal species were recorded in pre-Monsoon (March) and post-Monsoon seasons (Sep to Dec). Thereby a fall in green algae was found in station 2 Muduga from July to September as compared to station 1 Majali where a good luxuriant growth of green algae was noticed. Additionally the gradual increase in red algae noticed in pre-Monsoon and post-Monsoon as compared to Monsoon, similar observations were pointed by Sowjanya & Sekhar[31]. Another congregates of red algae along with green algae such as *Chaetomorpha antennina* and *Chaetomorpha linum* occurred from November to February, and there by degeneration from March to April. Similar observations recorded by Agadi & Untawale[2], Agadi[1], Rao and Sreeramulu[26], Sowjanya & Sekhar[31]. Among Phaeophyceae, one or the other species belonging to Family Sargassaceae were present at both the study stations. The species *Sargassum ilicifolium* and *Sargassum tenerrimum* were present in ample at both stations especially good growth in Monsoon and post-Monsoon seasons. *Sargasssum polycystum* was found mostly absent in study

Table-2. Occurrence, Abundance and Monthly distribution of Seaweeds at Study Station 2, Muduga, Karwar Coast.

| Table 2: | | | Monthly Observations at Majali Beach | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | | Marine Macro algae (Scientific names) | 2018 | | | | | | | | | | | | 2019 |
| Sl.No. | | Family | POM | PREM | | | | MON | | | | POM | | | |
| | | | J | F | M | A | M | J | J | A | S | O | N | D | J |
| **Chlorophyta** | | | | | | | | | | | | | | | |
| 1 | **Ulvaceae** | *Ulva intestinalis* | + | ++ | + | + | + | - | - | - | + | + | + | + | - |
| | | *Ulva clathrata* | - | + | + | - | - | - | - | - | - | - | - | - | - |
| | | *Ulva lactuca* | + | + | + | - | - | - | - | - | - | - | - | + | - |
| | | *Chaetomorpha linum* | + | - | + | + | + | - | - | - | - | - | - | - | - |
| 2 | **Cladophoraceae** | *Cladophora vagabunda* | - | + | - | - | - | - | - | - | - | - | - | - | - |
| **Phaeophyta** | | | | | | | | | | | | | | | |
| 3 | **Sargassaceae** | *Sargassum swartzii* | + | + | - | + | + | - | - | + | + | - | - | + | - |
| | | *Sargassum ilicifolium* | + | + | - | + | + | - | - | + | + | - | - | + | - |
| | | *Sargasssum polycystum* | - | + | - | + | - | - | - | - | - | - | - | - | - |
| | | *Sargassum tenerrimum* | + | - | - | + | - | - | - | + | + | - | - | - | - |
| 4 | **Sphacelariaceae** | *Sphacelaria tribuloides* | - | - | - | + | + | - | - | - | - | - | - | - | - |
| **Rhodophyta** | | | | | | | | | | | | | | | |
| 5 | **Gelidiaceae** | *Gelidium pusillum* | + | + | + | - | - | - | - | - | + | + | + | - | - |

+ represents present; - represents absent; PREM-pre-Monsoon; MON-Monsoon; POM-post-Monsoon in the above Table-2

station 2 Muduga in all seasons. Similar studies regarding brown algae were supported by Nair *et al*.[19] Rani *et al*.,[23]. Maximum number of species were recorded in post-Monsoon and pre-Monsoon compared to Monsoon season which is in support of studies by Rao *et al*.,[24].



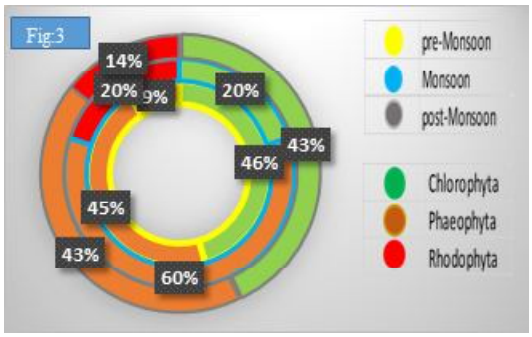




Fig. 2&3: Seaweed dominance in percentage at Station 1 Majali and Station 2 Muduga

*Analysis of biodiversity indices:*

The diversity indices mentioned in (Table-3) for two stations indicated that study station Majali had good seaweed diversity than Study station Muduga. The Mean Shannon Wiener diversity index at Station 1 Majali was maximum during pre-Monsoon (2.26), followed by post -Monsoon (2.10) in comparison to monsoon (1.42), indicating that the seaweeds diversity was higher during post-Monsoon and pre-Monsoon (Table-3). The values of Margalef's species richness indicated that the species richness was also the highest during pre-Monsoon (3.65) and lowest in Monsoon (1.91) (Table-3). The evenness of species was found less even in during pre-Monsoon (0.87) and more even in post-Monsoon (0.77) according to species Pielou's evenness analysis (Table-3).

The Mean Shannon Weiner diversity index at Station 2 Muduga was maximum during pre-Monsoon (0.63), followed by post-Monsoon (0.41) in comparison to Monsoon (0.35), indicating that the seaweeds diversity was higher during post-Monsoon and pre-Monsoon (Table-3). The values of Margalef's species richness indicated that the species richness was also the highest during pre-Monsoon (0.87) and lowest in Monsoon (0.57) (Table-3).

The evenness of species was found less even in during Monsoon (0.98) and more even in pre

Table-3. Seaweed Diversity Indices with mean values at Majali and Muduga during different seasons

| | Mpom | Mprem | Mmon | MUPom | MUprem | MUmon |
|---|---|---|---|---|---|---|
| Shannon index | | | | | | |
| Min | 1.75 | 1.74 | 1.09 | 0 | 0.51 | 0.65 |
| Max | 2.36 | 3.02 | 1.77 | 0.56 | 0.72 | 0.78 |
| Mean | 2.10 | 2.26 | 1.42 | 0.41 | 0.63 | 0.35 |
| Margalef's index | | | | | | |
| Min | 2.21 | 2.21 | 1.44 | 0.40 | 0.65 | 0 |
| Max | 5.07 | 6.05 | 2.25 | 1.01 | 0.95 | 1.14 |
| Mean | 3.58 | 3.65 | 1.91 | 0.66 | 0.87 | 0.57 |
| Equitability(Evenness) | | | | | | |
| Min | 0.71 | 0.72 | 0.63 | 0.62 | 0.56 | 0.97 |
| Max | 0.92 | 0.94 | 1 | 0.97 | 0.87 | 0.98 |
| Mean | 0.77 | 0.87 | 0.84 | 0.81 | 0.71 | 0.98 |

–Monsoon (0.71) according to species Pielou's evenness analysis (Table-3).

The species diversity of floral community was estimated based on Margalef's species richness (d) and Shannon Weiner Index (H') (Table-3). Margalef's index which has good discriminating ability clearly brought out the variation in species richness amongst two study stations. It is surmised from the data that higher species richness and species diversity was recorded in post-Monsoon and pre-Monsoon seasons compared to Monsoon, this may be due to the changing abiotic parameters and the new successive generation growth in vital environmental parameters. Though the richness of species might be high in the pre-Monsoon and post-Monsoon seasons but was less diverse in species especially at study station Muduga as compared to Majali. Here, probably single or two dominant species could have been supported richness, but Majali study station has created suitable substratum for diverse population. Similar findings were also found by Naik *et al.*,[18,] Saparna e*t al.*,[32] and contrast result to[14]. The differences in the species diversity and abundance from the other researcher is due to the variability of spatio-temporal parameters like variation of intensity of light, rainfall, and salinity and nutrients supply.

*Clustering :* In Clustering, the data pertaining to Species assemblage at two stations and three seasons were subjected to cluster analysis using Bray Curtis Similarity. The samples collected got channelled under various groups from higher percentage to lower percentage. Cluster analysis or classification is helpful in finding natural groupings of samples, such that samples within a group are more similar to each other than the samples in different groups. Presently, the dendrogram revealed clearly the grouping of samples collected from stations I-II (Fig. 4, 5, 6).

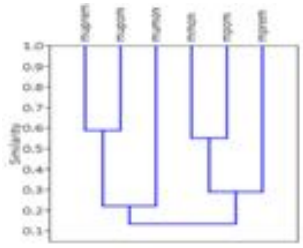


Fig. 4: Cluster analysis at both stations combined, where m-Majali and mu-Muduga.

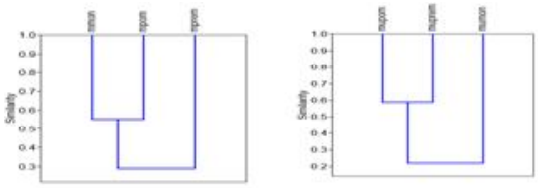


Fig 5&6: Cluster analysis at Majali (m) and Muduga(mu) performed season wise

*Cluster analysis (station wise) :*

Species assemblage was studied using the dendrogram drawn with three seasons of two study stations. The seaweed diversity for two stations formed 4 groups. The first group formed singly at 0.25% by Muduga monsoon, second group was formed by Majali pre-Monsoon at 0.27%,third group between Majali post-Monsoon and Monsoon at 0.55% and lastly the fourth group with highest similarity found at 0.58% between Muduga Pre-Monsoon and Post-Monsoon (Fig. 4).

Species assemblage was studied using the dendrogram drawn with three seasons of two study stations. The study was supported by Naik *et al.*, & Suparna *et al.*,[18,32]. It states that at Majali station 1 many different species are found and at Muduga less diverse species are found. At Majali some unique and

opportunistic species in Rhadophyta and Chlorophyta were found *Rhizoclonium ramosum*, *Rhizoclonium tortuosum, Grateloupia lithophila, Gracilaria corticata, Gracilaria foliifera, Gracilaria gracilis, Hypnea valentiae, Hypnea pseudomusciformis, Hypnea musciformis, Ulva intestinalis, Ulva clathrata, Ulva flexuosa, Ulva prolifera, Acanthophora muscoides and Acanthophora spicifera* which acted as a bio-indicator for maintaining the status of ocean. It is characterized by nutrient rich waters especially nitrates, nitrites and ammonium fluctuation due to season variability. The study under experimentation and interpretation regarding anthropogenic activities were supported by such species reported by Cox & Foster[5], Moreira *et al.*,[17].

*Cluster analysis (seasons wise):*

Species assemblage was studied using the dendrogram drawn with three seasons at Majali. The seaweed diversity for two stations formed 2 groups. The first group formed at pre-Monsoon lesser level of similarity of 0.27%.The second group formed between post-Monsoon and Monsoon with 0.55% similarity (Fig. 5). Species assemblage was studied using the dendrogram drawn with three seasons at Muduga. The seaweed diversity for two stations formed 2 groups. The first group formed at Monsoon lesser level of similarity of 0.19%.The second group formed between post -Monsoon and pre-Monsoon with 0.55% similarity (Fig. 6).

Species assemblage was studied using the dendrogram drawn with three seasons at Majali and Muduga (Fig. 5 & 6). The seaweed diversity for two stations formed 2 groups with differences in seasonal variability. Similar observation regarding the clustering based on Bray-Curtis similarity index applied for seaweeds abundance with single cluster mode was reported by Naik *et al.*,[18] Qureshi & Rathod[21] & Suparna *et al.*,[32].

**Diversity profile :**

The diversity profiles of two study sites emphasizing the monthly variation in alpha diversity was maximum in March (pre-Monsoon) and minimum in July (Monsoon) at Station 1, Majali. At Station 2, Muduga maximum species recorded in February and April (pre-Monsoon), whereas least in November (post-Monsoon). Peak in curve was noticed in March (pre-Monsoon) month at Majali, followed by rejuvenation of species in September and October (Monsoon and post-Monsoon) and finally equilibrium growth of species depicted in December and February (post-Monsoon). At Station Muduga, constant stability of seaweed species noticed in August (Monsoon) and November (post-Monsoon) with declination of species in June and July. Most Favourable months noticed for better growth of seaweeds were February, March and April.

The alpha diversity metrics summaries the structure of an ecological community with respect to its richness and evenness of the species. The abundance of species was plotted on Y-axis which inferred the diversity index (Shannon, alpha=1 and Simpson's, alpha=2) was plotted on the X-axis which is based on alpha value.(Fig. 7 & 8) The Shannon index takes into account the number of species and the evenness of the species. The Shannon index is increased by having greater species number, unique species in area or having greater species evenness which is seen in the

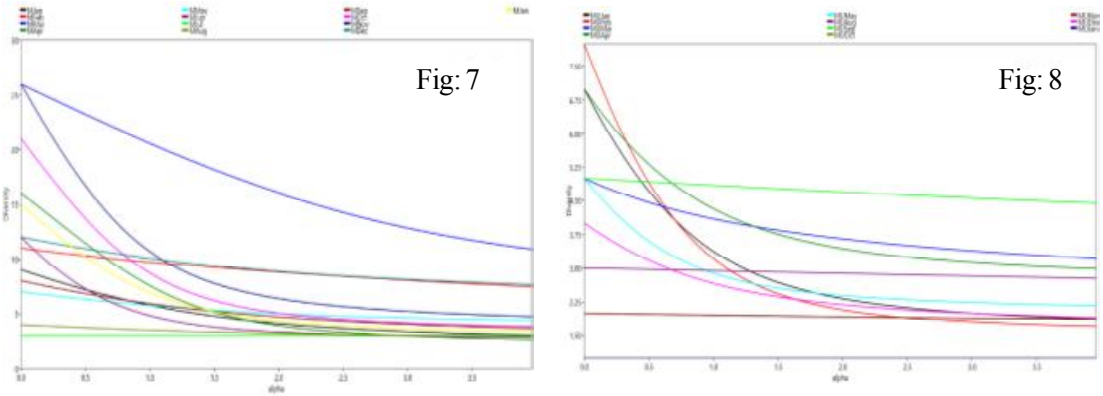



Fig 7&8: Diversity curves representing the species diversity months at station 1 Majali(M) and station 2 Muduga (MU) during study period

graph (alpha - 0.0 -1.9) and the result is in accordance to the biodiversity indices. The Simpson's index value more about the relative abundance seen in graph (alpha - 2.0 -3.0).

The two study stations were well diversified with three congregate groups of Marine macro alga such as Chlorophyceae, Phaeophyceae and Rhodophyceae. In total, 40 species of seaweed were recorded, of which 14 species belong to Chlorophyceae, 10 species to Phaeophyceae and 16 species belonged to Rhodophyceae. Majali due to its geomorphology and slope gradient, and substratum served as rich algal recolonization site with semi moderate environment during Post-Monsoon. Muduga with inappropriate geomorphology of coast for settlement of algae and excessive covering of intertidal area in Monsoon make it unfavourable for algal dominance except for the brown algal growth. During Pre-Monsoon season and Post-Monsoon maximum number of species recorded in ample compared to Monsoon due to heavy rains, in significant receeding of water, limited the exploration of area. Shannon diversity index and Margalef's richness index showed an excellent diversity among station Majali to Station Muduga.It revealed richness floral diversity of station Majali. Few congeries of seaweeds located at Majali especially the green algae can be used in nutrient removal strategies, since seaweeds are known to absorb significant amounts of nitrogen nutrients from sewage waters promoting healthy and stable marine biodiversity. The diversity indices speaks about the rarity, commonness, richness, addition or deletion of the species during succession, its abundance and evenness at the two stations, dendrogram aided in comparing the species similarity during the different seasons and stations. The diversity data of present study is a foundation for the upcoming researches.

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