Indian Journal of Marine Sciences
Vol. 19, December 1990, pp. 274-277

Phytoplankton characteristics of Chilka lake, a brackish water lagoon along east coast of India

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Received 3 May 1990, revised 5 July 1990

Examination of phytoplankton (September 1987) at 100 stations in Chilka lagoon revealed characteristic response gradients in species composition and abundance in relation to ambient water quality, particularly salinity. Altogether, 5 ecological zones could be distinguished in the study area each of which supported characteristic species of phytoplankton namely, *Peridinium brevipes* in zone I with relatively high salinity (av. 13.27×10^{-3}); *Oscillatoria limnetica* (zone II, 6.99×10^{-3}); *O. limnetica* and *Stephanodiscus* sp. (zone III, 4.34×10^{-3}) and *Stephanodiscus* sp. and *Navicula* sp. (zone IV, 1.24×10^{-3}). In zone V, influenced by sea (salinity 6.32×10^{-3}), in addition to several marine species, *Stephanodiscus* sp. occurred in large numbers.

Coastal lagoons, which occupy as much as 13% of the coastlines are extensively used as harbours, recreation areas and for their mineral resources. Each of these human requirements presents additional stresses on the lagoon ecosystem affecting its water quality and life. In recent years Chilka lake, situated on the east coast of India, has undergone considerable changes attributable to an upsurge of urban activity in that area. Over the years, the lagoon has become shallow due to heavy siltation caused by river inflows and land drainage. There is extensive weed growth in this area particularly at the periphery where much of the waters are effectively stagnant. The primary objective of the study has been to find out the effects of recent changes on phytoplankton standing crop in the lagoon as determined by diverse environmental factors in that area.

Materials and Methods

Chilka lake which is primarily brackish in nature is roughly pear shaped and covers a total area of nearly 900-1100 km^2. Topographically, the lagoon can be divided into 2 regions namely, the outer channel and the main area. Appreciable quantities of freshwater are discharged into the lagoon by a number of rivulets and rivers namely, Daya, Bhargabi and Nuna which open at the northeast side.

Physico-chemical and biological examination of surface and bottom waters was carried out at 100 selected stations in the lagoon (Fig. 1) from 4 to 26 September 1987 corresponding to the southwest monsoon period. The sampling stations were determined using a field compass obtaining bearings from land markings such as hills, islands, etc. Among the water quality parameters temperature, secchidisc transparency, turbidity, salinity, *p*H, dissolved oxygen, inorganic nitrogen, phosphate, silicate and chlorophyll (*a*, *b* and *c*) were studied following standard methods[1,2]. Qualitative and quantitative enumeration of phytoplankton was carried out following Lugol's iodine technique[3] based on unit samples (1 l) and net hauls. A Sedgwick-Rafter counting chamber was used for making cell counts. Phytoplankton diversity was calculated as suggested by Margalef[4].

Results and Discussion

During the study, marked variations in the water quality particularly salinity were noticed between different regions in the lagoon (Table 1). Based on this and phytoplankton distribution, it was possible to divide the lagoon into five ecological zones (Fig. 1) namely, zone I corresponding to Rambha Bay (salinity 10.76 -15.83 $\times 10^{-3}$); zone II, central sector (5.05-13.8 $\times 10^{-3}$); zone III, intermediate between central and north sectors (2.85-9.66 $\times 10^{-3}$); zone IV, north sector with dilute water (0.55-4.75 $\times 10^{-3}$); and zone V representing the channel area (4.75-7.59 $\times 10^{-3}$). Table 1 presents data on the physico-chemical and biological characteristics of waters in these zones.

Appreciable differences existed in the environmental conditions in the lagoon which showed characteri-

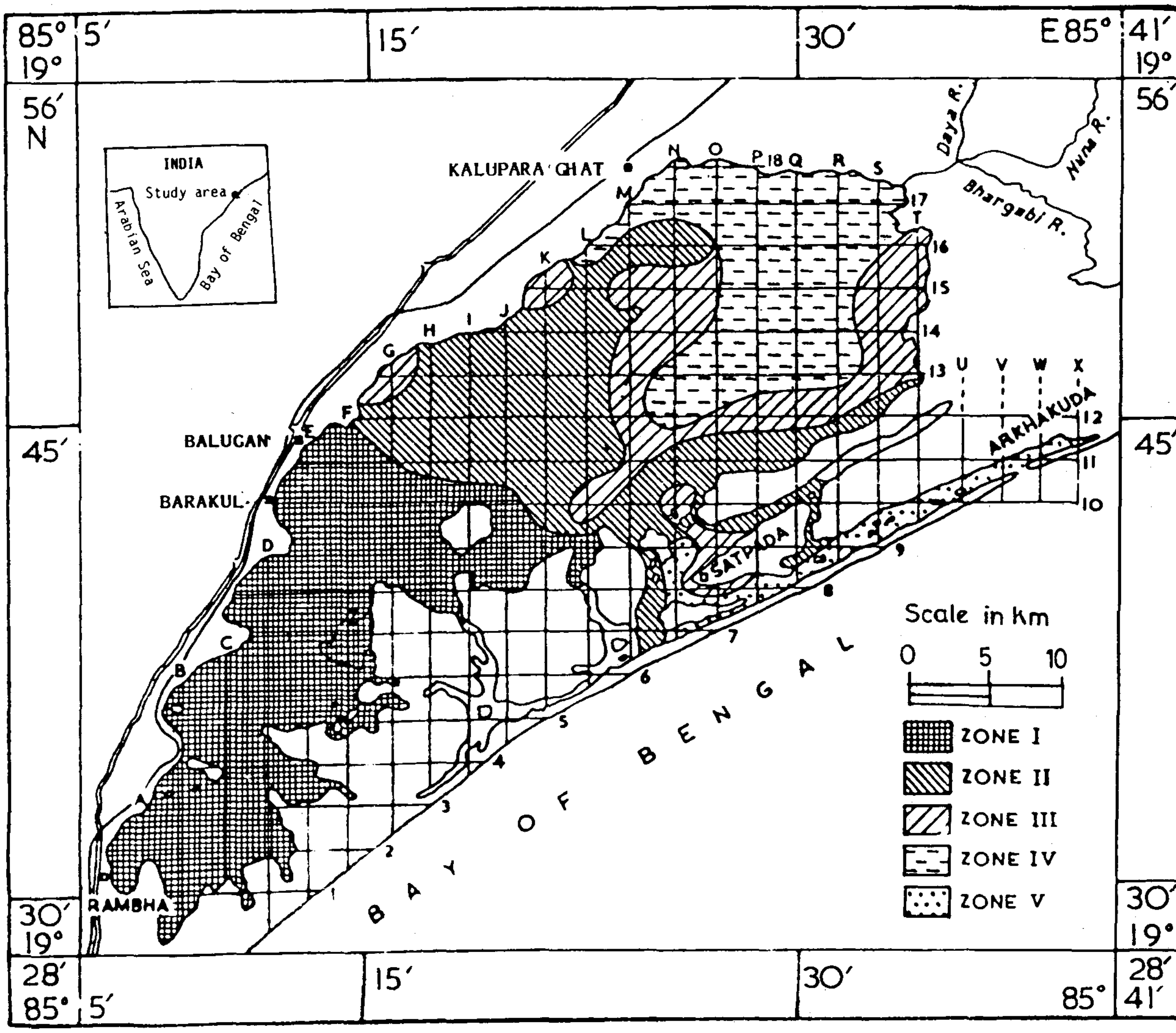

Fig. 1—Station locations and ecological zones in Chilka lake

stic response gradients. For instance, there was a steady decrease in lagoon depth (av.) from 1.4 m in zone I in the south to 0.9 m in zone IV in the north which was attributable to heavy siltation caused by the rivers opening in the north sector. Similarly, water transparency decreased from south (0.8 m) to north (0.2 m) while turbidity increased (25.6 to 86.2 ppm). The investigation also revealed a steady south-north gradation in salinity caused by dilution from rivers. It was found that salinity was maximum (15.83×10^{-3}) in Rambha Bay (zone I) free from any freshwater discharge and minimum (0.55×10^{-3}) in zone IV, subjected to maximum freshwater inflow. Variations in both *p*H (7-10) and dissolved oxygen (2.7-16.9 $mg.l^{-1}$) remained marked in zone I, where there was a rich growth of rooted hydrophytes. During the study, the concentration of inorganic nitrogen, phosphorus and silicon in general increased in the direction of zone IV in the north. This was particularly evident in the case of NO_2-N (0.13-0.81 $\mu g\text{-}at.l^{-1}$) and SiO_4-Si (48.5-83.4 $\mu g\text{-}at.l^{-1}$), attributable to greater nutrient inputs through river inflow. It was noted that while there was no appreciable difference in chl *a* and *b*, the concentration of chl *c* was relatively high (15.9 $mg.\ m^{-3}$) in zone IV (Table 1).

Altogether, 97 species of phytoplanktonic organisms were encountered during the study. The organisms consisted of chiefly members of the families Cyanophyceae, Euglenophyceae, Dinophyceae, Bacillariophyceae and Chlorophyceae. Among cyanophyceans, there were 13 species of which *Oscillatoria limnetica, Synechocystis aquatilis, Anabaena torulosa* and *Merismopedia tenuissima* were important in the order of their abundance. Of these, *O. limnetica* outnumbered others contributing 72.98% of the overall phytoplankton population. The euglenophyceans were re-

Table 1—Physico-chemical and phytoplankton parameters in Chilka lake

Parameters		Zones (no. of stations)				
		I (38)	II (20)	III (17)	IV (16)	V (9)
Depth (m)		0.5-3.0	0.3-1.7	0.4-1.6	0.2-1.5	0.4-2.1
Temperature (°C)	(S)	29.0-36.0	30.5-35.0	28.8-33.0	30.0-33.5	32.0-32.5
	(B)	28.0-34.5	30.2-33.0	30.0-32.5	29.5-32.6	31.2-32.4
Transparency (m)		0.4-2.2	0.2-1.2	0.1-0.9	Nil-0.7	0.3-0.6
Turbidity (ppm)	(S)	6.0-74.0	13.0-150	13.0-150	13.0-150	20.0-50.0
	(B)	8.0-150	26.0-150	43.0-150	20.0-150	28.0-126
Salinity ($\times 10^{-3}$)	(S)	10.76-15.10	5.05-9.0	3.05-4.75	0.55-4.75	5.55-7.15
	(B)	10.76-15.83	5.15-13.80	2.85-9.66	0.55-3.50	4.75-7.59
*p*H	(S)	7.0-10.0	7.7-9.0	7.5-9.0	7.0-9.0	7.5-8.5
	(B)	7.0-9.0	7.5-8.5	7.5-9.0	7.5-8.5	7.5-8.5
Dissolved oxygen (mg. l^{-1})	(S)	5.3-16.9	2.0-8.3	6.0-8.2	6.2-12.6	5.2-7.0
	(B)	2.7-10.6	1.9-7.7	5.3-7.7	5.6-10.6	5.7-6.7
NH_3-N (μg-at.l^{-1})	(S)	0.21-11.12	2.06-98.88	2.06-42.85	2.27-18.13	0.41-3.71
	(B)	0.21-18.54	0.21-21.42	4.53-61.80	7.00-16.18	1.24-5.56
NO_2-N (μg-at. l^{-1})	(S)	N.D.-0.73	0.03-2.40	0.06-3.75	0.17-2.69	0.06-0.47
	(B)	0.03-0.88	0.06-1.14	0.01-3.98	0.20-1.93	0.15-0.29
NO_3-N (μg-at.l^{-1})	(S)	N.D.-1.654	N.D.-2.035	N.D.-3.381	N.D.-1.973	0.098-0.923
	(B)	N.D.-3.584	N.D.-2.001	N.D.-3.146	N.D.-1.857	0.395-1.206
PO_4- P(μg-at.l^{-1})	(S)	0.07-1.01	N.D.-0.61	0.11-6.15	N.D.-0.90	0.27-1.09
	(B)	0.07-0.87	N.D.-0.36	0.14-0.94	0.14-1.19	0.22-0.94
SiO_4-Si (μg-at. l^{-1})	(S)	11.0-68.0	14.0-85.0	31.0-100.0	23.0-150.0	60.0-70.0
	(B)	14.0-68.0	19.0-85.0	25.0-100.0	24.0-130.0	35.0-70.0
Chlorophyll *a*(mg.m^{-3})	(S)	N.D.-5.58	N.D.-12.53	N.D.-13.38	N.D.-9.30	N.D.-3.98
Chlorophyll *b*(mg.m^{-3})	(S)	N.D.-18.60	N.D.-14.50	N.D.-16.32	N.D.-9.78	1.44-4.13
Chlorophyll *c* (mg.m^{-3})	(S)	N.D.-17.93	N.D.-32.50	N.D.-37.75	N.D.-59.03	0.94-15.36
Total chlorophyll (mg.m^{-3})	(S)	N.D.-36.57	N.D.-59.53	N.D.-67.05	4.18-60.16	5.86-17.89
Number of phytoplankton species		39	30	16	30	43
Species abundance (no. ml^{-1})		Nil-7360	10-600640	Nil-38850	Nil-9040	60-1830
Dominant species		*Peridinium brevipes*, 68.09% *Synedra affinis*, 7.9% *Mastogloia exigua*, 6.0%	*Oscillatoria limnetica*, 93.97% —	*Oscillatoria limnetica*, 65.28% *Stephanodiscus* sp. 22.39%	*Stephanodiscus* sp. 77.19% *Navicula* sp. II 16.10%	*Stephanodiscus* sp. 91.32% —
Salinity zone		α-mesohaline	β-mesohaline	α-oligohaline	β-oligohaline	β-mesohaline
Diversity-Margalef (*d*)		2.89	2.27	1.28	2.12	0.81

N.D. = Not detectable; S = Surface, B = Bottom

presented by 4 species of which *Euglena* sp. was relatively more important. The dinophyceans consisted of 3 species among which *Peridinium brevipes* (3.19) was numerically the most important. The Bacillariophyceae were the most conspicuous since they were represented by as many as 60 species that occurred at a majority (81) of stations studied. Among them, the predominant taxa were *Biddulphia heteroceros*, *Chaetoceros* sp., *Rhizosolenia* sp., *Stephanodiscus* sp., *Triceratium* sp., Nitzschia closterium, Navicula sp., *Pleurosigma affinis* and *Synedra affinis* of which *Stephanodiscus* sp. was the most important on account of its prevalence and relative dominance (15.13%). The chlorophyceans were represented by 16 species notably, *Spirogyra* sp., *Monoraphidium* sp., *Cosmarium* sp., and *Closterium* sp. in the order of their abundance.

Quantitatively, phytoplankton abundance in the lagoon varied from nil at stations (P15, Q13, R14, S13-16) located near river mouth (turbidity > 150 ppm) to a maximum of 60640 no. ml^{-1} at st I14 in zone II.

Different zones in the lagoon supported characteristic assemblages of phytoplankton dominated by one or two species which were greatly affected by salinity in that area. For instance, in zone I where the salinity was relatively high (av. 13.27×10^{-3}), the phytoplankton was dominated by *Peridinium brevipes* (58%) followed by diatoms, *Synedra affinis* (7.9%) and *Mastogloia exigua* (6%). In zone II (av salinity 6.99×10^{-3}), the population consisted of overwhelming numbers of the blue-green alga, *Oscillatoria limnetica* (93.77%). Similarly, in the transitional zone III (4.34×10^{-3}), the phytoplankton was dominated by *O. limnetica* (62.25%) and the diatom, *Stephanodiscus* sp. (22.39%). In zone IV where salinity was lowest (1.24×10^{-3}), the predominant species were *Stephanodiscus* sp. (77.19%) and *Navicula* sp. (6.1%). Similarly, while the number of phytoplankton species was maximum (39) in Rambha Bay (zone I) characterised by relatively high salinity, in zone IV, subjected to maximum dilution, there were only 16 species. Margalef diversity indices (*d*) revealed maximum values (2.89) in zone I and minimum (1.28) in zone IV (Table 1).

In zone V corresponding to outer channel, the environmental conditions were largely determined by its proximity to the sea. Here, both water transparency (av. 0.5 m) and turbidity (30.9 ppm) improved marginally; salinity increased relatively ($4.75\text{-}7.59 \times 10^{-3}$); dissolved oxygen (5.2-7.6 mg. l^{-1}) and *p*H (7.5-8.5) became more stable as also inorganic nutrients and phytoplankton pigments (Table 1). Biologically zone V remained markedly different since it supported as many as 43 species of phytoplankton of which 32 species remained restricted to this area.

Phytoplankton species composition in the lagoons depended to a great extent on the hydrological conditions[5]. Under brackish or hypersaline conditions of Mukwe Lagoon, Ghana, fewer species were present than in the adjacent estuarine Sakumo lagoon[6]. In lake Edku, an Egyptian lagoon[7] which received considerable freshwater runoff, most of the species were either freshwater or brackish water forms. Lagoons that receive rich dissolved organic matter, as lake Mariut, Egypt[8], Venice lagoon[9] and the lagoon of Alvardo, Mexico[10] had members of Eugleninae. Often a single taxonomic group constituted the bulk of the phytoplankton population. For example, in the oceanic lagoons of Faa[11], diatoms constituted nearly 50% of the phytoplankton population, while in Puttalam lagoon, Ceylon[12], 70 out of 75 taxa were diatoms. In the case of Puerto Rico lagoons[13] dinoflagellates dominated the phytoplankton crop. Monospecific blooms of microplankton such as euglenoids and pennate diatoms were common in southern coastal islets of Puerto Rico[14]. In the Barrier Island lagoon of Gulf of California[15], where microflagellates dominated nanoplankton, while smaller pennate diatoms constituted about 25% of the nanoplankton in the eutrophic areas, in the oligotrophic regions they never exceeded 1% and myxophyceans and a large number of dinoflagellates occurred as co-inhabitants there. In all these cases, distribution of phytoplankton was greatly determined by the salinity of the waters. Locally, phytoplankton distribution patterns observed in Chilka lagoon revealed characteristic response gradients as determined by salinity. For instance, in the southern sector (zone I) where the salinity was high, the principal dominants among the phytoplankton were dinoflagellates. In the intermediate regions of reduced salinity (zones II and III), the cyanophyceans were relatively more conspicuous. In the regions of maximum dilution (zone IV), the phytoplankton was dominated by diatoms and certain chlorophyceans of freshwater nature. In the outer channel (zone V) near the proximity of the sea, the inhabitants were mostly of marine origin.

Acknowledgement

Authors are grateful to Dr Kaza V. Ramarao of Zoological Survey of India, Regional Office, Berhampur for excellent facilities offered during the course of this investigation. They are also thankful to Dr. S.Z. Siddique, Zoological Survey of India, Calcutta, for exchanging data during the expedition.- This work was carried out with the financial assistance by the Indian Council of Agricultural Research, New Delhi.

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