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Phytoplankton community organization and species diversity in the Hugli estuary, north east coast of India

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Phytoplankton were collected from March 1988 to February, 1990 from four different stations in the Hugli estuary. Analyses such as relative abundance, dominance, richness, evenness indices and species diversity were made to detail the community organisation of the available phytoplankton. Maximum numbers of phytoplankton cells were observed between postmonsoon (SW) and early premonsoon months. Only two species, *Coscinodiscus radiatus* and *Coscinodiscus excentricus* out of 29 species dominated and they contributed >50% to the total population. A significant negative correlation was observed between species diversity ($\bar{H}$) and pollution index (R/Chl-*a*).

Community concept is one of the most important principles in ecological thought and practice. Competition, predation, symbiosis etc. are the various processes promoting community organisation. The diversity of a plankton community may be expressed based on the number of species present. The simplest expression of diversity is to determine the percentage composition of species in a population; the more species making up the total, the greater is the diversity of the organisms. Significant contribution concerning community organisation of different organisms has been rendered by different authors[1-4]. The present study deals with the phytoplankton community organisation and species diversity in the Hugli estuary.

Materials and Methods

Monthly observation on phytoplankton and water chemistry were made during spring tide from November 1988 to February 1990 at four stations along the mixing zone of the Hugli estuary (Fig. 1). Stations were selected on the basis of salinity gradient of the estuary. Water samples were collected from surface and physico-chemical properties were determined following standard procedures[5]. Chlorophyll-*a* concentration was estimated after filtration of one litre sample through the membrane filter by spectrophotometric method[5]. Gross primary production was measured using light and dark bottle method as described by Stirckland and Parsons[5]. Community respiration was measured from the differences between the amounts of dissolved oxygen in the control bottle and dark bottle. The light and dark bottles were incubated *in situ* after having been filled up with samples[5].

In order to determine the species composition one litre surface water samples were collected in a polythene bottle and fixed with Lugol's iodine solution. The bottles were kept undisturbed for 2 days till complete sedimentation was achieved. The supernatant was rejected and the plankton settled on the bottom were used for numerical counts. From a final volume of 20 ml settled aliquots, 1 ml subsample was taken for counting in a Sedgwick -Rafter

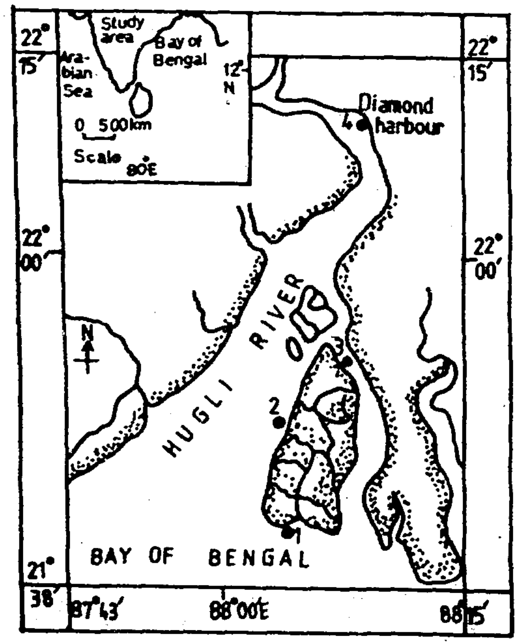

Fig. 1—Map showing station locations

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counting chamber[6,7]. The index of dominance[8], species richness or variety index[9], species diversity index[10] and species evenness index[11] were calculated by using the following expressions :

Index of dominance (C) = $(n_i/N)^2$

where n_i = importance value for each species, N = total of importance values.

Species richness of variety indices (d) = S/N where S = number of species, N = number of individuals.

Shannon-Weaver's index of species diversity

$\bar{H} = -(n_i/N) \log (n_i/N)$

where n_i = importance value for each species, N = total of importance values. Evenness index (e) = $\bar{H}/\log S$, where, $\bar{H}$ = Shannon-Weaver's index, S = number of species.

Results and Discussion

Data of various parameters studied are given in Table 1. The Hugli estuary has semidiurnal tides gaining a maximum amplitude of about 5.5 m and depth of water column varied between 2 and 9 m at the observed stations. This tropical estuarine ecosystem is well recognised by three seasons : premonsoon (February to May), southwest monsoon (June to September) and postmonsoon (October to January). Maximum temperatures at all stations were found in May which varied from 31° to 34.5°C in surface water. Minimum temperature were found in December when surface water temperature ranged between 19.5° and 22.5°C. Maximum values of salinity were observed at all stations during premonsoon. In April, salinity varied between 1.62 $\times 10^{-3}$ (st.4) and 25.92 $\times 10^{-3}$ (st.1). Low salinities were recorded during September and varied between 0.11 $\times 10^{-3}$ (st.4) and 6.21 $\times 10^{-3}$ (st.1). Large variations of suspended matter concentration down the estuary were observed. At st.4 it varied between 30 and 282 mg.l^{-1}. The corresponding values decreased to 3 and 120 mg.l^{-1} at st. 1. The maximum values were obtained at all stations during monsoon. Secchi disc transparency was found to vary between 19 and 121 cm. All four stations showed undersaturation (0.57-12.9%) with respect to dissolved oxygen except in postmonsoon and premonsoon at st.1 where water was found to be saturated with respect to dissolved oxygen (0.88-1.82%).

Higher values of nutrients were found in this estuary and the mean value of N/P ratio (14) at low chlorinity decreased to 9.8 at high chlorinity which reflects the decrease of nitrate concentration with chlorinity. At the sea end of the estuary nitrogen limited condition was observed.

Monthly variations of phytoplankton cells at different stations were given in Fig. 2. Total number of phytoplankton population varied between 12.2×10^5 and 77×10^5 cells.m^{-3}. Maximum number of phytoplankton cells were observed between postmonsoon and early premonsoon months. Average values of relative abundance of different species for four stations were given in Table 2. A total of 29 species of phytoplankton was observed. Almost similar pattern for relative abundance of all species was observed at all stations. Species belonging to the genera *Coscinodiscus, Thalassiosira, Pleurosigma, Skeletonema, Dityllum, Asterionella, Rizosolenia, Chaetoceros, Biddulphia, Diploreis, Silicoflagellate, Gyrosigma, Halosaphaera, Nitzschia, Bacillaria, Thallassionema, Eucampia, Ceratium, Bacteriastrum, Amorpha* occurred almost throughout the year.

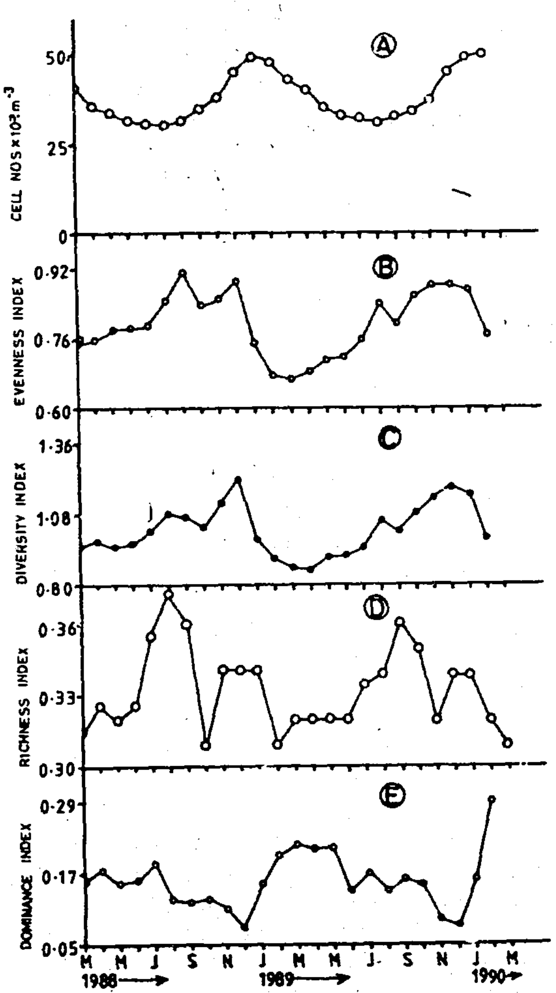

Fig. 2—Monthly variations of A) phytoplankton populations, B) eveness index, C) diversity index, D) richness index, E) dominance index for four stations

Table 1—Mean variations (1988-90) of some physico-chemical properties of surface water (Mean ± SD)

Parameters	St.1	St.2	St.3	St.4
Temp. (°C)	27.5±3.8	27.4±3.6	27.6±3.5	28.2±3.0
Chlor ($\times 10^{-3}$)	9.40±3.10	8.27±3.25	5.82±3.24	0.39±0.33
*p*H	8.16±0.23	8.13±0.20	8.11±0.21	8.05±0.21
Diss. Oxy. ($ml.l^{-1}$)	4.81±0.72	4.79±0.47	4.88±0.33	4.92±0.48
PO_4^{-3}-P (μg-at.l^{-1})	1.61±0.71	1.48±0.48	1.55±0.62	1.83±0.67
NO_3^--N (μg-at.l^{-1})	15.75±4.57	15.72±4.28	20.44±5.75	25.96±8.73
SiO_4^{-4}-Si (μg-at.l^{-1})	75.38±20.03	79.86±22.47	91.50±28.28	120.87±25.95
Gross Pr. Prod. (mg $C.m^{-3}.h^{-1}$)	24.9±5.4	26.7±4.04	27.5±5.6	38.3±11.9
Respiration (mg $C.m^{-3}.h^{-1}$)	30.51±5.75	28.24±4.04	30.07±6.47	38.45±8.16
Chlorophyll-*a* (mg m^{-3})	3.024±0.598	3.158±0.667	2.67±0.84	2.547±0.789

Monthly variation of evenness index, diversity index, richness index and dominance index are given in Fig. 3. Values of dominance index varied between 0.052 and 0.252. Dominance index showed high values in premonsoon and low values during postmonsoon. During premonsoon higher values of dominance index indicated that the community was dominated by fewer number of species in comparison to the total number of individual and its lower values during postmonsoon could be due to the dominance being shared by large number of species[13]. Species richness or variety index is expressed as simple ratio between total species and total numbers. In the present study species richness or variety index varied between 0.281 and 0.48. The lower ratio between species number and total population made variety index value minimum during premonsoon months. Also species diversity which is the ratio between the number of species and importance values (number) of individuals showed minimum values during premonsoon and maximum values were obtained between late monsoon and early postmonsoon. It is of interest to note that diversity index $\bar{H}$ behaves inversely to the dominance index (C) since its high values indicate a low concentration of dominance. Similarity in behaviour between diversity index ($\bar{H}$) and evenness index was also noticed. However, Shannon-Weaver's diversity index ($\bar{H}$) showed relatively more pronounced amplitudes in comparison with that of variety index (d) and evenness index (e). Sharp decline of peak values of diversity index was observed in February (early premonsoon) when total number of phytoplankton showed maximum values because majority of the phytoplankton population was dominated by the two species in this month. Dominance of only two species, *Coscinodiscus radiatus* and *C. excentricus* out of 29 species has been found (Table 2). Further decline of values of diversity index in April was due to the disappearance of less competitive species such as *Eucampia zoadicus, Ceratium tripos, Bacteriastrum hyalinum, Amorpha hyalina* etc. However their contribution never exceeded 5% of the total population. Values of diversity index never exceded 1.308 which was low indeed because of the dominance of *Coscinodiscus radiatus* and *C. excentricus*, almost throughout the year. Predominant genus *Coscinodiscus* contributed 34 to 70.8% to the total population. *Ceratium tripos* was the only dominant species among dinoflagellates which contributed only 0 to 1.4%. Occurrence of high concentration of nutrients in the estuarine water possibly favours the abundance of diatoms over dinoflagellates[14]. The ratio of the centric and pennate diatoms varied between 1.3 and 2 during the study period in the estuary and predominance of centric diatom over pennate diatom could be due to organic pollution and nutrient enrichment[15]. Average values of gross production always were less than the community respiration (Table 1) thus indicating the unhealthy condition of the estuary. The ratio between community respiration and chlorophyll-*a* (R/chl-*a*)

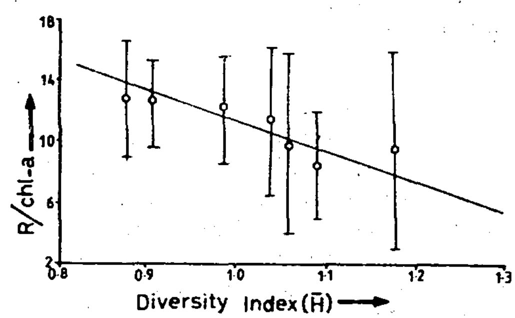

Fig. 3—Correlation between R/chl-*a* and diversity index ($\bar{H}$)

Table 2—Average relative abundance of different species for four stations
Months (1988-1990)

Species	1988-1989												1989-1990											
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Coscinodiscus radiatus	23.8	20.6	20.1	20.7	18.16	15.9	17.0	16.74	15.05	12.04	21.6	23.5	24.22	24.3	20.7	18.66	18.1	14.6	16.3	16.4	14.3	12.4	13.6	22.5
Cosscinodiscus excentricus	29.3	28.4	30.2	32.2	30.13	24.8	24.8	26.3	25.4	19.9	28.8	37.0	38.0	36.6	37.4	38.3	33.5	28.2	28.4	30.8	21.1	19.29	21.99	30.6
Coscinodiscus lineatus	7.76	6.83	8.53	6.65	6.40	5.55	6.92	8.23	5.5	4.36	8.74	7.91	6.24	5.01	4.86	4.95	5.03	4.31	5.11	6.77	6.06	5.04	5.16	7.37
Thalassiosira decipiens	1.79	2.19	2.01	1.90	3.43	2.02	1.96	2.43	1.90	1.75	1.37	1.21	1.19	1.31	1.65	1.46	1.93	2.75	1.70	2.04	2.03	1.88	1.78	1.28
Rhizosoielnia alata	2.11	1.91	2.77	3.03	3.48	4.21	5.79	3.95	3.39	4.08	2.27	1.29	1.00	1.77	2.08	2.32	3.59	3.21	5.15	3.83	4.70	4.42	3.35	2.06
Rhizosolenia nebetata	1.11	1.07	1.19	0.90	1.30	1.12	1.47	2.26	1.61	1.86	1.04	1.06	1.03	0.43	0.48	0.52	0.91	1.25	1.44	1.62	1.69	1.98	2.09	1.00
Rhizosolenia stolteriotni	0.85	0.95	0.69	1.32	0.71	1.34	0.89	0.73	2.24	1.77	0.92	0.60	0.93	0.88	0.97	1.26	0.32	1.29	0.50	0.58	1.80	1.91	1.87	1.40
Rhizosolenia shrubsolei	1.88	1.76	2.23	2.32	2.06	1.71	1.53	2.08	2.77	3.22	1.27	1.10	1.14	1.18	1.11	1.65	1.64	2.39	1.75	1.84	2.32	2.93	2.34	1.28
Chaetoceros diversum	1.88	2.44	1.91	1.86	2.33	2.35	2.66	3.46	3.44	5.12	3.25	1.25	2.01	1.74	1.85	1.44	1.63	2.85	2.64	2.79	5.71	4.91	4.37	2.21
Chaetoceros lorenzianum	1.10	1.03	0.58	0.73	0.55	1.90	1.77	0.91	0.66	1.60	1.29	0.78	0.31	0.43	0.39	0.61	0.64	1.33	1.07	0.67	1.04	1.75	1.77	0.60
Chaetoceros curvisetum	1.15	1.24	1.43	1.45	1.80	2.20	2.39	1.74	3.21	3.60	1.46	1.18	1.24	1.20	1.74	1.50	1.91	2.44	2.07	2.11	4.25	3.21	2.20	1.40
Biddulphia sinensis	1.76	2.64	2.55	2.82	2.59	2.79	2.68	3.52	3.59	4.08	3.10	1.95	2.02	1.27	2.51	1.56	2.0	2.70	2.77	3.85	4.35	4.76	4.1	2.27
Biddulphia regia	1.75	2.13	1.92	2.09	2.39	2.61	2.90	2.85	2.22	3.65	2.29	1.20	0.91	1.50	1.41	2.12	1.50	4.30	3.75	2.75	2.90	3.08	4.08	1.93
Biddulphia mobiliensis	1.57	1.03	1.62	1.49	1.56	1.79	1.98	1.85	2.82	3.02	0.87	1.46	1.38	1.27	2.26	1.52	2.5	2.61	2.78	4.08	2.57	2.38	2.86	1.19
Dityllum brightwelli	2.11	4.20	3.00	3.13	2.53	3.57	3.44	3.66	3.78	4.07	1.77	3.37	4.58	3.95	2.36	3.12	1.80	3.15	2.79	2.62	3.40	3.65	3.09	3.19
Asterionella japonica	4.94	3.41	3.95	4.14	3.69	3.92	4.1	4.08	5.12	6.21	5.66	2.91	2.59	2.33	3.21	3.01	3.53	3.66	3.61	4.33	5.1	3.48	5.81	3.09
Skeletonema costatum	1.24	1.25	0.69	1.04	1.32	1.00	0.91	1.04	1.99	3.28	2.11	1.15	0.47	0.86	0.98	1.34	1.38	1.18	0.99	0.76	1.73	2.92	2.72	1.48
Pleurosigma angula	1.19	1.24	1.59	1.19	1.1	2.01	1.74	1.00	1.63	1.47	0.75	0.85	0.79	1.21	1.26	1.35	1.66	1.50	1.50	1.85	1.52	1.75	1.74	1.14
Gyrosigma sp.	0.83	0.91	0.99	1.27	1.20	2.58	1.22	0.91	1.16	1.47	0.59	0.36	0.48	0.96	0.49	0.81	1.48	0.75	0.71	0.58	0.78	1.32	1.25	1.28
Bacillaria paradoxa	–	0.18	0.40	0.95	1.19	1.00	0.41	0.73	1.12	0.90	0.52	0.85	–	0.43	0.40	0.61	1.02	0.54	0.50	0.56	1.02	0.90	1.23	0.87
Nitzschia closterium	0.58	0.85	0.88	–	0.55	1.9	0.11	0.82	0.83	1.28	0.70	0.64	0.33	0.78	0.78	0.51	0.53	0.43	0.60	0.58	0.52	0.99	0.96	1.12
Halosaphaera viridis	0.58	1.56	1.26	1.17	1.35	1.57	1.27	1.22	1.73	1.28	0.90	0.84	0.77	1.83	1.36	1.48	0.91	1.85	1.50	1.65	1.36	1.11	0.69	0.85
Thalassionema nitzschiodes	2.53	1.75	1.80	2.26	1.19	1.90	1.85	2.82	1.78	2.46	0.67	0.99	1.17	1.21	1.93	1.99	2.49	1.49	1.51	1.65	1.78	2.71	2.28	1.26
Eucampia zoadicus	1.15	1.07	–	–	1.46	0.33	0.09	–	3.26	2.29	1.70	0.79	0.40	0.43	–	–	0.96	1.03	0.19	–	2.56	2.91	3.09	0.99
Ceratium tripos	0.33	0.46	–	–	–	–	0.31	–	0.51	0.40	0.52	0.72	0.32	0.45	–	–	–	–	0.10	–	0.35	0.4	0.44	0.60
Bacteriastrum hyalinum	0.25	0.28	–	–	0.55	0.34	0.30	–	0.43	0.41	0.45	0.29	0.34	0.17	–	–	0.42	0.21	0.20	–	0.35	0.32	0.22	0.39
Amorpha nyalina	0.25	0.09	–	–	–	–	0.20	–	–	0.16	0.22	0.29	0.43	–	–	–	–	–	0.70	–	–	0.23	0.15	0.27
Diploreis sp.	2.43	1.98	3.77	1.84	3.4	2.46	2.57	2.05	2.24	1.3	1.36	1.01	1.47	1.60	2.02	2.85	4.35	3.03	2.08	2.14	2.39	1.36	1.63	1.33
Silicoflagellale sp.	3.66	6.34	3.77	3.31	4.54	7.37	6.62	4.45	1.68	2.86	3,41	3.03	4.12	4.81	5.74	5.0	4.35	6.82	7.98	4.28	2.05	3.26	4.2	3.19

can be used as a pollution index. Its high value indicated organic pollution in the estuary[16]. A significant negative correlation ($r = -0.87$) was found between pollution index (R/chl-*a*) and species diversity ($\bar{H}$) (Fig. 3). The corresponding regression equation was $\bar{H} = 1.584-0.051$ (R/chl-*a*). Therefore in the event of increase in the ratio of community respiration and chl-*a* there has been decrease of species diversity in the Hugli estuary. The lower stretch of the Hugli river received 396×10^6 m^3 of sewage and wastes annually and as a result the entire estuary was undersaturated with respect of dissolved oxygen, almost throughout the year indicating unhealthy condition of the estuary[17]. Light limitation to use resources[18] and predator pressure[19] combined with physical stresses like tide induced turbulent motion[20], short flushing time[20] along with organic pollution stress make the phytoplankton struggle for survival in Hugli estuary. As a result the species diversity of phytoplankton is found to be considerably low i.e. this typical tropical estuarine ecosystem is being dominated by a relatively small number of phytoplankton species.

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