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Interrelationship between Hydrological Parameters and chlorophyll a Concentration in and around Indian Sundarbans

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ABSTRACT

Phytoplankton are minute, free floating, floral communities that are widely available in the marine and estuarine waters. They are totally dependent on nutrient availability, transparency, salinity and temperature of the water body. A comparative study was conducted to monitor the interrelationship between selected hydrological parameters (like surface water temperature, transparency, pH, salinity, dissolved oxygen, nitrate, phosphate and silicate) and Chlorophyll a (chl a) concentration at twenty different sampling stations in and around Indian Sundarbans during 2015 on seasonal basis. Significant positive correlation values were observed between salinity, pH and chl a, confirming high salinity and slightly alkaline pH to be extremely favorable for the growth and survival of the phytoplankton species in the present geographical locale. The importance of transparency in promoting the growth of phytoplankton has also been confirmed. The significant negative relationships between phytopigments level and nutrient (nitrate and phosphate) concentrations of the ambient water confirm the necessity of nutrients as building blocks of marine phytoplankton. However an insignificant relationship was observed between chl a and silicate. This may be due to less abundance of siliceous diatoms in comparison to flagellates in the present study area
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Keywords- *Indian Sundarbans; Phytopigment; Phytoplankton; Nutrients; Correlation.*

I. INTRODUCTION

The Indian Sundarbans at the apex of the Bay of Bengal (between 21°13′ to 22°40′ N latitude and 88°03′ to 89°07′ E longitude) is located on the southern fringe of the state of West Bengal, covering the major portions of the north and south 24 paraganas districts. The region is bordered by Bangladesh in the east, the Hooghly River in the west, "Dampier-Hodges Line" in the north and the Bay of Bengal in the south. The biosphere reserve of Indian Sundarbans is presently occupying an area of 9630 sq. km. supporting 34 species of true mangroves and several associates. The area is extremely dynamic from the point of view of physico-chemical variable and is a unique reservoir of a galaxy of flora and fauna. This highly dynamic zone supports a marvellous gene pool of micro- and macro biotic community in which the mangrove vegetations occupy a special status.

The present sampling stations were selected in the aquatic phase around this mangrove dominated deltaic lobe with an aim to monitor the interrelationship between chl *a* and few relevant physico-chemical variables (like surface water temperature, transparency, pH, salinity, dissolved oxygen, nitrate, phosphate and silicate), and also to investigate the distribution pattern of the phytopigment (chlorophyll *a*) through seasons.

II. MATERIALS AND METHODS

The entire network of the present programme comprised of the estimation of chlorophyll *a* and few relevant physico-chemical variables during 2015 at twenty different sectors in and around Indian Sundarbans. For pigment analysis, 1 litre of surface water, collected from each of the sampling station was filtered through a 0.45 µm Millipore membrane fitted with a vacuum pump. The residue along with the filter paper was dissolved in 90% acetone and kept in a refrigerator for about 24 hours in order to facilitate the complete extraction of the pigment. The solution was centrifuged for about 20 min under 5000 rpm and the supernatant solution was considered for the determination of the chlorophyll pigment by recording the optical density at 750, 664, 647 and 630 nm with the help of SHIMADZU UV 2100 spectrophotometer. All the extinction values were corrected for a small turbidity blank by subtracting the 750 nm signal from all the optical densities, and finally the phytoplankton pigment was estimated as per the following expression [1]:

$$\text{chl } a = 11.85\ OD_{664} - 1.54\ OD_{647} - 0.08\ OD_{630}$$

The value obtained from the equation was multiplied by the volume of the extract (in ml) and divided by the volume of the water (in litre) filtered to express the chlorophyll *a* content in mgm^{-3}. All the analyses were done in triplicate on the basis of collection of three water samples from the same site in order to ensure the quality of the data.

Analysis of the ambient surface water was also carried out simultaneously to monitor the selected physico-chemical variables influencing the chlorophyll *a* concentrations in the study area. Surface water temperature was recorded from the selected sampling stations by a Celsius thermometer. The surface water salinity was recorded in the field by means of a refractrometer, which was cross-checked in the laboratory by argentometric method. The dissolved oxygen was measured by a D.O. meter in the field and subsequently cross-checked in the laboratory by Winkler's method. The pH of the surface water was analyzed by a portable pH meter (sensitivity = ±0.02). Transparency, being an important variable affecting the assemblage of phytoplankton, was measured using a Secchi disc of 30 cm in diameter.

Surface water for nutrient analysis was collected from each of the selected stations in clean TARSON bottles and transported to the laboratory in ice-freezed condition. Triplicate samples were collected from the same collection site to maintain the quality of the data. The standard spectrophotometric method [2] was adopted to determine the nutrient concentrations in surface waters. Finally the interrelationship between the selected variables was evaluated through computation of correlation coefficient (r).

III. RESULTS AND DISCUSSION

It was observed that the value of chl *a* was relatively greater (Table 1, 2, 3) in those stations which are nearer to the sea, which confirms the zone of high salinity and transparency to be conducive for the growth of phytoplankton. Significant positive correlation values were observed between salinity, pH, dissolved oxygen and chl *a*, confirming high salinity, and slightly alkaline aquatic phase to be extremely favorable for the growth and survival of the phytoplankton species in the present geographical locale. Earlier workers confirmed the presence of 102 species of phytoplankton from the high saline zone of the present study area [3]. The chlorophyll *a* concentration was also directly proportional to the transparency of water at 1% level of significance (Table 4) which confirms the complete dependency of the phytoplankton on the penetration of light in the aquatic phase. The correlation coefficient values suggest a negative relationship of chlorophyll *a* with nutrients like nitrate and phosphate.

Table 1. Physico-chemical variables of the selected sampling stations during 23rd April, 2015 (Premonsoon), data taken during high tide condition.

Stations	*Water temperature* (°C)	*Salinity* (‰)	*pH*	*DO* (mg/l)	*Transparency* (m)	*NO_3* (µgat/l)	*PO_4* (µgat/l)	*SiO_3* (µgat/l)	*Chl a* (mgm^{-3})
Diamond harbour	32.6	4.76	8.21	4.86	12.9	19.70	2.46	88.72	1.98
Kakdwip	32.7	6.82	8.28	4.66	14.3	14.06	2.48	78.18	2.00
Kachuberia	32.8	13.37	8.32	5.05	14.7	15.39	2.53	67.28	2.73
Chemaguri	32.8	22.30	8.32	5.01	15.9	13.18	1.64	51.78	4.54
Harinbari	32.7	20.95	8.32	5.32	15.2	13.76	1.70	63.10	3.98
Sagar South	33.4	26.88	8.33	5.33	16.1	14.10	1.52	101.23	4.70
Sand heads	33.6	30.46	8.34	6.14	17.7	18.74	2.17	111.11	6.11
Frazergaunge	33.5	28.05	8.34	6.02	16.7	16.14	1.73	41.29	5.07
Prentice Island	32.9	29.10	8.34	6.17	17.0	12.65	1.02	39.85	5.17
Lothian Island	33.0	29.43	8.34	6.05	17.3	10.59	0.98	37.46	5.39
Canning	32.6	10.16	8.30	4.93	14.5	18.17	2.01	76.45	2.02
Sandeshkhali	32.7	11.29	8.31	4.95	14.6	15.23	2.70	71.02	2.50
Sonakhali	32.9	21.45	8.32	5.20	15.4	11.23	1.65	50.44	4.02
Gosaba	32.7	16.22	8.31	5.00	15.0	14.02	1.12	78.49	3.16
Bali	33.1	24.09	8.34	5.85	18.0	9.18	0.66	66.40	6.04
Sajnekhali	32.9	24.13	8.34	6.01	16.6	8.14	0.86	70.48	4.99
Jharkhali	33.1	28.77	8.34	5.69	16.9	8.76	0.99	44.81	5.13
Chotomollakhali	33.0	18.02	8.32	5.46	15.1	9.53	0.93	65.19	3.85
Satjelia	32.9	23.01	8.32	5.14	16.4	10.85	1.19	86.20	4.58
Kumirmari	32.8	23.78	8.32	5.28	16.7	9.94	1.83	49.17	4.66

Table 2. Physico-chemical variables of the selected sampling stations during 8th October, 2015 (Monsoon), data taken during high tide condition.

Stations	Water temperature (°C)	Salinity (‰)	pH	DO (mg/l)	Transparency (m)	NO_3 (µgat/l)	PO_4 (µgat/l)	SiO_3 (µgat/l)	Chl a (mgm^{-3})
Diamond harbour	32.4	0.02	7.98	5.13	11.9	21.78	4.19	70.08	1.12
Kakdwip	32.6	2.95	8.20	5.04	13.5	26.05	4.68	69.42	1.40
Kachuberia	32.6	2.98	8.28	5.01	13.7	18.59	3.93	58.79	1.76
Chemaguri	32.6	7.50	8.28	5.20	14.8	16.42	3.70	56.84	3.80
Harinbari	32.6	6.93	8.27	5.34	14.6	17.65	3.56	59.05	2.79
Sagar South	32.9	13.09	8.29	6.71	15.4	19.18	2.80	90.13	3.95
Sand heads	33.2	17.90	8.30	6.80	16.8	20.37	4.07	120.68	4.78
Frazergaunge	33.0	16.02	8.30	5.99	15.6	19.45	3.76	56.39	4.34
Prentice Island	32.8	17.05	8.30	6.05	15.9	15.79	3.43	54.48	4.45
Lothian Island	32.8	17.18	8.30	6.11	16.5	14.56	2.80	52.33	4.71
Canning	32.4	3.50	8.28	5.00	13.6	22.50	4.30	66.17	1.46
Sandeshkhali	32.5	3.02	8.29	4.99	13.9	19.20	3.10	62.59	2.08
Sonakhali	32.4	6.90	8.30	5.34	14.2	16.39	3.50	80.08	2.75
Gosaba	32.5	5.14	8.29	5.56	14.0	17.71	2.79	89.36	2.56
Bali	32.8	10.99	8.29	5.99	16.0	10.99	2.00	66.42	4.13
Sajnekhali	32.8	11.80	8.30	5.81	15.0	12.50	2.17	80.17	3.00
Jharkhali	32.9	15.34	8.30	6.06	15.3	11.24	2.30	59.99	3.90
Chotomollakhali	32.7	7.02	8.29	5.50	14.0	13.41	2.60	86.31	2.70
Satjelia	32.6	9.54	8.29	5.33	14.8	14.83	2.99	97.43	2.89
Kumirmari	32.6	9.70	8.29	5.41	14.9	13.17	3.12	52.76	2.97

Table 3. Physico-chemical variables of the selected sampling stations during 3rd January, 2016 (Postmonsoon), data taken during high tide condition.

Stations	Water temperature (°C)	Salinity (‰)	pH	DO (mg/l)	Transparency (m)	NO_3 (µgat/l)	PO_4 (µgat/l)	SiO_3 (µgat/l)	Chl a (mgm^{-3})
Diamond harbour	27.5	3.10	8.19	5.06	12.0	20.52	3.12	73.49	1.28
Kakdwip	27.7	6.09	8.21	4.69	14.0	24.79	3.50	68.24	1.50
Kachuberia	27.7	9.75	8.22	4.87	14.5	17.02	2.97	61.15	2.03
Chemaguri	27.8	21.58	8.29	5.14	15.3	15.55	2.80	53.28	3.99
Harinbari	27.8	20.10	8.28	5.21	16.0	15.71	2.70	60.04	2.85
Sagar South	27.9	24.75	8.30	6.08	16.2	18.66	1.99	83.17	4.16
Sand heads	28.0	29.12	8.31	5.85	17.1	21.44	3.10	101.60	4.80
Frazergaunge	28.1	26.00	8.30	5.75	15.9	18.28	2.98	50.05	4.40
Prentice Island	27.8	26.18	8.30	5.69	16.3	14.51	2.56	48.15	5.49
Lothian Island	27.7	26.93	8.30	6.02	17.4	13.40	1.90	55.43	4.76
Canning	27.6	8.14	8.22	4.98	14.3	21.35	3.43	70.42	1.50
Sandeshkhali	27.6	6.70	8.23	4.73	15.0	18.27	2.29	59.83	2.14
Sonakhali	27.7	19.20	8.26	5.12	15.1	14.11	2.64	56.21	2.81
Gosaba	27.8	12.05	8.25	5.40	15.3	16.54	1.87	58.24	2.60
Bali	27.9	20.38	8.30	5.38	17.0	10.72	1.08	56.23	4.19
Sajnekhali	27.9	21.11	8.31	5.46	16.2	11.29	1.41	55.12	3.10
Jharkhali	27.9	23.02	8.31	5.97	16.3	10.83	1.43	48.79	4.00
Chotomollakhali	27.7	15.70	8.29	5.18	15.1	12.67	1.78	70.41	2.76
Satjelia	27.6	19.98	8.30	5.26	15.8	13.54	2.00	65.28	2.94
Kumirmari	27.5	20.06	8.30	5.17	15.9	12.70	2.13	57.48	3.05

Table 4. Inter-relationship between the relevant physico-chemical variables and chl *a* in the selected stations during 2015.

Seasons	Combination	'r'-value	'p'- value
Premonsoon	Chl *a* × *water temperature*	0.7288	< 0.01
	Chl *a* × salinity	0.9506	< 0.01
	Chl *a* × pH	0.7642	< 0.01
	Chl *a* × D.O.	0.5801	< 0.01
	Chl *a* × *transparency*	0.9567	< 0.01
	Chl *a* × nitrate	-0.4826	< 0.01
	Chl *a* × phosphate	-0.6528	< 0.01
	Chl *a* × silicate	-0.2258	Insignificant
Monsoon	Chl *a* × *water temperature*	0.8050	< 0.01
	Chl *a* × salinity	0.9395	< 0.01
	Chl *a* × pH	0.5443	< 0.01
	Chl *a* × D.O.	0.8357	< 0.01
	Chl *a* × *transparency*	0.9463	< 0.01
	Chl *a* × nitrate	-0.4907	< 0.01
	Chl *a* × phosphate	-0.4227	< 0.01
	Chl *a* × silicate	0.0608	Insignificant
Postmonsoon	Chl *a* × *water temperature*	0.6519	< 0.01
	Chl *a* × salinity	0.9275	< 0.01
	Chl *a* × pH	0.8378	< 0.01
	Chl *a* × D.O.	0.8194	< 0.01
	Chl *a* × *transparency*	0.8316	< 0.01
	Chl *a* × nitrate	-0.3995	< 0.01
	Chl *a* × phosphate	-0.3539	< 0.01
	Chl *a* × silicate	-0.1282	Insignificant

Several earlier workers also obtained similar results from Indian coastal waters [4] which confirms the dependency of phytoplankton on nutrients. The average composition of phytoplankton is found to be as $(CH_2O)_{108}(NH_3)_{16}H_3PO_4$ and in case of diatoms it is slightly modified as $(CH_2O)_{108}(NH_3)_{16}H_3PO_4(SiO_4)_{40}$ as stated in the standard literature [5]. The constituents of phytoplankton suggest the necessity and subsequent utilization of nitrate, phosphate and silicate from the ambient waters [6, 7, 8, 9 and 10]. This conclude in favor of the uptake of nutrients by the phytoplankton, as this nutrients act as building blocks of marine phytoplankton. The distribution of siliceous diatom is greatly dependent on silicate level of the ambient water. However the present study shows insignificant relationship between chl *a* level and silicate concentration. This anomalous interrelationship with phytopigment concentration may be due to less abundance of siliceous diatoms in comparison to flagellates in the present study area.

Phytoplankton, being the foundation of the marine and estuarine food webs has special importance with respect to maintenance of ecological stability. Hence regular monitoring and conservation of this community is extremely important to upgrade the ecological health of the system. The dependency of phytoplankton on nutrients demands the preservation of mangrove in the present geographical locale as this vegetation contributes appreciable amount of nitrate and phosphate into the surrounding water bodies through litter and detritus.

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