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PHYTOPLANKTON STANDING CROP AND ITS DIVERSITY IN THE BURAGAURANGA RIVER ESTUARY IN RELATION TO CHEMICAL ENVIRONMENT*

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Abstract

Chemical and biological features of Buragauranga river estuary stretching about eight kilometers beside Rangabali of Galachipa Upozilla, Patuakhali district, Bangladesh showed that the water of the estuary was moderately alkaline (pH 7.8 - 8.21). Conductivity had moderate to very strong and perfect significant correlations (at 5% level) with the chemical variables. Magnesium was found to have very strong relationship with different fractions of hardness whereas Ca had moderate correlation. The phytoplankton community was represented by 10 genera belonging to Chlorophyceae, Euglenophyceae and Bacilariophyceae. Bacillario-phyceae was the dominant algal class (8 genera, 80%). *Trachelomonas* sp. of Euglenophyceae was present in all the 12 sampling units of 3 locations indicating its dominancy and capacity to tolerate habitat fluctuations. Location 2 showed higher generic diversity than the other two locations. Principal component analysis showed that *Trachelomonas* sp. has negative significant correlation with principal component one i.e. Mg, K, conductivity, dissolved oxygen, biological oxygen demand and salinity have negative effect on the distribution of *Trachelomonas* sp. whereas these variables have positive effects on *Coscinodiscus* sp.

Introduction

An estuary acts as a linkage between the drainage basin and sea at the coast and also as a filter and recorder of river catchments changes due to human activities (Chen *et al.* 2007). A variety of complex physicochemical processes resulted in the poor understanding of estuaries of all coastal systems though studied most, and various factors such as growth of human population, agriculture and changes in land use pattern in the watershed have resulted in an increase of nutrient input to the estuaries of the world (Caffrey *et al*. 2007). The estuaries and coastal systems of different parts of the world faced hypoxia and anoxia due to excessive algal growth and eutrophication.

About 6000 years ago the coastal zone of Bangladesh started to form and it is the lowest-lying part of the Himalayan river-basin ecosystem (Islam 2001). But there is little comprehensive survey to determine the oceanographic features and organic productivity of the Bay of Bengal and its estuary which resulted in a general lack of basic information (Wyritki 1971, Krey 1976). Islam and Aziz (1975, 1977) have described and illustrated the phytoplankton and water chemistry of the Bay of Bengal and phytoplankton of the Karnaphuli river estuary. Except this, other parts of the estuarine ecosystems of Bangladesh such as Khulna, Barisal and Patuakhali areas remain almost unstudied. However, Ahmed *et al.* (2010 a, b) studied the edaphic conditions of different offshore islands with different hydrological regimes, elemental concentrations of the leaves of mangrove tree *Sonneratia apetala* Buch.-Ham, from the estuary of Patuakhali, but no information does exist on water and phytoplankton quality from the same area.

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Materials and Methods

Buragauranga river estuary, Patuakhali (21°53'10" - 22°00'00" N and 90°27'00" - 90°30'30" E), situated about 300 km south of Dhaka Metropolis, was studied. Three locations were selected and these were: Location 1: across the river near Char Motherbunia; Location 2: east of Char Taposhi and Location 3: between the Char Taposhi and Char Kashem, details of which are available in Ahmed *et al.* (2010a). Engine driven country boat was used in sampling on 28th February 2006 during high tide.

At each station pH, conductivity, free CO_2, salinity and dissolved oxygen (DO) of water were measured by using respective field meters. Four replicates of water samples, each 500 ml in quantity were collected from each location from a depth of 60 cm with the help of a water sampler (Lakshminarayana 1965, Ahmed 2004). Water samples were also collected for measuring the diversity of phytoplankton via sedimentation technique. For these purpose 100 ml capacity plastic bottles each containing 200 µl Lugols iodine were used. After collection, all samples were brought to the Department of Soil, Water and Environment, University of Dhaka for laboratory analyses. The concentration of chloride, BOD_5 (at 25 ± 3º C), hardness, filtrable and non-filtrable total residue were determined according to APHA (1976). Alkalinity was determined by the method described by Wetzel and Likens (1979). Na and K were determined by flame photometry and Ca and Mg by atomic absorption spectrophotometer. Sulphate was measured by the method of Hunt (1980). The density of phytoplankton was determined with the help of a Sedgewick-rafter counting chamber (Wetzel and Likens 1979).

Chemical variables of water were subjected to the ANOVA. Locations were used as factors. To compare water samples of the three locations of the river Buragauranga, ANOVA was performed using general linear model procedures in SAS 9.1 program. For the measurement of generic diversity the Shannon-Weiner diversity index (H) was calculated following Ruggiero and Merchant (1979). Principal component analysis (PCA) was done by using Stata 11 program (Stata 2010).

Results and Discussion

The chemical variables of Buragauranga river estuary on 28 February 2006 during high tide are shown in Fig. 1. Location 3 significantly differed from location 2 in salinity, non-filtrable residue, and total residues content only. Other variables did not show significant differences. On the other hand, location 3 showed significant differences from location 1 on salinity, non-filtrable residue, total residue, DO, oxygen saturation, BOD_5, permanent, temporary and total hardness and in Mg content.

Location 1 showed highest value for free CO_2 content with the concomitant of lowest DO. Higher value of conductivity in the location 2 of the river Buragauranga might be due to shallow nature of the place, and the area was also characterized by higher filterable residues. Lower conductivity and salinity in the location 1 can be explained by higher mixing of fresh water in this zone as it is far away from sea than locations 2 and 3. Safe standard of DO concentration in estuary was a median value of 7 mg/l with changes of <1 mg/l (Painting *et al.* 2007). But in the present study a high median value 11.2 mg/l was observed. The minimum and maximum values were observed 7.7 and 12.0 mg/l, respectively. In a study of Biscayne Bay, Florida, the median DO was found to be 6.3 mg/l with minimum and maximum values ranged between 2.8 and 11.6 mg/l (Caccia and Boyer 2005). DO_{sat} values had been found within a range of 41.1 - 161.0% with the median 92.0% in the same study. The present study showed that the values of both DO and DO_{sat} were in between the ranges of Biscayne Bay. The primary sources of oxygen in the marine

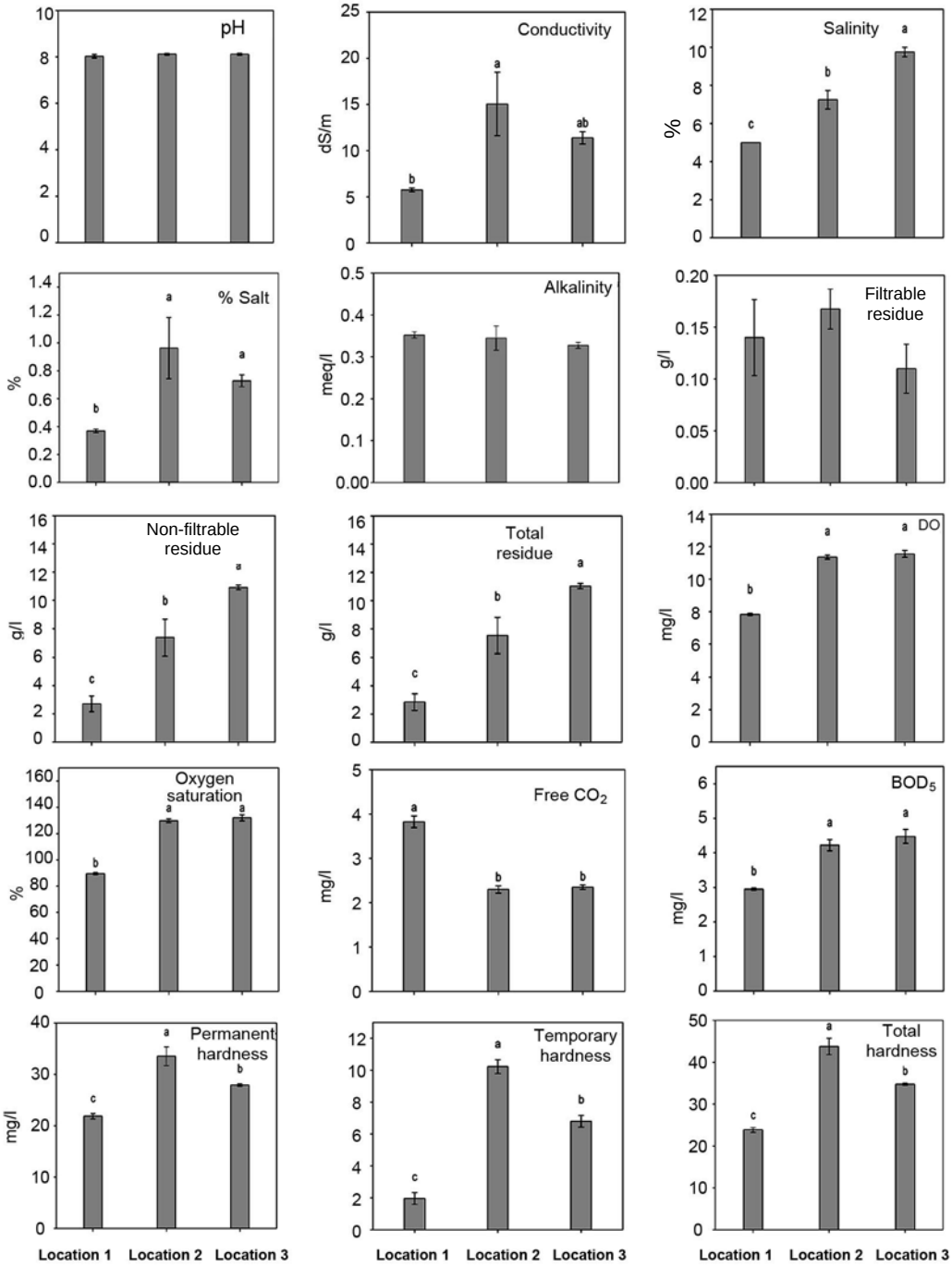

Fig. 1. Location wise variations in the chemical and biological variables of the Buragauranga estuary. Values are in mean with ±1SE. Different letters at the top of the bars indicate that they are significantly different at the p = 0.05 level.

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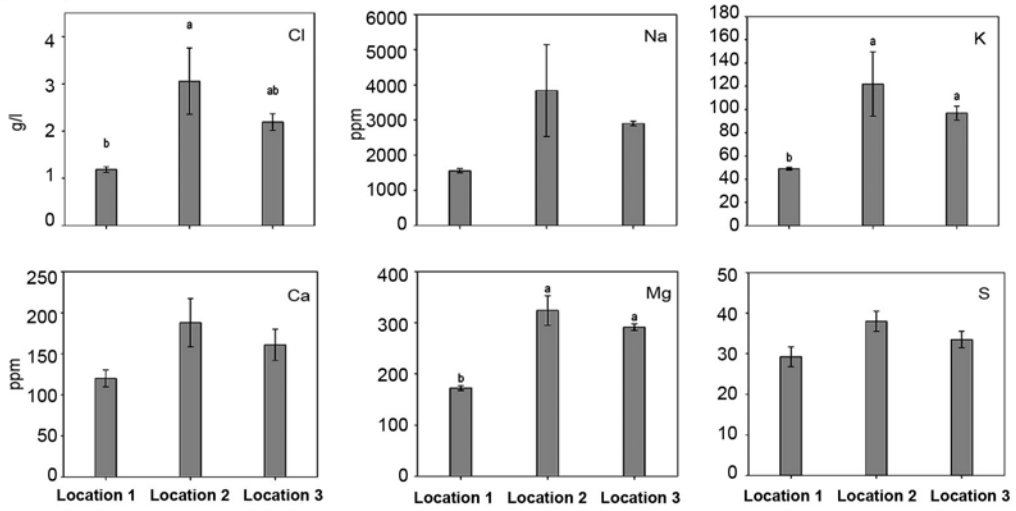

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environment is the gaseous exchange of atmospheric oxygen across the air-sea surface interface and *in situ* production by photosynthesis (Best *et al*. 2007). In estuaries the dynamic pattern of dissolved oxygen is a result of complex interactions among physical, chemical and biological processes (Borsuk *et al*. 2001). Strong dissolved oxygen gradient is formed in estuaries due to combination of variations in temperature, freshwater discharge, saltwater intrusion, circulation, biological productivity and respiration (Stanley 1993). Higher BOD_5 found in the present study in the location 2 than the location 1 may be due to higher number of phytoplankton.

Statistical analysis of the data revealed that conductivity had moderate to very strong and perfect correlations with the variables studied (Table 1). It had perfect positive correlation with % salt, whereas, had very strong significant correlation with Na, K, Mg, Cl, permanent hardness and total hardness. It has moderate significant correlation with DO, oxygen saturation, free CO_2, BOD_5 and with temporary hardness. Free CO_2 and alkalinity had negative correlations with the factors analyzed except between them. Though the correlation between and alkalinity and other variables are non-significant, free CO_2 has significant moderate to very strong correlation with the variables (Table 1). Salinity showed very strong positive significant correlation with DO, oxygen saturation, BOD_5, non-filtrable and total residue. It had negative non-significant correlation with filtrable residue. Although it had positive non-significant moderate correlation with the elements studied and with the different fractions of hardness, it had strong significant correlation with Mg. DO, oxygen saturation and BOD_5 showed moderate to very strong positive significant correlation with the elements analyzed and different fractions of hardness. The elements had strong to very strong significant correlation among themselves except with Ca. Mg showed very strong relationship with different fractions of hardness whereas Ca had moderate correlation.

In estuaries, phytoplankton assemblage structure and growth are affected by the different environmental factors that include salinity, nutrient, temperature etc. (Morais *et al.* 2003, Gasiunaite *et al.* 2005). The assemblage and distribution of phytoplankton and their density in the estuary is shown in Table 2. The phytoplankton community was represented by 10 genera belonging to Chlorophyceae, Euglenophyceae and Bacillariophyceae. The class Bacillariophyceae was represented by 8 genera, whereas Chlorophyceae and Euglenophyceae were represented by

Table 1. Correlation matrix of chemical variables of Buraguaranga river estuary.

p value/r	pH	Cond	Sal	% salt	Alk	FR	NFR	TR	DO	Osat	FCO_2	BOD_5	PHd	THd	TtHd	Na	K	Ca	Mg	S	Cl
pH		0.30	0.22	0.34	0.81	0.82	0.29	0.29	0.15	0.15	0.12	0.12	0.28	0.31	0.28	0.38	0.26	0.14	0.21	0.05	0.37
Cond	0.32		0.11	0.00	0.16	0.49	0.31	0.29	0.01	0.01	0.04	0.01	0.00	0.006	0.00	0.00	0.00	0.26	0.00	0.00	0.00
Sal	0.38	0.49		0.11	0.34	0.30	0.00	0.00	0.001	0.001	0.002	0.00	0.112	0.08	0.09	0.18	0.08	0.15	0.02	0.30	0.15
% salt	0.32	1.00	0.49		0.16	0.49	0.31	0.30	0.01	0.01	0.036	0.01	0.000	0.006	0.00	0.00	0.00	0.26	0.00	0.003	0.00
Alk	–0.08	–0.43	–0.30	–0.43		0.34	0.97	0.96	0.49	0.49	0.53	0.53	0.38	0.90	0.57	0.27	0.21	0.16	0.26	0.69	0.41
FR	0.07	0.22	–0.32	0.22	–0.30		0.51	0.54	0.85	0.85	0.77	0.68	0.39	0.68	0.49	0.71	0.55	0.19	0.66	0.63	0.64
NFR	0.33	0.32	0.90	0.32	–0.01	–0.21		0.00	0.001	0.001	0.002	0.001	0.16	0.045	0.09	0.47	0.24	0.08	0.04	0.35	0.38
TR	0.33	0.33	0.89	0.33	–0.02	–0.19	1.00		0.001	0.001	0.002	0.001	0.15	0.043	0.09	0.46	0.24	0.08	0.04	0.35	0.37
DO	0.45	0.68	0.85	0.68	–0.22	–0.06	0.85	0.85		0.00	0.00	0.00	0.002	0.000	0.001	0.06	0.01	0.04	0.00	0.04	0.02
O_2 sat	0.45	0.68	0.85	0.68	–0.22	–0.06	0.85	0.85	1.00		0.00	0.00	0.002	0.000	0.001	0.06	0.01	0.04	0.00	0.04	0.02
FCO_2	–0.47	–0.61	–0.79	–0.61	0.20	0.09	–0.79	–0.80	–0.96	–0.97		0.00	0.004	0.000	0.001	0.15	0.03	0.04	0.001	0.04	0.05
BOD_5	0.47	0.68	0.86	0.68	–0.20	–0.13	0.84	0.84	0.97	0.97	–0.87		0.007	0.001	0.003	0.04	0.01	0.03	0.001	0.05	0.02
PHd	0.34	0.92	0.48	0.92	–0.28	0.27	0.43	0.44	0.79	0.79	–0.77	0.73		.000	0.000	0.001	0.00	0.09	0.00	0.007	0.00
THd	0.32	0.74	0.51	0.74	–0.04	0.13	0.59	0.59	0.88	0.88	–0.86	0.81	0.91		0.000	0.03	0.007	0.03	0.00	0.02	0.008
TtHd	0.34	0.87	0.51	0.86	–0.18	0.22	0.51	0.51	0.85	0.85	–0.82	0.77	0.99	0.97		0.005	0.00	0.05	0.00	0.008	0.001
Na	0.28	0.96	0.42	0.96	–0.34	0.12	0.23	0.23	0.55	0.55	–0.44	0.60	0.82	.061	0.75		0.00	0.22	0.001	0.005	0.000
K	0.35	0.995	0.52	0.99	–0.39	0.19	0.37	0.37	0.70	0.70	–0.61	0.70	0.91	0.73	0.85	0.97		0.22	0.00	0.002	0.00
Ca	0.45	0.35	0.44	0.35	0.43	–0.41	0.52	0.52	0.59	0.59	–0.60	0.61	0.51	0.64	0.57	0.38	0.38		0.10	0.14	0.15
Mg	0.39	0.93	0.67	0.93	–0.35	0.14	0.59	0.60	0.88	0.88	–0.84	0.84	0.95	0.885	0.94	0.84	0.93	0.50		0.002	0.00
S	0.58	0.78	0.33	0.78	–0.13	0.15	0.29	0.30	0.59	0.59	–0.59	0.57	0.73	0.67	0.72	0.75	0.80	0.45	0.79		0.005
Cl	0.28	0.97	0.44	0.96	–0.41	0.15	0.28	0.28	0.64	0.64	–0.58	0.65	0.90	0.73	0.85	0.96	0.95	0.45	0.90	0.75	

(Cond = Conductivity, Alk = Alkalinity, FR = Filtrable residue, NFR = Non-filtrable residue, DO = Dissolved oxygen, FCO_2 = Free CO_2, PHd = Permanent hardness, THd = Temporary hardness, TtHd = Total hardness).

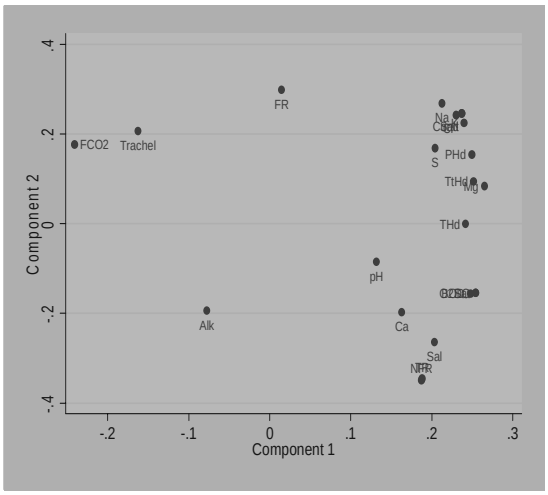
Table 2. Distribution and density of phytoplankton (values are in thousand per liter) and Shannon-Weiner index of diversity (H) at three different locations.

Phytoplankton genera	Location 1				Location 2				Location 3				Overall density	H
	1	2	3	4	1	2	3	4	1	2	3	4		
Cocconeis sp.	-	-	-	-	10	-	-	-	-	-	-	-	0.83	
Coscinodiscus sp.	-	-	-	20	40	20	10	10	20	20	10	10	13.33	
Cyclotella sp.	10	40	-	10	10	10	-	10	-	-	10	10	9.17	
Dunaliella sp.	-	-	-	-	20	-	-	10	-	-	-	-	2.5	2.823
Fragilaria sp.	-	50	20	-	-	10	-	-	-	-	-	-	6.67	
Gyrosigma sp.	10	-	-	-	-	-	-	-	-	-	-	-	0.83	
Melosira sp.	10	20	10	-	-	-	-	-	-	-	-	-	3.3	
Nitzschia sp.	-	-	-	-	-	10	10	-	10	20	-	10	5.0	
Pleurosigma sp.	-	-	-	-	30	10	10	10	-	-	-	-	5.0	
Trachelomonas sp.	30	40	20	20	20	20	10	20	20	10	20	10	20.0	
H	1.792	1.933	1.522	1.522	2.411	2.5	2.0	2.252	1.522	1.522	1.5	2.0		

– = Indicates absence.

one genus in each. In terms of density *Trachelomonas* sp. (Euglenophyceae) dominated with 20 × 10^3 individual/l followed by *Coscinodiscus* sp., *Fragilaria* sp., and *Cyclotella* sp. etc. (Bacillariophyceae). *Trachelomonas* sp. was present in all the 12 sampling units of 3 locations. The only representative of the class Chlorophyceae, *Dunaliella* sp. (3.3 × 10^3 individual/l) was present in location 2. The values of Shannon-Weiner index of diversity (H) are also shown in the Table 2 along with values of all sampling units. Different sampling units of location 2 showed higher generic diversity than the other two locations. Quick and unpredictable phytoplankton changes are characteristics of fast-changing ecosystems (Naselli-Flores *et al.* 2003). It has been revealed from principal component analysis (PCA) that *Trachelomonas* sp. showed negative correlation with principal component one, that is Mg, K, conductivity, DO, BOD_5, and salinity has negative effect on the distribution of this algae. On the other hand, *Coscinodiscus* sp. has shown positive correlation with these variables and negative correlation with free CO_2 and alkalinity (Fig. 2).

Variable	Comp1	Comp2	Comp3
Trachel	−0.1626	0.2065	0.2995
pH	0.1315	−0.0856	−0.0115
Cond	0.2369	0.2459	−0.0019
Sal	0.2032	−0.2642	−0.2177
Salt	0.2368	0.2462	−0.0023
Alk	−0.0778	−0.1946	0.6487
FR	0.0144	0.2977	−0.2905
NFR	0.1873	−0.3492	−0.1011
TR	0.1880	−0.3459	−0.1057
DO	0.2541	−0.1544	−0.0526
O2Sat	0.2541	−0.1543	−0.0525
FCO2	−0.2412	0.1762	0.0412
BOD	0.2476	−0.1562	−0.0258
Na	0.2125	0.2688	0.0872
K	0.2395	0.2239	0.0159
Ca	0.1629	−0.1975	0.4849
Mg	0.2650	0.0840	−0.0140
S	0.2039	0.1686	0.1957
Cl	0.2300	0.2423	0.0500
PHd	0.2492	0.1536	0.0583
THd	0.2418	−0.0004	0.1721
TtHd	0.2514	0.0934	0.1064



Variable	Comp1	Comp2	Comp3
Coscin	0.1333	0.2092	−0.4825
pH	0.1246	−0.0938	0.1909
Cond	0.2415	0.2170	0.0873
Sal	0.1989	−0.2667	−0.1785
Salt	0.2415	0.2174	0.0874
Alk	−0.0807	−0.2486	0.4165
FR	0.0212	0.3528	−0.2784
NFR	0.1831	−0.3489	−0.1920
TR	0.1839	−0.3448	−0.1967
DO	0.2536	−0.1618	−0.1163
O2Sat	0.2536	−0.1617	−0.1162
FCO2	−0.2396	0.1775	0.1065
BOD	0.2464	−0.1754	−0.0526
Na	0.2166	0.2268	0.2028
K	0.2436	0.1910	0.1082
Ca	0.1572	−0.2494	0.4037
Mg	0.2681	0.0670	−0.0093
S	0.2061	0.1193	0.2810
Cl	0.2338	0.2139	0.1374
PHd	0.2533	0.1400	0.0319
THd	0.2451	−0.0193	0.0223
TtHd	0.2553	0.0772	0.0286

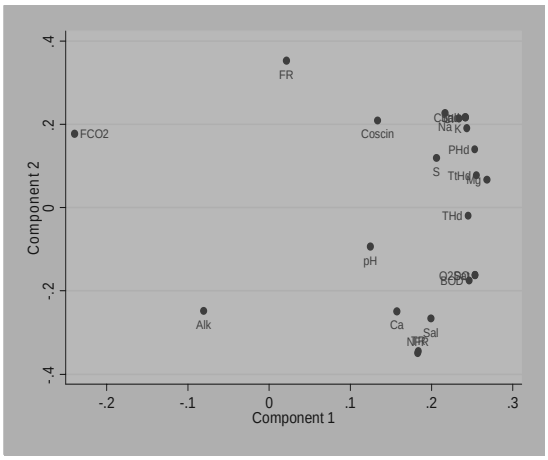


Fig. 2. Principal component analysis showing two significant groupings of variables and their relationship with *Trachelomonous* sp. and *Coscinodiscus* sp. (elaboration of the variables are same as Table 1. except Trachel = *Trachelomonous* sp. and Coscin = *Coscinodiscus* sp.).

The distribution of phytoplankton assemblage is often studied in relation to physical and chemical variables like gradient in salinity in coastal ecosystems. It helps in coastal ocean characterization in spatial variability found horizontally or vertically (Lunven *et al*. 2005). In the present study, phytoplankton structure and assemblage showed an important spatial change in horizontal distribution. Typical river phytoplankton *Melosira* sp. (Reynolds 1988) were found only in location 1 where the salinity was low. Presence of *Trachelomonas* sp. in all sampling locations might be due to the capacity of the genus to tolerate habitat fluctuation and free CO_2 and alkalinity might have strong effect on their distribution to overcome the influences of the other variables.

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