The Bioscan 10(3): 1123-1129, 2015
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

SEASONAL VARIATION IN BIOMASS AND DISTRIBUTION OF BROWN SEAWEEDS (PHAEOPHYCEAE) IN GULF OF MANNAR, TAMILNADU, INDIA

V. RANI*, P. JAWAHAR AND R. JEYA SHAKILA
Fisheries College and Research Institute,
Tamil Nadu Fisheries University, Thoothukudi - 628 008, INDIA
e-mail: ranidarshini@gmail.com

KEYWORDS
Brown seaweeds
Biomass
Seasonal variation
Number
Gulf of Mannar

Received on :
10.06.2015

Accepted on :
12.09.2015

***Corresponding author**

ABSTRACT
Seasonal variation in the biomass and distribution of brown seaweed (Phaeophyceae) in three locations *viz*,Valinokkam, Hare Island and Amalinagar of Gulf of Mannar, Tamil Nadu were analysed from August 2012 to July 2013. In total, 21 species of brown seaweeds were recorded, which constituted 14 spp of *Sargassum*, 2 spp of *Padina*, 2 spp of *Turbinaria* and one species each of *Spatoglossum*, *Stoechospermum* and *Dictyota*.At Valinokkam, the maximum number of 16 species was recorded followed by 13 species in Hare Island and 9 species in Amalinagar. *Turbinaria*, *Sargassum acinerium*, *S. Plagiophyllum* and *S.swartzii* were recorded only at Valinokkam while *Spatoglossum asperum* and *Stoechospermum marginatum* were found in the other two locations. The total biomasses of brown seaweeds in the intertidal region were estimated as 26.789kg/m^2 in Valinokkam, 16.537kg/m^2 in Hare Island and 3.813 kg/m^2 in Amalinagar. Based on the diversity estimates like Shannon Wiener index, Margaleaf species Richness and Simpson Evenness, Valinokkam and Hare Island were found to be highly diverse than Amalinagar. Bray-Curtis similarity plot estimation showed about 42-55% of location wise similarities and 45-85% seasonwise similarities in the brown seaweed biomass.

INTRODUCTION

Seaweeds are macrophytic algae widely distributed in Indian waters. The brown seaweeds belonging to the Phylum, Heterokontophyta and Class, Phaeophyceae constitute about 1,760 species and are currently arranged in 18 orders in the world (Guiry and Guiry, 2014). In India, there are about 191 species of brown seaweeds among the total of 844 available seaweeds (Oza and Zaidi, 2000). Studies on brown seaweeds have been carried out in the tropical waters of Hong Kong (Kong and Ang, 2004), Japan (Shimabukuro *et al.*, 2007), Thailand (Mayakun and Prathep, 2005) and India (Krishnamoorthy and Baluswamy. 2010; Krishnamoorthy and Ezhili. 2013).

The seaweed resources of Tamil Nadu were studied earlier by Chacko and Malupillai, (1958); Thivy, (1960), Varma and Krishna Rao, (1962); Rao, (1972, 1973); Kannan and Krishnamurthy (1978) and Subbaramiah *et al.* (1979). Chennubhotla *et al.* (1987) indicated the availability of 12 species of brown seaweeds along Tuticorin to Tiruchendur.

Authors have also indicated that species richness and distribution of the brown seaweeds are understudied in most part of the world (Wysora andClerck, 2003; Wang and Phang, 2004; Kitayama and Lin, 2012). Climatological and extreme environmental events can bring new drifted seaweeds to various parts of the world. Such events might have also occurred in the Gulf of Mannar region post Tsunami 2004. As there are no updated reports on the seasonal variation of brown seaweeds in terms of number, biomass as well as species composition in the intertidal area of Gulf of Mannar region, the present study was carried out to assess the biomass and seasonal distribution pattern of brown seaweeds at the three selected locations of this region.

MATERIALS AND METHODS

Study location

A preliminary survey was conducted in the Gulf of Mannar coast from Keelakarai (N 09° 02'31.4 E 78°12'54) to Kulasekarapattinam (N: 08°29' 355'' E 78°07' 254) to select three locations for this study. Three locations namely Valinokkam (N: 08°29.355', E: 78°07.254), Hare Island (N: 08°04.254' E: 78°11.884') and Amalinagar (N: 08°29.355' E: 78°07.254) were selected based on the availability of seaweed (Fig. 1).

Sampling

Sampling was carried out at 3 locations once in a month for a period of one year from August 2012 to July 2013. Intertidal seaweed collection procedure as described by Dhargalkar (2004) was followed for collection of seaweeds. Low tide was identified based on Tide Table in order to sample the algae biomass at the depth of 0-1m of sea bottom. The line transect method was adopted for biomass estimation (Thakur *et al.*, 2008), in which the line transect was laid perpendicular to the coast from high tide to the low tide with the help of long rope at 5m intervals. A quadrant of area 0.25 m^2 made of wooden

planks was used in twelve places to cover an area of 1m² at each sampling locations. A portion of collected seaweeds was cleaned thoroughly in seawater and kept in polythene bags with proper labelling, while another portion was preserved with 5% formalin for identification in the laboratory.

Species Identification

The species identification was performed based on gross morphology and internal features following species genera algarum-1 (Jha *et al.,* 2009; Krishnamoorthy and Baluswamy, 2010; Krishnamoorthy and Ezhil, 2013). The herbarium of each species was sent to Dr. Krishnamoorthy (Late), Director, Krishnamoorthy Institute of Algology, Chennai for confirmation.

Diversity Studies

The diversity indices were estimated using the PRIMER v6 statistical package developed by Plymouth Marine Laboratory, UK (Clark and Warwick, 2001) was used to find out the significant difference for month wise variation among species, on their number, dominance, evenness and richness with respect to each station.

RESULTS

Species Richness

A total of 21 seaweeds belonging to the class, Phaeophyceae were collected from Gulf of Mannar coast (Table.1). They constituted 14 species of *Sargassum*, two species each of *Turbinaria* and *Padina* and one species each of *Spatoglossum*, *Stoechospermum* and *Dictyota*.The diversity, number and biomass of the species varied from season to season and among the locations. At Valinokkam, 16 species of brown algae were recorded, which included 13 species of *Sargassum*, 2 species of *Turbinaria* and 1 species of *Dictyota*, whereas in Hare Island, a total of 13 species were observed, which constituted 8 species of *Sargassum*, 2 species of *Padina* and one species each of *Spatoglossum*, *Stoechospermum* and *Dictyota* . The dominance of *P. tetrastromatica* was observed at Hare Island. Among the brown seaweeds, *S. ilicifolium*, *S. wightii* and *S. oligocystum* were found to flourish well in all the locations.

Species Diversity

The abundance, similarity, dominance, richness, evenness and diversity of brown seaweeds were investigated and results are given in Table 2. The spatial variation in the biomass as assessed by the Shannon-Wiener diversity value showed that the highest H' value was observed at Valinokkam (3.52), followed by Hare Island (2.76) and Amalinagar (2.49). The Taxonomic Diversity and Species Richness were also high at Valinokkam. The Evenness was found to be high at Amali Nagar. The Bray – Curtis similarity values are presented in Figs. 2 and 3. The similarity value was found to be higher between Valinokkam and Hare Island than between Valinokkam and Amalinagar. The dominance plot for 3 locations of Gulf of Mannar is presented in Fig.4. The seasonal variability analysis in Bray-Curtis similarity index indicated higher similarity of abundance within Hare Island. The Analysis of Similarity (ANOSIM) plot for the 3 locations was used to compare three stations for its dominance is presented in Fig. 5.

Biomass and distribution of Brown Seaweeds

The total biomass documented in the intertidal region was 26.789 kg/m² in Valinokkam, 16.537 kg/m² in Hare Island, 3.813 kg/m² in Amalinagar (Table.3). The biomass of intertidal brown seaweeds varied with the season. The highest biomass of *S. oligocystum* was estimated to be 4.944kg fresh wt/m² during July to November in Valinokkam. No seaweed was found during the months of February, April and May in Amalinagar. The fruiting period of majority of brown seaweeds was observed from September to October and during this period, high biomass was recorded in all the three locations. The biomass declined from November onwards during the rainy season ie., North East Monsoon. Later their growth increased from February during hot dry season. The seasonal abundance of algae was poor in Amalinagar. *Sargassum spp*, *Dictyota spp*. and *Padina* spp. were the conspicuous partners that formed major part of the intertidal algal biomass in Gulf of Mannar region.

DISCUSSION

The present study revealed the availability of 21 species of brown seaweeds from the three selected locations of Gulf of Mannar. Earlier Rao (1987) hasdocumented 17 taxa of economically important brown seaweeds in Indian coast, while Thakur *et al.* (2008) has reported 14 species of stranded brown algae at Okha coast while Kalimuthu *et al.* (2000) indicated the availability of 20 species of brown seaweeds at Mandapam. In Gulf of Mannar, the recent survey by Gulf of Mannar Biosphere Trust (Compendium of GOMBRT, 2012) and Sahayaraj *et al.* (2014) reported the availability of ten and nine species of brown seaweeds respectively. In the present study, a maximum of 21 species of brown seaweeds were recorded along the coast of Gulf of Mannar. At Valinokkam, 16 species of brown seaweeds were recorded with the dominance of *Sargassum oligocystum*. This location is characterized by sandy rocks and rough waves. Earlier reports indicated the availability of common brown seaweeds like *Dictyota dichotoma* and *Sargassum ilicifolium* at Valinokkam to Kilakarai (Anon, 1978) and dominance of *Spatoglossum asperum* (Kaliaperumal, 1987) but not *S. oligocystum* as a

Figure 1: Map showing the study area at Gulf of Mannar

Table 1: Species distribution of brown seaweeds of Gulf of Mannar coast during August 2012–July 2013

	Species	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13
	Valinokkam												
1	*Sargassum wightii*(Grev. in J.Agardh)	+ +	+ +	+ +	+ + +	+	+	+	+	+	+ +	+ + +	+ + +
2	*S.oligocystum* Montagne	+ + +	+ + +	+ + +	+ + +	+ +	+ +	+ +	+ +	+ +	+ + +	+ + +	+ + +
3	*S.polycystum* (C. Agardh.)	+ +	+ + +	+ +	+ +	-	-	-	-	-	-	-	+ +
4	*S.gracile*(C. Agardh)	+ +	+ + +	+ + +	+ +	-	-	-	-	-	-	-	+ +
5	*S.ilicifolium*(Turn.) (C. Agardh).	+ + +	+ + +	+ + +	+ +	+ +	+ +	+ +	+ +	+ + +	+ +	+	+ +
6	*S.cristaefolium*(C. Agardh)	+ +	+	+	+ +	-	-	-	-	-	-	+	+
7	*S.plagiophyllum*(C. Agardh)	+ + +	+ +	+ +	-	-	-	-	-	-	-	-	+ +
8	*S.swartzii*(Turn.)(C. Agardh).	+ + +	+ + +	+ + +	+ + +	-	-	-	-	-	-	-	+ + +
9	*S.tennerimum*(J. Agardh)	+ +	+ +	+ + +	-	-	-	-	-	-	-	-	-
10	*S. vulgare*(C. Agardh)(J. Agardh)	+ + +	+ +	+ +	+	-	-	-	-	-	-	-	-
11	*S.echiocarpum* (J. Agardh)	+ +	+ +	+	-	-	-	-	-	-	-	-	-
12	*S. acinerium*(L.) Setchell	+ +	+ +	+ +	+ +	-	-	-	-	-	-	-	+ +
13	*S.duplicatum*(C.Agardh)	+ +	+	+	-	-	-	-	-	-	-	-	+
14	*Turbinaria ornata* (Turner) (J. Agardh)	+ +	+	+ +	-	-	-	-	-	-	-	-	+
15	*T.decurrens* Bony de St Vincent	+ +	+	+ +	-	-	-	-	-	-	-	-	+
16	*Dictyota dichotoma* (Hudson) Lamouroux	+ + +	+ +	+	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ + +	+ + +
	Hare Island												
1	*Sargassum wightii*(Grev. in J. Agardh)	+ + +	+ +	+	+ +	+	+ +	+ +	+	+ +	+	+ +	+ +
2	*S.oligocystum* Montagne	+ + +	+ +	+	+ +	-	+ +	-	+	+	+ +	+ +	+ +
3	*S.polycystum* (C. Agardh.)	+	+ +	+ +	+ + +	+ +	+	+ +	+	+	+ +	+ +	+ +
4	*S.ilicifolium*(Turn.) C.Agardh.	+	+ +	+	+	+	+ + +	+	+	-	-	+	+ + +
5	*S.cristaefolium*(C. Agardh)	+ +	+ +	+	+	+	+	-	-	-	+	+	-
6	*S.tennerimum*(J. Agardh)	+ +	+ + +	+	+ + +	+ +	+ + +	+	+	+	-	+ + +	-
7	*S. echiocarpum* (J. Agardh)	+	+ + +	+ +	+	+	+	+	-	-	+ +	+ + +	+
8	*S. cervicorne*Greville	+ + +	+ + +	+ +	+	-	+	+	-	-	+	+	+
9	*Padina tetrastromatica* Hauck	+ + +	+ + +	+ + +	+ + +	+ +	+ +	+ +	+ +	+ +	+ +	+ + +	+ +
10	*P. boergesenii* Allender& Kraft	+ +	+	+	+	+	+	-	-	+	-	-	+
11	*Spatoglossum asperum* (J.Agardh)	+ +	+	+	+	-	-	-	+	+	+	+ +	+
12	*Stoechospermum marginatum* (C. Agardh.) Kutzing	+ + +	+	+	+	+	-	+	+	+	+ +	+ + +	+ + +
13	*Dictyota dichotoma* (Hudson)	+ +	+	+ +	+	+	+ +	+ + +	+ +	+	+ +	+ + +	+ +
	Lamouroux Amalinagar												
1	*S. wightii*(Grev.in J. Agardh)	-	-	-	+	+	-	-	-	+	-	-	+
2	*S. oligocystum* Montagne	+ +	+ + +	+ + +	+ +	+ +	+	-	-	-	-	+ +	+ + +
3	*S.ilicifolium*(Turn.)C. Agardh.	-	-	-	+	-	-	-	-	-	-	-	+
4	*S.cristaefolium*(C.Agardh)	+ +	+	+ +	+	+	-	-	-	-	-	-	-
5	*S.swartzii*(Turn.)(C.Agardh).	+ +	+ +	+ +	+	-	-	-	-	-	-	-	-
6	*S.tennerimum* (J.Agaardh)	-	+	+ +	-	-	-	-	-	-	-	-	-
7	*S.echiocarpum* (J.Agardh)	+	-	+	+ +	+	-	-	-	-	-	-	-
8	*Spatoglossum asperum* (J. Agardh)	+	+	+	+	-	-	-	+ +	-	-	-	+
9	*Stoechospermum marginatum* (C. Agardh.) Kutzing	-	+	-	+	-	-	-	+	-	-	-	-

+ + +: Dominant; + +: Average; +: Meagre and - Absent

Table 2: Values of Shannon-wiener diversity index (H'(loge), Margalef species richness(d), Pielou'sevenness (J') and dominance(Lambda) of brown seaweeds during all seasons to the three stationsof Gulf of Mannar

	No. of speciesS	(N)	Shannon-wienerDiversity(H'(log_e)	Margalef species richness (d)	Pielou's evenness J'	1-Lambda'
VN	16	70.55838	2.653076	3.524071	0.956895	0.931857
HI	13	77.18815	2.477273	2.761003	0.965818	0.918921
AN	9	24.86506	2.15178	2.489526	0.979317	0.915513

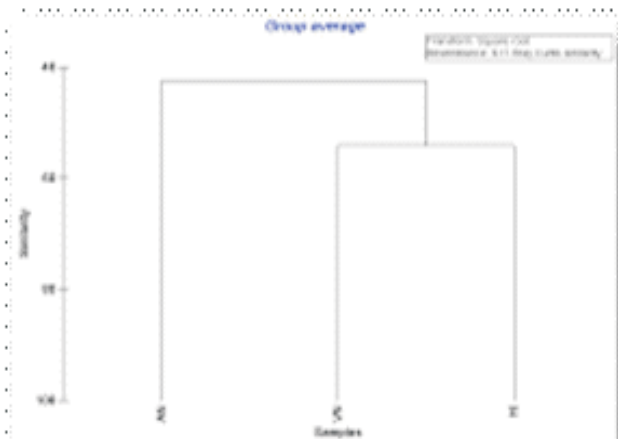

Figure 2: Dentrograms of brown seaweed diversity(No/m2) showing the station wise among the three stations of Gulf of Mannar

Figure 3: Similarity between various seasons in different station of Gulf of Mannar

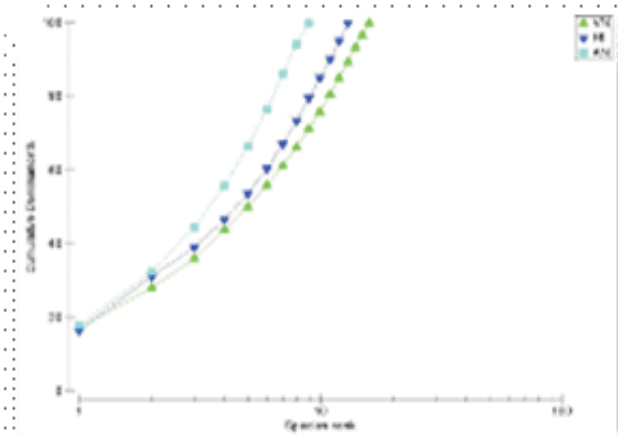

Figure 4: Dominance plot for 3 stations in Gulf of Mannar

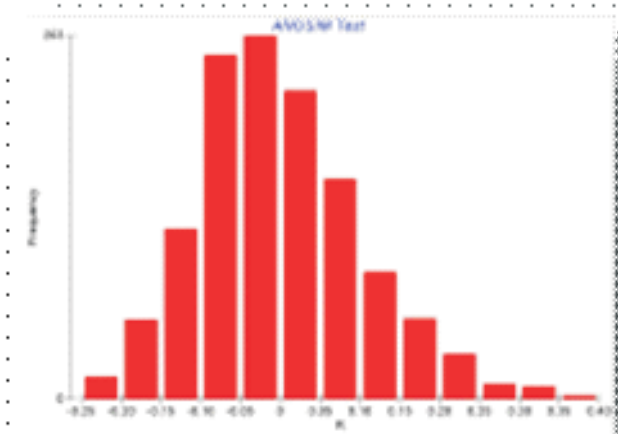

Figure 5: Analysis of Similarity indicating the seasonal variation in similarity of seaweed species collected from thee localities of Gulf of Mannar

dominant species. The occurrence of brown seaweed like *Sargassum wightii, S. myriocystum, S. ilicifolium , Turbinaria conoides, T. ornata* and *T. decurrens* were recored throughout the year and this finding was in accordance with a report of Kalimuthu (2000).

In general, Gulf of Mannar is characterized by hot and arid climate most of the year and enriched with seaweeds, seagrass, coral reef, pearl bank, sacred chank beds, fin and shellfish resources, mangroves and number of endemic species and endangered species. Jagadeesan *et al.* (2013) indicated that the direction of the ocean current around the Indian subcontinent during the South West monsoon is from West to the East, which brings Arabian Sea waters into the Gulf of Mannar. Therefore, the direction of wind towards North-Easterly from June to December at Valinokkam region can influence the great diversity of brown seaweeds during South West Monsoon period. It was observed that the strong sea breeze, distinctive from July to November is responsible for the huge quantity of brown seaweeds along the Valinokkam coast. The seaweed harvest activities by fisherfolk nearby Anaipar and Valimunai during this period also enhance the brown seaweed availability at the shore region.

At Hare Island, 13 species of brown seaweeds were recorded with the dominance of *Padina tetrastromatica, Stoechospermum marginatum, Sargasssum tennerimum, S.echinocarpum, S. polycystum* and *D. dichotoma*.

Sargassum tennerimum exhibited the highest biomass during January in this location, probably due to the fruiting period (Kesava Rao, 1994). This location is characterized with rocky corals, sandy habitats, semi exposed shallow water body and partly surrounded by land with moderate wave action.Water motion has been found to be one of the most important variables influencing seaweeds because it regulates turbidity, light penetration and nutrient availability (Nishihara and Tereda, 2010; Kang *et al.,* 2011). In addition, nutrient enhancement occurred during North East monsoon (Asha and Diwakar, 2007) can also play a crucial role to flourish the algae. Earlier investigations have reported that*S argassum wightii* was the dominant species in Gulf of Mannar throughout the year (Rao, 1969; Kaliaperumal *et al.,* 1987; Chennubhotla *et al.,* 1990; Vasuki *et al.,* 2000; Murugaiyan *et al.,* 2012; Sahayaraj *et al.,* 2014). On the other hand, we found that *S.oligocystum* was the dominant species in Valinokkam while only average distribution of *S.wightii* was found in other locations. The occurrence of *S.oligocystum, S. plagiophyllum, S.swartzii, S. gracile,* and *S. acinerium* was reported for the first time in Valinokkam while the occurrence of *S. echinocarpum* and *S. cervicorne* was reported in Hare Island.

Of the three locations, in Amalinagar, only 9 species of brown seaweeds were observed which was primarily due to the sandy bottom existing in this region. Chennubhotla *et al.* (1990) reported only 12 species of brown algae from Tuticorin to Tiruchendur coast consisting four species of *Sargassum*. The abundance of brown seaweeds in this region was October, November and December probably because of heavy wind and wave action. Shannon Wiener index is used to compare different habitats with a value ranged between 0 to 4.6. In the present study, this index was ranged between 2.48 and 3.52,in Valinokkam which indicated that the seaweed diversity is in good ecological status (Borja *et al.,* 2003, 2004). Similarly, Shannon and Wiener diversity index (H′) was studied for insects in Bhendi ecosystem, in which the index value of herbivores and predators was 2.286 and 2.882 and 2.294 and 2.757, respectively, indicating more or less similar diversification in all the seasons(Chakraborty *et al.,* 2014). Pielou's Evenness index (J′) normally range between 0-1. In the present study, this value fluctuated narrowly in between sampling sites and found to be very close to the range of 0.9. This indicated that 54.11% similarities existed between Valinokkam and Hare Island. ANOSIM was used to compare the three locations of brown seaweeds dominance, which showed that high abundance and biomass were recorded during North East monsoon followed by South West monsoon.Valinokkam and Hare Island represented relatively stable and rich brown seaweed diversity than Amalinagar.

In this study, the total biomass of *S. oligocystum* was 12.51kg/m^2 in Valinokkam, which specifies the dominance of this species. The maximum biomass of this species was recorded as 1.536kg/m^2 during September. Thakur *et al.* (2008) reported a higher average biomass of stranded seaweeds as 3.10kg/m^2 in Okha coast. Untawale *et al.* (1989) stated that the biomass variation in a seaweed species was related to a number of biotic factors including species composition, ecological factors like phenological change, recruitment to the local populations and predation by grazers. In this study, the highest biomass

Table 3: Seaason wise abundance of biomass of brown seaweeds species in the selected locations of Gulf of Mannar during 2012-2013 (Fresh wt g/m^2)

S.No	Brown seaweed species (Fresh wt g/m^2)	Winter (Jan-Feb) STATIONS			Summer (Mar-May)			North East Monsoon (June-Aug)			South East Monsoon (Sep-Dec)			Total Biomass			Mean Biomass		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	*Sargassum wightii*	140	504	-	524	520	-	1033	741	65	806	678	107	2503	2443	172	625.75±192	610.75±59	43±26
2	*S.oligocystum*	1642	160	50	2288	365	-	3644	641	861	4944	679	126	12518	1845	1037	3129.5±735	461.25±122	259.25±202
3	*S.polycystum*	-	396	-	-	345	-	285	463	-	598	811	-	883	2015	0	220.75±143	503.75±105	0
4	*S.gracile*	-	-	-	-	-	-	388	-	-	672	-	-	1060	0	0	265±164	0	0
5	*S.ilicifolium*	245	362	-	400	173	-	484	271	-	806	532	75	1935	1338	75	483.75±118	334.5±76	18.75±19
6	*S.cristaefolium*	-	45	-	-	46	-	541	657	58	547	421	292	1088	1169	350	272±157	292.25±150	87.5±70
7	*S.plagiophyllum*	-	-	-	-	-	-	496	-	-	567	-	-	1063	0	0	265.75±154	0	0
8	*S.swartzii*	-	-	-	-	-	-	685	-	158	1201	-	320	1886	0	478	471.5±292	0	119.5±77
9	*S.tennerimum*	-	279	-	-	105	-	105	347	-	365	922	90	470	1653	90	117.5±86	413.25±177	22.5±23
10	*S.vulgare*	-		-	-	-	-	197	-	-	559	-	-	756	0	0	189±132	0	0
11	*S.echiocarpum*		126	-		203	-	89	839	651	272	769	493	361	1937	1144	90.25±64	484.25±186	286±168
12	*S.cervicorne*	-	125	-	-	30	-	-	287	-	-	487	-	0	929	0	0	232.25±100	0
13	*S.acinerium*	-	-	-	-	-	-	393	-	-	340	-	-	733	0	0	183.25±106	0	0
14	*S.duplicatum*	-	-	-	-	-	-	215	-	-	177	-	-	392	0	0	98±57	0	0
15	*Padina tetrastromatica*	-	148	-	-	268	-	-	227	-	-	246	-	0	889	0	0	222.25±26	0
16	*P.boergesnii*	-	18	-	-	8	-	-	21	-	-	59	—	0	106	0	0	26.5±11	0
17	*Turbinaria ornata*	-	17	-	-	-	-	268	37	-	178	-	-	446	54	0	111.5±67	13.5±9	0
18	*T.decurrens*	-		-	-	-	-	112	12	-	67	-	-	179	12	0	44.75±27	3±3	0
19	*Spatoglossum asperum*	-		-	-	232	152	-	187	69	-	247	132	0	666	353	0	166.5±57	88.25±34
20	*Stoechospermum argimatum*	-		-	-	235	35	-	325	-	-	237	75	0	797	110	0	199.25±70	27.5±18
21	*Dictyotadichotoma*	154	168	-	185	102	-	240	136	-	329	144	-	908	550	0	227±38	137.5±14	0

observed during September and October, was attributed to the fruiting period of the brown seaweeds in Gulf of Mannar. Further, it has been identified that diversity and biomass declined towards the end of South West monsoon due to the fluctuation of salinity which leads to the deterioration of seaweed.In addition to that, the distribution of brown seaweeds depends on the nature of sea shore and wave action. Thus, the use seaweed is an economically important in agricultural crops as it was used as natural organic fertilizer to enhance the growth, yield and nutrient uptake in black gram (Dwivedi *et al.,* 2014). Seasonal variation of brown seaweed distribution in Valinokkam was recorded as 16 species, followed by 13 species in Hare Island and 9 species in Amalinagar. The total biomasses of brown seaweeds in the intertidal region were estimated as 26.789kg/m^2 in Valinokkam, 16.537kg/m^2 in Hare Island and 3.813 kg/m^2 in Amalinagar and the diversity and biomass declined towards the end of South West monsoon period in all three locations.

ACKNOWLEDGEMENT

The authors are thankful to Dr.V.Krishnamoorthy (Late), The Director, Krishnamoorthy Institute of Algology, Chennai, for supporting the identification of brown algae. Authors thank the Dr.G. Sugumar, Dean i/C for continuous support and inspiration during the study. The financial assistance from Tamilnadu Veterinary and Animal Sciences University, Chennai is gratefully acknowledged.

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