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Seaweed Species Diversity in RelationtoHydro Chemical Characters of Okha Coast, Western India

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***Abstract-* The aim of the present investigation focused on different group of seaweeds collected from Okha coast, Gujarat, India during November 2013 to February 2014, to understand their distribution pattern and pigments with subsequent analysis of relevant physico-chemical variables. In this study, the relationship between the pigment content of seaweed species and the ambient hydrochemical characters was established. It was observed that seaweeds were not found permanently during study period but some species were observed only for short periods while other species occurred for two to three months. A total of 70 species has been recorded,with highest number of Rhodophyta species than Phaeophyta and Chlorophyta. From the recorded groups of seaweeds, chlorophyll contents were higher in Chlorophyta. On the other hand carotenoids were recorded more in members of Phaeophyta. A significant positively correlation recorded between Chlorophyll content with temperature, DO and salinity. Carotenoid shows positive correlation with salinity of selected site. Statistical analysis computed among the environmental parameters and pigment could suggest the potential role played by the hydro-chemical characters on biosynthetic pathways of seaweed.**

***Keywords-* pigment content, physico-chemical variables, seaweeds, Okha coast**

I. INTRODUCTION

Seaweeds are one of the important marine living resources in the world. These macroalgae have been a source of food, feed and medicine in the east as well as in the west, since ancient times [1-2]. Seaweeds are key space occupiers of rocky shores, interact with other organisms, and hence play a key role in overall coastal biodiversity. They are found on rocks in the intertidal zone as a giant underwater forest. From the literature, it is observed that the edible seaweeds contain a significant amount of the protein, vitamins and minerals essential for the human nutrition [3]. Seaweeds are considered as a source of bioactive compounds as they are able to produce a great variety of secondary metabolites characterized by a broad spectrum of biological activities [4].Many seaweed species are used in the industry, principally for the extraction of phycocolloids [5] and as a source of pharmaceutical substances. In addition, they are used as herbal medicine, fertilizer, fungicides, and herbicides and for the direct use in human nutrition, too [6,7,8]. Seaweeds are known as a highly nutritive food containing vitamin, protein, mineral, fiber contents, and essential fatty acids [6].On the one hand, the power of algal resources has been sought for thousands of years for their ability to prevent disease and prolong life. However, they have shown high potential in controlling antimicrobial, antitumor, anticoagulant, and cytotoxic activity [9]. Nirmal kumar *et.al*. [10] studied that seaweed crud extract have potential activity against fungal pathogen. The health beneficial bioactive compounds of untapped seaweeds have emerged as an appealing attribute to the functional food industry [11]. Seaweeds appear to be an interesting source for ethno medicinal and phytochemical studies. Carotenoids, chlorophyll 'a' and chlorophyll 'b' are natural pigments found in green seaweeds [12].The environmental variation in light, temperature and nutrients can influence and bring about changes in the concentration of pigments in the thallus [13]. High light exposure requires seaweeds to acclimatize, avoiding inhibition of photosynthesis and degradation of the photosynthetic apparatus [14].

The seaweeds show great variation in the nutrient contents, which are related to several environmental factors as water temperature, salinity, light and nutrients [15]. Most of the environmental parameters vary according to season and change in ecological conditions can stimulate or inhibit the biosynthesis of several nutrients [16]. Moreover, the variations of the concentration of dissolved nutrients, temperature and salinity of sea water influence on the content of the organic and inorganic compounds [17-18], growth rate [19] and morphology of a species [20,21]. The nutritional composition of seaweeds varies with species, geographic area, season, and environmental conditions [22].

Therefore,the present paper focused to analyze the seasonal variations of the levels of proximate chlorophyll and carotenoid of seaweeds of Okha coast ,Gujarat with respect to relevant hydrological parameters such as surface water temperature, pH, salinity, dissolved oxygen (DO),hardness, sulphate (SO4) nitrate (NO_3), phosphate (PO_4),

II. MATERIALS AND METHODS

A) Study area

Okha Coast, is situated at 22°28'N and 69°05'E in the mouth of "Gulf of Kutch" on the north- westernmost part of Saurashtra in Gujarat (Fig. 1.) and is one of the most important places of interest for algal growth in India. This coast being at the mouth of "Gulf of Kutch" experiences strong water currents round the year as compared to other parts of the country. The coast is characterized by rocks made up of tertiary formations alternating with patches of sand deposits making the area more hospitable for the growth of all types of marine algae throughout the year.

B) Sampling

The seaweeds samples were collected from November 2013 to February 2014, picked with hand and immediately washed with seawater to remove the foreign particles, sand particles and epiphytes.The species were identified by BhavanathJhaet. Al. [23]. Thedry air samples were placed in an oven at 50 °C. Pulverized in the grinder and the powdered material was kept in airtight plastic bottles at room temperature until further analysis.

C) Biochemical Analysis

The amount of chlorophyll-a present in the alga was estimated by Arnon [24] whileParsons and Strickland, [25] determined amount of carotenoid.

D) Analysis of hydrological parameters

Analyses of water sample were done as per the standard methodology outlined in Strickland and Parsons [26] and APHA [27].

E) Statistical Analysis

Multivariate analysis to estimate the correlation between pigments and hydro-chemical parameterswas carried out. The statistical analysis was carried out using KY plot.

III. RESULTS AND DISCUSSION

Okha coast is rich with diverse group of seaweed species. Presence of suitable substratum both due to coral reefs and other rocks, provide appropriate habitat for most of the algal species. During the study period, stranded seaweeds constituted 70 species enlisted as per the classes (Table I). The major part of the stranded seaweed is represented by thirty-six species of Rhodophyta accounting for 51.42%, followed by 18 species of Phaeophyta with 25.71% and 16 species of Chlorophyta contributing 22.85% (Fig. 2). Thus, Rhodophyta shows more prevalence in the seaweeds flora at selected site. In the previous study from Saurashtra coast, Jha et.al [23] also observed more number of Rhodophyta members as compare to Phaeophyta and Chlorophyta.

The maximum diversity number of seaweeds occurred during February 2014 with as many as 50 species, and a minimum of 15 was registered in November 2013

Table I

Distribution Pattern of Seaweeds (Chlorophyta, Phaeophyta, Rhodophyta)

Sr.No	Chlorophyta	Family	November	December	January	February
1	Ulvalactuca L.	Ulvaceae	-	+	+	+
2	EntromorphaflexuosaJ.Agardh	Ulvaceae	-	-	+	+
3	EntromorphaproliferaJ.Agardh	Ulvaceae	-	-	+	-
4	MonostromalatissimumWiltrock	Ulvaceae	+	-	-	-
5	Ulvafasciatadelite	Ulvaceae	-	-	-	+
6	Ulvareticulataforsskal	Ulvaceae	-	-	-	+
7	ChaetomorphacrassaKutzing	Cladophoraceae	-	-	+	+
8	Cladophorasp	Cladophoraceae	+	-	-	-
9	ValoniautricularisC.Agardh	Valoniaceae	-	-	+	-
10	ChamaedorisausiculataBorgesen	Siphonocladaceae	-	+	-	-
11	BryopsispennataLamouroux	Bryopsidaceae	-	+	-	-
12	CaulerparacemosaJ.Agardh	Caulerpaceae	-	+	+	+
13	CaulerpasertularioidesS.Gmelin	Caulerpaceae	-	+	-	+
14	CaulerpaveravalensisThivy&Charhan	Caulerpaceae	-	-	+	-
15	CladophoropsisjavemicaP.silva	Boodleaceae	-	-	+	-
16	CaulerpataxifoliaC.Agardh	Caulerpaceae	-	-	-	+
Sr No	**Phaeophyta**	**Family**	**November**	**December**	**January**	**February**
1	Turbinaria ornate J.agardh	Sargassaceae	+	+	-	-
2	SargassumcinereumJ.Agardh	Sargassaceae	+	-	-	-
3	SargassumvulgareC.Agardh	Sargassaceae	+	-	-	-
4	SargassumswartziiJ.Agardh	Sargassaceae	-	-	+	-
5	Sargassumjohnstoniisetchell&Gardner	Sargassaceae	-	-	+	-
6	Sargassumtenerrimum J.G Agardh	Sargassaceae	+	+	+	-
7	CystoseiraindicaHuirh	Sargassaceae	+	-	-	+
8	SargassumcinctumJ.Agardh	Sargassaceae	+	-	-	-
9	SargassumplagiophyllumJ.Agardh	Sargassaceae	+	-	-	-
10	PadinaboergeseniiAllender&Kraft	Dictyotaceae	+	-	-	+
11	DictyopterisacrostichoidesBornet	Dictyotaceae	+	+	-	+
12	DictyotadichotomaLamouroux	Dictyotaceae	+	-	+	+
13	SpatoglossumasperumJ.Agardh	Dictyotaceae	-	+	-	+
14	StoechospermummarginatumKutzing	Dictyotaceae	-	+	-	-
15	Padinatetrastromatica Hauck	Dictyotaceae	-	-	+	-
16	DictyotapinnatifidaKutzing	Dictyotaceae	-	-	+	+
17	Lobophoravariegata	Dictyotaceae	-	-	-	+
18	Iyengaria stellate Borgesen	Scytosiphonaceae	-	-	+	+

SrNo	Rhodophyta	Family	November	December	January	February
1	Champiaindicabogesen	Champiaceae	-	+	-	-
2	Laurenciasp	Rhodomelaceae	+	+	+	-
3	Lausencia obtuse lamouroux	Rhodomelaceae	-	-	+	-
4	LausenciaglanduliferaKutzing	Rhodomelaceae	-	-	+	-
5	Botryocladialeptopodakylin	Rhodomelaceae	-	-	+	+
6	AcanthophoraspeciferaBorgesen	Rhodomelaceae	-	+	+	+
7	Odontothuliaverovalensis Krishnamurthy et Vijaya	Rhodomelaceae	-	-	+	-
8	RhodymeniasonderiP.Silva	Rhodymeniacea e	-	-	-	+
9	CoelarthrummuelleriBorgesen	Rhodymeniacea e	-	-	-	+
10	Cyastexlomiumiyenagariik.srinivasa n	Champiaceae	-	-	+	-
11	Hypnervalentiae Montage	Cystocloniaceae	-	-	+	-
12	HypnerflagelliformisGreville	Cystocloniaceae	-	-	+	+
13	Hypneavalentiae Montagne	Cystocloniaceae	-	+	-	+
14	SarcomemafiliformeKylin	Solieriaceae	-	-	+	-
15	Solieriarobuster –kylin	Solieriaceae	-	-	+	+
16	GriffiphsiacorallfnoidesC.Agardh	Wrangeliaceae	-	-	+	-
17	CentrocesaeclavulatumMontayne	Ceramiaceae	-	-	+	+
18	PlatysiphoniadeliataCremaeles	Sarcomeniaceae	-	-	+	+
19	Heterosiphoniamulleri De Toni	dasyaceae	-	-	+	-
20	Lophocladialallemandi Montagne	Rhodomelaceae	-	-	-	+
21	ChondriaclasyphyllaC.Agardh	Rhodomelaceae	-	-	-	+
22	Wrangaliatanegana Harvey	Wrangeliaceae	-	-	-	+
23	AnotrichiumtenueC.Agardh	Wrangeliaceae	-	-	-	+
24	LaurenciaclaviformisBorgesen	Rhodomelaceae	-	-	-	+
25	LaurenciapapillosaC.Agardh	Rhodomelaceae	-	-	-	+
26	GracillariasalicorniaC.Agardh	Gracilariaceae	-	-	-	+
27	Gracillariatextori De toni	Gracilariaceae	+	-	-	+
28	GracillariacorticataJ.Agardh	Gracilariaceae	-	-	-	+
29	Scinaiacomplanata Collins	Scinaiaceae	-	-	-	+
30	LiagoraviscidaC.Agardh	Ligoraceae	-	-	-	+
31	GysiffithsiacorallinoidesTrevisan	Scinaiaceae	-	-	+	-
32	GyrateloupiaindicaBorgesen	Halymeniaceae	-	-	+	-
33	GelidiumJ.Agardh	Gelidiaceae	+	-	-	-
34	Cheilrsporymspectabile Harvey	Corallinaceae	-	-	+	+
35	Ahnfeltiaplicata Fries	Ahnfeltiaceae	-	+	-	-
36	SarcomemascinaioidesBorgesen	Solieriaceae	-	-	-	+

Table II

Correlation Matrix of Biochemical constitutes of species of Chlorophyta members with Hydrochemical parameters

	Chlorophyll	Carotenoid	pH	Temperature	DO	Salinity	Ca-hardness	Alkalinity	Phosphate	Sulphate	Nitrate
Chlorophyll	1										
Carotenoid	0.90	1									
pH	-0.40	0.02	1								
Temperature	0.33	-0.06	-0.97	1							
DO	0.42	-0.006	-0.99	0.94	1						
Salinity	0.86	0.75	-0.31	0.15	0.38	1					
Ca-hardness	-0.75	-0.39	0.85	-0.74	-0.88	-0.76	1				
Alkalinity	-0.43	-0.42	-0.07	0.28	-0.02	-0.81	0.40	1			
Phosphate	-0.38	0.04	0.99	-0.96	-0.99	-0.32	0.85	-0.03	1		
Sulphate	-0.29	-0.44	-0.42	0.60	0.33	-0.64	0.07	0.93	-0.39	1	
Nitrate	0.38	0.70	0.66	-0.74	-0.62	0.47	0.18	-0.60	0.66	-0.81	1

Table III

Correlation Matrix of Biochemical constitutes of species of Phaeophytawith Hydrochemical parameters

	Chlorophyll	Carotenoid	pH	Temperature	DO	Salinity	Ca-hardness	Alkalinity	Phosphate	Sulphate	Nitrate
Chlorophyll	1										
Carotenoid	0.02	1									
pH	-0.27	-0.09	1								
Temperature	0.05	0.06	-0.97	1							
DO	0.37	0.10	-0.99	0.94	1						
Salinity	0.82	0.52	-0.31	0.15	0.38	1					
Ca-hardness	-0.64	0.22	0.85	-0.74	-0.88	-0.76	1				
Alkalinity	-0.92	0.14	-0.07	0.28	-0.02	-0.81	0.40	1			
Phosphate	-0.31	-0.12	0.99	-0.96	-0.99	-0.32	0.85	-0.03	1		
Sulphate	-0.73	0.21	-0.42	0.60	0.33	-0.64	0.07	0.93	-0.39	1	
Nitrate	0.28	-0.62	0.66	-0.74	-0.62	0.47	0.18	-0.60	0.66	-0.81	1

Table IV

Correlation Matrix of Biochemical constitutes of species of Rhodophytawith Hydrochemical parameters

	Chlorophyll	Carotenoid	pH	Temperature	DO	Salinity	Ca-hardness	Alkalinity	Phosphate	Sulphate	Nitrate
Chlorophyll	1										
Carotenoid	0.005	1									
pH	0.06	0.88	1								
Temperature	-0.15	-0.75	-0.97	1							
DO	-0.03	-0.92	-0.99	0.94	1						
Salinity	0.83	0.51	-0.31	0.15	0.38	1					
Ca-hardness	-0.41	0.88	0.85	-0.74	-0.88	-0.76	1				
Alkalinity	-0.60	0.34	-0.07	0.28	-0.02	-0.81	0.40	1			
Phosphate	0.08	0.90	0.99	-0.96	-0.99	-0.32	0.85	-0.03	1		
Sulphate	-0.60	-0.01	-0.42	0.60	0.33	-0.64	0.07	0.93	-0.39	1	
Nitrate	0.77	0.47	0.66	-0.74	-0.62	0.47	0.18	-0.60	0.66	-0.81	1

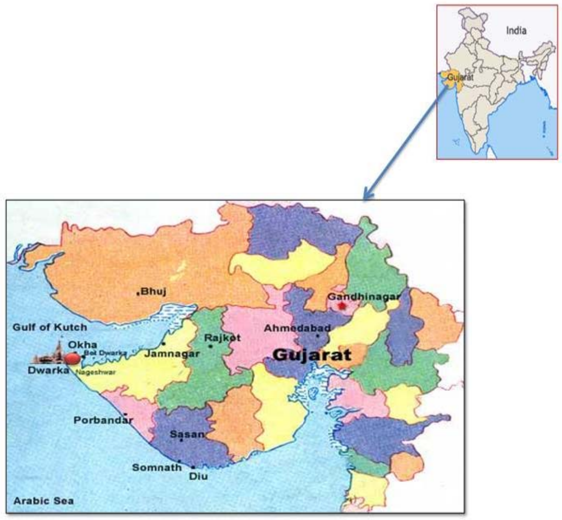

Fig 1.Map of Gujarat showing the study site of Seaweeds at Okha Coast, Gujarat.of Okha Coast, Gujarat, India.

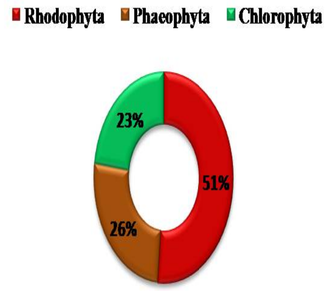

Fig 2. Percent distribution of three groups

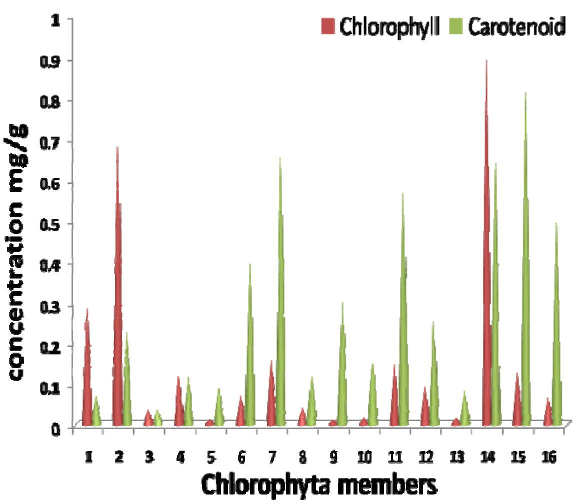

Fig 3. Chlorophyll a and Carotenoid content of seaweed species of Chlorophyta

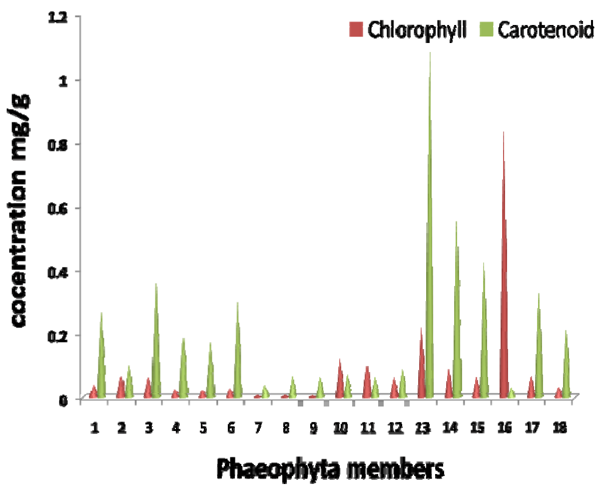

Fig 4. Chlorophyll a and Carotenoid content of seaweeds species of Phaeophyta.

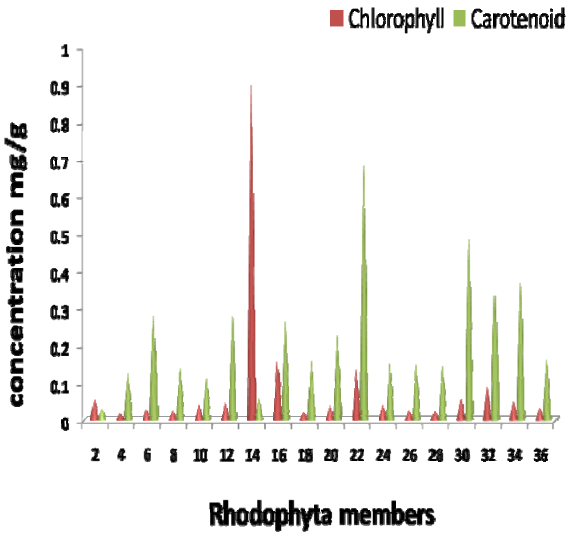

Fig 5a. Chlorophyll a and Carotenoid content
of seaweed species of Rhodophyta.

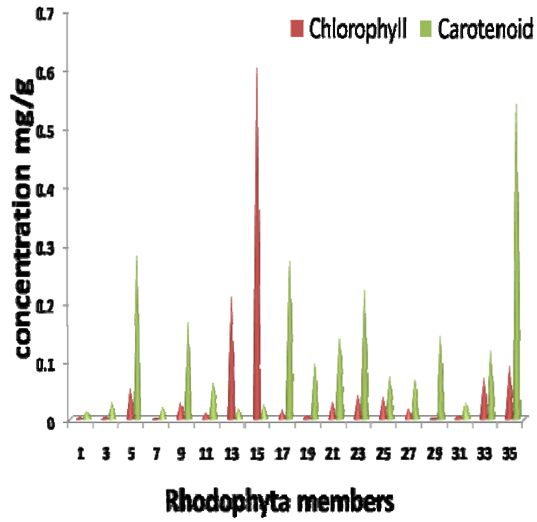

Fig 5b. Chlorophyll a and Carotenoid content
of seaweed species of Rhodophyta.

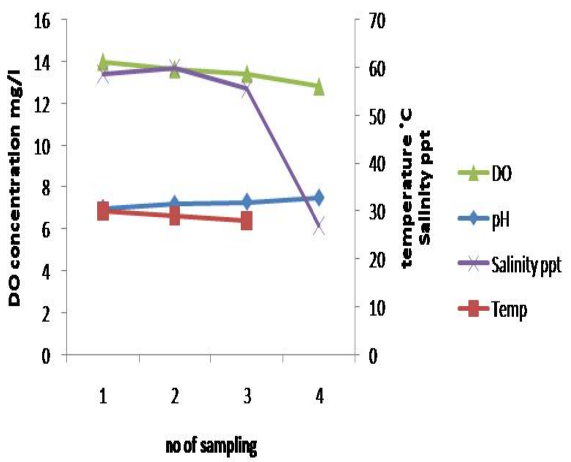

Fig 6. DO, pH, Salinity and Temperature of water

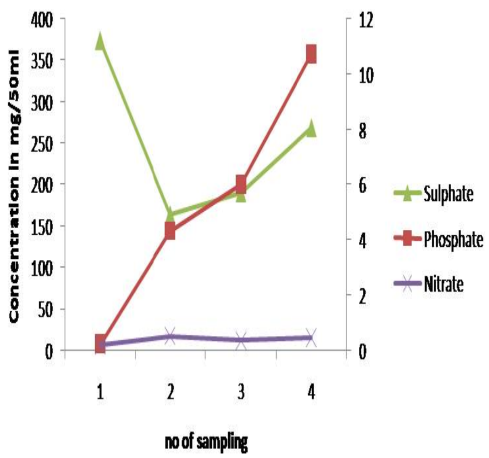

Fig 7.Sulphate, Phosphate and Nitrate content of water

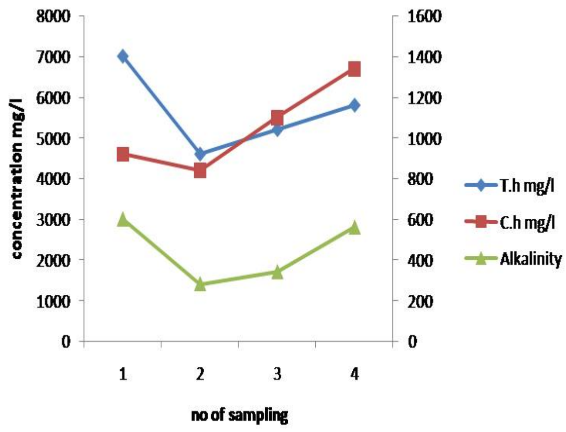

Fig 8. Total hardness, Ca-hardness and Alkalinity of water

A) Biochemical analysis

1) Chlorophyta species:

The chlorophyll a., concentration ranged from 0.010±0.001 to 0.94±0.02 mg/g; maximum found in C. veravalensis (0.94±0.02), E. flexuosa (0.743±0.02) and U. lactuca (0.3±0.01). The minimum content was observed in V. utricularis (0.010±0.001), U. fasciata (0.012±0.002) and C. sertularioides (0.014±0.001).The carotenoid concentration fluctuated from 0.037±0.001 to 0.70 ±0.1; the content was greater in C. crassa (0.70±0.1) followed by C. javemica (0.85 ±0.1) and C. veravalensis (0.69±0.1). The lower concentration was found in E. prolifera (0.037±0.001) followed by U. lactuca(0.075±0.002) and C. sertularioides (0.084±0.002) (fig. 3).

2) Phaeophyta species:

The chlorophyll a. consist accessory pigment, which indirectly involve in photosynthesis. The concentration in tested seaweeds ranged from 0.006±0.0001 to 0.88 ±0.01 mg/g; maximum found in D. dichotoma (0.88±0.01), P.boergesenii (0.12±0.02) and D. acrostichoides (0.10±0.01). The minimum content was observed in S. plagiophyllum (0.006±0.0001), C. indica (0.007±0.0002) and S. cinctum(0.0072±0.0001). The carotenoid concentration fluctuated from 0.03±0.002 to 1.16±0.1; the content was greater in S. asperum (1.16±0.1) followed by S. marginatum (0.58±0.2) and P. tetrastromatica (0.45±0.1). The lower concentration was found in D. dichotoma (0.03±0.002) followed by C. indica (0.039±0.002) and P. Boergesenii (0.06±0.002) (fig.4).

3) Rhodophyta species:

The chlorophyll a., concentration ranged from 0.0012±0.0001 to 0.57 ±0.03 mg/g; maximum found in S. filiforme (0.57 ±0.03), S. robuster (0.64±0.01) and H. valentiae (0.22±0.01). The minimum content was observed in O. verovalensis (0.0012±0.0001), S. complanata (0.0013±0.0002) and C. indica (0.0034±0.0001). The carotenoid concentration fluctuated from 0.014±0.001 to 0.60±0.4; the content was greater in W. tanegana (0.60±0.4) followed by A. plicata (0.590±0.2) and L. viscida(0.52±0.1). The lower concentration was found in C. indica (0.014±0.001) followed by H. valentiae (0.02±0.001) and O. verovalensis (0.023±0.002) (fig. 5a, 5b).

B) Hydrochemical Parameters

The variation in the biochemical contents of seaweeds is associated with several environmental factors such as water temperature, salinity, light and nutrients [15]. The environmental parameters differ with seasonal periods and the changes in ecological conditions can influence the synthesis of nutrients in seaweeds [16]. During the study period water temperaturefound highest during November (32.5± 0.05˚ C) and lowest in February(28± 0.03˚C). Salinity oscillated between 31±0.12 to 27.02± 0.2 %, maximum recorded in the month of December whereas minimum in February. The pH noted more during February and less in November. Dissolve Oxygen is vary from 7 to 5.31 mg/l, higher during November and lower in February, respectively (fig.6).Phosphate and Nitrate content were recorded highest in the month of February (10.71 and 0.46 mg/l) and lowest in November (0.22 to 0.183 mg/l) respectively. Sulphate content of water was maximum 373.28 mg/l in November and minimum 164.06mg/l in December (fig. 7). Calcium hardness was ranged from 1340 mg/l in February to 850 mg/l in December. Alkalinity was found maximum 600 mg/l in November and minimum 280mg/l in December (fig. 8).

The present study revealed that pigment composition vary with species and with respect to hydrochemical characters or factors. The highest total chlorophyll was recorded in the green alga C. veravalensisand minimum in the red alga S. filiformeand gives positive correlation with temperature, salinity and DO. Similarly, Muthuraman and Ranganathan (2004) reported maximum chlorophyll in the green alga Caulerpascalpelliformis. The chlorophyll content of S. wightiiis more than the red alga A. spicifera, this also in conformity with the results of Jeyasankar et.al., [28].The highest carotenoid content was recorded in the brown seaweed S. asperum, similarly Muthuraman and Ranganathan [29] reported maximum carotenoid content in the brown seaweed S. wightii. Carotenoid content in all the species showed positive correlation with salinity. Chakraborty et al., [30], recorded similar result from eight macroalgae of Sunderban Estuary.

In Chlorophyta species chlorophyll compounds is positively correlated with temperature, DO, salinity and nitrate while carotenoid showed positive correlation with salinity (table II). As the Phaeophytaspecies, content higher amount of carotenoid is positively correlate with all the parameters except phosphate, sulphate and pH (Table III). In Rhodophytachlorophyll content showed negative correlation with almost all the parameters as it content low amount of chlorophyll whereas carotenoid content positively correlate with salinity and negatively correlate with temperature, DO and sulphate (table IV).

IV. CONCLUSION

The present study revealed that seaweeds are rich source of different biochemical compounds.Species belongs to Rhodophytafound higher in number with variety of species than Chlorophyta and Phaeophyta. Okha Coast is unique in terms of environmental factors and several anthropogenic categories influence the seaweed diversity and water quality. Physico-chemical properties influence on biochemical constituents. Temperature, dissolved oxygen,light intensity and salinity mainly support the growth of seaweeds and pigment composition varies with these factors. From the habitat of the seaweeds, species and distribution pattern at selected site suggest influence of different environmental factors on species distribution.

V. ACKNOWLEDGEMENTS

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