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Spatio-temporal diversification and abundance of Intertidal Macroalgal species at Northern District of Karnataka, India

***[1]Gulnaz Qureshi and [2]J.L. Rathod**

Department of Studies in Marine Biology, Karnatak University, Post Graduate Centre, Kodibag, Karwar-581303 (India)
*Author for correspondence afreensyed115@gmail.com

Abstract

Seasonal variation of seaweed diversity was studied in three stations namely Majali, Tilmati and Muduga of Karwar, kanara coast of Karnataka, India. An extensive survey on seasonal changes of seaweed diversity was performed and the data were analyzed for seaweeds abundancy. The rocky intertidal zone was visited fortnightly to record the occurrence of seaweeds during study period from Jan 2018 to Jan 2019. Congreg ated species of seaweeds were collected and segregated according to variable groups from Majali, 40 species, Tilmati consists of 23 species and Muduga consists of 11species.Pre-monsoon and Post-monsoon seasons were viable for seaweeds abundancy whereas Monsoon played important season for some of strong tensile genus *Sargassum* at all three study stations. Abundance of seaweeds (no/m^2) were represented as pie chart in form of percentage showed good numbers in Pre-monsoon and Post-monsoon seasons. Pearson's correlation coefficient 'r' was used to state the weak and strong relationship between parameters and species. The baseline data generated will aid in conservation of the seaweeds in the areas.

Key words : Seaweeds, seasons, correlation and environmental parameters.

Karwar is a sea side taluka and administrative headquarters of Uttara Kannada district lying at mouth of river Kali on the kanara coast of Karnataka, India. According to Indian meteorological department, the prominent seasons prevailed in Karnataka, India are Pre-Monsoon (Feb-May), Monsoon (June-Sep) and Post-Monsoon(Oct-Jan) which owes to the variation in environmental parameters. The Pre-Monsoon season is identified by intense high temperature and salinity,the monsoon season is characterised by heavy rainfall with dilution in salinity parameter. The Post-Monsoon season is known for stable and flourishing environment with high biological productivity. The Uttara Kannada coast is predominantly rocky with relatively short stretches of sandy beaches and capes projecting into the sea. Karwar coast exhibits various geographical demarcation with respect to marine ecosystem with numerous biotopes. The study confined to three rocky cum sandy beaches of karwar, Uttara kannada namely Majali, Tilmati and Muduga.

Majali is a village with rocky beach ahead 12kms towards North from district headquarters, Karwar with Lat 14^{o}53’54.42"N and Long 74^{0}05’ 45.65"E. The topography comprises of sandy as well as rocky shoreline submerged and exposed rocks which harbours enormous rich macro algae and associated fauna.Tilmati Beach with Lat 14^{O}53’’58.38’’N and Long 74^{O}05’’30.56"E is suitated1.5 kms besides Majali beach having dead shells and black soil with rocky boulders, gravel beds and submerged rocks.Muduga Beach with Lat 14^{O}44’ 44.47"N and Long74^{O}13’39.48"E, having sampling area consists of huge boulders generally rough in nature in upper littoral area. Initial appearance of the beach showed low algal diversity and absence of different habitats.

Many researchers from both east and west regions worked on the similar parameters like Rao *et al*[19] studied critical seasonal variation in hydrographical parameters from March 2009 to February 2010 in relation to distribution of seaweeds at Bhimili coast. Sowjanya and Sekhar[20] studied the seasonal and vertical seaweed community variations in littorial systems combating by environmental parameters such as exposure to sun irradiation (Hameed and Ahmed[7], variability in salinity Thom[21], water temperatures McQuaid and Branch[12] and nutrient variability Jhansi and Ramadas[9]. Naik *et al.,*[13] made an attempt to explain the relationship between the environmental condition and macro algae. The aim of study was to analyze the populace growth of seaweeds in relation to the reverberating environmental parameters following the three seasons Pre-Monson, Monsoon and Post-Monsoon, Karnataka, India.

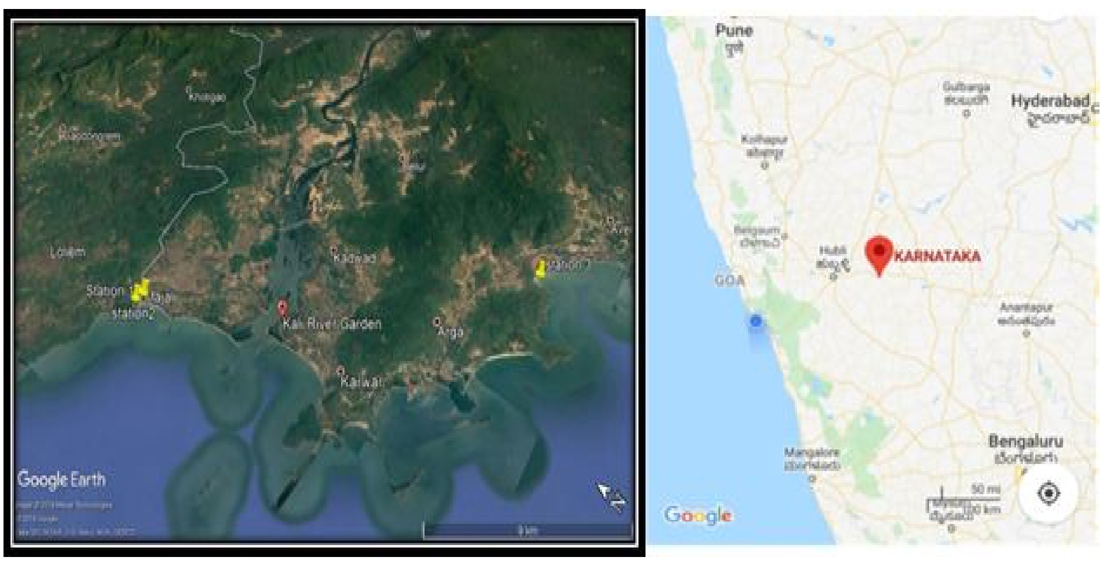


Fig. 1: Geographical position of Study Stations

Hydrological parameters :

The coast receives torrential rain during Monsoon with lower saline conditions whereas the pre-Monsoon season depicts extreme weather profiles. Post-Monsoon season experiences a moderate climate condition with favourable environmental parameters for vital growth of seaweeds. The pH, Water temperature (WT), Air temperature (AT), Salinity (SA) and Dissolved oxygen (DO) using pH meter, Thermometer, Refractometer and DO meter respectively. Nutrients analysis was done using nutrient analysis methods following APHA[1] guidelines.

Water and air temperatures measured in ^{o}C ranged from 22 in post-Monsoon to 30.1 in pre-Monsoon, 24 in post-Monsoon to 32 in pre-Monsoon respectively. Salinity ranged from 30 ppt in Monsoon to 35 ppt in pre-Monsoon. Dissolved oxygen ranged from 3.7 mg/L in pre-Monsoon to 5.2 mg/L in Monsoon. Nutrients like nitrate (NA), nitrite (NI) and ammonium (AMM) measured in micromoles kept fluctuating throughout the sampling period. Nitrate-(7.28 in post-Monsoon to 15.47micromoles in pre-Monsoon); Nitrite-(0.66 in Monsoon to 3.96 in post-Monsoon); Ammonium-(4.3 in post-Monsoon to 31.5 in Monsoon).

Sampling procedures: Inter tidal seaweed collection procedure :

Sampling procedures and analysis of seaweeds were performed with reference to Beligiriranga[4]

The rocky intertidal zone was visited fortnightly to record the occurrence of seaweeds 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. For authentication of the sample taxonomic identification keys were referred, described by Beligiriranga[4] and Wells[22].

Samples were preserved in buffered formalin (4%). Abundance of seaweeds (no/m^2) were represented as piechart in form of percentage. Correlation (Clarke[5]), Pearson's correlation coefficient 'r' signify the numerical measure of degree of linearity between two variables. To study the interaction between seaweeds abundancy and ecological parameters, Correlation methodology was used which inferred strong variance; good and weak correlation as both positive and negative.

Congregated species of seaweeds were collected and segregated according to variable groups from Majali, 40 species of which 14 spp belongs to green algae, 10 spp belongs to brown algae and 16 spp belongs to red algae. Tilmati consists of 23 species of which 8 spp belongs to green algae, 10 spp belongs to brown algae and 5 spp belongs to red algae. Muduga consists of 11 species of which 5spp belongs to green algae, 5 spp to brown algae and 1 spp to red algae. Species checklist of seaweeds (marine macro algae) of Karwar coast encountered at different study stations represented in (Table-1).

Table-1. Species checklist of seaweeds (marine macro algae) of Karwar coast encountered at different study stations

Sl. No.	Family	Codes	Species	Site 1 Majali	Site 2 Tilmati	Site 3 Muduga
1	Ulvaceae	UI	*Ulva intestinalis* (Linnaeus) Nees, 1820	*	-	*
2		UC	*Ulva clathrata* (Roth) Greville, 1830	*	-	*
3		UL	*Ulva lactuca* (Linnaeus),1753	*	-	*
4		UCM	*Ulva compressa* (Linnaeus)Nees,1753	*	-	-
5		UP	*Ulva prolifera* (O.F. Muller 1778)	*	-	-
6		UR	*Ulva rigida* (C. Agardh,1823)	*	-	-
7		UF	*Ulva flexuosa* (Wolfen ex Roth) J.Agardh,1883	*	-	-
8	Cladopho-raceae	CA	*Chaetomorpha aerea* (Dillwyn)Kutz.,1849	-	*	-
9		CL	*Chaetomorpha linum* (O.F. Muller) Kutzing, 1845	*	*	*
10		CC	*Chaetomorpha crassa* Kutzing,1845	-	*	-
11		CAN	*Chaetomorpha antennina* (Bory de Saint-Vincent) Kutzing,1847	*	-	-
12		CV	*Cladophora vagabunda* (Linnaeus, 1753)	*	-	*
13		CR	*Cladophora rupestris* (Linnaeus) Kutzing, 1843	*	*	-
14		RR	*Rhizoclonium ramosum* sp. nov (Z.Zhao & G.Liu,2016)	*	-	-
15		RT	*Rhizoclonium tortuosum* Kützing 1845	*	-	-
16		CSE	*Cladophora sercenica*(Borgesen,1935)	*	*	-
17	Caulerpaceae	CT	*Caulerpa taxifolia* (Vahl) C. Agardh,1817	-	*	-
18		CS	*Caulerpa sertularioides* (S.G.Gmelin) M.A. Howe, 1905	-	*	-
19	Bryopsi-daceae	BP	*Bryopsis hypnoides* (J.V. Lamouroux,1809)	-	*	-
20	Dictyotaceae	DD	*Dictyota dichotoma* (Hudson) Lamouroux,1809	*	*	-
21		PT	*Padina tetrastromatica* (Hauck,1887)	*	*	-
22		SA	*Spatoglossum asperum* (J.Agardh,1894)	*	*	-
23		SP	*Stoechospermum polypodiodes* (C.Agardh) Kutzing, 1843	*	*	-

24	Sargassaceae	SC	*Sargassum cinereum* (J. Agardh),1848	*	*	-
25		SI	*Sargassum ilicifolium* (Turner) C. Agardh, 1820	*	*	*
26		SS	*Sargassum swartzii* C.Agardh,1820	*	*	*
27		ST	*Sargassum tenerrium* (J.Agardh),1848	*	*	*
28		SPO	*Sargasssum polycystum* C. Agardh,1824	*	*	*
29	Sphacela-riaceae	STR	*Sphacelaria tribuloides* (Meneghini),1840	*	*	*
30	Lithophyl-laceae	AF	*Amphiroa fragilissima* (Linnaeus) Lamouroux, 1816	*	-	-
31	Gelidiellaceae	GA	*Gelidiella acerosa* (Forsskal) Feldmann&Hamel, 1934	*	-	-
32	Gelidiaceae	GP	*Gelidium pusillum* (Stackhouse) Le Jollis, 1863	*	-	*
33	Corallinaceae	JS	*Jania (Cheilosporum) spectabile* (Harvey ex Grunow), 1874	*	*	-
34	Gracilariaceae	GG	*Gracilaria gracilis* (StackHouse) Steentoft, L.M. Irvine & Farnham, 1995	*	*	-
35		GCO	*Gracilaria corticata* (J. Agardh, 1852)	*	-	-
36		GFO	*Gracilaria folifera* (Forsskal) Borgesen, 1932	*	-	-
37	Ceramiaceae	CCL	*Centroceras clavulatum* (C. Agardh) Montagne,1846	*	*	-
38		CCR	*Ceramium cialiatum* (J.Ellis) Ducluzeau,1806	-	-	-
39	Lomenta-riaceae	CIN	*Ceratodictyon intricatum* (C. Agardh) R.E.Norris,1987	*	*	-
40	Cystoclo-niaceae	HV	*Hypnea valentine* (Turner 1809) Montagne 1841	*	*	-
41		HP	*Hypnea pseudomusciformis* (Nauer, Cassano & M.C.Olivieria), 2015	*	*	-
42		HM	*Hypnea musciformis* (Wufen) Lamouroux, 1813	*	-	-
43	Rhodom-elaceae	AM	*Acanthophora muscoides* (Linnaeus) Bory de Saint Vincent, 1828	*	-	-
44		ASP	*Acanthophora specifera* (Vahl) Borgesen, 1910	*	-	-
45	Halymen-iaceae	GLI	*Grateloupia lithophila* (Borgesen),1938	*	-	-

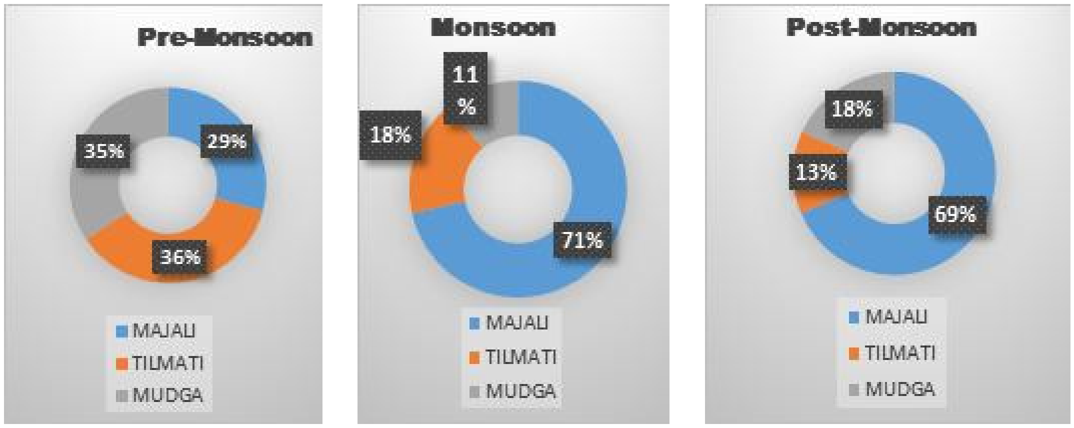


Fig. (2,3,4) Station wise percentage composition of macro algae during all three season at Karwar coast

In Pre-Monsoon, maximum species abundance (density) was recorded at Tilmati (57no/m^2) followed by Muduga (54no/m^2) and minimum at Majali (46 no/m^2). In Monsoon, maximum species were recorded at Majali (45 no/m^2) and minimum at Muduga (7 no/m^2). In Post-monsoon, maximum species were recorded at Majali (83no/m^2) and minimum at Tilmati (16no/m^2). Among all three sites Majali represented maximum density in Post monsoon (83no/m^2) and lowest density in Monsoon at Muduga (7 no/m^2). Station wise percentage composition (density) of macro algae during variable season at Karwar coast represented in (Fig 2,3,4).

The occurrence, diversity and abundance of rich marine macro algal composition of Chlorophyta, Phaeophyta and Rhadophyta along Karwar coast (Majali, Tilmati and Muduga) was attributed to geomorphology of the coast, species requirement of particular substratum as a suitable niche for the algal diversity and immediate environmental parameters as stated by Osman *et al.,*[15] while research through Mutton coastal waters, South Coast of India.

Majali due to its geomorphology and slope gradient, rich tidal pools, substratum served as rich algal recolonization and growth 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 abundance.

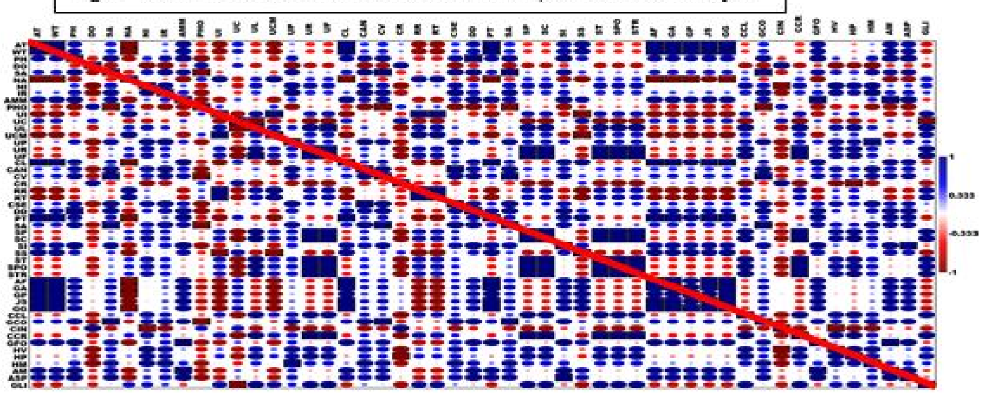
Seasonal distribution of seaweeds reveals that regeneration of seaweeds groups occur in Post-Monsoon and adult matured species were found in Pre-Monsoon season of almost all study stations. The moderate and feasible environmental parameters of Pre-monsoon in January and February make it possible in good collection of species and allow the thriving of species with later months of March and April with extreme environmental parameters. Similar observation was noticed at (Visakhapatnam coast by Rao &

Sreeramulu[18]; Sowjanya and Sekhar[20]; at Karnataka coast by Agadi[2]; at Goa coast by Agadi and Untawale[3]; at Gujarat by Gopalakrishnan[6] which indicated the periodic succession in growth of the seaweed species with relation to changing environmental parameters. Monsoon period experienced torrential rain where most of the intertidal area is submerged and leads to decaying of the algae. Therefore few number of species were encountered from different study sites. During Pre-Monsoon season and Post-Monsoon maximum number of species were recorded compared to Monsoon due to heavy rains, in significant receding of water limits the exploration of area declination in species were noticed. Similar observations of declination of species in Monsoon were recorded by Hodgson[8]; Ogata.[14]; Qadi[17]; Kurve[11].

Pearson linear correlation test (significance level $p<0.05$) were analysed with ten physico chemical environmental parameters with respective sites species. Significant relationship signifies any change in environmental parameters influence immediate change in species abundancy. In all the stations, both negative and positive relationship were inferred between species abundancy and environmental parameters. Positive relationship inferred direct proportionality which signify both increases and decreases (parameter relation with species) simultaneously whereas negative relationship inferred inversely proportionality which signify one increases and other decreases between species and parameters. In the (Fig. 4, 5, 6) the circumference of circle (shades of blue and red) represented the strength of the relationship between species abundancy and environmental parameters mentioned as scale on the right-hand side of the diagram (representing r). Blue colour denotes positive relationship and red colour denotes negative relationship. The circumference of the circles signifies the decreasing or increasing intensity of relationship among different parameters and species.

Fig. 4,5,6 Pearson's Correlation pictodiagram explaining significant relationship between physicochemical parameters and seaweeds abundancy of study stations Majali, Tilmati and Muduga with pearson's correlation coefficient 'r' value range below the diagaonal

Fig:4 Seaweeds abundance correlation with parameters at Majali



At Majali, the correlation pictodiagram represented in (Fig. 4) explained significant relationship between species abundancy and environmental parameters stated as below. *Cladophora vagabunda* (CV), *Spatoglossum asperum* (SA) were positively correlated with salinity and negatively correlated with pH. *Chaetomorpha linum* (CL), *Padina tetrastromatica* (PT), *Amphiroa fragilissima* (AF), *Gelidiella acerosa* (GA), *Gelidium pusillum* (GP), *Gracilaria gracilis* (GG) were positively correlated with air and water temperature and negatively correlated with nitrate.

Dictyota dichotoma (DD) a brown algal species was positively correlated with pH. *Jania spectabile* (JS) a red algae positively correlated with air and water temperature, *Gracilaria corticata* (GCO) was positively correlated with salinity and negatively correlated with phosphate. *Ceratodictyon intricatum* (CIN) was negatively correlated with nitrite, Gracilaria *folifera* (GFO), *Acanthophora muscoides* (AM) were positively correlated with ammonium.

At Tilmati, the correlation pictodiagram represented in (Figure: 5) significant relationship between species abundancy and environmental parameters stated as below.

Almost many of green algal species *Chaetomorpha linum* (CL), *Chaetomorpha crassa* (CC), *Caulerpa taxifolia* (CT), *Caulerpa sertularioides* (CS), *Cladophora sercenica* (CSE), *Cladophora rupestris* (CR), and a red alage *Hypnea pseudomusciformis* (HP) were positively correlated with air temperature

Brown algal species such as *Padina tetrastro-matica* (PT) was negatively correlated with phosphate; *Sargassum cinereum* (SC) was negatively correlated with ammonium and salinity; *Sargassum swartzii* (SS), *Sargasssum polycystum* (SPO) were negatively correlated with dissolved oxygen and *Sargassum tenerrium* (ST) was positively correlated with phosphate. *Two of red algal species Jania spectabile* (JS) and *Ceratodictyon intricatum* (CIN) were positively correlated with water temperature.

Fig:5 Seaweeds abundance correlation with parameters at Tilmati

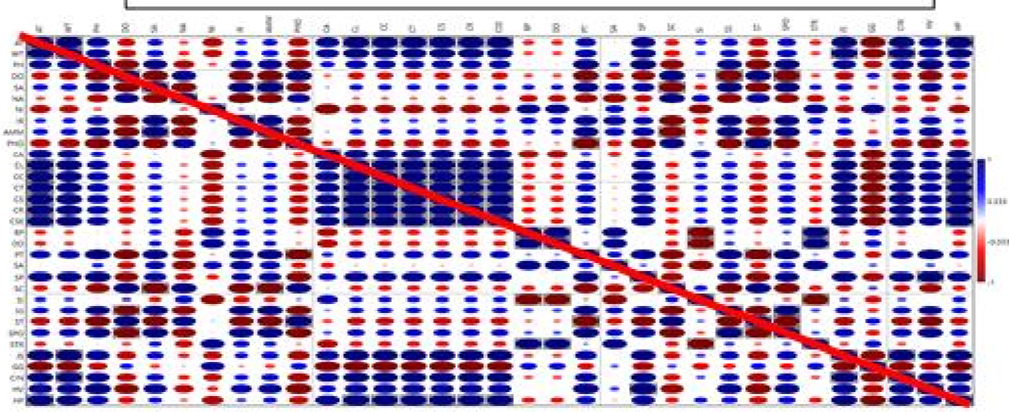
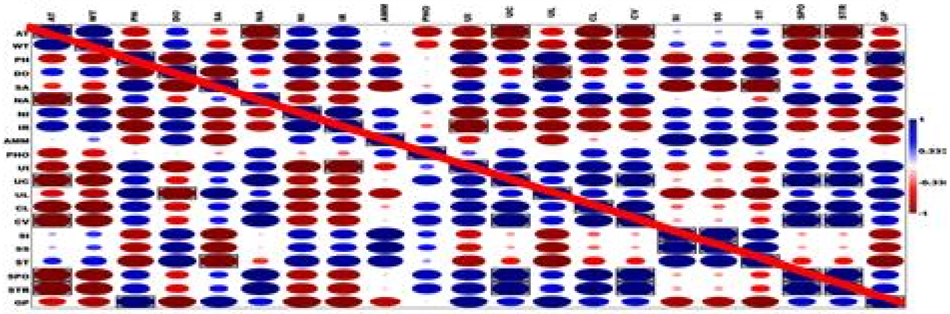


Fig:6 Seaweeds abundance correlation with parameters at Muduga



At Muduga,the correlation pictodiagram represented in (Figure: 6) explained significant relationship between species abundancy and environmental parameters stated as below.

Ulva clathrata (UC), *Cladophora vagabunda* (CV) were negatively correlated with air temperature;*Ulva intestinalis* (UI) was negatively correlated with iron content; *Ulva lactuca* (UL) was negatively correlated with dissolved oxygen; *Cladophora vagabunda* (CV), *Sargasssum polycystum* (SPO), *Sphacelaria tribuloides* (STR) were negatively correlated with air temperature ;*Sargassum tenerrium* (ST) was negatively correlated with Salinity and *Gelidium pusillum* (GP) was positively correlated with pH.

Jansi and Ramadhas[9]; Naik *et al.,*[13] and Yogamoorthi[23] have pointed that four types of seaweeds abundance were affected by the level of nutrients (ammonia, nitrate and phosphate) when remained moderately high. Similar records were represented by correlation in present study where the nutrients play important relationship with seaweeds, positive with green algae, negative with red and brown algae. In the present study, ammonium concentrations were recorded as parts more than nitrates on which the seaweeds species thrived upon, *Gracilaria folifera* was positively correlated with ammonium concentration as seen in Perason's Correlation. Studies on seasonal fluctuation of nutrients (phosphorus and nitrogen) revealed essentiality for the growth of seaweeds Kokabi *et al*[10] and development of green algae mostly *Ulva* spp which is among the fast growing species Philips and Hurd[16].

The study aids in the spatio-temporal variation of seaweeds abundance in relation to the various fluctuating environmental parameters. This study provides evidence that the most abundantly distributed seaweed species in Majali area are green and brown seaweeds whereas at Tilmati brown algal species were prominent. However, brown seaweed namely; *Sargassum* species are found to be the commonest in the area most exposed to harsh environment and found to be negative with salinity,air temperature and dissolved oxygen studied from three stations. Red algae was found to be positively correlated with all parameters except nitrate and nitrite. Green seaweeds was found to be positively correlated with air temperature. Further observation stated changing patterns of distribution in communities of seaweeds among three stations. It is pronounced that there is a marked difference of respective seaweed communities in study stations. However, further investigations are essential to establish assertive correlations among seaweed community, structure and distribution in these study stations.

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