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Congregated Seaweed abundance and diversity with vibratory environmental parameters of Karwar coast, Karnataka, India

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Abstract

The aim of the present study exploration centred on divergent assemblage of the marine macro algae visualized from Majali coast, Karnataka from Jan 2018-Jan 2019, to apprehend the seaweed diversity with consequential reverberating environmental parameters. Seaweed diversity was studied using random sampling method for computing the ecological diversity indices through three seasons Pre-Monsoon, Monsoon and Post-Monsoon, to know the richness and diverse nature in species population. In the present study, ANOVA one way ($p<0.05$) was performed between total seaweed abundance and the hydrological parameters, where the Tukey's test projected the effect of environmental parameters on seaweeds abundance. The result showed significant differences in the mean of parameters during seasons in comparison to seaweeds diversity. The hydrological parameters differ with seasonal periods, geographical location and temporal variation. All the parameters showed significant changes in mean except for salinity,depicting some species like *Ulva* are capable of vital growth in all seasons, even in lesser than 15ppt or zero salinity regime. Clustering was used for representation of dendrogram using Bray-Curtis Similarity for identifying the seasonal variation in species assemblages and similarities between the groups.

Key words : Marine macro algae, seasons, clustering, ANOVA.

Algae (micro and macro) are found in diverse habitats such as water (fresh water,marine or brackish), land, they grow as an endophytic, epiphytic ,endozoic and even in extreme conditions possessing chlorophyll like terrestrial plants (Sahoo and Seckbach[23], Lee[9], Pereira and Neto[15]). Marine algae are the association of the photosynthetic picoplanktonic occupying the world ocean to megascopic, pluricellular kelps of littorial habitats attached to rocky or sandy surfaces categorized into three groups based on cellular architecture ,its chromatic absorption and reflexive of colors as green, red and brown[8,26].

Seaweeds are of various morphology (types and sizes), composition, forms like filaments, foliose, encrusting, coenocytic, cartilaginous and colours growing and settling on various rocky substratum through holdfasts in rock pools, crevices, couloirs (or large crevices), ledges and overhangs whereas few species found afloat as algal mats or colonies.[11,28]. The present knowledge on Indian marine macro algae largely emanate from the publications of Boergesen[3] who carried out research on rich algal vegetation of different coasts like Bombay and Tuticorin in southern India. Sahayaraj *et al.,*[22] put forth formative researcher on study of occurrence and seasonal variations of seaweeds from Southern districts of Tamil Nadu where a total of 1050 specimens of macroalgae were collected from July 2009 to June 2010.

Naas[12], Venkataraman and Wafar[27] listed 39 species of seaweeds from Karnataka coast. Kaladharan *et al.,*[7] communicated report on coastal flora of Karnataka coast comprising planktonic algae (phytoplankton), macroalgae and seagrass collected from estuaries, sea, 48 intertidal regions and 12 islands spread over 9 grids from Mangalore to Karwar. Rao *et al.*[17] studied critical seasonal variation (November and February) with environmental parameters, comparison and distribution of 39 marine algal species at three different study sites of Bhimili coast from March 2009 to February 2010. The variation in number of seaweeds recorded was attributed to significant changes in the environmental parameters of different locations. In the present study, ample diversity of seaweeds was encountered in rocky pools, cervices and littorial habitat. Hence in the study the diversity and abundance of seaweeds of Karwar coast were determined with the fluctuating parameters during three seasons to enhance the information of availability on congregated seaweeds at the coast.

Sampling procedures :

The rocky intertidal zone of Majali village (Fig. 1) in Karwar (Lat 14^0 53' 54.42" N and Long $74^0$05' 45.65"E) was visited fortnightly to record the species in all three seasons namely pre-Monsoon (Feb-May), Monsoon (Jun-Sep) and post-Monsoon represented in (Table-1) during study period

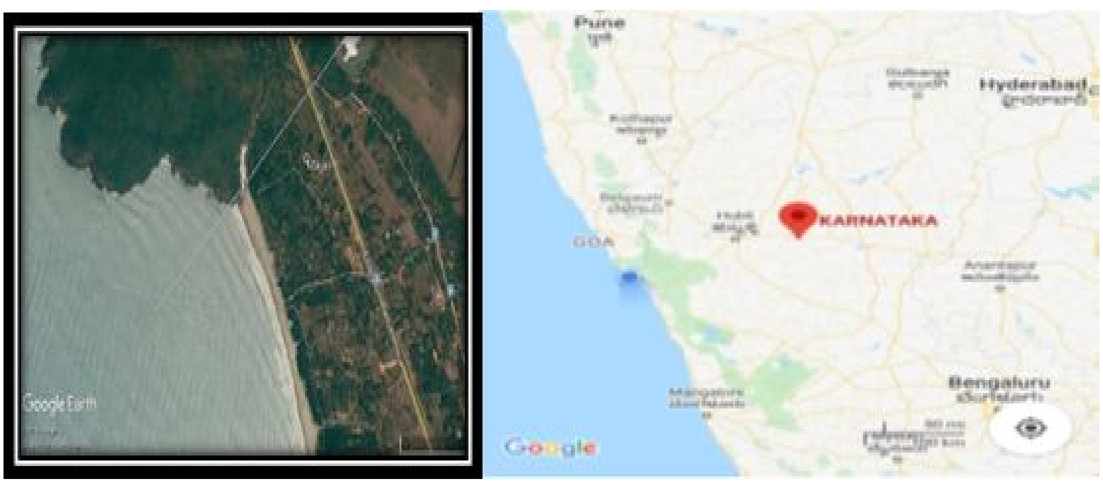

Fig. 1. A map showing the study site Majali Beach, Karnataka, West coast of India

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 Beligiriranga[2]. For authentication of the sample taxonomic identification keys were referred, described by[2,28]. Samples were preserved in buffered formalin (4%). Abundance of seaweeds (No/m^2) were represented by Ecological diversity indices (Table-2) and in percentage in (Table-1).

Environmental parameters:

Laboratory mercury thermometer was used for measuring the air temperature and water temperatures and expressed in °C. To determine the salinity of seawater, titrimetric method (Mohr's Knudsen) given by APHA[1], were followed. The reading expressed as ppt. The dissolved oxygen in seawater was calculated by titration method "Winkler's method" and expressed as mg/L (APHA[1]). Nutrients: Water samples were collected from the respective study sites to estimate the amount of different nutrients which includes nitrate, nitrite, ammonium, iron content and phosphate as per standard methodology described by APHA[1] and values expressed in µ M. The hydrogen ion concentration (pH) of water samples were estimated at study site itself by using portable pH meter.

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[4].

Clustering :

The similarity of groups was found out with the help of cluster analysis. Clustering by[5], was used for representation of dendrogram using Bray-Curtis Similarity for identifying the seasonal variation in species assemblages and similarities between the three groups. 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 Σ indicated the matrix overall rows, k represent the absolute value of the sample.

One-way ANOVA: One-way ANOVA was carried out for hydrological parameters and seaweeds abundancy to show the significant difference in parameters means over seasons ($p<0.05$, significant; $p>0.05$, nonsignificant). Tukey's test was used to show the significant and insignificant relation of seaweeds with hydrological parameters.

Pearson linear correlation test (significance level $p<0.05$) were analysed with ten physico -chemical environmental parameters

Table-1. Percentage density (abundance) of seaweeds of Majali, along Karwar coast

Sl. No.	Family	Codes	Species	PREM (%)	MON (%)	POM (%)
			Chlorophyta			
1	Ulvaceae	UI	*Ulva intestinalis* (Linnaeus)Nees,1820	2	5	4
2		UC	*Ulva clathrata* (Roth) Greville, 1830	6	5	0
3		UL	*Ulva lactuca* (Linnaeus),1753	0	1	2
4		UCM	*Ulva compressa* (Linnaeus)Nees,1753	1	2	2
5		UP	*Ulva prolifera* (O.F. Muller 1778)	3	2	2
6		UR	*Ulva rigida* (C. Agardh,1823)	0	0	2
7		UF	*Ulva flexuosa* (Wolfen ex Roth) J. Agardh,1883	0	1	0
9		CL	*Chaetomorpha linum* (O.F. Muller) Kutzing,1845	6	0	0
10	Cladophoraceae	CAN	*Chaetomorpha antennina* (Bory de Saint-Vincent) Kutzing,1847	4	0	3
11		CV	*Cladophora vagabunda* (Linnaeus,1753)	2	0	0
12		CR	*Cladophora rupestris* (Linnaeus) Kutzing,1843	3	4	0
13		RR	*Rhizoclonium ramosum sp. nov* (Z. Zhao & G.Liu, 2016)	0	30	24
14		RT	*Rhizoclonium tortuosum* Kützing 1845	0	30	24
15		CSE	*Cladophora sercenica* (Borgesen,1935)	10	2	5
			Phaeophyta			
16	Dictyotaceae	DD	*Dictyota dichotoma* (Hudson) Lamouroux, 1809	2	0	0
17		PT	*Padina tetrastromatica* (Hauck,1887)	2	0	0
18		SA	*Spatoglossum asperum* (J.Agardh,1894)	1	0	0
19		SP	*Stoechospermum polypodiodes* (C. Agardh) Kutzing,1843	0	0	0
20	Sargassaceae	SC	*Sargassum cinereum* (J. Agardh), 1848	0	0	0
21		SI	*Sargassum ilicifolium* (Turner) C. Agardh, 1820	2	1	2
22		SS	*Sargassum swartzii* C. Agardh, 1820	2	1	0
23		ST	*Sargassum tenerrium* (J. Agardh),1848	1	1	1
24		SPO	*Sargasssum polycystum* C.Agardh,1824	0	0	1
25	Sphacelariaceae	STR	*Sphacelaria tribuloides* (Meneghini),1840	0	0	1
			Rhodophyta			
26	Lithophyllaceae	AF	*Amphiroa fragilissima* (Linnaeus) Lamouroux, 1816	2	0	0

27	Gelidiellaceae	GA	*Gelidiella acerosa* (Forsskal) Feldmann &Hamel, 1934	1	0	0
28	Gelidiaceae	GP	*Gelidium pusillum* (Stackhouse) Le Jollis, 1863	4	2	2
29	Corallinaceae	JS	*Jania(Cheilosporum) spectabile* (Harvey ex Grunow), 1874	17	0	0
30	Gracilariaceae	GG	*Gracilaria gracilis* (Stack House) Steentoft, L.M.Irvine & Farnham, 1995	5	3	1
31		GCO	*Gracilaria corticata* (J. Agardh, 1852)	4	0	2
32		GFO	*Gracilaria folifera* (Forsskal) Borgesen,1932	4	1	1
33	Ceramiaceae	CCL	*Centroceras clavulatum* (C. Agardh)	1	0	3
34		CCR	Montagne, 1846 *Ceramium cialiatum* (J.Ellis)Ducluzeau,1806	0	0	2
35	Lomentariaceae	CIN	*Ceratodictyon intricatum* (C.Agardh) R.E. Norris, 1987	4	8	0
36	Cystocloniaceae	HV	*Hypnea valentina* (Turner 1809) Montagne 1841	2	0	3
37		HP	*Hypnea pseudomusciformis* (Nauer, Cassano & M.C. Olivieria), 2015			
38		HM	*Hypnea musciformis* (Wufen) Lamouroux, 1813	2	0	6
39	Rhodomelaceae	AM	*Acanthophora muscoides* (Linnaeus) Bory de Saint Vincent,1828	3	0	2
40		ASP	*Acanthophora specifera* (Vahl) Borgesen, 1910	3	0	3
41	Halymeniaceae	GLI	*Grateloupia lithophila* (Borgesen),1938	0	1	0

with respective seasonal species. In the (Fig. 6, 7, 8) 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 at $p<0.05$.

A total of 40 species were recorded during quantitative assessment of seaweeds, among which 14 spp belongs to green algae,10 spp belongs to brown algae and 16 spp belongs to red algae. A checklist of the different seaweed species abundance (%) recorded during the study period was presented in Table-1 classwise.In present study the red and green algae dominance outnumbered brown algae,similar observations were noticed by (Naik *et al.,*[13]) at Devagad Island) and the Kurumagad Island along Karwar Bay. Of total 32 species of seaweeds belonging to 19 genera comprising red, brown and green groups with

8, 5, 6 genera respectively was recorded. (Sahayaraj *et al.,*[22]) putforth formative researcher on study of occurrence and seasonal variations of seaweeds from Southern districts of Tamil Nadu. A total of 1050 specimens of macroalgae were collected from July 2009 to June 2010 which included 25 taxa to Rhodophyta, 18 taxa to Chlorophyta and 14 taxa to Ochrophyta with similar observation as in the present studies.

Algae was mostly distributed in the lower shore rockpools which was densely filled with a number of foliose and filamentous red and green species. Large rockpools can provide a wealth of algal diversity including many morphological forms such as cartilaginous forms, gelatinous, filamentous and encrusting and erect coralline forms.Turfs of algal species consisting of numerous red, brown and green species were locatedin moist crevices, on the sides of boulders, steep rock outcrops and on overhangs.Many of the brown species are quite conspicuous and easier to locate such as the *Sargassum* species which often cover large areas or the intertidal and subtidal. The green algae *Ulva* spp. and *Chaetomorpha antennina* are more commonly found on the upper shore often forming mats on the rock surface but are also found attached to larger algae.Seasonal difference in appearance due to new growth or reproductive bodies were noticed, seaweeds with thin membranous parts may decompose in monsoon storms, leaving only the tougher midrib or stipe.

Diversity indices refers to statistical representation of the types of species into quantitative measures amongst community in various aspects like Shannon diversity, Species evenness and Species richness.

Univariate statistics such as Shannon Weiner Index, Species evenness and Species richness was calculated for study station seasonally, depicted in as mean in (Table-2). At Majali, highest mean species diversity index was found in pre-Monsoon season with value (2.26) and lowest in Monsoon (1.42). Species evenness was found less even in pre-Monsoon season with value (0.87) and more even in post-Monsoon (0.77). Species evenness of species are mostly influenced by substratum, coast geomorphology, wave action, predatorship and also other environmental parameters. Species richness was found in pre-Monsoon season with value (3.65) and lowest mean species richness in Monsoon (1.91).

Shannon diversity index was higher which varied from 2.26 in Pre-Monsoon and 2.10 in Post-Monsoon indicating higher taxa with many individuals (Table-2). Maximum diversity of seaweeds recorded during pre-monsoon and post-Monsoon was attributed to favourable environmental conditions with respect to variables like temperature, salinity, dissolved oxygen, nutrients and settling of algae during monsoon. Similar observations were noticed by Pawar and Mohammad[14] at Uran coast, Rao *et al.,*[17] surveyed at the Bhimili east coast of India, Reddy *et al.,*[19] recorded in seaweed resources of India, Rath and Adhikary[18], Prasanna and Rao[16], Sarojini *et al.,*[24], Naik *et al.*[13], inferred during their study of environmental parameters at Karwar bay, Rode and Sabale[21] inferred during their study at Malvan and Kunakeshwar area's in Sindhudurg district of Maharashtra.

Table-2. Univariate statistics calculated for three seasons during study period along Karwar coast

Ecological diversity indices	Pre-Monsoon	Post-Monsoon	Monsoon
Shannon index	2.26	2.10	1.42
Species Evenness(Equitability)	0.87	0.77	0.84
Margalef's index	3.65	3.58	1.91

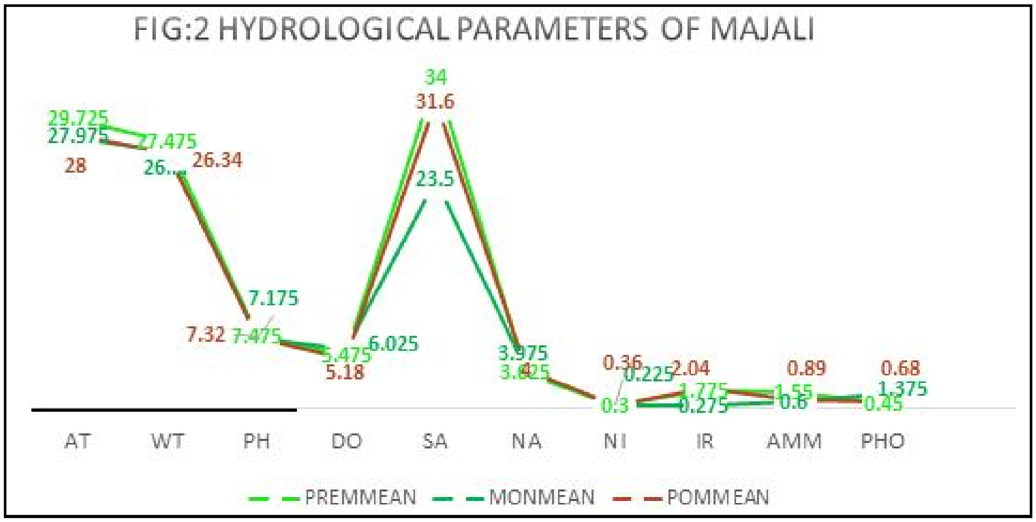

Fig. 2. Hydrological parameters of majali

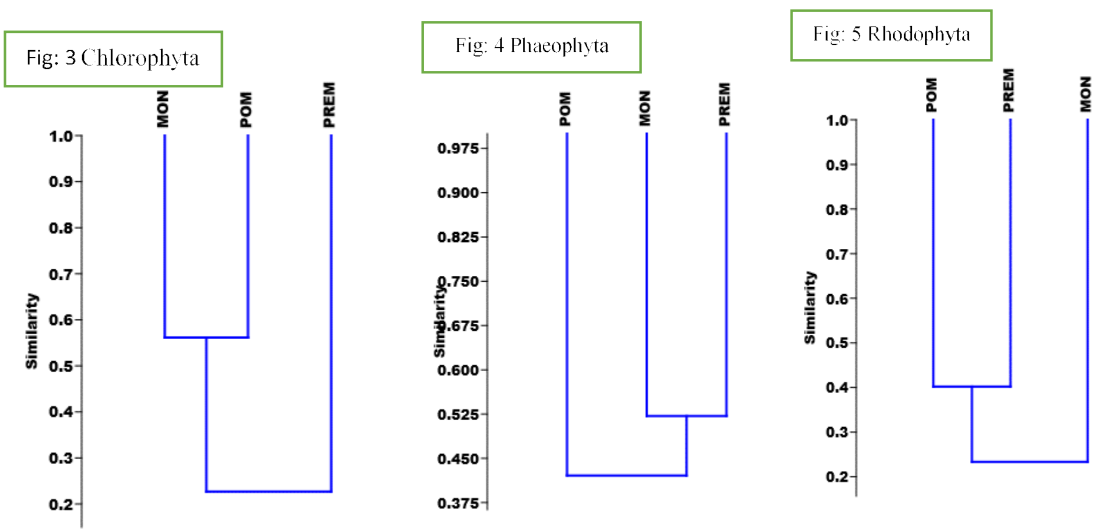

Fig. 3,4,5 Dendogram of complete linkage of flora diversity showing similarity matrix of Seaweeds classes season wise

Clustering :

Species assemblage was studied using the dendrogram drawn with three seasons classwise. Dendrogram were drawn for Chlorophyta, Phaeophyta and Rhodophyta separately over three seasons were represented in (Fig. 3,4,5). The seaweed diversity formed two groups. On the basis of Bray-Curtis similarity index applied for seaweeds abundance, with single linkage cluster mode,firstly for Chlorophyta, the first group was formed at 24.12% by pre-monsoon, second group was clustered by post-Monsoon and Monsoon at 56.14%.Secondly for Phaeophyta group, the first group was formed at 35.29% by post-monsoon, second group was clustered by pre-Monsoon and Monsoon at 52.17%.

Lastly for Rhodophyta, the first group was formed at 27.2% by Monsoon, second group was clustered by post-Monsoon and pre-Monsoon at 40.12%.Clustering showed seaweeds diversity were controlled by the peak seasons, different types and groups of seaweeds prominently had abundancy in particular season, be due to ideal condition of environment establishing favourable regime of temperature, salinity and nutrients.

Environmental parameters: The ten environmental parameters over three seasons namely pre-Monsoon, Monsoon and post-Monsoon with mean values was represented in (Fig. 2). Water and air temperatures were more constant over seasons with slight fluctuation in Monsoon. Salinity remained in nominal range $> 30 < 35$. pH was in optimum range. Dissolved oxygen was comparatively more, probably with higher range in Monsoon than other two seasons. Nitrite and nitrates range was countered higher in post-Monsoon. Phosphate, Ammonium and Iron content recorded in higher range in Monsoon than other two seasons.

According to the Anova there was significant differences in the environmental parameter mean (df=10,22) $F=10.47$, $p<0.05$. (Table-3). Tukey's post doc test revealed the significant and non-significant relation of seaweeds and environmental parameters.All the species were significant with parameters like air and water temperature, nutrients, dissolved oxygen and pH whereas with salinities fluctuating throughout seasons the relation was insignificant which showed the species abundance of few species of Genus (*Ulva, Chaetomorpha*) were in effect with variable salinities.Such observation with other species were recorded (Fig. 6,7,8).

Gihan[6] exemplified the macroalgae under temperature-tolerant species according to their seasonality appearance, included the green algae *Enteromorpha compressa, E. prolifera* and *E. tubulosa* in winter, the red alga *Hypnea cornuta* in autumn and *Urospora penicilliformis* in spring. Similarly in present study *Ulva intestinalis, Ulva clathrata, Ulva prolifera* were temperature tolerant in all seasons,brown algae-Genus *Sargassum* all species were found temperature tolerant in pre-Monsoon and Monsoon, red algae - *Hypnea valentine*, *Hypnea pseudomusciformis* were found temperature tolerant in pre-Monsoon.

Shams[25] listed Genus *Enteromorpha* among the euryhaline and eurythermal genera that can proliferate over a wide range of temperature and salinities. Messyasz and

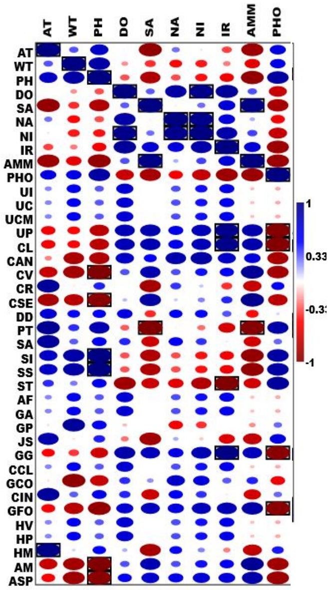

Fig. 6. Pre-monsoon

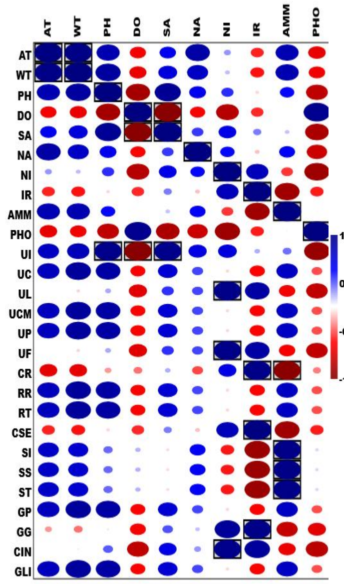

Fig. 8. Post-monsoon

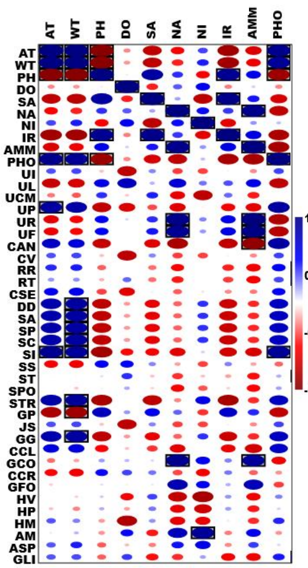

Fig. 7. Monsoon

Rybak[10] studied the influence of nine environmental parameters on the development of *Ulva* species from three streams located in Poznan, Poland. The study revealed, nitrate and phosphate was positively correlated to seaweeds diversity, ammonium and salinity was negatively correlated with seaweed diversity and were not statistically significant. As in present study ten environmental parameters effect on *Ulva* species diversity showed the nitrate and ammonium were positive correlated in post- Monsoon and were statistically significant,positive and significant relation with salinity in Monsoon, negative and significant relation with phosphate in pre-Monsoon, whereas positive and significant relation with phosphate in Monsoon. (Fig. 6,7,8).

Fig. 6,7,8 Pearson's Correlation pictodiagram explaining significant relationship between physicochemical parameters and seaweeds abundancy seasonally at Majali with pearson's correlation coefficient 'r' value range.

Naik *et al.,*[13] studied the numerical abundance, temporal variations of the seaweeds diversity at different areas of Arabian Sea and distribution along with hydrographic parameters during September 2001 to September 2002 at Devagad Island and the Kurumagad Island along Karwar Bay.Investigation revealed dominant species *Sargassum* sp., *Ulva fasciata, U. lactuca,Padina* sp., *Caulerpa* sp. attributed due to fluctuating environment parameters, as there was high temperature profile during pre and post monsoon season, the atmospheric and water temperature could be another factor to register high density of these weeds in the area (Naik *et al.,*[13]), as recorded in the present study the brown and green algae were influenced by the water and air temperatures during pre and post monsoon season.

Table-3. Representing Tukey's post hoc test and significant comparisons ($p<0.05$) are demarked in given table

	AT	WT	PH	DO	SA	NA	NI	IR	AMM	PHO	SEWEEDS
AT		1	0.2889	0.1997	1	0.1378	0.05725	0.07601	0.06852	0.06545	0.03963
WT	0.3206		0.4037	0.2906	1	0.2071	0.09061	0.1186	0.1075	0.1029	0.02428
PH	3.728	3.408		1	0.2207	1	0.9977	0.9995	0.9991	0.9988	0.000101
DO	4.044	3.723	0.3152		0.1487	1	0.9998	1	1	0.9999	6.14E-05
SA	0.2327	0.5533	3.961	4.276		0.1007	0.04053	0.05426	0.04876	0.04651	0.05601
NA	4.335	4.014	0.6061	0.2909	4.567		1	1	1	1	3.90E-05
NI	4.964	4.643	1.235	0.9199	5.196	0.6291		1	1	1	1.48E-05
IR	4.767	4.447	1.039	0.7238	5	0.4329	0.1962		1	1	2.00E-05
AMM	4.84	4.519	1.111	0.7962	5.073	0.5053	0.1238	0.07238		1	1.79E-05
PHO	4.872	4.551	1.143	0.8279	5.104	0.5371	0.09199	0.1042	0.03179		1.71E-05
SEAW-EEDS	5.211	5.532	8.94	9.255	4.978	9.546	10.17	9.979	10.05	10.08	

The present study reveals that the fluctuation in environmental parameters decides the presence and absence of seaweeds in various seasons. It is surmised from these data that, pre and post monsoon seasons are favourable period for seaweeds to escalate their growth rate as well as density. In addition to this, the air and water temperatures were another factor which governs and prosper these macrophytic flora especially in inter tidal zone. During monsoon the species equitable with nutrients grew at faster rates. Correlation aided in knowing the positive and negative significant as well as non-significant relations between parameters and seaweeds diversity. The ecological indices- Shannon-Weiner's Index takes into account the abundance and evenness of the species present. It varied from '0' for communities having only one or two species, whereas higher value suggests communities with many individual species. Pielou's Evenness Index also termed as Equitability measures or compared the Shannon -Weiner's Index against the species individual distribution between the observed species which maximize the diversity. It was constrained between 0 and 1. The evenness level was signified by 0 being presence of varied species with less evenness whereas 1 signified presence of one dominant group with more evenness, less diverse nature of species. Species richness is simplest measure of biodiversity and simply the count of different species in a population of given area. Margalef's diversity index measures the species richness and strongly depend on sampling size and sampling effort. Cluster analysis was statistical tool used to group a set of observations in such a discipline that the observations in the same cluster are more similar to each other than to those in other clusters. Clustering used for seaweed diversity highlighted the cluster group to similar abundance of seaweeds among seasons.

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