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Limnological Studies on Dal Lake, Srinagar
III. Biological Features

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Myriophyllum spicatum-Ceratophyllum demersum is the most dominant submersed community and *Typha-Phragmites* is the main helophytic representative of the Dal lake. Emergents have low coverage but high production and submersed species contribute low production. The phytoplankton crop of the lake generally consists of members belonging to Chlorophyceae, Bacillariophyceae and Cyanophyceae. Zooplankton are mostly represented by rotifers. There is significant site variation with regard to plankton distribution. Tubificidae and Chironomidae are numerically high in those areas which receive waste water. *Cyprinus carpio*, an introduced fish comprises 60–70% of the total catch of the lake. On the basis of estimated annual production of phytoplankton, the open area of the lake depict low trophic level. The limnological features of various basins of the Dal lake differ significantly as a result of which it is not justified to assign a single trophic status to the entire lake system.

Key Words : Macrophytic vegetation, Plankton population, Benthos, Fish, Trophic status

Introduction

Dal lake (lat. 34°9′ N long. 74°6′ E, alt. 1584 m) is regarded as one of the most beautiful lakes in the world. Its open area of water, imposing aspect of the mountain amphitheater which surrounds it on three sides and the charming Moghul gardens and orchards around it attract tourists from all over the world. Zutshi and Vass (1978) and Vass and Zutshi (1979) have reported on morphometry, physical features and water chemistry of the lake. The present paper deals with the biological features investigated during 1972–76. Data have been obtained on distribution, production and dynamics of macrophytic vegetation, qualitative and quantities aspects of plankton population, colonization of benthic fauna and the nature of fish population. The results are used to evaluate the present trophic status of the lake and to develop baseline for future ecological surveillance.

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Materials and Methods

The distribution of submersed macrophytic vegetation from various parts of the lake was studied with the help of a grappler and an Ekman dredge of known aperture. The nomenclature of aquatic associations is after Zutshi (1975) and identification of species is based on Kaul and Zutshi (1976). Vegetation surveys were carried out during the growing period (March–October). In winter there is little growth of macrophytes and this has not been considered in the present investigation. The coverage of macrophytic species was calculated from vegetation maps prepared in the field. Harvesting of emergent vegetation was done by laying random quadrats (0.25–0.5m^{-2}) along the shallow regions of the lake. The number of quadrats varied depending upon their size and the lake area covered. The sites used for plant collection have been described in an earlier publication (Zutshi & Vass 1978). Biomass estimations were carried out by drying the harvested plants in an oven at 105°C and ashing at 550°C in a muffle furnace. Organic matter production has been calculated from ash free dry weight. Samples of live plankton were used for species identification after Ward and Whipple (1959). For quantitative determinations plankton were collected with the help of a Ruttner sampler and concentrated by passing through a standard No. 12 bolting nylon net. The samples were centrifuged and counted in one ml Sedgwick Rafter cell. The results are expressed as units per litre (u/l). Phytoplankton production has been obtained using the oxygen method (Vollenweider 1969). The *in situ* exposure of light and dark bottles was carried out for 4 hr. (1100–1500 hr.). The daily production was obtained by multiplying the values of production by a factor of three. Annual production was calculated from the mean daily production using graphic integration. Benthic population was collected with the help of a dredge having standard aperture. Data on fish population has mainly been collected from the landing sites. Occasional fish catches were made using cast nets from the lake itself in order to cross check the figures of the landing sites.

Observations

(*a*) *Macrophytic Vegetation*: Table 1 presents the extent of cover of some important aquatic species of the lake in relation to water level. The maximum water depth at which an emergent form is able to colonize successfully is 50 cm. Usually these forms achieve maximum development in silted regions. Floating forms have wide range of depth distribution but maximum amplitude is recorded for *Myriophyllum-Ceratophyllum* which

Table 1 *Depth and cover relationship of some important aquatic species*

Plant community/ Species	Depth range, cm above or below (—)the soil level	Depth showing max. % of cover
Typha-Phragmites	—20–35	—2
Phragmites communis	—20–50	—8
Carex-Juncus	0–15	2
Nelumbo-Nymphoides	125–197	129
Nymphaea sp.	152–213	155
Potamogeton natans	25–215	35
Nitella hyalina	150–175	150
Ceratophyllum demersum	25–600	500
Myriophyllum-Ceratophyllum	40–300	175
Myriophyllum-Potamogeton	150–300	200
Myriophyllum verticillatum	30–60	45
Potamogeton pectinatus	50–250	160
Hydrilla verticillata	10–95	25

is a submersed community. The various basins of the Dal lake depict a certain degree of variability in so far as the dominant macrophytic species are concerned (table 2)

In Gagribal basin *Myriophyllum spicatum* is the most dominant form and covers extensive water areas. In certain areas of the lake the weed has become so extensive and prolific that its eradication is posing a great problem. The other species usually associated with *Myriophyllum* are *Potamogeton filiformis*, *P. lucens* and *P. nodosus*. Late in the season *Nitella hyalina* is seen forming gregarious patches close to the lake bottom. Among the floating types *Nymphoides peltata* and *Nymphaea alba* are quite common close to lake bank, in shallow water. *Typha angustifolia* is a main helophtic form collected from this basin. In the Bod Dal basin the dominance of various aquatic forms is very much identical with the Gagribal basin except that *P. filiformis* and *Nitella hyalina* are not so common. *Hydrilla verticillata* is well established close to water inlets. The common floating forms are *P. natans*, *Trapa natans*, *Nelumbo nucifera* and species of *Nymphaea* and *Nymphoides*. Emergents are mainly represented by *Typha* and *Phragmites*. A community of *Myriophyllum-Ceratophyllum* is well represented in the Hazratbal basin. Thick patches of *Potamogeton pectinatus* colonize close to lake banks. Emergent vegetation is quite luxuriant and well established in the silted regions towards the north-west part of the basin. *Nelumbo* is abundant in the eastern part and *Salvinia* cover large areas of open water in the northern sector of the lake. In Nagin basin *Ceratophyllum demersum* is the most dominant species which forms monospecific meadows, particularly in the central part. *Myriophyllum spicatum* is observed in patches close to bank. The common floating species are *Nymphaea alba*, *Nymphoides peltata* and *Potamogeton natans*. *Typha* and *Phragmites* are the two main representatives of helophytes. Charales have limited distribution. *Salvinia natans*, *Hydrocharis dubia* and *Lemna* spp. are quite common in lake channels.

From table 2 it is observed that emergents have wide ecological amplitude. *Ceratophyllum*, *Salvinia* and *Hydrocharis* develop dense patches of vegetation but only in certain areas of the lake. *Myriophyllum-Ceratophyllum* is the most common submersed community. In table 3 production data of three main macrophytic life-forms have been provided. It is observed that submersed forms have maximum coverage but minimal organic matter production. As

Table 2 *Distribution of common macrophytes in the Dal lake*

Species	1	2	3	4	5
Ceratophyllum demersum	p	p	+ +	+ + +	+
Hydrilla verticillata	p	p	+	+	+ +
Hydrocharis dubia		p	p		+ +
Lemna spp.			+	p	+
Myriophyllum spicatum	+ +	+	+	p	+
Nelumbo nucifera	+	+ +	+	+	
Nymphaea alba	+	+	p	+	
Salvinia natans	p	p	+ +	p	+ + +
Phragmites communis	p	p	+	p	+
Typha angustifolia	p	p	+	+	+

1=Gagribal *2*=Bod Dal *3*=Hazratbal
4=Nagin *5*=Channels
p=Present; +; 5–25% coverage;
+ +: 25–50 coverage; + + +: >50 coverage

against this, helophytes have low coverage but high rate of production. The values set in table 3 are for the main basins of the lake.

(*b*) *Phytoplanktan:* In the present studies 84 species have been recorded of which 32 belong each to Chlorophyceae and Bacillariophyceae, 13 to Cyanophyceae, 4 to Dinophyceae and 3 forms represent Euglenophyceae. Chlorophyceae is mainly represented by unicellular and colonial forms, filamentous forms being less frequent. The dominant genera are *Chlorococcum*, *Pandorina*, *Pleodorina*, *Scenedesmus*, *Closterium*, *Tetrastrum* and *Pediastrum*. The yearly average percentage distribution of Chlorophyceae is 33 at Hazratbal, 31 at Bod Dal, 30 at Boulevard and 18 at the Nishat site (table 4). The seasonal behaviour of this class is well marked but the seasonal events show slight difference within the different basins. The population is dominant during summer-autumn but is low in winter-spring period. The overall quantitative changes are quite significant in various basins. In Boulevard 8 u/l of Chlorophyceae was recorded in winter which rose to a level of 1032 u/l in summer. In Hazratbal the maximum population of 654 u/l was recorded in autumn and 12 units in winter. Bacillariophyceae is represented by *Navicula*, *Amphora*, *Cocconeis*, *Cymbella*, *Tabellaria*, *Gomphonema*, *Diatoma* and *Fragilaria*. *Amphora* and *Navicula* were recorded throughout the year at all the sites. On yearly basis the percentage population is 40 at Boulevard, 58 at Nishat, 33 at Bod Dal and 60 at Hazratbal. Generally maximum diatom population appeared in spring and winter and minimum during summer. In Nishat 2200 u/l were recorded during early spring and only 6 units were obtained in summer. At Boulevard 10 μ/l were reported in summer and 636 units in spring. The same trend was discernible at other sites also. The main genera that constitute Cyanophyceae are *Anabaena*, *Chroococcus*, *Merismopedia*, *Microcystis* and *Oscillatoria*. At Boulevard the population density ranges between 6 to 286 u/l, maximum was recorded in spring-autumn and minimum in winter with peak values obtained in March. The range was between 8 to 500 u/l at Nishat with upper values observed in winter and low in summer. In Bod Dal basin density range was from 6 to 470 u/l with maximum population encountered during spring and minimum in winter. The peak values were obtained in April. At Hazratbal, the population ranged from 2 to 254 u/l. The maximum numbers were obtained in spring and minimum in autumn with high values recorded in April. *Euglena* is the main representative of Euglenophyceae. It occurred at the Boulevard site during autumn-winter period. The population density varied from 2 to 118 u/l with peak values recorded in October. At other sites the class was not well represented and appeared only for a short duration.

Table 3 *Macrophytic Production of Dal Lake**

Life-form	Coverage		organic matter production	
	ha	%	g $m^{-2}d^{-1}$	t $ha^{-1}yr^{-1}$
Helophytes	50	5	10.5–15.0	27.6
Floating forms	280	25–30	1.24–5.4	8.81
Submersed	680	55–65	0.77–2.4	4.62

* Data based on dominant species

(*c*) *Phytoplankton Production:* The gross primary production rate depicted temporal and spatial variation. The values ranged from 13 to 70 mg C $m^{-2}hr^{-1}$ at Boulevard, 11 to 47 mg C at Nishat,

12 to 45 mg C at Hazratbal and 7 to 40 mg C at Bod Dal basins. The low production values were recorded during winter and high in summer. The yearly average phytoplankton production was calculated at 27 mg C, 24 mg C, 23 mg C and 18 mg C m^{-2} hr^{-1} at Boulevard, Nishat, Hazratbal and Bod Dal basins respectively.

(*d*) *Zooplankton:* A total of 93 zooplankton species were recorded in this study out of which 37 belong to Rotifera, 27 to Cladocera, 12 forms belong to Rhizopoda, 9 to Ciliophora and 8 are from Copepoda. Rotifers are the dominant group of zooplankton. This is particularly true of Boulevard basin. Copepods and Cladocerans remain numerically low in the Nishat basin. The main representatives of rotifers are: *Ascomorpha*, *Asplanchna*, *Brachionus*, *Conochilus*, *Monostyla*, *Keratella*, *Polyarthra*, *Philodina*, *Filinia* and *Notholeca*. The yearly percentage occurrence and population density is provided in table 4. In Hazratbal basin maximum rotifer population was encountered during autumn and minimum in winter. But at the other three sites (basins) maximum rotifer density was recorded in spring and late summer. *Alonella*, *Alona*, *Bosmina*, *Ceriodaphnia* and *Daphnia* are the main cladoceran forms found in the lake. The population depicted low numerical density and was recorded for a short duration. Peak values were encountered during spring.

The time of the appearance of maximum zooplankton in the Dal lake differed at various sites. It was recorded in March in Boulevard, during late February at Bod Dal, in April at Nishat and during October in Hazratbal basin. The percentage density of the zooplankton population is represented in table 4.

Ciliophora and Rhizopoda are the two main groups that constitute protozoa. The dominant forms are *Arcella*, *Centropyxis*, *Difflugia* and *Paramecium*. The population density is provided in table 5. Rhizopoda range between 2–54 u/l at Boulevard, 1–5 at Bod Dal, 2–37 at Nishat and 39 u/l at Hazratbal basin. Protozoa were recorded only during April and July and for rest of time the population was absent.

The main forms under Copepoda are *Cyclops* and *Diaptomus*. The population ranged from 5 to 31 u/l at Boulevard, 1–50 at Bod Dal, 1 to 90 at Nishat and 4 to 60 u/l at Hazratbal basin. This group was present throughout the year. At Boulevard site, three peaks, in

Table 4 *Population density (u/l) and percentage occurrence (parenthesis) of phyto and zooplankton of Dal lake**

	Hazartbal	Nishat	Bod Dal	Boulevard
Chlorophyceae	190(30)	94(18)	36(31)	145(30)
Bacillariophyceae	217(60)	478(58)	41(33)	130(40)
Cyanophyceae	30(7)	76(11)	60(28)	56(25)
Euglenophyceae	1(1.5)	0.6(1.5)	4(2)	16(4)
Protozoa	5(2)	14(5)	13(1)	9(4)
Rotifera	60(45)	48(23)	47(49)	73(53)
Cladocera	6(6)	5(2)	10(2)	2.4(1)
Copepoda	30(18)	44(20)	26(13)	16(10)

* Yearly averages

September, February and in May were recorded. In Bod Dal maximum population was observed from April to June with high values encountered in April. In Hazratbal maximum values were recorded in summer and in winter.

(*e*) *Benthos*: This group was mainly represented by Oligochaetes, Diptera and Mollusca (gastropods, mostly dead). However, the presence of Mollusca is not a regular feature. Oligochaetes were maximum (15–667 m^{-2}) at Hazratbal and minimum (81–178 m^{-2}) at Bod Dal. Chironomids were maximum (22–400m^{-2}) at Boulevard and minimum (22–67 m^{-2}) at Bod Dal. The combined population of Tubificidae and Chironomidae was maximum (78–534 m^{-2}) at Boulevard and minimum (22–88 m^{-2}) at Bod Dal (table 5).

(*f*) *Fisheries:* The commercially important fish of the Dal lake are *Cyprinus carpio-specularis* and *C. carpio-communis* which comprise 60–70% of the total catch. Both of these are exotic forms. The endemic ones are *Schizothorax niger*, *S. esocinus*, *S. micropogan* and *S. plagiostomus*. The average fish catch per man hour during the year varied between 160–425 grams. The food of commercially important species of fish is decaying organic matter, plankton and insects. The main fishing gear that is being used by the local fishermen is cast net. Sometimes scoop net, multi-headed spear, rod and line and long lines are also used for fishing. Data on the amount of fish catch during three main seasons is provided in table 6.

Discussion

The observations recorded here show that macrophytic vegetation has overgrown the Dal lake basin. The most extensive coverage is of submersed forms which develop monospecific meadows in some areas. According to Zutshi (1975) richness of macrophytes in the Dal lake is associated with shallow saucer shaped basin having high content of organic matter and little wave action. The authors observed that aquatic communities are 'habitat opportunists' and hence it is difficult to dislodge a community once it is established in a particular lake. Export of nutrients from water-shed, human settlements and house-boats may also be responsible for luxuriant growth of some aquatics. Goulder and Boatman (1971) reported that *Ceratophyllum* requires a high inorganic nitrogen level in the medium and that may be the reason why this plant reaches nuisance level in lakes receiving effluents from human settlements and agricultural

Table 5 *Seasonal variation in population density (m^{-2}) of Chironomidae and Tubificidae of Dal lake**

	Hazrat-bal	Nishat	Bod Dal	Boule-vard
Spring	89	311	67	534
Summer	112	178	56	78
Autumn	112	15	22	101
Winter	178	155	88	96

*Average value

Table 6 *Seasonal variation in the average fish catch (%) from Dal lake*

	Summer	Autumn	Winter
Cyprinus carpio	77.27	51.63	54.42
Schizothorax niger	9.03	6.01	1.33
S. esocinus	2.74	6.54	0.42
S. curviformis	7.09	0.64	3.08
Crossochelius latius latius	2.63	32.07	29.54
Others	1.23	1.03	0.72

lands. The explosive growth of *Ceratophyllum* in some areas of the Dal lake is therefore an indication of eutrophication. *Myriophyllum spicatum-Potamogeton lucens* community is dominant in those parts of the lake where water clarity is quite high. Similar results were reported by Khan (1978) from some rural lakes of Kashmir. The high incidence of *Salvinia natans* in side channels of the Dal lake have been attributed to increasing levels of pollution by Zutshi and Vass (1971).

Although submersed forms have high coverage they contribute very little to an overall organic matter production. But helophytes with only 5% coverage have very high production rates. These observations are in agreement with the findings of Kaul et al. (1972).

A significant relationship has been obtained between dominance of a particular algal class and the proximity of waste disposal sites, e.g. Chlorophyceae had high numerical representation at Hazratbal than at Nishat. Euglenophyceae and Cyanophyceae was better represented at the Boulevard, According to Rawson (1956) the characteristic algal groups of oligotrophic lakes are mainly Chlorophyceae. The eutrophic waters harbour Cyanophyceae. Mitchell and Marshall (1974) reported dominance of blue-green algae in many eutrophic lakes of Rhodesia and according to Khan (1978) abundance of Cyanophyceae followed by low population of Chlorophyceae and Bacillariophyceae is an indication of high trophic evolution. Zooplankton depicted definite variability in their numerical population at the four sites. The stations in open areas of water had low population in comparison to inshore areas which are close to human settlements and house-boats. One of the reasons for zooplankton abundance may be high food availability in areas where large quantity of sewage is discharged.

Data on benthos reveal that Tubificidae and Chironomidae which are known to thrive under anaerobic conditions have high population density in places where human and other waste is discharged, e.g., Boulevard basin. Anderson et al. (1956) reported fairly large population of worms in the benthos of Kanawha river, USA which was polluted by sewage. Worms feed on the organic matter and their abundance generally reflect the nutrient content of the sediments. *Cyprinus carpio* was introduced in Kashmir in 1956 and since then this fish has shown remarkable adaptation in various water bodies of the State. The observations reported here indicate that the carp has well established itself in the Dal lake. Our results on the fish catch are in close agreement with those of Raina (1978). Prolonged spawning period, plenty of aquatic vegetation for spawning and high rate of fecundity are some of the factors responsible for predominance of carp in the catches. Similar conclusions have been drawn by Shyam Sunder et al. (1978). Das and Singh (1969) reported high population of carp in the Dal lake, in comparison to indigenous fish. According to Das et al. (1969), Dal lake is very rich in aquatic vegetation and is, therefore, highly suitable for cultivation of herbivorous fish. It is most likely that enriched waters and increased quantity of organic matter favour high production of common carp while indigenous fish seem to be losing its ground because of low fecundity and high juvenile mortality.

On the basis of annual estimated phytoplankton production of 70–245 gC $m^{-2}yr^{-1}$ Dal lake can be classified as mesotrophic. However, while considering this parameter for trophic classification it is

important to note that primary production assessment have been obtained in open water areas of the lake and not at sites close to inshore areas. Rodhe (1969) considers a production level of 300 gC m^{-2} yr^{-1} as an indication of pollution.

In conclusion it may be stated that to assign a particular trophic level to the Dal lake is an over simplification. The lake unmistakingly depicts depressional individuality. The areas close to human settlements and house-boats show definite indications of cultural eutrophication because they receive waste water in large quantities. The sites located in open areas of the lake are at a low trophic evolution. The waters of these sites are still unpolluted with high Secchi transparency. In order to have better perspective of the Dal lake ecology it is rather imperative to obtain detailed information on the watershed ecosystem, movement and deposition of silt within the lake bed, change in the water flow pattern and overall impact of increasing discharge of wastes on the nature and structure of biotic community.

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