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Seasonal Variation of Proximate Composition of Common Seaweeds in Indian Sundarbans

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ABSTRACT- We conducted a first order analysis on the proximate composition (protein, carbohydrate, fat and astaxanthin) of three dominant seaweed species *viz. Enteromorpha intestinalis*, *Ulva lactuca* and *Catenella repens* inhabiting Indian Sundarbans. The study was conducted at three stations (Gosaba, Bali Island and Jharkhali) during premonsoon, monsoon and postmonsoon of 2014-15. The relevant hydrological parameters (surface water temperature, salinity, pH, dissolved oxygen and dissolved nutrients) were monitored simultaneously during the tenure of the work. ANOVA carried out on the observed data reflects pronounced variations of all hydrological parameters except surface water temperature and salinity between stations. Pronounced seasonal variations were observed for all the selected hydrological parameters. In the domain of proximate composition, ANOVA results exhibit pronounced variations between stations and seasons (except carbohydrate in *U. lactuca* and *C. repens* between stations and astaxanthin in *U. lactuca* between seasons).

Keywords - Seaweed, Indian Sundarbans, Proximate composition, ANOVA, Seasonal variation

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INTRODUCTION

Marine algae or seaweeds are macroscopic and non flowering thallophytic plants. They are attached to rocks, corals and other submerged strata in the coastal regions, river mouth and estuaries. They are also found on the pneumatophores (specialized roots of mangrove species that grow upward out of water or mud to obtain oxygen for the trees in tidal regions), trunk of mangrove trees and other hard substrata like boulders, sluice gate *etc*. Although structurally dissimilar from higher plants, yet they produce own food through photosynthesis by their substitute organs (holdfast, stipe and blade). They are mainly used as raw materials in different industries like food, cosmetics, paint, crop, textile, paper, rubber etc [1-3].

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Seaweeds are considered as a part of healthy diet because it contains beneficial nutrients like protein, vitamins, minerals, antioxidants *etc* [4]. According to many researchers seaweeds are good sources of antioxidants [5-6]. Indian Sundarbans is a mangrove dominated Gangetic delta (Figure 1) in the north east coast of Indian sub-continent which sustains some 34 species of true mangroves along with several seaweed species [3,7]. The three seaweed species *Enteromorpha intestinalis*, *Ulva lactuca* and *Catenella repens* are dominantly found in Indian Sundarbans. The present study aimed to analyse the proximate composition of these three seaweed species collected from three stations in Indian Sundarbans through seasons during 2014-15 along with the hydrological parameters to which these seaweed species are exposed to through tidal actions.

MATERIALS AND METHODS

Sampling site

The Indian Sundarbans at the apex of the Bay of Bengal (between 21°30′N to 22°30′N latitude and 87°25′E to 89°10′E longitude) is located on the southern fringe of the state of West Bengal (a maritime State in the northeast coast of India). The Sundarban Biosphere Reserve (SBR) occupies an area of about 9630 sq. km, of which the forest

area is about 4200 sq. km. The region is demarcated by Bangladesh in the East, the Hooghly River in the West, the Dampier and Hodges line in the North and the Bay of Bengal in the South. With a considerable degree of marine characteristics in major portion of the ecosystem, the important geomorphologic features of deltaic Sundarbans are beaches, mudflats, coastal dunes, sand flats, estuaries, creeks, inlets and mangrove swamps [8] (Figure 1).

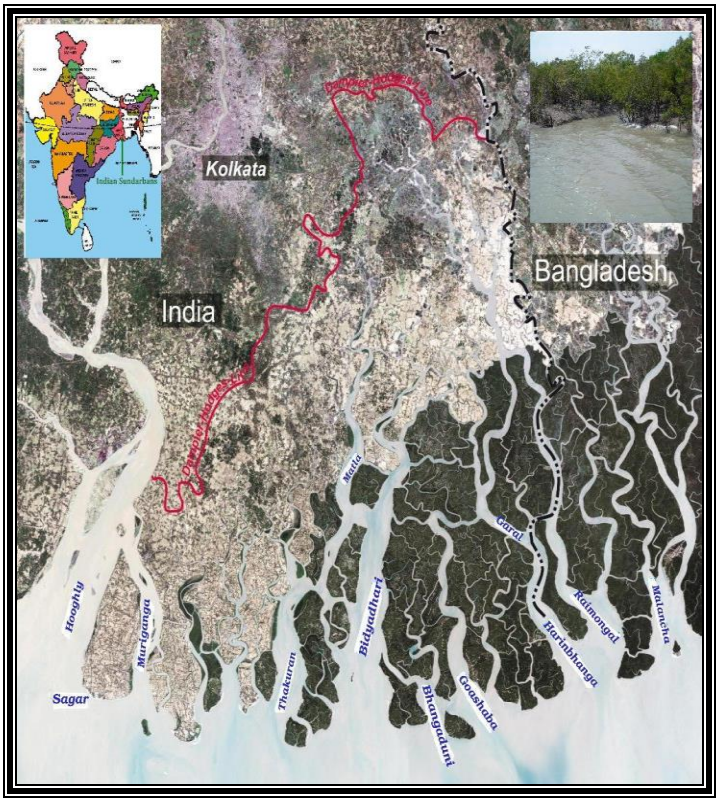

Fig. 1: Map of Indian Sundarbans

Three stations *viz*. Gosaba (22°08'53.66"N; 88°56'34.20"E), Bali Island (22°04'35.17"N; 88°44'55.70"E) and Jharkhali (22°05'52.82"N; 88°41'47.25"E) in the central part of the Indian Sundarbans were selected for the present study during 2014-15.

Sample collection

Three species (*E. intestinalis*, *U. lactuca* and *C. repens*) were collected from the hard substrata (preferably exposed jetties during low tide) at each station and thoroughly washed with ambient water and then double distilled water and brought to the laboratory in ice-freezed condition for further analysis.

Analysis of hydrological parameters

The surface water temperature was instantly measured by using portable thermometer after water collection. Surface water salinity was recorded by means of an optical refractometer (Atago, Japan) in the field and cross-checked in laboratory by employing Mohr-Knudsen method [9]. Portable pH meter (which has an accuracy of ±0.01) was used for recording the surface water pH. Dissolved oxygen was measured by DO meter in the field and subsequently cross checked in the laboratory by Winkler's method [10]. Dissolved nutrients (nitrate, phosphate and silicate) were analyzed in the laboratory as per the standard method [9].

Analysis of proximate composition

The collected fresh seaweed samples were dried in hot air oven at 105°C for 6 hrs and then the difference in weight was recorded for moisture content [11]. The ash content of the each dried sample was analyzed by burning at 550°C for 6 hours in a Muffle furnace according to the standard method [11].

The protein content in each seaweed species was estimated by Lowry method [12]. The analysis of total carbohydrate was done by using phenol-sulphuric acid and then calculated from standard glucose curve [13]. Fat was determined by Soxhlet method as per the standard protocol [14]. The organic solvent extract from each sample was used in spectrophotometer for the analysis of astaxanthin [15]. All of the biochemical parameters were expressed as the percentage dry weight except astaxanthin, which was expressed in ppm dry weight.

STATISTICAL ANALYSIS

Analysis of Variance (ANOVA) was performed through SPSS 16.0 to assess whether all the selected hydrological parameters and biochemical parameters varied significantly between stations and seasons; possibilities less than 1% ($p < 0.01$) were considered statistically significant. Data of proximate composition were subject to analysis of correlation coefficient (r) in order to evaluate the inter-relationships between biochemical parameters of each selected species with the selected hydrological parameters.

RESULTS

The results of the hydrological analysis of the three selected stations are presented in Figure 2. The surface water temperature varied from 29.8°C (in Gosaba during postmonsoon) to 34.5°C (in Jharkhali during premonsoon). The values of surface water salinity and pH were observed between 18.9 psu (in Gosaba during monsoon) and 30.1 psu (in Jharkhali during premonsoon), 8.29 (in Gosaba during monsoon) and 8.32 (in Jharkhali during premonsoon) respectively. The minimum level of DO was observed during premonsoon (4.75 ppm in Jharkhali) and maximum was observed during monsoon (5.44 ppm in Gosaba). The dissolved nutrient levels in three selected stations during three seasons are shown in Figure 3. The dissolved nitrate and phosphate ranged from 17.11 µgat l^{-1} (in Bali Island during premonsoon) to 29.1 µgat l^{-1} (in Jharkhali during monsoon) and 2.03 µgat l^{-1} (in Bali Island during premonsoon) to 4.66 µgat l^{-1} (in Jharkhali during monsoon) respectively. The dissolved silicate varied from 54.29 µgat l^{-1} (in Bali Island during premonsoon) to 83.14 µgat l^{-1} (in Jharkhali during monsoon).

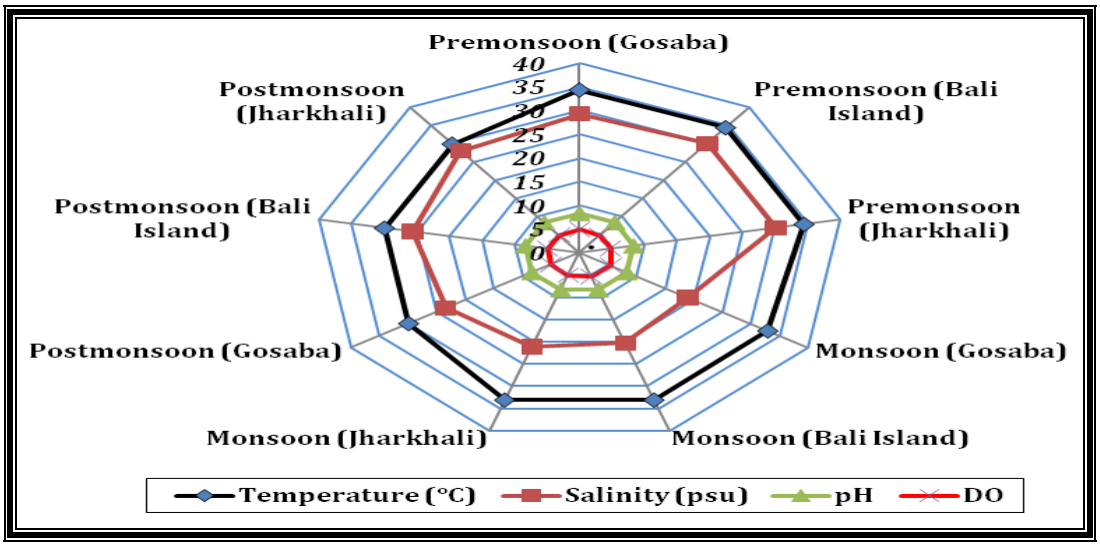

Fig. 2: Spatio-temporal result of four hydrological parameters during study period

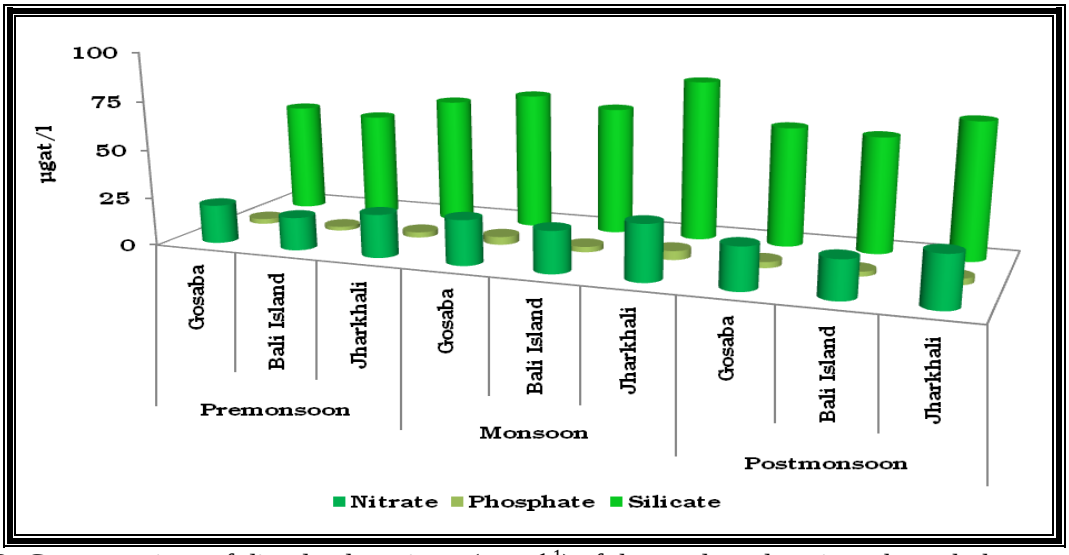

Fig. 3: Concentrations of dissolved nutrients (µgat l^{-1}) of three selected stations through three seasons

The moisture content ranged from 79.97 % (in Jharkhali during premonsoon) to 86.55 % (in Gosaba during monsoon) in *E. intestinalis*, 80.31 % (in Jharkhali during premonsoon) to 87.21 % (in Gosaba during monsoon) in *U. lactuca* and 77.19 % (in Jharkhali during premonsoon) to 80.21 % (in Gosaba during monsoon) in *C. repens*.

The ash content varied between 12.15 % (in Gosaba during monsoon) and 17.51 % (in Jharkhali during premonsoon) in *E. intestinalis*, 11.47 % (in Gosaba during monsoon) and 16.20 % (in Jharkhali during premonsoon) in *U. lactuca* and 14.23 % (in Gosaba during monsoon) and 19.01 % (in Jharkhali during premonsoon) in *C. repens*.

Figure 4 represents the proximate composition of the three selected seaweed species. The protein percentage varied from 5.03 (in *C. repens* in Jharkhali during premonsoon) to 10.64 (in *U. lactuca* in Gosaba during monsoon). The range of carbohydrate was from 29.42 % (in *C. repens* in Gosaba during monsoon) to 55.76 % (in *E. intestinalis* in Jharkhali during premonsoon). The fat content varied between 0.09 % (in *C. repens* in Jharkhali during premonsoon) and 0.74 % (in *U. lactuca* in Gosaba during postmonsoon). The maximum amount of astaxanthin was observed in *C. repens* (257.90 ppm dry weight in Jharkhali during premonsoon) and minimum was in *E. intestinalis* (163.22 ppm dry weight in Gosaba during monsoon) which is shown in Figure 5.

The average percentage of protein was highest in *E. intestinalis* (9.67 %) followed by *U. lactuca* (8.77 %) and *C. repens* (7.1 %). The same order was also followed for carbohydrate content with average value 44.71 %, 37.87 % and 31.45 % in *E. intestinalis*, *U. lactuca* and *C. repens* respectively. The average fat content followed the order *U. lactuca* (0.38 %) > *E. intestinalis* (0.22 %) > *C. repens* (0.16 %). The average value of astaxanthin was highest in *C. repens* (229.08 ppm dry weight) followed by *U. lactuca* (192.31 ppm dry weight) and *E. intestinalis* (181.76 ppm dry weight).

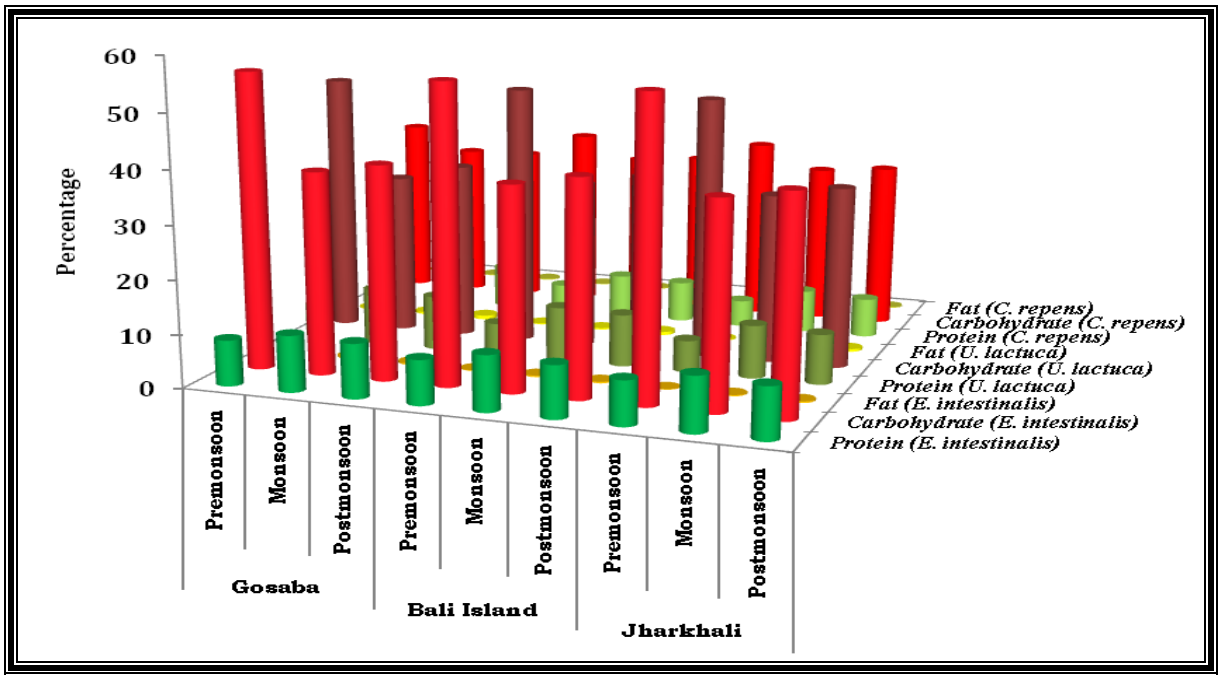

Fig. 4: Concentrations of protein, carbohydrate and fat (%) of the three selected seaweeds of three selected stations through seasons

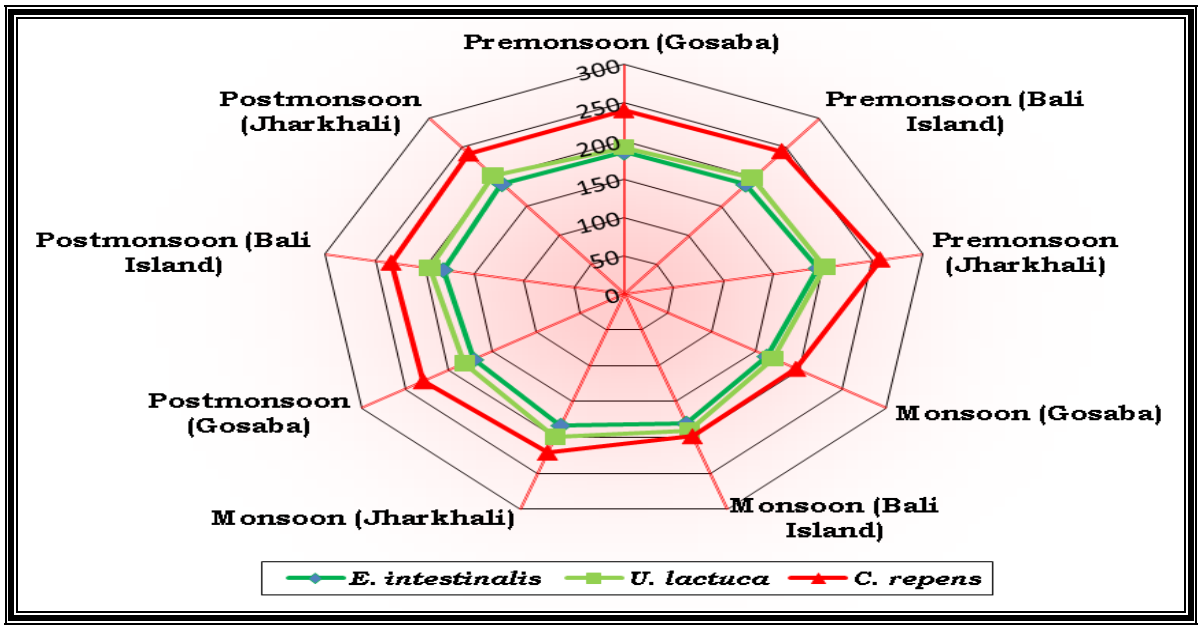

Fig. 5: Concentration of astaxanthin (ppm dry weight) of three selected seaweeds of three selected stations through seasons

DISCUSSION

In the present study the proximate composition of seaweed species followed the order carbohydrate > protein > fat > astaxanthin. The maximum amount of protein and carbohydrate were noticed in *E. intestinalis* followed by *U. lactuca* and *C. repens*. However, this order was completely reverse for astaxanthin. Several studies reveal that the variation in the nutrient concentration of seaweeds is related to several environmental factors such as surface water temperature, salinity, light, and dissolved nutrients [16,17].

The moisture content in all the selected seaweed species was found to be highest during monsoon and lowest during premonsoon. High temperature during premonsoon causes more transpiration which may be attributed to the less moisture content in all the seaweed species. The seasonal order of the percentage of ash content was completely opposite to the moisture content in all the selected species. Previous studies have reported that ash content of seaweed varies between 8 and 40% [18], which are similar to the range observed in the present study.

The present study also confirms significant effects of the

hydrological parameters on the proximate composition of selected seaweeds species (Table 1). The significant positive correlation between surface water temperature and carbohydrate for all stations reflects the enhancement of photosynthesis due to increase of solar radiation that is reflected through surface water temperature. The significant negative correlation between surface water temperature and protein level reflects the denaturation of protein at high temperature. In fact the peptide bonds are broken at elevated temperature. The significant negative correlation between surface water temperature and fat may be the result of dissolution of fat at higher temperature. The surface water temperature showed strong correlation with astaxanthin level (except at Bali Island).

The impact of salinity on the proximate composition of selected seaweeds was also pronounced. The significant positive correlation between ambient aquatic salinity and carbohydrate indicates that the selected seaweed species are capable of performing the process of photosynthesis in all salinity gradients. The picture is however negative for protein. Such observations were recorded by earlier workers in the same geographical locale [1]. The significant positive correlations between ambient aquatic salinity and astaxanthin of the selected seaweeds conclude that the stress posed by hypersaline condition accelerate the synthesis of astaxanthin.

The aquatic pH exhibited significant positive correlations with carbohydrate and astaxanthin content of the selected seaweeds. However, high pH exhibited an adverse impact on the protein content of the seaweed species.

The selected dissolved nutrients exhibited significantly positive correlations with protein content of the seaweeds. The protein concentration in marine organism depends on the dissolved nutrients [19-20]. The highest percentage of protein in seaweeds during monsoon might be attributed to the accumulation of more nitrogen from organic wastes brought to the estuaries and coastal waters by the land run-off [1,21-23] (Figure 4).

The presence of nutrients enriched sewage increases the turbidity of water due to which the photosynthesis is adversely affected. This is confirmed through significant negative correlations between nitrate and carbohydrate, phosphate and carbohydrate, silicate and carbohydrate.

ANOVA carried on the observed data reflects pronounced variations of all hydrological parameters except surface water temperature and salinity between stations (Table 2). This is due to the fact that all the selected stations are located in the central Indian Sundarbans, where the salinity profile is almost similar. Pronounced seasonal variations were observed for all the selected hydrological parameters (Table 2). In the domain of proximate composition, ANOVA results exhibit pronounced variations between stations and seasons (except carbohydrate in *U. lactuca* and *C. repens* between stations and astaxanthin in *U. lactuca* between seasons) (Table 3). This may be attributed to spatio-temporal variations of most of the hydrological parameters in the study area, which is a characteristic feature of Indian Sundarbans [2-3,8,24-25].

The overall discussion thus directs us to conclude that the water quality of this mangrove dominated World Heritage Site must be monitored and managed on regular basis to maintain optimum proximate composition of seaweeds, which may be a source of food for the future world.

CONCLUSIONS

Seaweeds in the lower Gangetic delta region are rich in protein and carbohydrates and can be a source of food. Considerable spatio-temporal variations are witnessed for proximate composition of the seaweeds, irrespective of species. Ambient hydrological parameters have regulatory influences on the proximate composition of the selected seaweed species.

Table 1: Inter-relationships between biochemical parameters of selected three seaweed species and hydrological parameters in three selected stations

Combination	'r' value			'p' value		
	Stn. 1	**Stn. 2**	**Stn. 3**	**Stn. 1**	**Stn. 2**	**Stn. 3**
E. intestinalis$_{protein}$ × SWT	-0.6232	-0.5082	-0.5135	<0.01	<0.01	<0.01
E. intestinalis$_{protein}$ × SWS	-0.9592	-0.9616	-0.8714	<0.01	<0.01	<0.01
E. intestinalis$_{protein}$ × pH	-0.6312	-0.7331	-0.9772	<0.01	<0.01	<0.01
E. intestinalis$_{protein}$ × DO	0.6990	0.8569	0.8928	<0.01	<0.01	<0.01
E. intestinalis$_{protein}$ × D. NO_3	0.9719	0.9973	0.9991	<0.01	<0.01	<0.01
E. intestinalis$_{protein}$ × D. PO_4	0.8257	0.9877	0.8703	<0.01	<0.01	<0.01
E. intestinalis$_{protein}$ × D. SiO_3	0.9341	0.9897	0.9162	<0.01	<0.01	<0.01
E. intestinalis$_{carbohydrate}$ × SWT	0.6631	0.6585	0.6767	<0.01	<0.01	<0.01
E. intestinalis$_{carbohydrate}$ × SWS	0.9432	0.8944	0.7540	<0.01	<0.01	<0.01
E. intestinalis$_{carbohydrate}$ × pH	0.5899	0.5949	0.9139	<0.01	<0.01	<0.01
E. intestinalis$_{carbohydrate}$ × DO	-0.6608	-0.7470	-0.7831	<0.01	<0.01	<0.01
E. intestinalis$_{carbohydrate}$ × D. NO_3	-0.9583	-0.9669	-0.9700	<0.01	<0.01	<0.01
E. intestinalis$_{carbohydrate}$ × D. PO_4	-0.7952	-0.9418	-0.7525	<0.01	<0.01	<0.01
E. intestinalis$_{carbohydrate}$ × D. SiO_3	-0.9142	-0.9990	-0.8161	<0.01	<0.01	<0.01
E. intestinalis$_{fat}$ × SWT	-0.8796	-0.8467	-0.9554	<0.01	<0.01	<0.01
E. intestinalis$_{fat}$ × SWS	-0.7721	-0.7286	-0.3206	<0.01	<0.01	IS
E. intestinalis$_{fat}$ × pH	-0.2773	-0.3394	-0.5852	IS	IS	<0.01
E. intestinalis$_{fat}$ × DO	0.3634	0.5249	0.3633	IS	<0.01	IS
E. intestinalis$_{fat}$ × D. NO_3	0.8024	0.8531	0.7155	<0.01	<0.01	<0.01
E. intestinalis$_{fat}$ × D. PO_4	0.5391	0.8059	0.3185	<0.01	<0.01	IS
E. intestinalis$_{fat}$ × D. SiO_3	0.7199	0.9449	0.4140	<0.01	<0.01	IS
E. intestinalis$_{astaxanthin}$ × SWT	0.4212	0.5695	0.4206	IS	<0.01	IS
E. intestinalis$_{astaxanthin}$ × SWS	0.9988	0.9391	0.9181	<0.01	<0.01	<0.01
E. intestinalis$_{astaxanthin}$ × pH	0.7963	0.6816	0.9940	<0.01	<0.01	<0.01
E. intestinalis$_{astaxanthin}$ × DO	-0.8479	-0.8171	-0.9352	<0.01	<0.01	<0.01
E. intestinalis$_{astaxanthin}$ × D. NO_3	-1.0000	-0.9894	-0.9979	<0.01	<0.01	<0.01
E. intestinalis$_{astaxanthin}$ × D. PO_4	-0.9355	-0.9737	-0.9172	<0.01	<0.01	<0.01
E. intestinalis$_{astaxanthin}$ × D. SiO_3	-0.9919	-0.9975	-0.9532	<0.01	<0.01	<0.01
U. lactuca$_{protein}$ × SWT	-0.6781	-0.6866	-0.6533	<0.01	<0.01	<0.01
U. lactuca$_{protein}$ × SWS	-0.9363	-0.8768	-0.7742	<0.01	<0.01	<0.01
U. lactuca$_{protein}$ × pH	-0.5735	-0.5639	-0.9262	<0.01	<0.01	<0.01
U. lactuca$_{protein}$ × DO	0.6455	0.7211	0.8022	<0.01	<0.01	<0.01
U. lactuca$_{protein}$ × D. NO_3	0.9524	0.9565	0.9771	<0.01	<0.01	<0.01
U. lactuca$_{protein}$ × D. PO_4	0.7828	0.9284	0.7728	<0.01	<0.01	<0.01
U. lactuca$_{protein}$ × D. SiO_3	0.9058	0.9967	0.8338	<0.01	<0.01	<0.01
U. lactuca$_{carbohydrate}$ × SWT	0.6290	0.6523	0.6673	<0.01	<0.01	<0.01
U. lactuca$_{carbohydrate}$ × SWS	0.9571	0.8980	0.7623	<0.01	<0.01	<0.01
U. lactuca$_{carbohydrate}$ × pH	0.6254	0.6014	0.9190	<0.01	<0.01	<0.01
U. lactuca$_{carbohydrate}$ × DO	-0.6936	-0.7524	-0.7909	<0.01	<0.01	<0.01
U. lactuca$_{carbohydrate}$ × D. NO_3	-0.9701	-0.9689	-0.9730	<0.01	<0.01	<0.01
U. lactuca$_{carbohydrate}$ × D. PO_4	-0.8215	-0.9445	-0.7608	<0.01	<0.01	<0.01
U. lactuca$_{carbohydrate}$ × D. SiO_3	-0.9314	-0.9994	-0.8234	<0.01	<0.01	<0.01
U. lactuca$_{fat}$ × SWT	-0.9966	-0.9982	-0.9990	<0.01	<0.01	<0.01
U. lactuca$_{fat}$ × SWS	-0.4517	-0.1940	0.0176	IS	IS	IS

U. lactuca$_{fat}$ × pH	0.1320	0.2713	-0.2773	IS	IS	IS
U. lactuca$_{fat}$ × DO	-0.0415	-0.0683	0.0277	IS	IS	IS
U. lactuca$_{fat}$ × D. NO_3	0.4950	0.3901	0.4380	IS	IS	IS
U. lactuca$_{fat}$ × D. PO_4	0.1553	0.3109	-0.0199	IS	IS	IS
U. lactuca$_{fat}$ × D. SiO_3	0.3803	0.5779	0.0828	IS	<0.01	IS
U. lactuca$_{astaxanthin}$ × SWT	0.2438	0.1640	-0.0492	IS	IS	IS
U. lactuca$_{astaxanthin}$ × SWS	0.9902	0.9959	0.9971	<0.01	<0.01	<0.01
U. lactuca$_{astaxanthin}$ × pH	0.8956	0.9288	0.9306	<0.01	<0.01	<0.01
U. lactuca$_{astaxanthin}$ × DO	-0.9323	-0.9851	-0.9926	<0.01	<0.01	<0.01
U. lactuca$_{astaxanthin}$ × D. NO_3	-0.9822	-0.9565	-0.8541	<0.01	<0.01	<0.01
U. lactuca$_{astaxanthin}$ × D. PO_4	-0.9851	-0.9777	-0.9973	<0.01	<0.01	<0.01
U. lactuca$_{astaxanthin}$ × D. SiO_3	-0.9981	-0.8720	-0.9845	<0.01	<0.01	<0.01
C. repens$_{protein}$ × SWT	-0.5977	-0.6527	-0.6090	<0.01	<0.01	<0.01
C. repens$_{protein}$ × SWS	-0.9679	-0.8979	-0.8092	<0.01	<0.01	<0.01
C. repens$_{protein}$ × pH	-0.6560	-0.6011	-0.9463	<0.01	<0.01	<0.01
C. repens$_{protein}$ × DO	0.7218	0.7521	0.8350	<0.01	<0.01	<0.01
C. repens$_{protein}$ × D. NO_3	0.9791	0.9688	0.9877	<0.01	<0.01	<0.01
C. repens$_{protein}$ × D. PO_4	0.8436	0.9444	0.8078	<0.01	<0.01	<0.01
C. repens$_{protein}$ × D. SiO_3	0.9452	0.9994	0.8641	<0.01	<0.01	<0.01
C. repens$_{carbohydrate}$ × SWT	0.7193	0.5827	0.5800	<0.01	<0.01	<0.01
C. repens$_{carbohydrate}$ × SWS	0.9146	0.9335	0.8298	<0.01	<0.01	<0.01
C. repens$_{carbohydrate}$ × pH	0.5255	0.6698	0.9573	<0.01	<0.01	<0.01
C. repens$_{carbohydrate}$ × DO	-0.6006	-0.8078	-0.8543	<0.01	<0.01	<0.01
C. repens$_{carbohydrate}$ × D. NO_3	-0.9333	-0.9870	-0.9927	<0.01	<0.01	<0.01
C. repens$_{carbohydrate}$ × D. PO_4	-0.7458	-0.9699	-0.8285	<0.01	<0.01	<0.01
C. repens$_{carbohydrate}$ × D. SiO_3	-0.8800	-0.9985	-0.8816	<0.01	<0.01	<0.01
C. repens$_{fat}$ × SWT	-0.9562	-0.9366	-0.9514	<0.01	<0.01	<0.01
C. repens$_{fat}$ × SWS	-0.6315	-0.5757	-0.3334	<0.01	<0.01	
C. repens$_{fat}$ × pH	-0.0822	-0.1429	-0.5960	<0.01	IS	<0.01
C. repens$_{fat}$ × DO	0.1723	0.3426	0.3758	IS	IS	IS
C. repens$_{fat}$ × D. NO_3	0.6688	0.7305	0.7249	<0.01	<0.01	<0.01
C. repens$_{fat}$ × D. PO_4	0.3623	0.6701	0.3312	IS	<0.01	IS
C. repens$_{fat}$ × D. SiO_3	0.5687	0.8595	0.4263	<0.01	<0.01	IS
C. repens$_{astaxanthin}$ × SWT	0.0234	-0.0159	0.3237	IS	IS	IS
C. repens$_{astaxanthin}$ × SWS	0.9348	0.9635	0.9545	<0.01	<0.01	<0.01
C. repens$_{astaxanthin}$ × pH	0.9718	0.9803	1.0000	<0.01	<0.01	<0.01
C. repens$_{astaxanthin}$ × DO	-0.9892	-1.0000	-0.9670	<0.01	<0.01	<0.01
C. repens$_{astaxanthin}$ × D. NO_3	-0.9163	-0.8885	-0.9859	<0.01	<0.01	<0.01
C. repens$_{astaxanthin}$ × D. PO_4	-0.9987	-0.9241	-0.9538	<0.01	<0.01	<0.01
C. repens$_{astaxanthin}$ × D. SiO_3	-0.9598	-0.7699	-0.9796	<0.01	<0.01	<0.01

Stn. 1: Gosaba; Stn. 2: Bali Island; Stn. 3: Jharkhali; SWT: Surface Water Temperature; SWS: Surface Water Salinity; DO: Dissolved oxygen; D. NO_3: Dissolved Nitrate; D. PO_4: Dissolved Phosphate; D. SiO_3: Dissolved Silicate

Table 2: Spatio temporal variations of hydrological parameters

Parameters	Variables	F_{cal}	F_{crit}
Temperature	Between Stations	4	6.944
	Between Seasons	4773	
Salinity	Between Stations	5.144	
	Between Seasons	75.529	
pH	Between Stations	13	
	Between Seasons	13	
DO	Between Stations	8.702	
	Between Seasons	29.570	
Dissolved Nitrate	Between Stations	46.299	
	Between Seasons	27.490	
Dissolved Phosphate	Between Stations	10.339	
	Between Seasons	14.408	
Dissolved Silicate	Between Stations	44.030	
	Between Seasons	53.645	

Table 3 Spatio temporal variation of proximate composition

Species	Variables	F_{cal}				F_{crit}
		Protein	Carbohydrate	Fat	Astaxanthin	
E. intestinalis	Between Stations	9.253	53.769	8	12.095	6.944
	Between Seasons	404.652	134058.9	182	9.792	
U. lactuca	Between Stations	24.911	4.54	8.622	12.594	6.944
	Between Seasons	1200.136	2037.156	74.235	3.688	
C. repens	Between Stations	7.914	5.745	13.818	11.884	6.944
	Between Seasons	151.536	155.715	86.364	62.498	

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