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SEAWEED DIVERSITY OF ROCKY REEFS OF SOUTHERN KERALA COAST, INDIA

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Abstract: This paper summarizes the reef associated macro algal diversity of Mulloor, Vizhinjam, Kovalam and Thirumullavaram, southern Kerala coast. A total of 26 species of macro algae was reported from these study regions, including 10 species belong to the Phylum Ochrophyta, followed Chlorophyta and Rhodophyta sharing 8 species in each. Among the 26 species reported, only *Bryopsis plumosa* was commonly observed in all the four sites. *Ulva prolifera*, *Asteronema sp*., *Hydropuntia edulis* (Mulloor), *Caulerpa racemosa*, *Chnoospora implexa*, *Spyridia hypnoides* (Vizhinjam), *Palisada perforata* (Kovalam) and *Valoniopsis pachynema*, *Dictyota bartayresiana*, *Dictyota dichotoma* and *Lobophora variegata* (Thirumullavaram) were site-specific. Total algal species diversity was higher in Thirumullavaram (34%; 14 species), followed by Vizhinjam (28%; 12 species), Mulloor (26%; 11 species) and Kovalam (6 species).

Key words: Rocky Reefs, Seaweeds Diversity, South Kerala, Site speficity, Species distribution

INTRODUCTION

Marine macro algae or seaweed is an important biotic component of the unique ecosystems like rocky reefs and many other coastal ecosystems such as estuaries and lagoons (Smith, 2004; Eluvakkal *et al.*, 2010). They have been extensively used for various needs ranging from human and animal food to industrial production of phytochemicals like agar-agar, algin, carrageenan, etc. (Falcao, 2006). The worlds' reported seaweeds or marine macro algae diversity accounts 80% of the world's total plant species diversity, which is mainly found in the intertidal zones and tropical waters of the oceans (Jha and Zi-Ron, 2004). Marine macro algae are important ecologically and commercially to many regions of the world, especially in Asian countries such as China, Japan, Indonesia and Korea (Smith, 2004). Ecological and biological importance of the macro algal communities of near-shore coastal ecosystems are studied worldwide (Mann, 1973). These inter- and sub tidal communities are highly productive (Hurd *et al.*, 2004) and provide habitat complexity for a large range of species, including invertebrates such as *Haliotis iris* and *Evechinus chloroticus*, (Cheshire *et al.*, 1996). Macro algae occupy an important role in structuring the marine environment for a variety of other organisms and have the ability to influence them at various stages of their life cycles (Santelices, 1990; Edgar and Burton, 2000; Hurd *et al.*, 2004; Taylor and Schiel, 2005). For example, the addition of macro algae (*Ecklonia radiata* and *Carpophyllum* species) to a coastal marine habitat can greatly enhance the recruitment of juvenile reef fish such as the wrasse, *Notolabrus celidotus* (Jones,

1984). Furthermore, the abundance of juvenile and adult *N. celidotus* has been found to increase in areas of dense macro algal beds (Choat and Ayling, 1987). The presence or absence of macro algal diversity of temperate reef is strongly influenced by the composition of fish assemblages present in the reef ecosystems (Jones, 1988; Meekan and Choat, 1997; Cole, 2001).

India is endowed with wide range of algal diversity with the country coastal line of 8129 km enjoying the distinct range of habitats supporting rich seaweed biodiversity (Joshi, 2012). Biswas (1945), Desai (1967), Chauchan and Krishnamoorthy (1968) and Agadi (1983) reported on the marine algal ecology, distribution, biochemical composition and taxonomy in different regions of Indian coasts. Luxuriant growth of seaweeds belongs to green, brown and red algae is seen on the south east coast of Tamil Nadu from Mandapam to Kanyakumari which cover an area of 21 islands in the Gulf of Mannar, Gujarat coast, Lakshadweep and Andaman-Nicobar Islands etc. Bombay, Karwar, Ratnagiri, Goa, Varkala, Vizhinjam, Pulicat and Chilka also endowed with seaweed species, these places, chiefly in the North West and South West coast of the country (Kaliaperumal *et al.*, 1989). The marine algal flora of Indian coast are largely known from the effort of Iyenkar (1927) and Børgesen (1930) that carried out extensive studies on seaweed collections from the Indian coast. Subsequently, Thivy (1958), Srinivasan (1973), Krishnamurthy (2000), Desikachary *et al.* (1998) and many others built on this knowledge and published detailed floristic accounts of Indian benthic marine algae. Srinivasan (1973) was the first phycologist to publish a book entitled Icons of Indian Marine Algae and enlisted on about 50 species collected from different Indian coastal waters. Sahayaraj *et al.*, (2014) reported the distribution and diversity of marine micro algae from four south most districts of Tamil Nadu. In an elaborate study, Balakrishnan *et al.* (1986) recorded 127 of algae species belonging to 60 various genera. Panikkar and Ampili (2011) solved the taxonomic ambiguity of *Sargassum* species found in the Kerala coast. Through a study Sulekha, and Panikkar (2006) explained the taxonomy of marine algal diversity of Kollam coast of south Kerala. Palanisamy *et al.* (2013) studied the marine macro algal diversity of Mahe coast in Kerala.

A perusal of available literature reveals that though there are reports on seaweed diversity from Kerala coast, the biodiversity of rocky reef ecosystems and the associated macro algal diversity is least documented. The present study is made with a view to estimate the species composition, abundance, distribution and seasonal variations of seaweeds in rocky reefs of south Kerala coast.

MATERIALS AND METHODS

The study focused to assess the diversity of reef associated seaweeds from the selected sites of Kerala coast. The study area extends from Mulloor, a south most point of the state, belongs to the district of Trivandrum to Thirumullavaram, which is situated in the neighbouring district Quilon. A quadrant having the sampling area of 50 cm^2 was used for the preliminary assessment of species diversity and monthly variations. Observations were done by means of snorkelling, videos and underwater photography also was made using Cannon G 15 underwater cameras fortnightly during the study period. The available species in all the stations were collected and their morphological features were carefully analyzed for species identification with the aid of pioneer references on the taxonomy of seaweeds (Bhandari and Trivedi, 1975; Chennubotla *et al.*, 1987; Gopinathan and Panigrahy, 1983; Jagtap, 1983; Michanek, 1975; Subbaramaiah *et al.*, 1979; Koya, 2000).

RESULTS AND DISCUSSION

A total of 26 species of macro algae was reported during the study, including 10 species belonging to the Phylum Ochrophyta and eight each in Chlorophyta and Rhodophyta (Table 2). Among the 26 species reported, only *Bryopsis plumose* was observed as a common member in all the in four sites. *Caulerpa racemosa, Valoniopsis pachynema, Ulva prolifera, Dictyota bartayresiana, Dictyota dichotoma, Lobophora variegata, Stoechospermum polypodioides, Chnoospora implexa, Asteronema* sp, *Acanthophora spicifera, Palisada perforate, Spyridia hypnoides, Gracilaria millardetii* and *Hydropuntia edulis* were site specific (species show the presence only in that site).

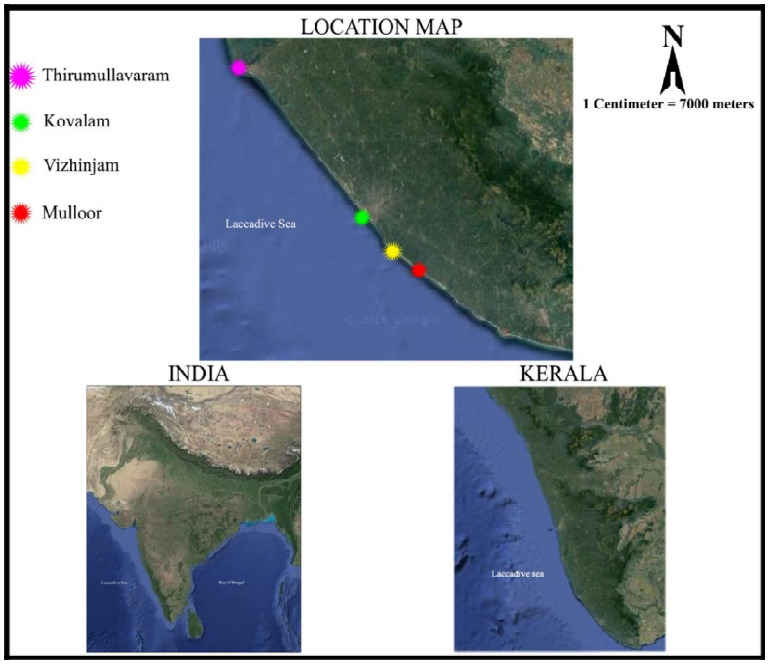

Fig. 1. Map showing the location of study sites along south Kerala, India

Of the 26 species, 10 were from the phylum Ochrophyta (38 %), remaining 16 species divided into two Phyla Chlorophyta and Rhodophyta with 8 for each (31 %) (Fig: 2).

Site-wise algal diversity

Among the four stations IV (Thirumullavaram) showed maximum species representation (14 species), followed by Station II (Vizhinjam; 12

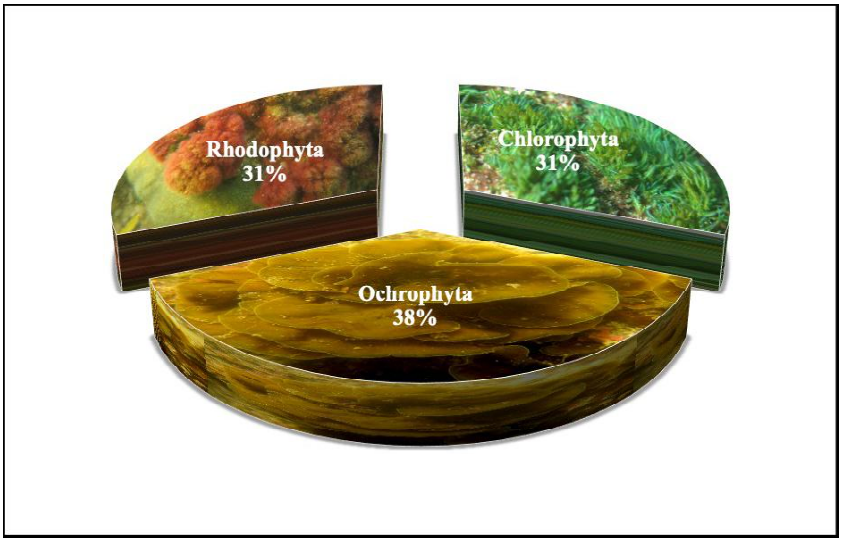

Fig. 2. Percentage contribution of algal species of each Phylum

speices), Station I (Mulloor; 11 species) and Station III (Kovalam; 6 species) respectively (Table 2). For the total algal species diversity Thirumullavaram contributed 34%, followed by Vizhinjam (28%), Mulloor (26%) and Koavalam. Out of 26 algal species reported in the present study, *Ulva prolifera, Asteronema sp, Hydropuntia edulis* (Mulloor), *Chnoospora implexa*, *Spyridia hypnoides* (Vizhinjam), *Palisada perforate* (Kovalam) and *Valoniopsis pachynema*, *Dictyota bartayresiana, Lobophora variegate, Stoechospermum polypodioides, Acanthophora spicifera Gracilaria millardetii* (Thirumullavaram) have shown the site specific distribution.

Table 1. Station-wise algal species diversity

Stations	Class	Phylum	Order	Family	Genus	No of species
Station I	3	3	10	10	10	11
Station II	3	3	8	9	10	12
Station III	3	3	5	6	6	6
Station IV	3	3	6	8	11	14

Table 2. Taxonomy of algal species collected from southern Kerala coast

Scientific Name	Abundance
Empire: Eukaryota	
Kingdom: Plantae	
Phylum: Chlorophyta	
Class: Ulvophyceae	
Order: Bryopsidales	
Family: Bryopsidaceae	
Bryopsis plumosa (Hudson) C. Agardh, 1823	C
Family: Caulerpaceae	
Caulerpa peltata J. V. Lamouroux, 1809	C
Caulerpa racemosa (Forsskal) J. Agardh, 1873	SS (V)
Caulerpa taxifolia (M.Vahl) C. Agardh, 1817	C
Order: Cladophorales	
Family: Cladophoraceae	
Chaetomorpha antennina (Bory de Saint-Vincent) Kützing, 1847	C
Order: Siphonocladales	
Family: Valoniaceae	
Valoniopsis pachynema (G. Martens) Børgesen, 1934	SS (T)
Order: Ulvales	
Family: Ulvaceae	
Ulva prolifera O. F. Müller, 1778	SS (M)
Ulva lactuca Linnaeus, 1753	C
Phylum: Ochrophyta Yellow-green Algae	
Class: Phaeophyceae	
Order: Dictyotales	
Family: Dictyotaceae	
Dictyota bartayresiana J. V. Lamouroux, 1809	SS (T)
Dictyota dichotoma (Hudson) J. V. Lamouroux, 1809	
Lobophora variegata (J. V. Lamouroux) Womersley ex E. C. Oliveira, 1977	SS (T)
Padina gymnospora (Kützing) Sonder, 1871	C
Padina tetrastromatica Hauck, 1887	C
Stoechospermum polypodioides (J. V. Lamouroux) J. Agardh, 1848	SS (T)

Order: Fucales	
Family: Sargassaceae	
Sargassum wightii var. petiolatum Grunow, 1884	C
Order: Scytosiphonales	
Family: Scytosiphonaceae	
Chnoospora bicanaliculata V. Krishnamurthy and Thomas,1977	C
Chnoospora implexa J. Agardh, 1848	SS (V)
Order: Scytothamnales	
Family: Asteronemataceae	
Asteronema sp. Delépine and Asensi, 1975	SS (M)
Phylum: Rhodophyta	
Class: Florideophyceae	
Order: Ceramiales	
Family: Ceramiaceae	
Gayliella fimbriata (Setchell and N. L. Gardner) T. O. Cho and S. M. Boo, 2008	SS (T)
Family: Rhodomelaceae	
Acanthophora spicifera (M. Vahl) Børgesen, 1910	SS (T)
Palisada perforata (Bory de Saint-Vincent) K. W. Nam, 2007	C
Family: Spyridiaceae	
Spyridia hypnoides (Bory de Saint-Vincent) Papenfuss,1968	SS (V)
Order: Corallinales	
Family: Corallinaceae	
Corallina officinalis Linnaeus, 1758	C
Order: Gigartinales	
Family: Solieriaceae	
Kappaphycus alvarezii (Doty) Doty ex P. C. Silva, 1996	SS (M)
Order: Gracilariales	
Family: Gracilariaceae	
Gracilaria millardetii (Montagne) J. Agardh,1885	SS (T)
Hydropuntia edulis (S. G. Gmelin) Gurgel and Fredericq, 2004	SS (M)

Species-wise Seasonal Variation

Station I: Mulloor: Monthly data on the station I shows high degree of seasonal variations in the occurrence and diversity of algal species. All species show a reduction in diversity during monsoon season in two years of study. The species like *Chaetomorpha antennina, Gayliella fimbriata* and *Hydropuntia edulis* are the least observed species in the site. *Padina tetrastromatica, Bryopsis plumosa* and *Kappaphycus alvarezii* were observed more frequenty. *Ulva prolifera, Asteronema sp*. and *Hydropuntia edulis* were present only in Mulloor (Fig. 3).

Station II: Vizhinjam. Most species from this station showed the discontinuous distribution in the study period. Out of 11 species reported from the site only *Corallina officinalis* showed continuous presence in all the seasons. *Caulerpa racemosa, Padina gymnospora, Chnoospora implexa* and *Spyridia hypnoides* showed restricted distribution at Vizhinjam. *Corallina officinalis* and *Kappaphycus alvarezii* were observed in most of the months from the station (Fig. 4).

Station III: Kovalam: The station is recognized by the lowest algal species recorded in the study. *Padina tetrastromatica* and *Corallina officinalis* are the most observed species from the site. *Palisada perforate* is the only species showing site-specific distribution (Fig. 5).

Station IV: Thirumullavaram: This is the station with maximum number of algal species in the study. *Gayliella fimbriata* is the species most common and abundant in the site. Almost half of the reported species are site-specific. *Valoniopsis pachynema,*

Dictyota bartayresiana, Dictyota dichotoma, Lobophora variegate, Stoechospermum polypodioides, Acanthophora spicifera and *Gracilaria millardetii* are the species showing site-specificity in the station. The species like *Gayliella fimbriata, Valoniopsis pachynema, Sargassum wightii* and *Acanthophora spicifera* were recurring in appearance in the station (Fig. 6).

Out of 26 species observed in the study, station IV was noticed with maximum number of species representation of (14) followed by Vizhinjam (12) and Mulloor (11) and Kovalam (6) is highlighted with the lowest number of species representation (Fig. 7). The result covering the site wise species merging, *B. Plumose* is only species observed in all four stations. *Padina tetrastromatica* and *S. wightii* were observed in three stations except Vizhinjam and Kovalam respectively. *C. antennina, C. bicanaliculata* and *K. alvarezii* (Mulloor and Vizhinjam), *C. peltata, P. gymnospora* (Vizhinjam and Thirumullavaram), *C. taxifolia,* (Kovalam and Thirumullavaram), *U. lactuca* (Mulloor and Kovalam), *G. fimbriata* (Mulloor and Thirumullavaram), and *C. officinalis* (Vizhinjam and Kovalam).

By assuming the results of the present study, both physical and chemical factors influence the algal diversity and density. The reef substratum of the study sites showing significant variations in their nature and morphology. Station IV were shown the highest species presence of 14 seaweeds. Among the four stations, station IV has distinction form the other three by the presence of lateritic rocky reefs substrate. These types of reefs are porous in nature which helps to the attachment of algal species. And physical atmosphere (depth and water turbidity) of these sites exerts a significant effect on the floral diversity of the coast. Another significant factor which influencing the diversity of seaweeds in each stations, that is the presence or absence of biological agents like fishes and other algal grazing animals (gastropods and echinoderms). The diversity difference among the sites is mainly due to the physical differences of reef structure and water. The station I (Mulloor) and station IV (Thirumullavaram) are the shallow water reef ecosystems of the coast.

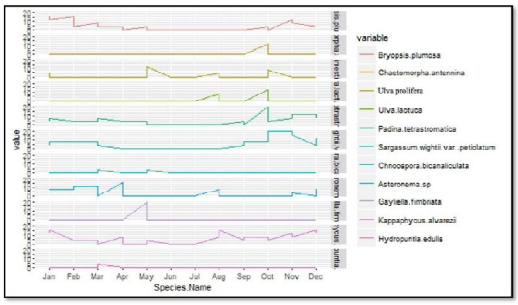

Fig. 3. Monthly species variations at station I

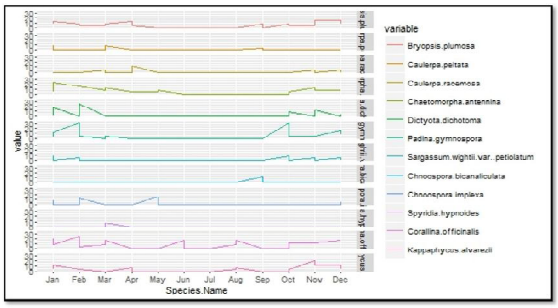

Fig. 4. Monthly species variations at station II

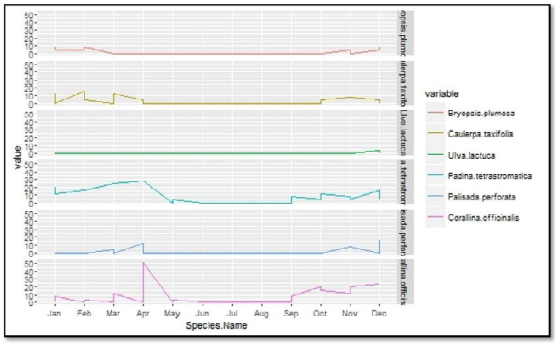

Fig. 5. Monthly species variations at station III

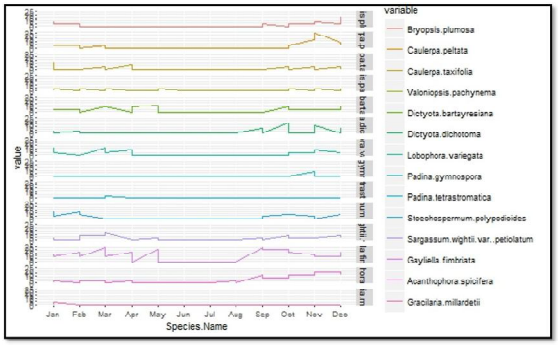

Fig. 6. Monthly species variations at station IV

Table 3. Station-wise representation of algal species

Species	MLR	VZHM	KVLM	TMVRM	Abundance
Bryopsis plumosa (Hudson) C. Agardh, 1823	+	+	+	+	C
Caulerpa peltata J. V. Lamouroux, 1809		+		+	C
Caulerpa racemosa (Forsskal) J. Agardh, 1873		+			R
Caulerpa taxifolia (M. Vahl) C. Agardh, 1817			+	+	C
Chaetomorpha antennina (Bory de Saint-Vincent) Kützing, 1847	+	+			C
Valoniopsis pachynema (G. Martens) Børgesen, 1934				+	R
Ulva prolifera O. F. Müller, 1778	+				R
Ulva lactuca Linnaeus, 1753	+		+		C
Dictyota bartayresiana J. V. Lamouroux, 1809				+	R
Dictyota dichotoma (Hudson) J. V. Lamouroux, 1809				+	R
Lobophora variegata (J. V. Lamouroux) Womersley ex E. C. Oliveira, 1977				+	R
Padina gymnospora (Kützing) Sonder, 1871		+		+	C
Padina tetrastromatica Hauck, 1887	+		+	+	C
Stoechospermum polypodioides (J. V. Lamouroux) J. Agardh, 1848				+	R
Sargassum wightii var. petiolatum Grunow, 1884	+	+		+	C
Chnoospora bicanaliculata V.Krishnamurthy & Thomas,1977	+	+			C
Chnoospora implexa J. Agardh, 1848		+			R
Asteronema sp. Delépine & Asensi, 1975	+				R
Gayliella fimbriata (Setchell & N. L. Gardner) T. O. Cho & S. M. Boo, 2008	+			+	C
Acanthophora spicifera (M.Vahl) Børgesen, 1910				+	R
Palisada perforata (Bory de Saint-Vincent) K. W. Nam, 2007			+		R
Spyridia hypnoides (Bory de Saint-Vincent) Papenfuss,1968		+			R
Corallina officinalis Linnaeus, 1758		+	+		C
Kappaphycus alvarezii (Doty) Doty ex P. C. Silva, 1996	+	+			C
Gracilaria millardetii (Montagne) J. Agardh,1885				+	R
Hydropuntia edulis (S. G. Gmelin) Gurgel & Fredericq, 2004	+				R

And the station II (Vizhinjam) and station III (Kovalam) was observed as the deeper than the 1st and 4th. The station III recorded the lowest diversity. A total of 26 reef associated macro algal species belonging to to 3 phyla, 3 classes, 12 orders, 15 families and 20 genera were identified from the reefs of Mulloor, Vizhinjam, Kovalam and Thirumullavaram come under Thiruvananthapuram and Kollam coasts. Mihir *et al.* (2011) reported the first observation of two species of galactans (*Gracilaria millardetii* and *G. textorii* (Gracilariales, Rhodophyta) from Indian waters. They claimed that these species are growing naturally along the west coast of India. The present study observed the presence of *Gracilaria millardetii* from Thirumullavaram. Lakshmi and Rao (2009) conducted a study on distribution of marine algae on the intertidal rocky surfaces of the Visakhapatnam and identified 31 species belonging to three classes, while this study was able to report 26 species of algal species from three classes.

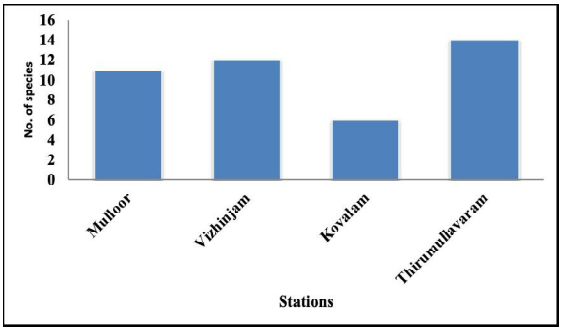

Fig. 7. Algal species diversity at each station along south Kerala

Sathianeson *et al.* (2012) recorded a total of 32 species of algae belonging to 15 Chlorophyta, 8

Phaeophyta and 9 Rhodophyta in the Kudankulam region of Tamil Nadu. Cosman *et al.* (2013) comprehensively studied the diversity and distribution of seaweeds in the Muttom coastal waters, south-west coast of India. Out of the 38 species reported in the study, 19 were from the class of Florideophyceae (50%), 11 species from Phaeophyceae (28.9%), and eight species each from Bryopsidophyceae and Ulvophyceae (10% and 11% respectively).

Kollam coast (Thirumullavaram) was recognized as an exclusive habitat for brown algae and this study supports this observation; brown algal species like *Lobophora variegata, Dictyota bartayresiana* and *Stoechospermum polypodioides* were found only in this region. Ravinesh and Biju Kumar (2010) reported 12 species of macro algae associated with rocky shores of the Thiruvananthapuram coast. Shynu *et al.* (2012) studied the ecology of seaweeds along Thirumullavaram shore line, Kerala and reported 20 species of chlorophytes, 15 species of rhodophytes and seven species of brown algae and this study observed 8 species of chlorophytes, 10 species of ochrophytes (which is not reported previously) and 8 species of rhodophytes associated with reefs. This study is highlighted by the presence of *Dictyota bartayresiana, Dictyota dichotoma,* and *Lobophora variegata* from the site Thirumullavaram. *Corallina officinalis* in Vizhinjam and Kovalam, *Kappaphycus alvarezii* in Mulloor, and *Gayliella fimbriata* in Thirumullavaram are the more frequently observed in the species. Aseer *et al.* (2012) also consider Thirumullavaram coast as an exclusive habitat for diverse seaweeds. Study conducted at the Mahe coast by Palaniswamy *et al.* (2013) reported 14 species of algae, which belong to Chlorophyceae (7 species), Phaeophyceae (l species) and Rhodophyceae (6 species). But this study shows the much higher diversity of seaweeds represented by 26 species.

Sahayaraj *et al.* (2014) reported the distribution and diversity of marine micro algae from four southern districts of Tamil Nadu and recorded the 57 macro algal diversity belongs to 37 genera representing Chlorophyta (18 species), Ochrophyta (14 species) and Rhodophyta (25 species). Rani *et al.* (2015) studied the seasonal variation in biomass and distribution of brown seaweeds (Phaeophyceae) in Gulf of Mannar, Tamil Nadu, India and reported the seasonal variation in the biomass and distribution of brown seaweed (Phaeophyceae). Doss and Rukshsna (2016) studied the distribution pattern of marine seaweeds in the Manapad coastal region and reported a total of 20 species of seaweeds. This study recorded a total of 26 species of macro algae associated with rocky reefs of south Kerala coast and the *Padina tetrastromatica, Bryopsis plumosa* and *Kappaphycus alvarezii*in (station I), *Corallina officinalis* and *Kappaphycus alvarezii* (station II), *Padina tetrastromatica* and *Corallina officinalis* (station III) and *Gayliella fimbriata, Valoniopsis pachynema, Sargassum wightii* and *Acanthophora spicifera* (station IV) were observed in more frequently. Yadav *et al.* (2013) studied the distribution, diversity and conservation of seaweeds of Thiruvananthapuram coast, Kerala and recorded 49 species of seaweeds which belongs to 22 species of Rhodophyceae (45%), 16 of Chlorophyceae (33%), 10 of Pheophyceae (20%) and a species of BGA (2%).

Because of its large and rough surface area, rocky reefs provide an ideal substratum for a variety of organisms such as sea weeds and other invertebrates. The diversity and density of algal species was observed comparatively high in the station IV, especially in the case of submerged algal species. The species such as *Valoniopsis pachynema, Dictyota bartayresiana, Dictyota dichotoma* and *Lobophora variegate* were observed abundantly and site specifically in the station IV. This could be because of the presence of lateritic rocks, which providing the perfect surface for attaching hold fast. In addition to this, presence of higher amounts of organic nutrients in the water may trigger the flourishment of algal species.

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