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Kaleidoscopic Intertidal Diversity Profile of Marine Macro Algae of Majali and Tilmati Beaches, Karwar, West coast of India

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Abstract

Majali is a hamlet in the Uttar Kannada district of Karnataka, India situated in coastal region called Kanara amidst Goa-Karnataka border. The village is a tourist destination for the beaches of Karwar, including Tilmati Beach ''BLACK SAND BEACH" which supports a huge habitat for growth of Macroalgae. Seaweeds are economically as well as ecologically important source of Marine ecosystem.In this study, diversity and distribution of seaweeds along rocky shores of south Karwar coast has been examined. Samplings were carried out for Pre Monsoon, South West Monsoon and Post Monsoon at both the stations, in accordance to the environmental parameters during study period. A total of 40 species were collected from Majali and 23species from Tilmati throughout study period with the absence of *Ulva* and *Chaetomorpha* species, excessive algal growth of Brown algae and invasive *Caulerpa* species at Tilmati station.Temporal variability in various diversity indices were calculated by using PAST software. The work highlights upon the influence of environmental parameters as well as the geomorphological pattern of the rocky shore (boulders and Gravel bed) on composition and survival of seaweeds withstanding the submergence and emergence of the tidal amplitude. An updated checklist and distribution of seaweeds is mentioned with rocky shore analysis.

Marine macro algae cited early in 2500years ago in Chinese literature are of medicinal and pharmaceutical importance referring to large marine benthic, multicellular, macro thallic differentiated forms of algae[33], playing important role ecologically in marine communities. Algae are utilized in food and nutritional aspects due to presence of macronutrients contents as well as essential vitamins,minerals,amino acids and rich source of Iodine[21].

Marine macro algae are the assemblage of macroscopic photosynthetic algae which are grouped under three, based on pigmentation and cell differentiation as green, brown and red.[8,17].

Marine macro algae superficially resemblance to the higher plants possessing false pseudo roots in form of holdfast, leaves, stems (stipe) and air bladders for drifting in water (*eg Sargassum*) which grow naturally in the marine environment on seabeds, rocky substratum with photosynthetic ability aiding the marine community. *Villares* and *Carballeira*,[34] experimented on marine *Ulva* species (*U. intestinalis, U.lactuca* and *U. rigida*) confirmed nutrient availability has influence on pigmentation of Thalli, photosynthetic ratio and degree of Branching of *Ulva intestinalis* is influenced by higher concentration of chloride concentration. Higher concentration of sodium chloride leaves negative impact on Ulva spp reduces the length, number of thalli and consequently decrease the mats surface area. Similar observation was seen in *Ulva clathrata* and *Ulva intestinalis* during South West Monsoon and Pre monsoon.

The coast provides an excellent bed of rocky substratum for distribution and attachment of seaweeds in spite of harsh environmental parameters like temperature, salinity, solar radiation, desiccation, tide emergence and submergence, wave action[10,26].

An unique hospitable habitat for luxuriant growth of Marine macro algae prefer a moderate temp (21.5^{o}C to30^{o}C), Salinity nearly to 37.3PSU with a coast range (0.7 to 0.9Kms) exposure of intertidal zone (3 to4 hrs) with semidiurnal amplitude ranging from 4 to 5 mts.[4,19]. Algae are found as epiphyte, endophyte and also in diverse habitats growing in extreme climates.

Many researchers both from East and West coast have been studied the seasonal variations of seaweeds with relation to environmental and hydrological parameters amongst which Satya Rao *et al*.[31] studied three different sites at Bhimili coast for a period of one year. Dadolahi -Sohrab *et al*.[7] evaluated the biomass and species composition of seaweeds in relation to seasonal variations for six sites along Bulshehr Province. Osman *et al*. (2013) studied different algal vegetation along intertidal region which aided help to explore richness of seaweeds along Mutton coastal waters of South coast of India. The observed richness of algal diversity and seasonal distribution of seaweeds likely relates to the life history of the seaweeds and also the topography of the intertidal area with hard rocky substratum which provides shelter from wave force and suitable niche for the algal diversity. Species composition, its diversity, distribution assemblage changes along with space, time and environmental parameters, hence an updated report is recorded during study period to know the ebb and flow. Status of seaweeds to that of environmental changes in marine communities.

Study area :

A survey of study area of Karwar coast; Majali (Lat:14^{o}53’54.42" N Long:74 ^{o} 05’ 45.65" E) and Tilmati (Lat:14^{o}53’’58.38’’N Long:74^{o}05’’30.56"E) was carried out in order to know the diversity of Marine macro algae (Fig. 1) m with relation to fluctuating environmental parameters like pH, nutrients, Water temperature, Air temperature, Salinity and Dissolved oxygen using pH meter, Thermometer, Refractometer and DO meter respectively. Nutrients analysis was done using

NICE Marine water kit which is improvised method of nutrient analysis following APHA[1] guidelines represented in fig. 2. The rocky intertidal zone was visited fortnightly to record algal species in all three seasons during study period from Jan 2018 to Jan 2019, with reference to Karwar Tide Chart between the Submergence and emergence hour.

Fig. 1 A map showing the study site Majali Beach and Tilmati Beach, Karnataka, West coast

Hydrological Parameters :

Physico chemical parameters at Kawar Coast; Majali and Tilmati are recorded and presented in fig. 2.

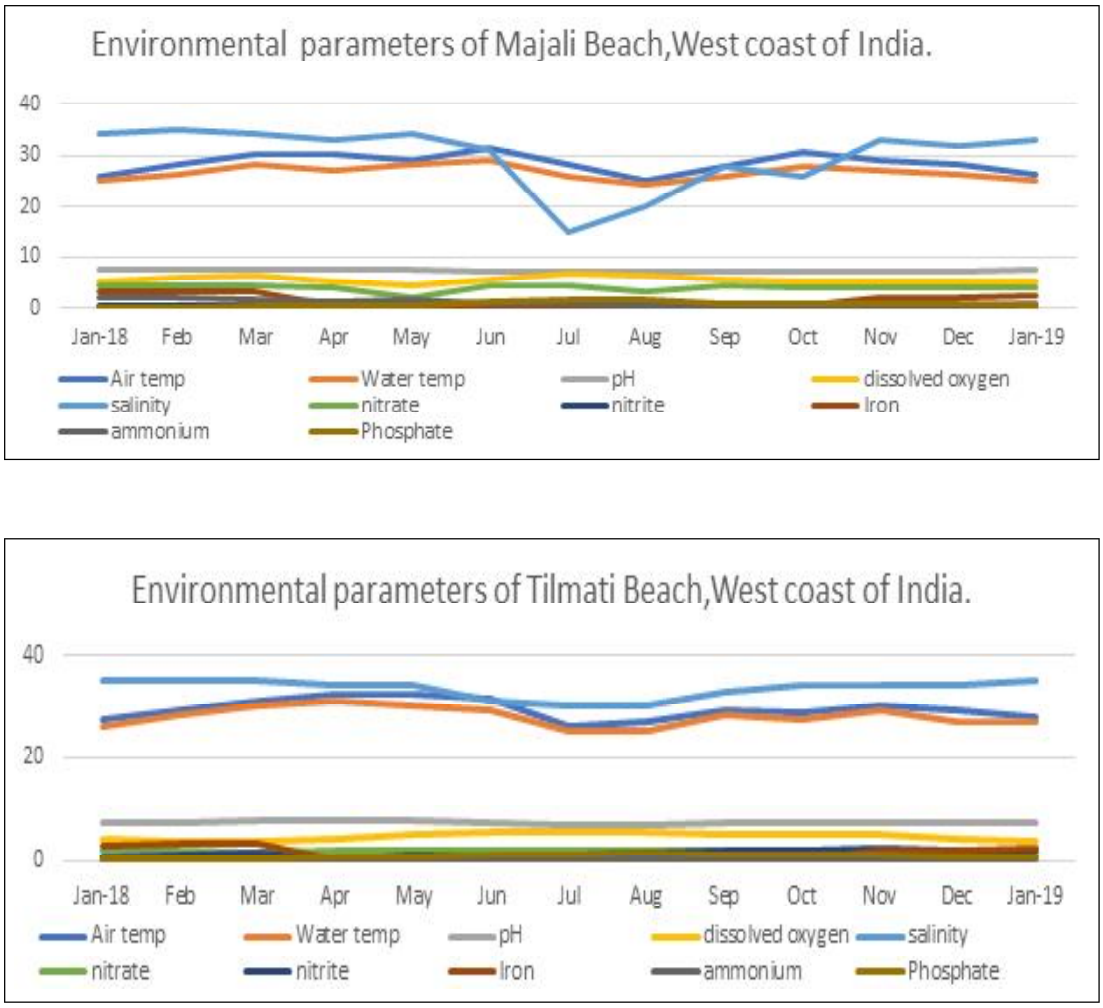

Fig. 2. Environmental parameters of both the sites of Karwar coast,West coast of India.

Seaweeds were handpicked from Intertidal region during submergence of tide using random sampling technique and brought to Laboratory in polythene bags. Fresh samples were viewed under light microscope for species identification. After careful wash and removal of dirt the samples were used for Herbarium preparation, leftover samples preserved in formalin (4%). Occurrence of seaweeds are categorized as abundant (+++), less abundant (++), sparsely abundant (+) and absent (-) based on visible observation made at sampling site. Seasons were classified as Pre Monsoon (Feb-May), South West Monsoon (Jun-Sep) and Post Monsoon (Oct-Jan) represented in Tables 1&2.

Table-1. Occurrence, Abundance and Monthly distribution of Seaweeds at Tilmati Beach, West coast of India

Marine Macro algae (Scientific names)	2018												2019
	J	F	M	A	M	J	J	A	S	O	N	D	J
					Chlorophyta								
Family: Caulerpaceae													
Caulerpa sertularioides	-	+	++	-	-	-	-	-	-	-	-	-	-
Caulerpa taxifolia	-	++	+	-	-	-	-	-	-	-	-	-	-
Family: Bryopsidaceae													
Bryopsis hypnoides	-	-	-	-	-	-	-	-	-	-	+	-	-
Family: Cladophoraceae													
Chaetomorpha aerea	-	-	+++	++	+	-	-	+	+	-	-	-	-
Chaetomorpha linum	-	-	+++	+	+	-	-	-	-	-	-	-	-
Chaetomorpha crassa	-	+	+	-	-	-	-	-	-	-	-	-	-
Cladophora rupestris	-	-	+	+	-	-	-	-	-	-	-	-	-
Cladophora sercenica	-	-	-	+	+	-	-	-	-	-	-	-	-
					Phaeophyta								
Family: Dictyotaceae													
Dictyota dichotoma	-	-	+	+	-	-	-	-	+	+	+	+	+
Padina tetrastromatica	-	+	+	+	+	-	-	-	-	+	+	+	-
Spatoglossum asperum	-	-	+	-	-	-	-	-	-	+	+	+	-
Stoechospermum polypodiodes	-	+	+	+	-	-	-	-	-	+	-	+	-
Family: Sargassaceae													
Sargassum cinereum	-	-	-	-	-	-	-	-	+	-	-	-	-
Sargassum swartzii	-	+	+	+	-	-	+	+	+	+	+	+	+
Sargassum ilicifolium	+	+	+	+	++	+++	-	-	-	-	-	-	-
Sargasssum polycystum	+	+	-	+	+	-	-	-	-	-	+	+	+
Sargassum tenerrium	-	-	+	-	-	-	-	+	+	-	+	+	+
Family: Sphacelariaceae													
Sphacelaria tribuloides	-	-	-	-	-	+	-	-	-	-	-	-	+
					Rhodophyta								
Family: Corallinaceae													
Jania spectabile	+	-	+	+	-	-	-	-	-	-	-	-	-
Family: Gracilariaceae													
Gracilaria gracilis	-	-	-	-	-	-	-	-	+	+	+	-	-
Family: Cystocloniaceae													
Hypnea valentine	-	-	+	+	-	-	-	-	-	+	+		
Hypnea pseudomusciformis	-	+	+	-	-	-	-	-	-	-	-	-	-
Family: Lomentariaceae													
Ceratodictyon intricatum	-	+	+	+	-	-	-	-	-	+	+	-	-

Abundant (+++), less Abundant (++), sparsely Abundant (+) and Absent (-). Pre Monsoon : (Feb-May) South West Monsoon : (Jun-Sep) Post Monsoon : (Oct-Jan)

Table-2. Occurrence, Abundance and Monthly distribution of Seaweeds at Majali, West coast of India.

Marine Macro algae (Scientific names)	2018												2019
	J	F	M	A	M	J	J	A	S	O	N	D	J
Chlorophyta													
Family: Ulvaceae													
Ulva intestinalis	-	-	+	-	-	++	-	-	++	-	+++	-	-
Ulva clathrata	-	-	+++	-	-	+++	-	-	—	-	-	-	-
Ulva lactuca	++	-	-	-	-	++	-	-	+	+++	-	-	++
Ulva compressa	-	-	+	-	-	++	-	-	-	-	+	+	+
Ulva flexuosa	+	-	-	-	—	-		-	+	-	+	-	-
Ulva prolifera	-	+	+	-	-	+	-	-	-	+	++	+	-
Ulva rigida	+	-	-	-	-	-	-	-	-	-	-	-	-
Family: Cladophoraceae													
Chaetomorpha antennina	-	++	+	+	-	-	-	-	-	+	+	+	+
Chaetomorpha linum	-	++	++	-	-	-	-	-	-	-	-	-	-
Cladophora vagabunda	-	+	-	-	-	-	-	-	-	-	+	-	-
Cladophora rupestris	-	-	+	++	-	-	-	+	++	-	-	-	-
Cladophora sercenica	+	+++	+	+	++	-	-	+	+	++	+++	++	+
Rhizoclonium ramosum	-	-	-	-	-	++	-	-	-	+	++	-	++
Rhizoclonium tortuosum	-	-	-	-	-	++	-	-	-	+	++	-	++
Phaeophyta													
Family: Dictyotaceae													
Dictyota dichotoma	-	-	+	++	-	-	-	-	-	+	+	-	-
Padina tetrastromatica	-	-	+	+	+	-	-	-	-	-	-	-	-
Spatoglossum asperum	-	-	+	+	-	-	-	-	-	-	-	-	-
Stoechospermum polypodiodes	-	-	-	-	-	-	-	-	-	+	+	-	-
Family: Sargassaceae													
Sargassum cinereum	-	-	-	-	-	-	-	-	-	+	+	-	-
Sargassum swartzii	-	-	+	+	+	+	+	-	-	-	-	-	+
Sargassum ilicifolium	-	-	+	+	+	+	+	-	-	+	+	+	-
Sargasssum polycystum	-	-	-	-	-	-	-	-	-	+	-	+	+

Sargassum tenerrium	-	-	-	+	+	+	+	-	-	+	+	-	+
Family: Sphacelariaceae													
Sphacelaria tribuloides	-	-	-	--	-		-	-	-	+	+	-	-
Rhodophyta													
Family: Rhodomelaceae													
Acanthophora muscoides	+	++	-	-	-	-	-	-	-	+	-	-	-
Acanthophora specifera	+	++	+	+	-	-	-	-	-	+	+	-	-
Family: Ceramiaceae													
Centroceras clavulatum	-	-	+	-	-	-	-	-	-	++	++	+	+
Family: Gelidiaceae													
Gelidium pusillum	+	+	+	+	+	+	-	-	-	-	-	+	+
Family: Gelidiellaceae													
Gelidiella acerosa	-	-	+	-	-	-	-	-	-	-	-	-	-
Family: Lithophyllaceae													
Amphiroa fragilissima	-	-	++	-	-	-	-	--	-	-	-	-	-
Family: Corallinaceae													
Jania spectabile	-	-	+	++	++	-	-	-	-	-	+	-	-
Family: Halymeniaceae													
Grateloupia lithophila	-	-	-	-	-	+	-	-	-	++	+	-	++
Family: Gracilariaceae													
Gracilaria corticata	++	++	+	+	-	-	-	-	-	+	+	-	-
Gracilaria folifera	+	++	+	+	-	-	-	-	+	+	+	-	-
Gracilaria gracilis	-	++	++	-	-	-	-	+	++	+	+	-	-
Family: Cystocloniaceae													
Hypnea valentine	-	-	++	-	-	-	-	-	-	-	+	++	+
Hypnea pseudomusciformis	-	-	+	-	-	-	-	-	-	-	+	+	+
Hypnea musciformis	-	-	+	+	-	-	-	-	-	-	+	+	-
Family: Gigartinaceae													
Chondrus crispus	-	-	-	-	-	-	-	-	-	-	-	+	+++
Family: Lomentariaceae													
Ceratodictyon intricatum	-	-	+++	++	-	+	-	+	+++	-	-	-	-

Abundant (+++), less Abundant (++), sparsely Abundant (+) and Absent (-). Pre Monsoon : (Feb-May) South West Monsoon : (Jun-Sep) Post Monsoon : (Oct-Jan)

Table-3. Number of Families and species of seaweeds recorded from Karwar, West coast of India

Sl no.		Chlorophyta		Phaeophyta		Rhodophyta	
	Station	Family	species	Family	species	Family	species
1	Majali	2	14	3	10	11	16
2	Tilmati	3	8	3	10	4	5

A total of 40 species was collected from Majali, of which 14species belong to Chlorophyta, 10species to Phaeophyta and 16species to Rhodophyta. A total of 16species were collected from Tilmati, of which 8 species belongs to Chlorophyta, 10 species belongs to Phaeophyta and 5 species belongs to Rhodophyta represented in Table-3. Significant variations in distribution and Abundance was observed during present study. Shannon diversity index for station Majali was higher to Station tilmati which varied from 2.26 in Premonsoon and 2.10 in Post Monsoon to 1.97 in pre-Monsoon and 1.66 in Post monsoon at Tilmati indicating higher taxa with many individuals. Both the stations incurred lower diversity in Monsoon due to Monsoon turbulence. As the initiation of the peak growth season of seaweeds from months of October, November (Post Monsoon) a very complex community of all three groups of algal species was observed, among Chlorophyta, *Chaetomorpha antennina* and *Ulva* species belt looses colour from vibriant green (after reproduction) subsequently changed to white colour belt with absence of species in South west Monsoon. Margalef's richness index was higher at Station Majali 3.65 in Pre-Monsoon where as 2.67 at Tilmati in Pre -Monsoon. Pielou's eveness index indicates maximum at tilmati in Post Monsoon 0.93 and Minimum 0.77 at Majali in Post Monsoon. Brays-curtis similarity shows similar cluster at Tilmati Pre-Monsoon and Monsoon nearly 29.1% and other cluster 59.2% at Majali in Monsoon and Post-Monsoon. (Table-4 and fig. 3)

Table-4. Temporal variability in various Diversity indices of station Majali and Tilmati.

Diversity indices	**MPrem**	**MMon**	**MPom**	**TPrem**	**TMon**	**TPom**
Shannon_H	2.26675	1.4255	2.1058	1.9795	0.672075	1.663
Evenness_e^H/S	0.74185	0.754175	0.55338	0.679725	0.9521	0.87928
Margalef	3.6595	1.91075	3.583	2.67825	0.70195	2.2484
Simpson_1-D	0.842175	0.710525	0.81162	0.806525	0.350675	0.77328
Equitability_J	0.87605	0.84805	0.7758	0.830275	0.4609	0.93286

M-Majali T-Tilmati Prem-premonsoon Mon-Monsoon Pom-Post Monsoon

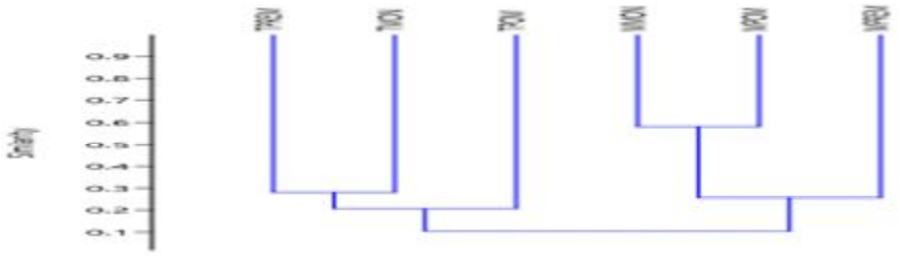

Fig. 3. Dendogram of complete linkage of flora diversity showing similarity matrix of seaweeds seasonwise in intertidal area of two stations.

Seaweeds require wide variety of nutrients for growth especially Nitrogen, Phosphorus, other macro nutrients,micro nutrients and Vitamins[18]. Nutrients load of the water causes eutrophication, toxic planktonic blooms and mostly of aquatic forms. Toxic blooms HAB's green tide dinoflagellates were recorded during May 2018.

Ulva intestinalis has enhanced ability to proliferate blooms in eutrophication with optimal salinity around 15-24% but varies genetically from other *Ulva* species adapt itself to develop and flourish in different salinity regime[5,15,16,20]. From the study nutrients composition of Nitrate,Nitrite and Ammonium influenced the growth of seaweeds in South West Monsoon especially *Ulva* species found as algal mass beds over rocks,entangled over fishing nets,ropes where the salinity ranges below 25ppt. The excretion of one organism in system often supply food for another[22]. *Ulva* species occur in many different habitats fresh,saline waters from rocky pools,ditches and pools occurring as epiphtically,epilithically and as monostramatic floating tubes and masses[2,13,28]. Some species are toxic due to its ability to produce toxins or due to accumulation of minerals in the water area.[14], as found in Tilmati *Caulerpa* species *(taxafolia)* which is invasive in nature known to produce toxins and was found in rocky pools competing other species of Algal diversity.

At Majali, in Division Chlorophyta, species of Family Ulvaceae (*Ulva intestinalis, Ulva prolifera, Ulva clathrata ad Ulva compressa*) showed abundance in season of Southwest Monsoon and Post Monsoon where as Family Cladophoraceae (*Chaetomorpha linum, Chaetomorpha antennia, Cladophora rupestris, Cladophora vagabunda*) showed presence in season of Pre Monsoon and Post Monsoon whereas at Tilmati *Chaetomorpha aerea, Chaetomorpha linum* showed prominence in month of March and presence of invasive species *Caulerpa taxafolia* and *Caulerpa sertularioides* in February and March, *Bryopsis hypnoides* marked importance in month of November.

Distribution and abundance of seaweeds is affected by local environmental parameters and the range of exposure to disturbances, nutrients, dessication factors like temperature, light, competition and salinity regime[12]. Tidal amplitude drives loss of marine

macro algal canopies forming on sea rocky beds/mats. Nitrate uptake is inhibited if Ammonium concentration is found more than 5μM concentration[32], where as opposite trend is followed by Rhodophyta species *Gracilaria folifera*[9]. Seaweeds utilize several inorganic nitrogen sources including Nitrate (1-500μM), Nitrite (0.1-50μM) and ammonia (1-50μM)[28]. Seaweeds are studied in past as well as recent years as auseful nutrient removal strategies, where it is an inexpensive technique which help in friendly environmental clearification[24]. Seaweeds are known to absorb significant amounts of nitrogen nutrients from sewage waters controlling eutrophication and promoting healthy and stable marine ecosystem[3].

In Phaeophyta group at both sites the species of brown algae *Dictyota* dichotomous, *Spatoglossum aspermum, Padina tetrastomica* were found prominently in Pre-Monsoon and Post Monsoon.Speecies of genus *Sargassum* found almost in all three seasons. In Rhodophyta at Majali, Chondrus crispus found in month of Dec and Jan, where as Acanthophora species and *Gracillaria* species in Pre-Monsoon and Post Monsoon season in rocky pools where the nutrient concentration meet the growth of Macro algal diversity. The result findings is in tallied to records of Rode and Sabale[29]. Only few species from Rhodophyta was found at Tilmati site with gravel bed and black soil as topographical feature of the beach.

Seaweeds cope with mechanical stress by having holdfast and cell differentiation as waves moves over them[11]. Maximum diversity of seaweeds was recorded during Pre and Post Monsoon which attributed to favourable environmental parameters were in South west Monsoon the ocean currents are strong enough to ripe the seaweeds. Our research findings are in resemblance to Reddy *et al*.(2004) in seaweeds resources of India, Naik *et al*.[23] in Karwar Bay and by Rode and Sabale[29] in Sindhudurg District of Maharashtra.

Fig. 4. *Chaetomorpha clathrata*

More number of branching noticed when salinity was less then 25ppt, where as less number of branching noticed when salinity was less than 15ppt in *Chaetomorpha clathrata.* (Fig. 4).

Sphacelaria tribuloides

Bryopsis hypnoides

Vibrant green colour of species changed to white colour after reproduction in *Chaetomorpha antennina*

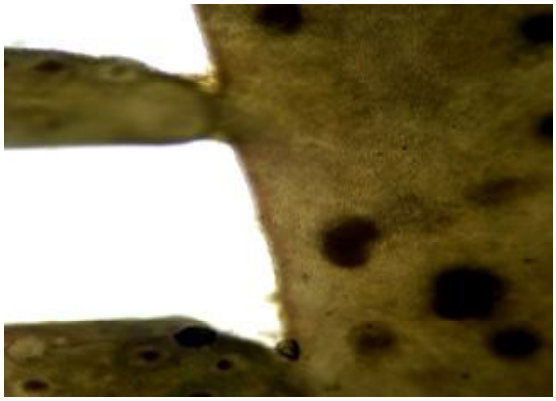

Fig. 5. Various types of Marine algae encountered at Majali and Tilmati beaches, Korwar, west coast of India.
Mastocarpus stellatus- cystocarps (female)existing as knobbles on the thallus in *Grateloupia lithophila*.

This study shows that species of Rhodophyta and Chlorophyta dominante at Majali, Species of Phaeophyta and Rhodophyta dominate at Tilmati in attribution to the environmental parameters especially (Nitrate, Nitrite, Ammonia, Salinity, Water and Air temperatures, Tidal amplitude). Air temperature, water temperature showed narrow range where as Dissolved Oxygen and Salinity showed wider (variation) fluctuation from Pre Monsoon to Post Monsoon. Dissolved oxygen and salinity were inversely related and showed converse relation with diversity of seaweeds (marine macro algae). Nitrite, Nitrate and Ammonia nutrients influenced the vital growth of Algae on supralittoral zones of Majali in contrast to infra littoral zone at Tilmati (gravel bed) Hence the environmental parameters correlate with the algal diversity canopies. The study provide the baseline data for future studies. Algae plays a vital role in the world's ecosystem as a reliable modern introduction to their Kaleidoscopic diversity with enormous implications. They also acts as a primary producers, Pollution indicators, source of several natural products, Biofertilisers and chemicals. The diversity indices speaks about the rarity and commonness of the species, its abundance and evenness at the two staions, dendrogram aids in comparing the abundance and species similarity during the different seasons.

Some marine algre encountered at the study sites have been shown in fig. 5.

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