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Thirty years of Ecological Research on Dal Lake Kashmir

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ABSTRACT

The paper reviews the ecological works carried out during the last three decades on Dal lake. While comparing the past limnological data with the present, a progressive increase in various chemical parameters viz., Specific conductivity, Total alkalinity, Sodium and Potassium is recorded while considerable increase is noticed in Silicate, Nitrate nitrogen, Ammonical nitrogen and that of Total phosphorus. A gradual decline in dissolved oxygen content is also observed in all the basins of Dal lake. However, no major shift in pH is recorded in lake waters. The dominance of eutrophic plankton species and macrophytic taxa are also noticed over a period of time. A drastic change in lake hydrology and that of the nutrient loads is observed during the last thirty years, resulting in undesirable change in the structure of biological communities and gradual deterioration of water quality. The large influx of human settlements around the Dal lake, extension of floating islands within the lake and tremendous increase in hamlet population (50,000 souls) has changed the very complexion of this fragile ecosystem.

Keywords: Ecological research, Dal lake, review.

The Dal lake known as 'Liquid heart" of Srinagar, the capital city of the J&K state is bedeviled by many maladies mainly arising out of human incursions both in the peripheral as well as within the lake itself. The stupendous problems the lake is facing include the unabated encroachments by converting the water bodies into floating vegetable gardens, construction of residential houses and mushroom growth of hotels. The entry of domestic sewage and sludge directly into the lake coupled with continuous siltation have not only resulted in excessive growth of the macrophytes (aquatic weeds) but has resulted in undesirable changes in the structure of biological communities and gradual deterioration of water quality. The lake has also attracted the attention of various aquatic ecologists, keeping in view the ecological and socio-economic importance of the lake.

The ecological studies conducted on Dal lake till 1970 were scanty, fragmentary and isolated and it was 1970 onwards a spurt in publications was witnessed dealing with various aspects of the lake ecology. The main aim of the present paper is to

focus and document on some important aspects of Dal lake studies that have been undertaken by various Ecologists during last thirty years, and an attempt has been made to review most important works published so far on the Dal lake which, would possibly help the present workers in drawing comparison between various ecological parameters of the past and the present in various basins of this ecologically important ecosystem.

Das and Akhtar (1970) for the first time reported on Cladoceran population from Dal lake. Studies on ecology and production of *Salvinia natans* were taken by Zutshi and Vass (1971). According to these authors one of the major causes for the spread of *Salvinia* was cultural eutrophication as a result of human and agricultural wastes going into the lake waters. Kaul *et al* (1972, 78) compiled information on distribution, biomass production and seasonality of dominant species of Dal and Anchar lakes. The authors observed that the submerged species have greater coverage than the emergent types, but the production was higher in the latter forms. Their investigations revealed that the Dal and Anchar lakes were not very fertile. Kant and Kachroo (1973, 74) investigated seasonal dynamics of phytoplankton and their distribution in addition to diurnal changes in temperature, pH of water and movement of phytoplankton in Dal lake. The authors observed that the phytoplankton were most abundant in surface layers during day time and at 2.5m depth at midnight. Kundangar (1973) provided limnological data on Dal and Nigeen Lake and reported 56 phytoplankton species. Based on many years of water analysis data Zutshi and Vass (1973) demonstrated the changing trophic status of Dal and Anchar lakes. The levels of COD and BOD were found to be progressively increasing. This study for the first time established the importance of long-term data in determining the extent of pollution in these lakes. During the course of exploration of hydrophytes in Dal lake Naqshi and Javeid (1973) collected two varieties of Potamogeton viz., *P. lucens* L. var. accuminatus and *P. crispus* var. serrulatus. Kant and Kachroo (1973, 74, 77) while investigating distribution, composition and periodicity of phytoplankton population of two basins of Dal lake reported domination of Chlorophyta and Chrysophyta. The author recorded the peak population of green algae during summer and that of the blue-green algae during autumn.

Using floristic and ecological approach, Zutshi (1975) presented data on structure and distribution of macrophytic communities form fifteen lakes of Kashmir recording 26 associations, 3 sub-associations within 6 classes, 8 orders and 16 alliances. The provisional character of the syntexa were emphasized and differences in floristic were found to be related to nutrient status and morphometric features. Most of the lakes according to author fall under the "Potamogeton Lake" category. Kant and Kachroo (1977) described Chlorophyceae and Bacillariophyceae as species rich group

and reported 150 species of Chlorophyceae and 86 species of Bacillariophyceae in Dal lake. Trisal (1977) holds *Typha angustata* the chief occupant of the littoral zones along the eastern and southern parts of Hazratbal basin of Dal lake. According to the author the rooted- floating leaf macrophytes occupied 29.20% of the total area of the Dal lake while submerged occupied 57.60%. The free floating macrophytic species were distributed throughout the lake area in the sheltered pockets. According to Kaul *et al.* (1978) the main contributors of photosynthetic carbon were the macrophytes in Dal lake and the emergent macrophytic-communities were more productive than floating and submerged communities. According to Enex (1978) a net flow of 5.5 tons of Phosphorus and 88.9 tons of Nitrogen are drained every year from the surrounding human settlements, hotels and arable land into the Dal lake. Kant and Kachroo (1977) revealed that the macrophytic vegetation in Dal lake have competitive advantage in absorbing and storing large quantities of essential nutrients early in the growing season. They held the luxuriant growth of macrophytes responsible for limiting the plankton growth in the ecosystem. In another publication Kaul *et al.* (1980) reported that the macrophytes growing in eutrophic lakes of Kashmir are more efficient in removal of N, Ca and K compared with P and Na form the nutrient pool. They also reported the use of *Sparganium* sp. as a possible way of reducing nutrient pollution in Kashmir lakes. The increase in phytoplankton biomass in various basins of Dal lake, associated with higher proportions of green and blue-green algae together with diatoms and euglenoids were attributed to higher trophic status by Pandit (1980) and Pandit and Kaul (1982). The authors hold that a considerable part of the phytoplankton biomass remains unutialized in highly eutrophic biotypes. While studying the comparative limnology of the lakes of the J&K Himalayas Zutshi et al (1980) observed the occurrence of Chlorophyceaen forms in the Nehru -park and Bod-Dal basins and Cyanophyta predominating in the Boulevard part. The authors recorded the diatoms as the main contributors of the algal population.

Kak (1981) while studying the aquatic and wetland flora of the Northwestern Himalayas reported *Batrachium drouetii, Ranunculus trichophyllum* and *R. lingua, Myriophyllum spicatum, M. verticellatum* and *M. tuberculatum* in and around Dal lake. In another publication Kak and Javeid (1982) reported collection of *Potamogeton tepperi* A. Benn., *P. polygonifolius* pourv, and P. *filiformis* pers. so far unknown from Indian sub-continent. Zutshi and Vass (1982) during their limnological studies on Dal lake found that *Typha angustata* and *Phragmites australis* achieve maximum development and colonize successfully in silted regions and at a depth of 0.5m. They also reported floating forms cover about 25-30% of the lake area. The role played by Diatoms in lake ecology during 1974-1976 was studied by Mir and Kachroo (1982), according to these authors Diatoms in Dal lake formed 20-60% of

the total biomass, while the green algae and blue-greens contribute 6-27% and 7-23% to the total biomass respectively. In 1983 Koul *et al* reported presence of 44 algal species in Dal lake during 1981-82, of these 34 belonged to green algae, 10 to blue greens. According to authors 8 taxa were the new records for India and one form *Scenedesmus longus* var. *naegelli* f. srin, new to science. In the same year Pandit while studying the periphyton in two lake ecosystems, reported 264 periphytic species and sub species spread over 84 genera on *Potamogeton lucens*, 239 taxa on *Myriophyllum spicatum*. An energy flow chart prepared by Vass and Zutshi (1983) for the Dal lake ecosystem, depicted an overall photosynthetic efficiency of about 1% of which the major contributors were the macrophytes. The plankton according to authors had low conversion efficiency ranging form 0.12% to 0.17%. Kak (1985) during his exploration of the aquatic and wetland flora recorded only few plants of *Eurayle ferox* salsib which was once a dominant plant species in various parts of Dal lake. He attributed its extinction to human interference. Yousuf and Parveen (1990) while studying the phytoplankton dynamics in Dal lake reported 84 taxa of phytoplankton, of these 50 belonged to Chlorophyceae, 16 each to Cyanophyceae and Bacillariophyceae and 2 to Euglenophyceae. The authors reported the dominance of Chlorophyceae, contributing about 48.06% and that of the Bacillariophyceae 26.33%. The authors recorded the variations in phytoplankton population and species composition in various basins of Dal lake and described it as an indication of the advanced eutrophy.

Kango *et al*. (1987) while using x-ray diffraction (XRD) and differential thermal analysis (DTA) to investigate clay mineral content of lake sediments reported the illite and chlorite being the main clay mineral types in Dal lake. Zutshi and Wanganeo in 1984 attempted for a nutrient load model to evaluate the present trophic status of some Kashmir lakes. According to authors export of Phosphorus and nitrogen from the catchment area, human wastes etc. entering into Dal waters was estimated as 49.17 tons and 636.67 tons per annum respectively. The authors used a load tolerance model incorporating the mean depth, flushing rate and critical level of phosphorus for obtaining the degree of eutrophication. Kachroo and Suri (1987) while discussing the decade of pollution in Dal lake revealed the relative abundance of some of the pollution indicator species which have increased during the last decade (1974-1985). The authors reported an increase in density of total phytoplankton as well as individual classes. Zutshi and Khan (1978) while studying the eutrophic gradient in Dal lake reported 58 genera of phytoplankton of which26 belonged to green algae, 21 to diatoms, and 7 to green algae and 2 to flagellates. The authors reported the high nutrient concentration of water at inshore sites as compared to offshore areas of Dal lake. Periphyton, though extremely heterogeneous and complex organisms on sub-aquatic natural and artificial substrates and useful tools as ecological indicators for

detecting the degree and severity of pollution were completely neglected for a period of time. The systematic Periphyton studies were initiated by Sarwar and Zutshi (1987) and in a series of publications, information on productivity and community structure of periphytic algae from Kashmir lakes was provided. Sarwar and Zutshi (1987) recorded 214 taxa of periphyton from natural and artificial substrates in Dal lake. According to the authors maximum number of species and the population density was observed on *Myriophyllum*. In 1988 and 1989, the same authors presented papers on species distribution, community structure of periphytic algae on artificial substrates (glass slides) incubated in various lake waters including Dal lake and reported 137 periphytic taxa on substrates. The authors studied the periphytic algae on various macrophytes viz. *Myriophyllum spicatum* Linn; *Ceratophyllum demersum* Linn; *Nymphodies peltota* Link; *Potamogeton natans* Linn; *Typha angustata* Bory and Chaub; and *Phragmites communis* Trim. The authors recorded that among all natural substrates, *Myriophyllum* supported rich and varied periphytic flora besides the population density.

The distribution and abundance of epiphytic rotifer populations on submerged macrophytes in Dal lake were studied during 1988-1989 by Ticku and Zutshi. The authors registered maximum colonization of rotifers on *Ceratophyllum demersum* and *Myriophyllum spicatum*. The dominant species being *Lepadella ovalis*. Naqshi and Kaweeta (1988) during their investigation on the genus *Nymphaea* reported the occurrence of seven species of *Nymphaea* from Dal lake which include *N.alba*, *N.lotus*, *N.candida*, *N.tetragona*, *N.stellata* and *N.mexicana*. In 1990 Mir and Kachroo while studying the limnology of Dal lake revealed that the highest density of the standing crop of phytoplankton occurred in Spring-Summer interphase. According to them bulk of phytoplankton comprised of bacillariophyceae with 20 to 60% of the total biomass, followed by Chlorophyta (6-20%) and Cyanophyta (7-25%).From 1991 to 1997 the monitoring of Dal lake ecology was carried out systematically by Hydrobiology research Laboratory of S.P. college which resulted in various publications. In 1992, Masood and Yousuf while studying the community structure of Crustacean plankton in relation to trophic conditions recorded 20 Cladoceran species from Dal lake. In 1993, Kundangar *et al.* while studying the distribution, periodicity and population of euglenoids in relation to physico-chemical environment, reported that the Gagribal basin contains the highest percentage of euglenoids as compared to Bod Dal basin of Dal lake. The authors related the higher density of euglenoids to $Cl+NO_3$ ratio and percent Na. In 1995, the same authors published the hydrobiological features of Nigeen basin of Dal lake, studied during 1991-1992.According to the authors the lake basin had enriched to a large extent due to the sewage and effluents from the immediate catchment. The authors reported high population density of diatoms, green algae and blue green algae besides 75 species

of zooplankton. In 1994 Wanganeo and Wanganeo while studying the hydraulic detention period-carrying capacity of three valley lakes of Kashmir and the impact of flushing rate on the lake metabolism reported that the Dal lake flushes out its waters five times in a year. According to these authors the flushing rate is one of the most important factors controlling lake metabolism. The authors opine significant improvement in the water quality as a result of flushing action. This has been proved quite true in case of Dal lake because of the reason whenever the exit lock gates at Dalgate and that of Nallah Amir Khan remain closed for a considerable period, numerous algal blooms and accumulation of nutrients is often observed. In 1996 and 1997, the two publications regarding the limnological features of Brari nambal lagoon of Dal lake (1992-1995) and Nehru park basin (Sept. 1996-Aug. 1997) by Kundangar *et al.* revealed that 106 phytoplankton species have been recorded from Brari Nambal lagoon with Chlorophyceae dominating other algal classes. However, in Nehru Park basin the Diatoms (bacillariophyceae) dominated contributing about 69% to the total biomass.

From 1996 onwards the impetus of limnology focused on the applied studies. Sarwar *et al.* (1996) studied the impact of floating gardens on the limnological features of Dal lake where under the author recorded higher values for Sp. Conductivity, Chloride, Calcium, sodium, Potassium, Nitrate and Total phosphorus near the floating gardens as compared to the open water of the lake. In the same year Kundangar while studying the impacts of wastewaters on the vegetational patterns of Dal lake observed increase in abundance of some eutrophic aquatic plants viz., *Ceratophyllum demersum, Myriophyllum spicatum, Hydrilla verticellata, Potamogeton crispus, P. lucens, Hydrocharis dubia* and *Salvinia natans*. The author attributes their prolific growth to inflow channels, sewage drains and domestic effluents entering the lake waters from the catchment and subsequent enrichment of waters due to nutrients like N, P and K. Kundangar and Abubakr (2001) studied the post dredging changes and comparative limnology of Dal lake and recorded the changes in the physico-chemical parameters, plankton communities between the dredged and undredged parts of Dal lake. The authors revealed that Nitrate- nitrogen and Total Phosphorus content depicted a decrease after dredging while increase in Ammonia and Ortho-phosphates was recorded. The plankton population did not show any significant change. Kundangar *et al.* (2003) while studying the impact of selective deweeding practices in Dal lake observed a significant decrease in specific conductivity, dissolved Oxygen, iron and total phosphorus while increase in Secchi transparency, nitrate-nitrogen was recorded after deweeding. The authors reported that deweeding practices do not have any noticeable effect on buffering potential of the lake waters. These authors further reported that phytoplankton population depicted an irregular behaviour, as there was an increase in phytoplankton population in one

basin and decrease in the other basin. However, zooplankton population depicted decrease in their numerical numbers after deweeding. The authors revealed that full scale deweeding resulted in hazardous Cyanobacterial bloom in Dal lake. Abubakr and Kundangar (2003) provided limnological features of 18 peripheral springs of Dal lake Kashmir and concluded that springs under anthropogenic pressures depict higher values for specific conductivity, chloride, iron, phosphorus, nitrogen and COD as compared to those which are protected. The authors reported number of phytoplankters in spring waters which include *Spirogyra, Oedogonium, Ankistrodesmus, Desmidium, Scenedesmus, Synedra, Chnanthes, Cymbella, Cocconeis*(bacillariophyceae) ,*Merismopedia, Microcystis, Oscillatoria* (cyanophyceae). In the same year one more communication of Abubakr on microbiological studies and that of chlorophyll "a" concentrations in Dal lake waters reveal higher total coliform, fecal coliforms and chlorophyll "a" concentration in polluted zones of Dal lake. The author recorded the maximum Total coliform and Fecal coliforms during summer in Nehru park basin with an average population of 43066 and 2895 CFU per 100ml. The author concluded that the highest bacterial population is recorded in houseboat areas and near settlements. The main reason of bacterial contamination according to the author being the tremendous sewage loads in these areas. Very recently Kundangar, *et al.*, (2003) in their studies on macrophytic taxa and their present status in Dal lake presented an updated check list of macrophytes and reported sharp decline in various species. The authors reported *Azolla* spp., *Berula erecta* and *Eichornia crassipes* as new records to Dal lake. Mention need to be made regarding the technical reports published by J&K Lakes and Waterways Development Authority (Anonymous, 1998, 99, 2000) whereunder the Dal lake waters have been monitored in a systematically drawn out programme at 20 sampling locations in all the lake basins. These reports deal with physico-chemical characteristics, biodiversity changes, effluent characteristics,-quantification of wastewaters entering the lake basins from point and non-point sources, impact assessment studies and hydrological studies. According to the reports a progressive increase in specific conductivity, calcium, magnesium, nitrate-nitrogen, amm.nitrogen and total dissolved solids in all the basins has been recorded in time and space. A slight decline in pH and total phosphorus has been reported. The higher values of COD, chlorophyll content, eutrophic algal population (cyanophyceae) including euglenoids have been recorded near houseboat areas in Nehru Park basin, Dhobighat station in Hazaratbal basin, near camel bridge (Nishat basin) and at Suderbal site in Nigeen lake.

The Brari nambal basin as per the reports continues to be the chemically polluted and proving to be an ecological disaster for the entire lake system. The post deweeding monitoring reveals that the parameters viz., Secchi transparency, dissolved oxygen

depicted an increasing trend while the parameters like Total phosphorus, Ammonia and Ortho-phosphate showed the decreasing trend after autumn'99 and spring 2000 deweeding operation. The report further reveals that about 11.24 lac cubic meters of slush and lake sediment has been removed till August 2000 through suction-cutter dredger along the lake shore and 54.56 MT of Phosphorus and 61.18 MT of nitrate stand removed along with the slush. The hydrological data of the report of April 2001 reveals that during August 1999 to July 2000, the total inflow of water to the lake was 131.64 millions m^3 against 291.9 million m^3 per year as recorded by Enex (1978). The out flow from the lake has been estimated as 100.5 millions m^3 against 275.6 millions m^3 per year during eighties. The wastewater study reveals that about 15 major drains find their way into the lake waters which are charged with nutrients, due to domestic sewage. These liquid wastes carry about 18.17 tons of Phosphorus and 25 tons of inorganic nitrogen, which not only enrich the lake sediment but also increase the fertility of lake waters

WATER QUALITY CHANGES

Table (1) provides the water quality changes in various basins of Dal lake as a result of unabated enrichment of waters due to incoming sewage during the last three decades. From the table a progressive increase in various chemical parameters viz., Sp. conductivity, Total alkalinity, Sodium, and Potassium contents can be observed while considerable increase is shown in Silicates, Nitrate-nitrogen, Ammonia-nitrogen and that of the Total phosphorus. Gradual decrease in Oxygen content is noted in all the basins however, no measure shift is observed in the pH of the lake waters, which continues to be alkaline. The chemical enrichment of the lake waters particularly due to inorganic nitrogen and phosphorus results in luxuriant weed growth and out burst of frequent algal blooms. The deteriorating water quality has brought in significant ecological changes in the bio-diversity as well. The dominance of eutrophic plankton species *Oscillatoria* spp., *Euglena* spp., *Phacus*, *Microcystis* spp., *Melosira* spp., (phytoplankton) *Brachionus* spp., *Keratella cochlearis* (zooplankton) besides prolific growth of eutrophic aquatic weeds like *Salvinia natans*, *Hydrocharis* spp., *Lemna* spp., indicate the eutrophic nature of the lake. From the aforementioned review of the research work carried out in Dal lake and comparing the various values over a period of time it is vivid that the Dal lake has passed through several stages of trophic evolution.

Extensive data establishes far-reaching changes in its physico-chemical and biological environment. The human interventions including those of expansion of floating gardens (Radhs) within the lake and agricultural development in the catchment, rapid and massive urbanization and discharge of wastewater have put the

Table 1. Water Quality Changes in Dal Lake over a Period of Three Decades.

Parameters	units	HAZRATBAL BASIN		NISHAT BASIN		NEHRU PARK		NIGEEN BASIN	
		1977*	2000	1977*	2000	1977*	2000	1977*	2000
pH		7.7-9.5	7.1-8.6	7.4-9.5	7.3-8.8	7.5-9.5	7.6-9.2	7.7-9.5	7.2-9.0
Conductivity	µscm^{-1} at25°C	290-485	226-670	279-431	170-485	302-543	221-631	305-490	282-1072
Dissolved oxygen	mg l^{-1}	2.2-12	3.6-9.4	5.5-11.5	5.2-9.8	4.5-10.5	2.0-9.2	0.8-10	3.2-10
Total Alkalinity	mg l^{-1}	70-120	39-161	22-120	36-120	70-125	40-135	80-134	65-221
Calcium	mg l^{-1}	19-39	24-61.5	18-39	19.2-55.4	21-36	20.7-42.3	19-39	18.9-86.2
Magnesium	mg l^{-1}	8.0-13	1.4-9.0	8.0-13	0.8-14.6	8.0-12	1.0-9.3	8-12	3.0-17.6
Sodium	mg l^{-1}	4.2-5.6	2.0-9.0	3.6-5.0	2.0-5.0	3.3-5.5	1.0-8.0	4.6-7.2	4.0-17
Potassium	mg l^{-1}	0.3-1.6	1.0-3.0	0.4-1.6	1.0-4.0	0.3-1.2	1.0-4.0	0.4-1.3	1.0-2.5
Silicate	mg l^{-1}	1.5-3.6	0.2-12.7	0.7-3.3	0.1-8.0	0.2-2.9	0.6-10	0.2-2.2	0.7-11.7
Nitrate-nitrogen	µg l^{-1}	80-650	120-1377	95-691	105-899	80-603	126-2350	90-632	105-3337
Amm. Nitrogen	µg l^{-1}	2.0-30	98-1519	5.0-28	98-729	9.0-26	105-352	5.0-25	93-1244
Total phosphorus	µg l^{-1}	62-623	400-700	65-620	415-712	70-506	403-815	90-873	330-891

* After Trisal (1977).

Dal lake to a great ecological stress. Hundreds of publications during the past thirty years reflect the wide spread interest in limnological research in the valley. However, a closer examination of the literature brings about episodic research activity as the researchers switched from one area of research to another without focusing intensively on one and gaining adequate understanding of any one field. The studies do not appear to have been driven by the need to understand the ecosystem and its biota but largely by factor governing the availability of financial resources through short term research projects and those of doctoral students for fulfillment of their degrees. There is an urgent need of well planned long term experimental research which requires training in appropriate methodology and development of infrastructure or strengthening of field and laboratory facilities through establishment of institutes. Such measures shall go a long way in managing the quality of water and aquatic biological resources for sustainable development of all fresh water bodies of J&K State.

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