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Phytoplankton Communities in Rudrasagar Lake, Tripura (North-East India) – A Ramsar Site

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Abstract

Phytoplankton is the integral link of food webs in the transfer of energy to higher aquatic communities that can also act as biological indicators for evaluation of trophic status of an aquatic ecosystem. The present study was carried out during October (2017) to May (2019) to assess the phytoplankton diversity and abundance of Rudrasagar lake, the largest freshwater wetland of Tripura. A total of 35 phytoplankton genera belonging to four main groups viz., Chlorophyceae (18 genera), Bacillariophyceae (9 genera), Cyanophyceae (7 genera) and Euglenophyceae (1 genus) were observed during the study. Chlorophyceae dominated the phytoplankton quantitatively followed by Cyanophyceae, Bacillariophyceae and Euglenophyceae. The phytoplankton constituted 82.21 – 88.05 percent of the total plankton population during the study period. The average monthly phytoplankton abundance varied between 14229–25970 cells l^{-1}. One way ANOVA revealed significant seasonal variation in the abundance of the phytoplankton groups. Maximum species richness was observed in pre-monsoon season. The phytoplankton communities of Rudrasagar lake showed high Shannon Weiner index (3.004–3.996) and high Pielou's evenness index (0.939–0.986). High Shannon Weiner and Pielou's indices indicated high phytoplankton diversity and even distribution of phytoplankton communities respectively. Abundance of different phytoplankton groups showed significant correlation with temperature, depth, transparency, pH, alkalinity and nutrient concentrations (nitrite, nitrate and phosphate). Knowledge about the phytoplankton communities of Rudrasagar lake in relation to its water quality parameters will help in planning possible options for management and optimum utilization of the lake's resources.

Keywords: Phytoplankton, species, diversity, abundance

1. Introduction

Wetlands, described as 'lands that are in transition between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water', are one of the most productive ecosystems on earth (Ramachandra and Solanki, 2007). Wetlands in India are life supporting systems that provide subsistence and livelihood to huge number of populations through fishing, fisheries, collection of edible aquatic plants, aquatic fodder, agriculture, water transport and irrigation beside the multitude of ecosystem services they offer (Bassi et al., 2014). Phytoplankton are the primary autotrophs in an aquatic environment that form an integral link of aquatic food webs in the transfer of energy to higher aquatic life forms. They form the base of the food chain in an aquatic system (Saravanakumar et al., 2008) and responsible for nearly half of the photosynthetic production on earth (Schimdt, 2000; Revathy and Krishnakumar, 2018). The occurrence of phytoplankton and algal blooms helps in enhancing productivity of wetlands as their large surface areas are exposed to sunlight for photosynthetic activity (Mustapha, 2010). Phytoplankton form integral components of freshwater wetlands that significantly contribute towards succession of zooplankton and fish (Paynne, 1997). Phytoplankton populations enhance the productivity in wetlands and the growth of useful phytoplankton can be considered as an important factor for fish production in these water bodies (Pradhan et al., 2008; Brraich and Kaur, 2015). These ubiquitous microscopic life forms also serve as biological indicators for monitoring and evaluation of water quality and health of aquatic water bodies (Tiwari and Chauhan, 2006). Phytoplankton diversity and abundance are ecological indicators of the trophic status of an aquatic ecosystem and helps in assessing the extent of eutrophication (Weysi et al., 2014). The study of phytoplankton is very vital as they act as primary producers, food for other higher aquatic organisms as well as bio-indicators of water quality of an aquatic system (Pradhan et al., 2008; Geethu and Balamurali, 2018). Phytoplankton communities are sensitive to any changes in their aquatic environment (Bhat et al., 2015). Any variations in the phytoplankton communities influence the productivity of wetlands where several organisms belonging to different trophic levels co-exist, due to which, phytoplankton not only act as indicator of water quality but also act as useful tool for biomontoring of these lentic water bodies (Shekhar et al., 2008). Biomonitoring is an integral part of studying and assessment of ecological health of wetlands (Bajpai et al., 2001). The study of composition, diversity and abundance of phytoplankton communities of a water body can be used as a tool for monitoring and assessment of its water quality which finally helps in its management and maintenance of general well being of the aquatic system (Pawar et al., 2006). It also helps in understanding the trophic status of wetlands which in turn aids in planning possible options for optimum usage of their resources (Das et al., 2018). Several studies have been made to study phytoplankton diversity, abundance and its seasonal variations in wetlands of the north eastern region of India, particularly in lakes of Manipur (Sharma, 2009, 2010) and floodplain beels of Assam (Sharma, 2004, 2012, 2015; Laskar and Gupta, 2009; Kalita et al., 2011; Devi et al., 2016; Sharma and Hatimura, 2017). There is still scarce information on the ecology, diversity and abundance of phytoplankton in the freshwater wetlands of Tripura, a north-eastern state of India. The present study aims at qualitative and quantitative assessment of phytoplankton communities of Rudrasagar lake, the largest and the only Ramsar designated wetland in Tripura.

2. Materials and Methods

The study was carried out during October, 2017 to May, 2019 at Rudrasagar lake, located at Sepahijala district of Tripura. Water samples for qualitative and quantitative assessment of phytoplankton were collected by filtering 60 litres of water through a nylon plankton net (No. 25) and preserved in 5% formalin. The samples were collected from four sampling stations viz., Site I, Site II, Site III and Site IV (Table 1, Figure 1), at monthly intervals during morning hours (8.00 to 10.00 o'clock). Phytoplankton taxa were identified following Needham and Needham (1962) and Adoni (1985). Abundance of the phytoplankton taxa was estimated with the help of a Sedgewick Rafter cell and expressed in cells l^{-1}. The ecological indices viz., Shannon-Weiner diversity index (H'), Margalef's species richness (d) and Pielou's (J) evenness index were estimated with the help of PRIMER v.7 software following Ludwig and Reynolds (1988). The biodiversity indices were computed based on the number of species and number of individuals of each species. The Shannon index was calculated to assess the diversity of phytoplankton of Rudrasagar lake. Pielou's index and Margalef's index were computed to assess species evenness and species richness respectively.

Table 1: Sampling sites at Rudrasagar lake during the study

Sampling site	Latitude	Longitude	Remark
Site I	23°30'14.8"N	91°18'57.1"E	Near Neermahal water palace built in the lake
Site II	23°30'00.0"N	91°19'04.4"E	Open central zone of the lake
Site III	23°29'36.2"N	91°18'59.3"E	Near brick kiln located at the lake's periphery
Site IV	23°29'46.6"N	91°19'10.0"E	Rajghat, a boatyard for tourist boats

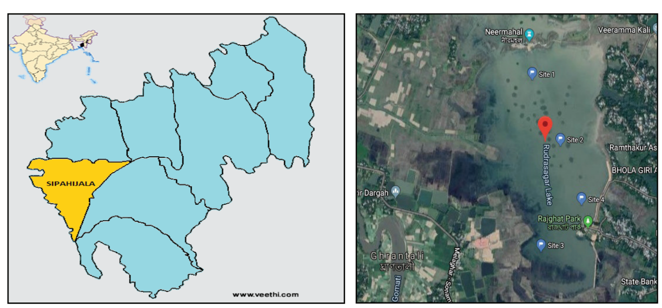

Figure 1: Study area (Rudrasagar lake)

The Margalef's Richness Index (d) was computed using the following formula: $d=(S-1)/\ln n$

where, S is the number of species and n is the total number of individuals

The Shannon index (H') was estimated using the following formula:

$$H' = -\sum_{i=1}^{S} (pi \ln pi)$$

where, S is the number of species in the sample, pi is the proportion of the i^{th} species in the total sample.

The Pielou's Evenness Index (J') was calculated using the following formula:

$$J' = H'/\ln S$$

where, S is the number of species in the sample and H' is the Shannon index

2.1. Statistical analysis

One way ANOVA was employed to study the significance in the variations of phytoplankton abundance between the different months of the study period and sampling locations in Rudrasagar lake. Pearson's Correlation was used to study the relationship of abiotic water parameters with phytoplankton abundance. The statistical analysis was done with the help of SPSS version 16 software.

3. Results and Discussion

The annual variations (Mean±S.D.) of the abiotic parameters of Rudrasagar lake are depicted in Table 2. A total of 35 phytoplankton taxa (Table 3) belonging to four main groups viz., Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae were observed during the study. Chlorophyceae (18 genera) dominated the phytoplankton population followed by Bacillariophyceae (9 genera), Cyanophyceae (7 genera) and Euglenophyceae (1 genus). The number of taxa observed in the present study was higher compared to the earlier 16 taxa in Rudrasagar lake (Datta, 2014). The present report of 35 taxa from Rudrasagar lake was lower compared to 52 species of phytoplankton in Samuajan beel, Upper Assam wherein, the population was dominated by Bacillariophyceae (Sharma, 2004); 52 species of phytoplankton observed in Ghorajan beel of Assam with dominance by Chlorophyceae (Sharma, 2012). However, it was more or less similar to the reports of 30 phytoplankton taxa with quantitative dominance of Chlorophyceae in Baskandi anua, an oxbow lake in Assam (Gupta and Devi, 2014) and, the occurrence of 41 phytoplankton taxa with Chlorophyceae contributing the highest abundance in the same lake of Assam (Devi et al., 2016). The phytoplankton constituted 82.21–88.05% of the total plankton population in different months during the study period. The average monthly phytoplankton abundance varied between 14229–25970 cells l^{-1}. The minimum abundance was observed during January (2018) while, the maximum abundance was recorded during April (2018) as presented in Figure 2.

Table 2: Annual variations of abiotic water parameters

Water parameters	Range	Mean (±S.D.)
Water temp. (°C)	21–30	26.03 (±2.551)
Water depth (m)	0.9–3.65	2.08 (±0.746)
Secchi disc transparency (cm)	32.5–170	54.27 (±28.13)
pH	6.1–7.2	6.51 (±0.27)
Dissolved oxygen (mg l^{-1})	2.4–9.2	6.77 (±1.03)
Free carbon dioxide (mg l^{-1})	4.49–14.98	9.07 (±2.12)
Biochemical oxygen demand (mg l^{-1})	0.2–3.2	1.69 (±0.62)
Chloride (mg l^{-1})	6.99–27.49	14.38 (±4.40)
Total alkalinity (mg l^{-1})	52–240	140.29 (±57.13)
Total hardness (mg l^{-1})	50–220	128.63 (±52.34)
Nitrite (NO_2-N) (mg l^{-1})	0.0016 –0.0129	0.0051 ±(0.0023)
Nitrate (NO_3-N) (mg l^{-1})	0.11–1.33	0.42 (±0.274)
Phosphate(PO_4-P)(mg l^{-1})	0.22–2.19	0.52 (±0.259)

Table 3: Phytoplankton taxa recorded in Rudrasagar lake

Chlorophyceae	*Chlorella sp., Cosmarium sp., Closterium sp., Spirogyra sp., Scenedesmus sp., Volvox sp., Ulothrix sp., Zygnema sp., Coelastrum sp., Microspora sp., Staurastrum sp., Oocystis sp., Actinastrum sp., Pediastrum sp., Selanastrum sp., Pandorina sp. and Euastrum sp.*
Bacillariophyceae	*Cymbella sp., Navicula sp., Nitzchia sp., Synedra sp., Pinnularia sp., Fragillaria sp., Melosira sp., Cyclotella sp. and Aulacoseira sp.*
Cyanophyceae	*Anabaena sp., Nostoc sp., Microcystis sp., Spirulina sp., Oscillatoria sp., Chroococcus sp. and Calothrix sp.*
Euglenophyceae	*Euglena sp.*

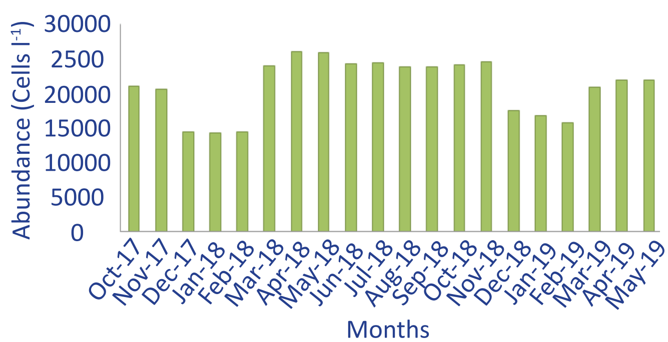

Figure 2: Monthly variations in abundance of phytoplankton in Rudrasagar lake

Table 4 presents the mean abundance of phytoplankton taxa and their percentage of the total phytoplankton population in Rudrasagar lake indicating *Mycrocystis* as

Table 4: Mean abundance of phytoplankton taxa and their percentage in Rudrasagar lake

Group	Species	Mean Abundance (cells l^{-1})	(%)
Chlorophyceae	*Chlorella*	360	1.71
	Cosmarium	603	2.87
	Closterium	659	3.14
	Spirogyra	682	3.25
	Scenedesmus	400	1.90
	Volvox	143	0.68
	Ulothrix	754	3.59
	Zygnema	540	2.57
	Coelastrum	393	1.87
	Microspora	178	0.85
	Oedegonium	401	1.91
	Staurastrum	487	2.32
	Oocystis	461	2.19
	Actinastrum	552	2.63
	Pediastrum	895	4.26
	Selanastrum	169	0.81
	pandorina	602	2.86
	Euastrum	101	0.48
Bacillariophyceae	*Cymbella*	596	2.84
	Navicula	754	3.59
	Nitzchia	630	3.00
	Synedra	660	3.14
	Pinnularia	353	1.68
	Fragillaria	600	2.86
	Melosira	440	2.09
	Cyclotella	524	2.49
	Aulacoseira	1161	5.52
Cyanophyceae	*Anabaena*	842	4.01
	Nostoc	1117	5.32
	Microcystis	1493	7.10
	Spirulina	527	2.51
	Oscillatoria	1174	5.59
	Chroococcus	890	4.24
	Calothrix	325	1.54
Euglenophyceae	*Euglena*	543	2.58

the most dominant taxa. The other dominant taxa were *Oscillatoria, Aulacoseira, Nostoc, Pediastrum, Chroococcus, Anabaena, Navicula, Ulothrix* and *Nitzchia.* Among the various phytoplankton groups, Chlorophyceae (39.89%) contributed maximum abundance during the study (Table 5), followed by Cyanophyceae (30.31%), Bacillariophyceae (27.22%) and Euglenophyceae (2.58%).

Chlorophyceae, the dominant phytoplankton group with its average monthly abundance ranging between 4905–11495 cells l^{-1}, constituted 28.02 - 48.22 percent of the total phytoplankton density. The abundance of chlorophyceae was found to be highest in September (2018) and lowest during December (2019). Cyanophyceae formed 18.11-48.58% of the lake's phytoplankton with its abundance fluctuating between 4312 - 8504 cells l^{-1}. The minimum abundance was observed in August (2018) and maximum abundance was recorded in December (2018). Bacillariophyceae comprised 19.93-35.17% of the total phytoplankton population with its abundance varying between 3149 - 8417 cells l^{-1}. The minimum abundance was observed in February (2019) while the highest abundance was found in August (2018). One way ANOVA revealed that the abundance of Chlorophyceae, Cyanophyceae and Bacillariophyceae showed significant difference ($p<0.05$) between the months but not among the sampling sites. The Figure 3 explains graphically the variation in abundances of the phytoplankton groups during the study. Euglenophyceae, the least dominant group contributed 1.63-4.10% of the total phytoplankton density, with its average monthly abundance varying between 258-979 cells l^{-1}. The group's abundance showed significant difference ($p<0.05$) between the months as well as between the sampling sites. The existence of highest abundance of Cyanophyceae in winter and record of maximum abundance of Euglenophyceae in post monsoon are in conformity with the findings observed in Chatla wetland, Assam (Laskar and Gupta, 2009).

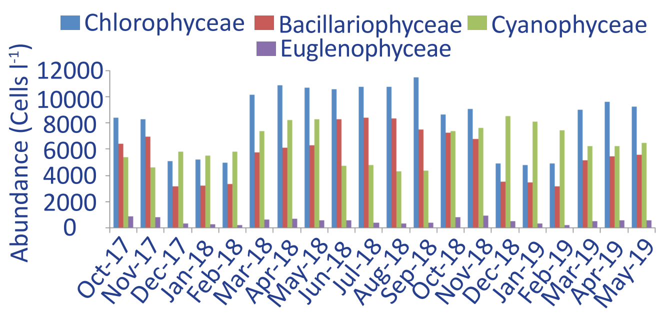

Figure 3: Monthly variations in abundance of different phytoplankton groups

The average monthly species richness ranged from 24 to 29 phytoplankton genera during the study (Figure 4). The species richness of different phytoplankton groups varied between 8 – 13 genera, 6 – 9 genera, 4 – 7 genera and 1 genus for Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae respectively. The maximum phytoplankton diversity observed in pre monsoon may be due to higher values of alkalinity and hardness which in turn may be attributed to the higher evaporation at high temperature and shallow water

Table 5: Group wise abunbance of phytoplankton in Rudrasagar lake

Year	Month	Chlorophyceae		Bacillariophyceae		Cyanophyceae		Euglenophyceae	
		Cells l^{-1}	(%)	Cells l^{-1}	(%)	Cells l^{-1}	(%)	Cells l^{-1}	(%)
2017	Oct	8416	39.95	6401	30.39	5384	25.56	865	4.10
	Nov	8271	40.10	6951	33.70	4593	22.27	812	3.94
	Dec	5092	35.17	3201	22.11	5820	40.20	365	2.52
2018	Jan	5237	36.81	3237	22.75	5493	38.60	261	1.84
	Feb	4985	34.60	3351	23.26	5821	40.40	250	1.74
	Mar	10171	42.56	5749	24.05	7358	30.78	623	2.60
	Apr	10902	41.98	6145	23.66	8239	31.72	685	2.64
	May	10671	41.25	6305	24.37	8310	32.12	583	2.25
	Jun	10605	43.78	8303	34.28	4750	19.61	562	2.32
	Jul	10726	44.04	8417	34.56	4776	19.61	436	1.79
	Aug	10746	45.15	8373	35.17	4312	18.11	373	1.57
	Sep	11495	48.22	7533	31.60	4387	18.40	425	1.78
	Oct	8662	35.90	7255	30.07	7389	30.63	821	3.40
	Nov	9094	37.14	6780	27.69	7636	31.18	979	4.00
	Dec	4905	28.02	3553	20.30	8504	48.58	542	3.10
2019	Jan	4829	28.76	3480	20.73	8124	48.39	354	2.11
	Feb	4924	31.15	3149	19.93	7473	47.28	258	1.63
	Mar	8982	43.07	5136	24.63	6230	29.87	506	2.43
	Apr	9614	43.86	5452	24.87	6255	28.53	600	2.74
	May	9280	42.30	5609	25.57	6487	29.57	562	2.56
Mean	8380	39.89	5719	27.22	6367	30.31	543	2.58	

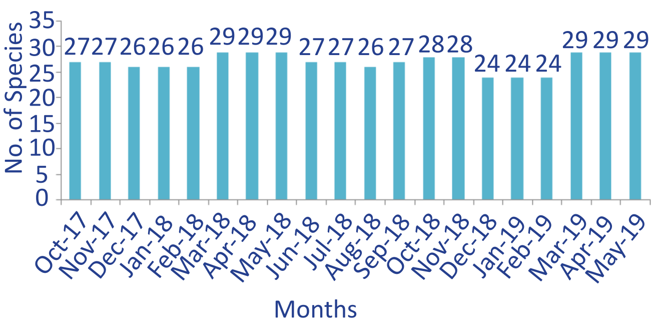

Figure 4: Monthly variation in species richness of phytoplankton in Rudrasagar lake

depth of the wetland (Ahmad et al., 2011; Kumar and Sharma, 2014). The maximum number of genera (29) was recorded during pre-monsoon season and the minimum number of genera (24) was observed during winter season. The highest number of species was recorded in pre monsoon followed by monsoon, post monsoon and winter although it was not so pronounced. Similar variations were observed in Chalta floodplain lake of Assam by Laskar and Gupta (2009). The lowest total number of individuals of phytoplankton (14229 units l^{-1}) was observed in winter and the highest total number of individuals (25970 units l^{-1}) was observed in pre-monsoon season. The lake's species diversity, expressed in the form of Shannon –Weiner index ranged between 3.004 – 3.996 during the study period. Similar range of Shannon index is observed in Khalsi and Akaipur beels of West Bengal (Kumari, 2017). Margalef's richness index varied between 2.354–2.815. The Pielou's evenness index ranged between 0.939–0.986 which indicated an even distribution of species in the lake.

The present study observed the abundance of phytoplankton to be influenced by several abiotic water quality parameters. The Pearson's correlation coefficients of abundance of phytoplankton groups with the abiotic water parameters are presented in Table 6. Chlorophyceae group was found to be significantly correlated with temperature, depth, pH, BOD, free carbon dioxide and nutrient concentrations (nitrite, nitrate and phosphate). Bacillariophyceae showed significant correlations with temperature, depth, transparency, pH, alkalinity and nutrient concentrations. Sharma (2004) also found the diatoms to be correlated with transparency significantly in Samuajan beel in Assam. The Cyanophyceae showed significant relationship with temperature, dissolved oxygen, chloride and alkalinity. Water depth and nitrite concentration influenced the abundance of Euglenophyceae.

Table 6: Pearson's correlation coefficients of abundance of phytoplankton groups with abiotic water parameters

Water parameter	Chlorophyceae	Bacillariophyceae	Cyanophyceae	Euglenophyceae
Temperature	.796**	.819**	-.231*	.167
Depth	.691**	.700**	-.139	.432**
Transparency	.298**	.532**	-.297**	.114
pH	-.545**	-.476**	-.051	-.192
DO	-.071	.112	-.239*	.116
FCO	.385**	.111	.161	.094
Chloride	.075	-.229*	.274*	-.048
BOD	.334**	.240*	-.003	.025
Nitrite	.696**	.401**	.016	.249*
Nitrate	.529**	.318**	.020	.100
Phosphate	.507**	.279*	.228*	.166
Alkalinity	-.156	-.517**	.262*	-.170

*Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed)

4. Conclusion

Chlorophyceae dominated the phytoplankton communities in Rudrasagar lake. High Shannon index observed indicated high phytoplankton diversity while high Pielou's evenness index showed even distribution of phytoplankton genera, revealing the lake to be productive. A profound relationship of water quality parameters with different phytoplankton groups was found with most of them observed within favourable range for fish and aquatic life. Understanding water quality with phytoplankton diversity and abundance can help in planning sustainable options for fish production enhancement as well as ecosystem management.

5. Acknowledgement

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6. References

Adoni, A.D., 1985. Workbook on limnology. Indian MAB Committee, Department of Environment, Government of India. Prathiba Publishers, 216.

Ahmad, U., Parveen, S., Khan, A.A., Kabir, H.A., Mola, H.R.A., Ganai, A.H., 2011. Zooplankton population in relation to physico chemical factors of a sewage fed pond of Aligarh (UP), India. Biology and Medicine 3(2), 336–341.

Bajpai, A., Bajpai, A.K., Pani, S., Misra, S.M., 2001. Pollution and trophic status indicator species of Bhoj wetland. Ecology, Environment and Conservation 7(3), 245–249.

Bassi, N., Kumar, M.D., Sharma, A., Pardha-Saradhi, P., 2014. Status of wetlands in India: A review of extent, ecosystem benefits, threats and management strategies. Journal of Hydrology: Regional Studies 2, 1–19.

Bhat, N.A., Wanganeo, A., Raina, R., 2015. Variability in watyer quality and phytoplankton community during dry and wet periods in the tropical wetland, Bhopal, India. J. Ecosys Ecograph 5(1), 160.

Brraich, O.S., Kaur, R., 2015. Phytoplankton community structure and composition of Nangal Wetland, Punjab, India. International Research Journal of Biological Sciences 4(3), 1–5.

Das, D., Pathak, A., Pal, S., 2018. Diversity of phytoplankton in some domestic wastewater-fed urban fish pond ecosystems of the Chota Nagpur Plateau in Bankura, India. Applied Water Science 8, 84.

Devi, M.B., Gupta, S., Das, T., 2016. Phytoplankton community of Lake Baskandi anua, Cachar District, Assam, North East India – An ecological study. Knowledge and Management of Aquatic Ecosystems 2, 417. DOI: 10.1051/kmae/2015034.

Datta, M., 2014. Study of trophic dynamic and fisheries potential of Rudrasagar Lake, Tripura (M.F.Sc Thesis), CIFE, Mumbai

Geethu, G., Balamurali, R.S., 2018. Study on distribution and diversity of phytoplankton in relation to physico-chemical parameters in Polachira wetland, Kerala. International Journal of Research and Analytical Reviews 5(2), 1961–1964.

Gupta, S., Devi, S.S., 2014. Ecology of Baskandi anua, an oxbow lake of South Assam, North East India. Journal of Environmental Biology 35, 1101–1105.

Kalita, J.C., Deka, U.S., Haque, A., Kalita, T.C., Deka, S., 2011. Assessment of fish biodiversity of Koya Kujiya beel, Abhayapuri, Assam in relation to certain physic-chemical and anthropogenic factors. The Bioscan 6(3), 425–431.

Kumar, A., Sharma, M.P., 2014. Application of water quality index for pollution assessment of Kankaria lake at ahmedabad, India. Journal of Civil and Environmental Engineering 4, 144. Doi: 10.4172/2165-784X.1000144.

Kumari, S., 2017. Plankton dynamics in inland floodplain wetlands of West Bengal with reference to enclosure culture. PhD Thesis (Unpublished), CIFE, Mumbai, 145.

Laskar, H.S., Gupta, S., 2009. Phytoplankton diversity and dynamics of Chatla floodplain lake, Barak Valley, Assam, North East India - A seasonal study. Journal of Environmental Biology 30(9), 1007–1012.

Ludwig, J.A., Reynolds, J.F., 1988. Statistical ecology: a Primer on methods and computing. John Wiley & Sons, New York, 337.

Mustapha, M.K., 2010. Seasonal influence of limnological variables on plankton dynamics of a small shallow, tropical African Reservoir. Asian Journal of Experimental Biological Science 1, 60–79.

Needham, J.G., Needham, P.R., 1962. A Guide to the study of Freshwater Biology. Fifth Edition, Holden-Day Inc., San Francisco, 108.
Pawar, S.K., Pulle, J.S., Shengde, K.M., 2006. The study on phytoplankton of Pethwadaj Dam, Taluka kandhar, District-Nanded, Maharashtra. Journal of Aquatic Biology 21, 1–6.
Payne, I., 1997. Tropical floodplain fisheries.In: Tsai, C., Ali, Y. (Eds.), Openwater fisheries of Bangladesh. The University Press Limited, Dhaka, 1–26.
Pradhan, A., Bhaumik, P., Das, S., Mishra, M., Khanam, s., Houque, B.A.,Mukherjee, I., 2008. Phytoplankton diversity as indicator of water quality for fish cultivation. American Journal of Environmental Sciences 4(4), 406–411.
Ramachandra, T.V., Solanki, M., 2007. Ecological assessment of lentic water bodies of Bangalore. The Ministry of Science and Technology 25, 96.
Revathy, D., Krishnakumar, A., 2018. Evaluation of phytoplankton diversity and environmental implications of two lacustrine wetlands, located in lowland and midland critical zones of Kerala, India. Journal of Environmental and Social Sciences 5(1), 135.
Saravanakumar, A., Sesh, S.J., Thivakaran, G.A., Rajkumar, M., 2008. Benthic macrofaunal assemblage in the arid zone mangroves of Gulf of Kuchchh-Gujarat. Journal of Ocean University of China 6, 33–39.
Schmidt, L.J., 2000. Polynyas, CO_2, and diatoms in the Southern ocean. In: NASA Earth Observatory. http://earthobservatory.nasa.gov/Features/Polynyas/
Sharma, B.K., 2004. Phytoplankton communities of a floodplain lake of the Brahmaputra river basin, Upper Assam. Journal of Inland Fisheries Association 31, 27–35.
Sharma, B.K., 2009. Phytoplankton communities of Loktak lake (a Ramsar site), Manipur (N.E. India): composition, abundance and ecology. Journal of Threatened Taxa 1(8), 401–410.
Sharma B.K., 2010. Phytoplankton diversity of two floodplain lakes (pats) of Manipur (N. E. India). Journal of Threatened Taxa 2(11),1273-1281.
Sharma, B.K., 2012. Phytoplankton diversity of a floodplain lake of the Brahmaputra River basin, Assam, north-east India. Indian Journal of Fisheries 59(4), 131–139.
Sharma, B.K., 2015. Phytoplankton diversity of Deepor Beel - a Ramsar site in the floodplain of the Brahmaputra River Basin, Assam, north-east India. Indian Journal of Fisheries 62(1), 33–40.
Sharma, B.K., Hatimuria, M.K., 2017. Phytoplankton diversity of floodplain lakes of the Majuli River Island of the Brahmaputra river basin, Assam, Northeast India. International Journal of Aquatic Biology 5(5), 295–309.
Shekhar, R.T., Kiran, B.R., Puttaiah, E.T., Shivaraj, Y., Mahadevan, K.M., 2008. Phytoplankton as index of water quality with reference to industrial pollution. Journal of Environmental Biology 29, 233–236.
Weysi, K., Nourmoradi, H., Samarghandi, M.R., Samadi, M.T., 2014. Investigation on the trophic status of Ekbatan reservoir: A Drinking water supply reservoir in Iran. Journal of Research in Health Sciences 14(1),64–68.