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Limnology of Kashmir Lakes. VII
The Ecology of Bacillariophyceae in Two Lakes in Srinagar

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In the lakes Dal and Nagin (Kashmir), the main bulk of the phytoplankton comprises Bacillariophyceae with highest standing crop in spring-summer interphase and the depression in winter. Local meteorological disturbances and the shallowness of the lake cause erratic fluctuations in physico-chemical parameters and alter the biological balance of the lake water. Phosphate and nitrate are in such low quantities that either may not be a limiting factor in growth of Bacillariophyceae. The silicon does not play a significant role in the development since the lakes are poor in its production, though factors, like temperature, dissolved oxygen, etc., have a profound effect on the ferri-silico-humate complex.

Key Words: Limnology, Hydrobiology, Phytoplankton, Lake sediments

Introduction

The Dal lake, situated in the north-east of Srinagar, lies within lat. 34.07° E and long. 74.52° N. The early ecological studies conducted in the lake have been given by Mir, Suri and Kachroo (1975). Mir and Kachroo (1978 a–c) have discussed biology of blue-green algae, phytoplankton-zooplankton composition and bottom soil characteristics in these lakes. The present communication deals with role played by Bacillariophyceae in lake ecology during 1974–1976.

Material and Methods

Of the 12 selected sampling stations (figure 1) 1,2,4,9,10 and 12 were off-shore along the length of the lake; and 3, 5 and 11 were inshore. The stations 6–8 were in Nagin basin (6 and 8 inshore). The samples for plankton and chemical analyses were collected fortnightly, at mid-day, during September 1974 to August 1976; those from the SL* were taken directly, and those from the BL* with the help of a glass sampler. The standard plankton hauls were made with the help of a specially designed differential net (based on Welch 1948). All the plankton counts were made under high magnification of the light

* SL, surface layer; and **BL, bottom layer of water

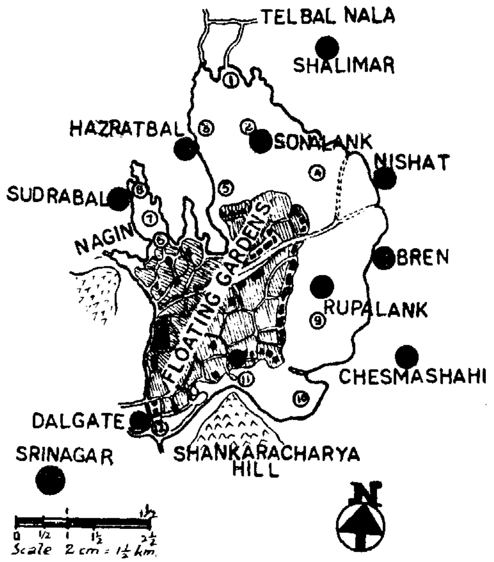

Figure 1 Collection stations in lakes Dal and Nagin

microscope, the units being a single cell, a colony, or a filament.

For chemical analyses, samples were kept in polythene bottles and analyses were done immediately after collection. For dissolved O_2, samples were fixed in the field and then tested by Winkler's method (1917). The *p*H was measured in the laboratory using Phillips *p*H meter (model PR 9405/90). Routine methods were followed for the estimation of total alkalinity, hardness, dissolved organic matter, silicates, chlorides, nitrogen as nitrates, nitrites and ammonia, phosphate and total phosphorus (APHA 1970, Voghal 1971, Meckereth 1955).

Results and Discussion

Bacillariophyceae

The diatoms represented the bulk of phytoplankton throughout the year, forming 20–60% of the total biomass. The Chlorophyceae was next forming 6–27%. followed by Cyanophyceae with 7–23%. In decreasing order of preponderance were Dinophyceae, Euglenophyceae and Chrysophyceae. Over 40 taxa of diatoms were identified in the samples (Appendix 1). In SL the largest standing crop (12×10^5 cells/l) was in May 1975 and the minimum (12×10^4 cells/l) in January 1976; while in BL, the maximum of 25×10^5 cells/l and 22×10^5 cells/l were recorded in June 1975 and 1976, respectively; and the minimum of 26×10^4 cells/l and 24×10^4 cells/l in January 1975, 1976 respectively. Seasonally, the peak occurred in late spring to early summer. A secondary pulse, in both the layers, was recorded in September, being followed by depression in winters. The phytoplankton density was highest (17×10^5 and 44×10^5 cells/l) in May 1975 in SL and in June 1975 in BL; and the lowest (18×10^4 cells/l) in January 1976 in SL and 29×10^4 cells/l in March 1976 in BL. A secondary peak was recorded in September (1974, 1975) prior to the depression period (figure 2).

A sharp distinction between the diatom flora of offshore and inshore stations was never discernible but the standing crop of total phytoplankton at the inshore stations was higher than that of from the central portion of the lake, (see also, Munawar & Nauwerck 1971). Further the number of species of a particular genus was comparatively higher at the inshore stations. An increasing trend with respect to the density of the standing crop of phytoplankton and nutrient concentration was noted from stations $1 < 2 < 4$; $1 < 3 < 5$; and $10 < 11 < 12$; but station 9 comparatively showed lower values. In Nagin basin also the inshore stations 6 and 8 showed higher values than station 7 which is the deepest part of the lake (depth, 6.5 m).

With respect to the trophic groups of

Duthie and Sreenivasa (1971), the Dal and Nagin fall under the category "eutrophic group" as typified by *Cyclotella glomerata*, *Stephanodiscus hantzschii* and *S. tenuis*. The dominant genera recorded in the lake were *Cymbella*, *Fragilaria*, *Diatoma*, *Eunotia*, *Gomphonema*, *Synedra*, *Tabellaria*, *Navicula*, *Pinnularia*. Genera like *Gyrosigma*, *Pleurosigma*, *Cocconeis*, *Rhopalodia*, *Nitzschia*, *Hantzschia*, *Achnanthes* were less common. *Surirella*, *Meridion*, *Melosira*, *Epithemia*, *Frustulia* and *Ceratoneis*, were rare.

Physico-Chemical Features

Temperature

The mean maximum air temperature (32.7°C) was recorded in July 1976 and it corresponded to the maximum water temperature (28.6°C and 26.7°C) for the SL and BL, respectively. The minimum air temperature (−0.5°C) was recorded in February 1975, whereas that in water in January 1975 (3.2°C in SL and 3.3°C in BL). The summers (1975, 1976) experienced highest temperatures and winters (1974, 1975) the lowest. The month to month variation in the temperatures was maximum (6.8°C) between April and May (1976) in SL and (7.0°C) between October and November (1975) in BL. The latter showed lower temperatures excepting in January 1975, when the reverse was the case. Both the layers showed the same temperature in January and April (1976). Between the layers the maximum difference of 3.5°C was recorded in June 1975. The SL showed higher temperature than that of the air in December 1974, February and March 1975, and January-February 1976, due to the prevalent cold wind. For rest of the period the air temperature was higher than that of the SL. The maximum difference (7.0°C) between the temperatures of air and SL was recorded in April 1976 and the minimum (0.4°C) in May 1975.

As the lake is shallow, only slight thermal stratification was recorded.

With the increase in temperature after winter, phytoplankton density also showed an increase reaching the peak in late spring. The temperature maxima were in early and mid summer (figure 2) and these were favourable for the optimum growth of phytoplankton in general and Bacillariophyceae in particular. This is supported by the occurrence of peaks in BL one

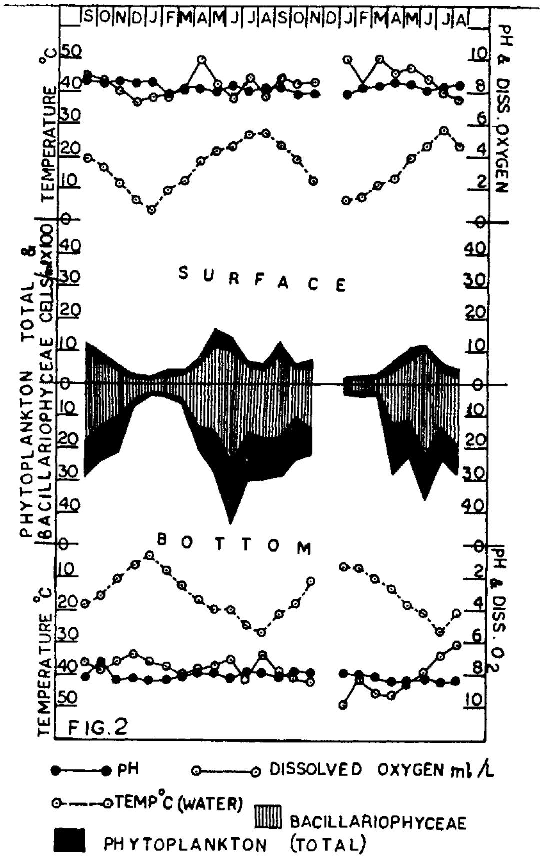

Figure 2 Monthly distribution of total phytoplankton, Bacillariophyceae, temperature, dissolved O_2, and *p*H in SL and BL

month ahead of the period recorded in SL (table 1).

Light and temperature have a definite effect on the diatom communities in lakes. Thus, Hutchinson (1967), Patrick (1969) and Round (1968) have concluded that the diatom species possess an optimum range of temperature for growth. Hustedt (1956) has even classified Diatomeae on the basis of their temperature tolerance range. The effect of temperature or light or both on the seasonal succession of diatoms and a clear proof of temperature tolerance of various species of diatoms was given by Rodhe (1949) and Wallace (1955). Stockner (1967) reported diatoms from thermal streams with a temperature exceeding 35°C and Patrick (1971) gave the range from 0–35°C; and Munawar (1974) extended the upper limit to 39°C. In the Dal and Nagin the range of temperature tolerance is from 0–28°C and for the optimum growth it is 24°C; and as per Hustedt's classification the species are "cold water to temperate" forms.

Transparency

Water was clear throughout the year, excepting during floods. The drought period led to evaporation; thus increasing concentration of nutrients and the density of phytoplankton but flooding led to dilution of the waters. Secchi disc transparency is expressed as the "percentage transparency" because a considerable variation in the depth of the lakes at the selected stations was recorded due to rains. The maximum value (90.1%) was recorded in April 1975 and the minimum (51.3%) in August 1976. Overall the transparency was high during autumn (1974), winter and early spring (1975). The summers (1975, 1976) showed low transparency values in the presence of high standing crop of phytoplankton. This could possibly have been modified due to rainfall during the period of phytoplankton bloom, and the lower values of transparency may not be attributed to the higher density of the standing crop of phytoplankton or the Bacillariophyceae; but apparently rain appears to be the cause for it.

Humidity

The mean relative humidity (expressed as percentage) showed the highest values (95% at 8.30 AM and 83% at 5.30 PM) in December 1974; and the lowest

Table 1 *Correlation between temperature, total phytoplankton and Bacillariophyceae*

	Surface				Bottom			
	Peak		Depression		Peak		Depression	
	1974–1975	1975–1976	1974–1975	1975–1976	1974–1975	1975–1976	1974–1975	1975–1976
Temperature °C	27.7 Aug.	28.6 July	3.2 Jan.	6.6 Jan.	27.0 Aug.	26.7 July	3.3 Jan.	6.6 Jan.
Total Phytoplankton Cells/l	17×10^{8} May	12×10^{5} June	21×10^{4} Jan.	18×10^{4} Jan.	44×10^{5} June	35×10^{6} June	35×10^{4} Jan.	29×10^{4} Jan.
Bacillariophyceae Cells/l	12×10^{5} May	1×10^{6} June	14×10^{4} Jan.	12×10^{4} Jan.	25×10^{5} June	22×10^{5} June	25×10^{4} Jan.	24×10^{4} Jan.

(67% at 8.30 AM and 46% at 5.30 PM) in June 1975. The humidity was highest during winters of 1974 and 1975 and the autumn of 1975, and the least during June 1975 and April to July 1976. The impact of humidity on the density of Bacillariophyceae is obscure.

Rainfall

Rainfall was maximum (259.2 mm) in August 1975 and minimum (6.6 mm) in November 1975. November 1974 and October 1975 were dry and in December 1975 rainfall was in traces (figure 3). The perhumid periods when the rainfall exceeded 100 mm were February, March, May, July and August 1975, February and August 1976. The arid periods were September, October, November 1974, June, September to December 1975 and May to July 1976 and the rest period was either humid or humid with precipitation. The developmental sequence of the humid period resembled to that of the phytoplankton in 1975 and 1976, whereas the perhumid period resulted in the dilution of the lake water thereby in the dilution of nutrients as well as the phytoplankton standing crop.

Suspended and Dissolved Solids

The suspended solids showed maximum value (135.8 mg/l) in August 1976 and the minimum (57.2 mg/l) in January 1976. Profound effect of rains and flooding was recorded on the concentration of suspended matter. Dissolved solids showed the maximum value (192.5 mg/l) in January 1976 and the minimum (77.16 mg/l) in November 1975. Overall, late autumns and winters showed higher values and summers the lower values. The relationship between the Bacillariophyceae and dissolved solids is obscure.

Chlorides

The concentration of chlorides ranged from 6.09 mg/l in August 1976 to 9.38 mg/l in December 1974. On the seasonal basis, higher values were recorded in winters and lower in springs and summers (1975, 1976). Overall, the chlorides showed an erratic behaviour and their relationship with phytoplankton does not appear meaningful.

Dissolved Oxygen

Because of the small depth, DO_2 concentration mostly depends on biological processes in the mud water interface. The highest concentration (10.18 mg/l) of DO_2 in SL was in March 1976 and the lowest (7.36 mg/l) in December 1974. The BL showed lower concentrations, the maximum (9.85 mg/l) being in January 1976 and the minimum (6.15 mg/l) in August 1976. Seasonally, the springs (1975, 1976) showed higher concentrations and the summers (1975, 1976) the lowest.

The high concentration in springs (1975, 1976), due to photosynthetic activity of the bottom flora, leads also to an increase in *p*H. The temperature and DO_2 show an intimate association and the variation observed in late spring and summer was due to heavy rainfall during the period. The presence of DO_2 at all the depths throughout the period may be due to the unstratified nature and unproductiveness of the water body. The high temperatures during summers may have led to the oxygen depletion in both the layers (figure 2).

*p*H

The *p*H ranged from 8.7 in January (1975) to 7.81 in February (1975) in the SL. In BL the maximum (8.24 and 8.44) was in January 1975 and June 1976, and the minimum (7.78) in July 1975.

Seasonally, the winters (1974, 1975) and springs (1975, 1976) had the highest values and the summers and autumns (1975, 1976) the lowest values. A considerable variation in the values on monthly basis or seasonally was not recorded. Overall, *p*H was always alkaline and ± 8.0, due to the high bicarbonate content in the lakes. BL always showed a lower *p*H. An intimate correlation existed between *p*H, HCO_3 and DO_2 contents but Bacillariophyceae appear to be unrelated with their monthly or seasonal rythm. (figure 2).

Alkalinity

The carbonate alkalinity was almost nil and the total alkalinity was due to bicarbonate content. The maximum concentration (138.66 mg/l) was recorded in February (1975) and the minimum (73.58 mg/l) in June (1975) in SL. The highest values were recorded in November to February (1974–1975) and January to April (1976). The lower concentrations were during May to October 1975 and May to August in 1976. In the BL values were higher, the maximum (156.84 mg/l) being in December 1974 and the minimum (75.48 mg/l) in June 1975. The seasonal trend in values was similar to those of the BL.

The reduction in the bicarbonate content at the time of algal bloom is attributed to the uptake of carbon by the bottom vegetation and the phytoplankton which also lead to changes in the calcium content of waters (Ahl 1966).

Dissolved Organic Matter (DOM)

The DOM in Dal lake is mostly of autochthonous nature and to a lesser extent of allochthonous origin. The maximum DOM concentration (3.74 mg/l) was in July 1976 and the minimum (1.44 mg/l) in May 1976 in SL. The BL had always higher concentration, the maximum (3.75 mg/l) being in March 1976 and the minimum (1.73 mg/l) in May 1976. The winters (1974, 1975) showed highest and the springs (1975, 1976) the lowest concentrations. The higher values in July 1976 were due to the floods following high rainfall. The relationship of DOM, Bacillariophyceae, and the total phytoplankton are obscure. Perhaps the factors controlling those substances (which have sediment origin) do not operate in this case.

Total Hardness

In SL calcium showed the maximum concentration (89.19 mg/l) in February 1976 and the minimum (40.44 mg/l) in June 1975; and in BL the maximum (84.37 mg/l) was in March 1976 and the minimum (39.28 mg/l) in July 1975. The winters (1974, 1975) showed highest concentration and the summers (1975, 1976) the lowest. In BL comparatively the values were higher.

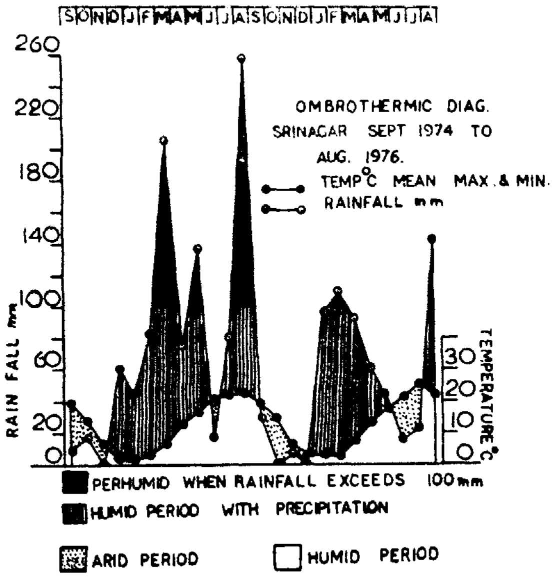

Figure 3 Ombrothermic diagram depicting humid and arid periods in Srinagar (Kashmir)

The magnesium followed nearly the same pattern as calcium, showing the maxima of 37.06 mg/l and 39.96 mg/l in March (1976) in SL and BL, respectively; and minima of 21.33 mg/l and 24.57 mg/l in May (1975) in both the layers. Seasonally, highest concentration was in winters and early springs (1975, 1976), and the lowest in summers (1975, 1976).

Both calcium and magnesium are important for growth of plants thus their concentration is lower at the time of peak development in Bacillariophyceae, as well as in algae as a whole. Calcium in the form of water soluble calcium formate is utilized in the formation of sheaths of blue green algae and magnesium is responsible for the healthy pigmentation (Fogg 1953 and Munawar 1974). Luxurient growth of diatoms in presence of higher concentration of calcium and magnesium (Munawar 1974) does not hold true in our lakes; no doubt an inverse correlation did exist between the two. Ahl (1966) has reported an intimate association between CO_2, HCO_3 and Ca; and the reduction in these parameters presumably is due to carbon uptake by the bottom vegetation and the phytoplankton (figure 4).

Phosphorus

For the living organisms, phosphorus is ecologically most important element. In the Dal and Nagin concentration of PO_4–P and total–P is not too high, the average PO_4–P concentration ranging from 9–26 μg/l (November 1975) to 18.41 μg/l (June 1976) in the SL; and in BL from (21.49 μg/l (July, 1976) to 11.92 μg/l (October, 1975). Seasonally, summers (1975, 1976) showed a higher concentration and the autumns (1974, 1975) lower concentration. In case of total–P the maximum concentration (83.38 μg/l) was in July (1976) and the minimum (32.39 μg/l) in April (1976) in SL; and in BL the maximum (78.39 μg/l) in July (1976) and the minimum (34.61 μg/l) in September 1975. Seasonally, higher concentration occurred in Summers (1975, 1976) and the lowest in autumns (1974, 1975).

Both, PO_4–P and total–P showed higher concentration in BL due to the sedimentation of sestonic–P from the higher layers and partly due to the release of PO_4–P, from the sediment. This is rapidly converted into sestonic form (Ahl 1966). The increase of PO_4–P and total–P in

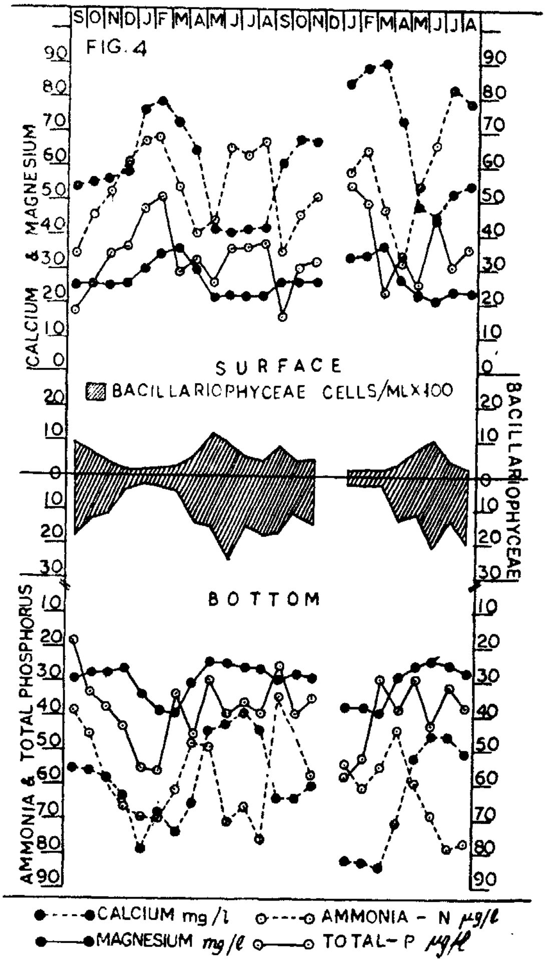

Figure 4 Monthly distribution of Bacillariophyceae calcium, magnesium, ammonia, and total–phosphorus

summers is associated with increase in temperature; the rising temperature increasing the regeneration of phosphorus from the sediment and littoral zone. The reduction in autumn may be due to slower regeneration.

Juday and Birge (1931) regarded phosphorus as a limiting factor; and Hutchinson (1944) found that when PO_4–P and NO_3–N are present in large amounts, they are less frequently the factors which control primary production.

In nutrient-rich lakes a remarkable rise in PO_4–P has been noticed in connection with the reduced O_2 concentration (Einsele 1936 and Mortimer 1941, 1942). This nearly holds true in our lakes. As recorded by Ahl (1966) when phytoplankton are related to total–P, the latter is largely made up of sestonic–P i.e., each change in phytoplankton volume will correspond with a change in total-P in the same direction; moreover, phytoplankton and total–P increase with the depth, as also in our lakes (figures 4 & 5).

Nitrogen

The possible sources of nitrogen for

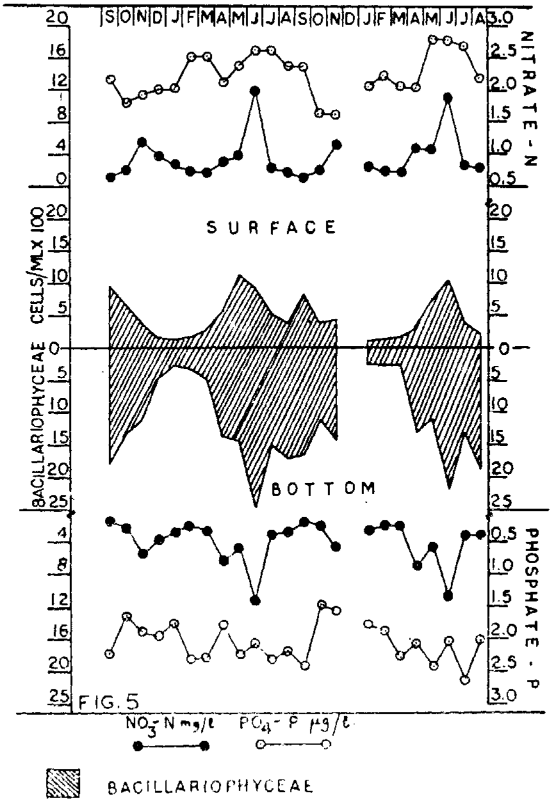

Figure 5 Monthly values of Bacillariophyceae, nitrate and phosphate

Table 2 *Correlation between temperature* DO_2*,* HCO_3*,* PO_4 *and total–P*

	Surface				Bottom			
	Peak		Depression		Peak		Depression	
	1974–1975	1975–1976	1974–1975	1975–1976	1974–1975	1975–1976	1974–1975	1975–1976
Temp.°C	27.7 Aug.	28.6 July	3.2 Jan.	6.6 Jan.	27.0 Aug.	26.7 July	3.3 Jan.	6.6 Jan.
DO_2 mg/l	10.0 Aug.	10.1 Jan.	7.3 Dec.	7.4 Aug.	8.38 Aug.	9.8 Jan.	6.7 Dec.	6.8 July
HCO_3 mg/l	138.6 Feb.	133.2 March	73.5 June	81.1 May	156.8 Dec.	133.2 March	75.4 June	84.4 June
PO_4–P μg/l	17.1 June	18.4 May	10.3 Oct.	9.6 Oct.	18.7 July	21.3 July	13.0 Oct.	11.9 Oct.
Total–P μg/l	67.6 Aug.	83.3 July	34.2 Sept.	35.0 Sept.	76.0 Aug.	78.3 July	38.5 Sept.	34.6 Sept.

green plants are nitrate-N, nitrite-N and ammonia-N. These occur in low concentration in our lakes. NO_3–N is maximum (1.501 mg/l) in June (1975) and minimum (0.154 mg/l) in September (1974), in the SL, and in BL maximum (1.34 mg/l) in June (1975) and minimum (0.19 mg/l) in September (1974, 1975). Seasonally, summers (1975, 1976) had higher concentration and autumns and winters (1974, 1975) the lowest.

The NO_2–N showed maximum concentration (8.37 μg/l) in May (1976) and the minimum (1.40 μg/l) in July (1975) in SL and BL followed the same trend in maximum concentration (10.44 μg/l) in May (1976) and the minimum (1.39 μg/l) in July (1975). Seasonally, higher concentrations were recorded in late spring and early summer (1975, 1976) and the lowest in late summer and autumn (1975, 1976).

The NH_4–N showed the maximum concentration (54.8 μg/l) in January (1976) and the minimum (16.33 μg/l) in September (1975) in the SL, and in BL maximum (58.19 μg/l) in January (1976) and minimum (18.19 μg/l) in September (1974). Seasonally, Higher values were recorded in winters (1974, 1975) and lower in autumns (1974, 1975), the same is recorded by Ahl (1966) and Lund (1970).

Whipple and Parker (1902), Pearsall (1923) and Lind (1938) have suggested that nitrate is the main factor controlling the periodicity of diatoms whereas, Rao (1955), Singh (1960) and Zafar (1967) did not find any correlation between the two. Komarvosky (1953) and Prowse and Talling (1958) reported an inverse correlation between the nitrates and diatoms.

Assimilation of NO_3–N by phytoplankton did never affect Bacillariophyceae or the total phytoplankton, because of such factors as temperature, CO_2, HCO_3 which operate in the ecosystem and

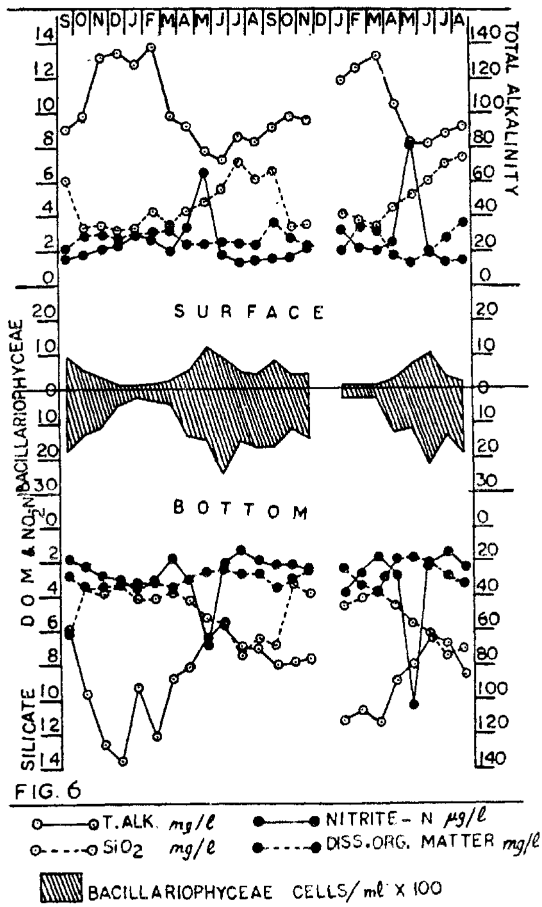

Figure 6 Correlation between Bacillariophyceae, nitrite silicate, DOM and total alkalinity

possibly shield the effect of NO_3. Further the process of nitrification, aided by Cyanophyceae (as evident by nitrite peak being followed by nitrate peak in SL as well as BL) may also operate.

Ammonia–N showed a quantitative relation to the changes in Bacillariophyceae volume (table 3).

Silicates

The silicon is the most important element which aids the development of diatom shells. Its maximum concentration (7.5 mg/l) was in June (1976) in both the layers and the minimum (3.2 and 3.3 mg/l) in December (1974). Seasonally, highest values were recorded in summers (1975, 1976) and the lowest in winters (1974, 1975). The BL comparatively always showed higher concentration but the difference in the values between the layers or on monthly basis in a layer were not marked. The vertical distribution of SiO_2 follows the trend of other substances which are given off by the sediment (Hutchinson 1957). With the decrease in DO_2

Table 3 *Correlation between Bacillariophyceae, total phytoplankton temperature with nitrogen sources (NO_3, NO_2, NH_4)*

	Surface				Bottom			
	1974–1975		1975–1976		1974–1975		1975–1976	
	p	d	p	d	p	d	p	d
Bacillariophyceae Cells/1	12×10^5 May	14×10^4 Jan.	10×10^5 June	12×10^4 Jan.	25×10^5 June	26×10^4 Jan.	22×10^5 June	24×10^4 Jan.
Phytoplankton Cells/1	17×10^5 May	21×10^4 Jan.	12×10^5 June	18×10^4 Jan.	44×10^5 June	35×10^4 Jan.	35×10^5 June	29×10^4 Jan.
Temperature °C	27.7 Aug.	3.2 Jan.	28.6 July	6.6 Jan.	27.0 Aug.	3.3 Jan.	26.7 July	6.6 Jan.
NO_3-N mg/1	1.50 June	0.15 Sept.	1.41 June	0.16 Sept.	1.43 June	0.19 Sept.	1.42 June	0.19 Sept.
NO_2-N µg/1	6.68 May	1.40 July	8.37 May	1.44 July	6.83 May	1.39 June	10.4 May	1.44 July
NH_4-N µg/1	51.0 Feb.	17.4 Sept.	54.8 Jan.	16.3 Sept.	56.2 Feb.	18.9 Sept.	58.1 Jan.	25.3 Sept.

p=peak; d=depression

Table 4 *Correlation between Bacillariophyceae, SiO_2, Diss.O_2, HCO_3 and temperature.*

Transter	Surface				Bottom			
	1974–1975		1975–1976		1974–1975		1975–1976	
	p	d	p	d	p	d	p	d
Bacillariophyceae Cells/1	12×10^5 May	14×10^4 Jan.	10×10^5 June	12×10^4 Jan.	25×10^5 June	26×10^4 Jan.	22×10^6 June	24×10^4 Jan.
SiO_2 mg/1	7.2 July	3.2 Dec.	7.5 July	3.4 Oct.	7.4 July	3.3 Dec.	7.5 July	3.3 Oct.
Diss. O_2 mg/1	10.0 Aug.	7.3 Dec.	10.1 Jan.	7.4 Aug.	8.3 Aug.	6.7 Dec.	9.8 Jan.	6.8 Jully
HCO_3 mg/1	138.6 Febr.	73.5 June	133.2 March	81.1 May	156.8 Dec.	75.4 June	133.2 March	84.4 June
Temperature°C	27.7 Aug.	3.2 Jan.	28.6 July	6.6 Jan.	27.0 Aug.	3.3 Jan.	26.7 July	6.6 Jan.

p=peak; d=depression.

content silica increased because of the breakdown of the ferri-silico-humate complex. Moreover, the changes in the silica concentration are also connected with the factors that regulate the variation in bicarbonate contents (table 4).

Ahl (1966) has also reported higher concentration of silica in winters and depression in summers in Osbysjon and explains that the movement of silica from the mud to the oxygenated water is presumably under the control of temperature. The increase in the silica content is the result of the release of silica from bottom vegetation. The reduction in the silica content depends on uptake of silica by the bottom vegetation, by diatoms and in reformation of the humate complex.

Presumably, in our waters abiogenic loss of silica is insignificant and also consumption of silica by nonplanktonic forms is negligible; but the amount of silica added due to breakdown of ferri-silico-humate complex surpasses the other phenomena; therefore, no silica depletion due to diatom abundance occurs, as also reported by Tessenow (1966).

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References

Ahl T 1966 Chemical conditions in Osbysjon, Djursholm. I. Factors related to organic production; *Oikos* **17** 23–61

APHA 1970 *Standard Methods for the Examination of Water and Waste Water* (30th Edn.) (New York: APHA)

Duthie H C and Sreenivasa M R 1970 Evidence for eutrophication of lake Ontario from the sedimentary diatom succession, Proc. 14th. Conf. Great Lakes Res.; *Internat. Assoc.* 1–13

Einsele W 1936 Uber die Beziehungen des Eisenkreislaufs zum phosphatkreislauf in eutrophen see; *Arch. Hydrobiol.* **29** 664–686

Fogg G E 1953 *The Metabolism of Algae.* (London: Mathuen and Co. Ltd.) 194p

Hutchinson G E 1944 Limnological studies in Connecticut VII; *Ecology* **25** 3–26

—— 1957 and 1967 *A Treatise on Limnology,* Vols. I and II. (New York: John Wiley and Sons Inc.) 2130 pp

Hustedt F 1956 *Kieselalgen* (Diatomeen). Kosmos, Stuttgart. 70 p

Juday C and Birge E A 1931 A second report on the phosphorus content of Wisconsin lake waters; *Trans. Wis. Acad. Sci. Arts Lett.* **26** 353–382

Komarosky B 1953 A comparative study of the phytoplankton of several fish ponds in relation to some of the essential chemical constituents of the water; *Bull. of Res. Council of Israel,* Vol. II. No. **4** 379–410

Lind E M 1938 Studies in the periodicity of algae in the Beau chef ponds, Sheffield; *J. Ecol.* **26** 257–274

Lund J W G 1970 Primary production; *Water treatment and Examination* **14** 332–358

Meckereth F J H 1955. Some methods of water analysis for limnologists; *Freshwater Biol. Assocn. Sci. Publ.* Ambleside

Mir A M, Suri B L and Kachroo P 1975 Fluctuations and density of phytoplankton in Dal lake, Kashmir; *Geobios* **1** 74–75

—— and Kachroo P 1978a Biology of blue green algae; *Proc. All India Seminar on Blue Green Algae and Their Viruses,* Madurai India

—— and —— 1978b Phytoplankton-zooplankton composition in the lakes Dal and Nagin (Kashmir); *Abst. Int. Congr. Ecol. Israel.,* Jerusalem 241 pp

—— and —— 1978c Bottom soil characteristics in the Dal and Nagin lakes (Kashmir); *ibid* 242p

Mortimer C H 1941–1942 Exchange of dissolved substances between mud and water in lakes; *J. Ecol.* **29** 280–329; **30** 147–201

Munawar M and Nauwerck A 1971 The composition and horizontal distribution of phytoplankton in lake Ontario during the year 1970; *Proc. 14th. Conf. Great Lakes Res.* **14** 69–78

—— 1974 Limnological studies on freshwater ponds of Hyderabad, India. IV. The biocenose-periodicity and species composition of unicellular and colonial phytoplankton in polluted and unpolluted environments; *Hydrobiologia* Vol. 45 **1** 1–32 p

Patrick R 1969 Some Effects of Temperature of Freshwater Algae; in *Biological Aspects of Thermal Pollution* eds P A Krenkel and F L Parker (Vanderbilt Univ Press)

Pearsall W H 1923 A theory of diatom periodicity; *J. Ecol.* **11-12** 165–183

Prowse G A and Talling J F 1958 The seasonal growth and succession of plankton algae in the White Nile. Limnol; *Oceanogr.* **3** 222–238

Rao C B 1955 On the distribution of algae in a group of six small ponds. II. Algal periodicity; *J. Ecol.* **43** 291–308

Rodhe W 1948 Environmental requirements of freshwater plankton algae; *Symb. Bot. Upsal* **10** 1–49

Round F E 1968 Light and temperature; in *Algae, Man and Environment* ed D F Jackson (Syracuse Univ Press) 554 pp

Singh V P 1960 Phytoplankton ecology of the inland waters of Uttar Pradesh, *Proc. Symp. Algology* (New Delhi: ICAR) 234–271

Stockner J G 1967 Observations of thermophilic algal communities in Mount Rainier and Yellowstone National Parks. Limnol; *Oceanogr.* **12** 13–17

Tessenow U 1966 Untersuchungen uber den Kiesselsaurehauthalt der Binnengewasser; *Arch Hydrobiol Supp. Band* 32, 136 p

Wallace N 1955 The effect of temperature on the growth of some freshwater diatoms; *Nat. Acad. nature Sci. Phila.* 280 11 p

Welch P S 1948 *Limnological Methods* (McGraw Hill Book Co.) 381 pp

Whipple C G and Parker H N 1902 On the amount of oxygen and carbonic acid dissolved in natural waters and the effect of these gases upon the occurrence of microscopic organisms; *Trans. Amer. Microsc. Soc.* **23** 103–114

Zafar A R 1967 On the ecology of algae in certain fish ponds of Hyderabad, India. III. *The Periodicity—Hydrobiologia* **30** 96–112

APPENDIX I

1 *Coscinodiscus lacustris* Grun.
2 *Cyclotella glomerata* Bachmann
3 *C. meneghiniana* Kuetz.
4 *C. meneghiniana* Kuetz. f. *bionata* Grun.
5 *Melosira granulata* Kuetz.
6 *M. crenulata* Kuetz.
7 *Stephanodiscus hantzschii* Grun.
8 *S. tenuis* Hust.
9 *Ceratonies arcus* (Ehr.) Kuetz.
10 *Diatoma nannum* Skabitsch
11 *D. vulgare* Bory
12 *Fragilaria leptostauron* (Ehr.) Hust.
13 *Meridion circulare* (Grev.) Ag.
14 *Synedra capitata* Ehr.
15 *S. Goulardi* (Breb.) Hust. v. *telezkoensis* Portzky
16 *S. pulchella* (Ralfs.) Kuetz.
17 *S. ulna* (Nitz.) Ehr.
18 *S. ulna* (Nitz.) Ehr. v. *subaegualis* Grun.
19 *Tabellaria fenestrata* (Lyngb.) Kuetz.
20 *Eunotia arcus* Ehr. v. *bidens* (H.V.H.)
21 *E. tschirchiana* O'Muell
22 E. major (Wm. Sm.) Rab.
23 *E. praerupta* Ehr.
24 *Achnanthes lanceolata* (Breb.) Grun.
25 *Cocconies plancentula* Ehr. v. *euglypta* (Ehr.) Grun.
26 *Amphipleura pellusida* Kuetz.
27 *Calonies amphisbaena* (Bory.) Cl.
28 *Calonies permagna* (Bail.) Cl.
29 *C. silicula* (Ehr.) Cl. v. *undulata* (Grun.) May.
30 *Amphiperora alata* Kuetz.
31 *Cymbella aspera* (Ehr.) Cl.
32 *C. cistula* (Hempr.) Grun.
33 *C. cistula* (Hempr.) Grun. v. *rostrata* Sax.
34 *C. gastroides* Kuetz. v. *minor* (H.V.H.)
35 *C. lanceolata* Ehr.
36 *C. naviculiformis* Auers.
37 *C. tumida* Breb.
38 *C. turgidula* (Green) V. *nippenica* Ekv.
39 *Frustulia rhomboides* (Ehr.) De Toni
40 *Diplonies elliptica* Kuetz. Cl.
41 *Gomphonema acuminatum* Ehr.
42 *G. acuminatum* Ehr. v. *coronata* (Ehr.) W. Sm.
43 *G. augur* Ehr.
44 *G. augur* Ehr. v. *gauteri* (H.V.H.)
45 *G. constrictum* Ehr.
46 *G. constrictum* Ehr. v. *capitata* (Ehr.) Cl.
47 *G. longiceps* Ehr. v. *subclavata* Grun
48 *G. subapiculatum* (Fritsh. & Rich)
49 *Mastogloia brauni* Grun.
50 Gyrosigma
51 *Navicula bengalensis* Grun.
52 *N. cuspidata* Kuetz.
53 *N. flabelata* Meist.
54 *N. gastrum* (Ehr.) Douk
55 *N. gibba* Kuetz.
56 *N. gracilis* Kuetz.
57 *N. gracilis* Kuetz. v. *schizonemoides* (H.V.H.)
58 *N. mesolepta* Ehr.
59 *N. pygmeea* Kuetz.
60 *N. vulpina* Kuetz.
61 *Pinnularia acrospheeria* (Breb.) W. Sm. v. *minor* Cl.
62 *P. brebissoni* Kuetz. Cl.
63 *P. interrupta* (W. Sm.) f. *biceps*
64 *P. nobilis* Ehr.
65 *P. subcapitata* Greg.
66 *P. sundaensis* Hust.
67 *P. viridis* (Nitz.) Ehr.
68 *P. viridis* (Nitz.) Ehr. v. *viridis* Petr. Rein.
69 *Pleurosigma attenuatum* W. Sm. v. *scalprum* (Gail.) Grun.
70 *Stauroneis phoenicentron* Ehr.
71 *Epithemia argus* Kuetz.
72 *E. argus* Kuetz. v. *amphicephala* Green
73 *E. gibba* Kuetz. v. *ventricosa* (H.V.H)
74 *E. sorex* Kuetz.
75 *E. turgida* (Ehr.) Kuetz. v. *granulata*
76 *E. zebra* (Ehr.) Kuetz. v. *porcellus* (Kuetz.) Grun.
77 *Rhopalodia gibba* (Ehr.) O. Muell
78 *Hantzschia amphioxys* (Ehr.) Green
79 *Nitzchia levidensis* -(W. SM.) Grun.
80 *N. sinuta* (W. Sm.) Grun. v. *tabellaria* Grun.
81 *N. obtusa*
82 *Campylodiscus clypeus* Ehr.
83 *C. clypeus* Ehr. v. *bicostatus* (W. Sm.) Hust.
84 *Cymatopleura elliptica* (Breb.) W. Sm.
85 *C. solea* (Breb.) Sm.
86 *Surirella ovata* Kuetz.