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Impact of mechanical deweeding on Dal Lake ecosystem

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Abstract

The accelerated nutrient enrichment of Dal Lake, Kashmir has augmented the production of aquatic vegetation to the point where many recreational activities have been severely impaired. For providing relief from nuisance conditions mechanical deweeding was introduced in the lake in 1986. The present study assesses the impact of large scale vegetation removal on water quality, plankton population, macrophyte and fish. The concentrations of electrical conductivity, dissolved oxygen, total phosphorus and nitrate-nitrogen changed significantly immediately after deweeding. Phytoplankton species which increased after deweeding include *Amphora ovalis*, *Cymbella cistula*, *Cosmarium sp.*: also rotifers increased (*Anuraeopsis fissa*, *Brachionus calyciflorus* and *Monostyla bulla*).

Introduction

Dal Lake is an important tourist recreational spot in Kashmir. Every year thousands of people use the facilities of the lake in a variety of ways which include swimming, boating, water skiing and living in houseboats. Because of ever-increasing tourist influx many hotels, houseboats and restaurants have come up along the lake shores. As a result of extensive urbanization the raw sewage which originates from both the residential and the commercial settlements is drained directly into the lake. According to some estimates (Enex, 1978) 636.7 tons of N and 49.2 tons of P are released into the lake water annually from various sources such as domestic, agricultural and natural. Due to high fertility of water and the nature of the lake basin the conditions are quite conducive to excessive growth of macro-vegetation which now covers large areas of the lake. In recent years attempts have been made to improve the lake environment and one of the viable alternative was the mechanical deweeding of submerged weeds. In 1984 two harvesters (Rolba Type) were imported from Switzerland and in 1986 two more harvesters were added which are presently in operation in the lake. During harvesting, stems are cut and plants floating to the surface are collected and removed. The cutter of the machine usually goes up to *ca.* 0.6 m but sometimes it may exceed so as to cut the upper portion of the weed. The cutter does not disturb the bottom as such but if depth is low the sediments are disturbed. The present programme of research was started in 1986 with the primary objective of assessing the environmental consequences in the Dal lake of vegetation removal on water chemistry, plankton population, macrophyte vegetation and on fish loss. An attempt is also made to evaluate the efficiency of using mechanical harvesters and their impact on ecosystem stability.

Description of the lake

Dal Lake is situated on the northeast of Srinagar, the summer capital of Jammu and Kashmir State (Fig. 1) at 1583 m above the sea level. The lake has a surface area of about 21 km^2 out of which open lake area is about 11.75 km^2. The data on various morphometric features of the lake is given in Table 1. The lake is fed by a perennial stream on its north side which brings water from a mountain lake. During its downward flow the stream collects large quantities of silt from the denuded catchment and deposits it in the northern basin. Dal Lake is divided into five basins which have maintained their individual characteristics. A number of ephemeral channels coming from the catchment area drain into south and eastern sides of the lake bringing large amounts of nutrients from the human settlements and houseboats. Towards the southwest side an outflow channel discharges into a tributary of Jhelum River. A small canal connects Dal Lake with Anchar Lake and acts as an additional outflow channel. The lake catchment area is 316 km^2, of which about

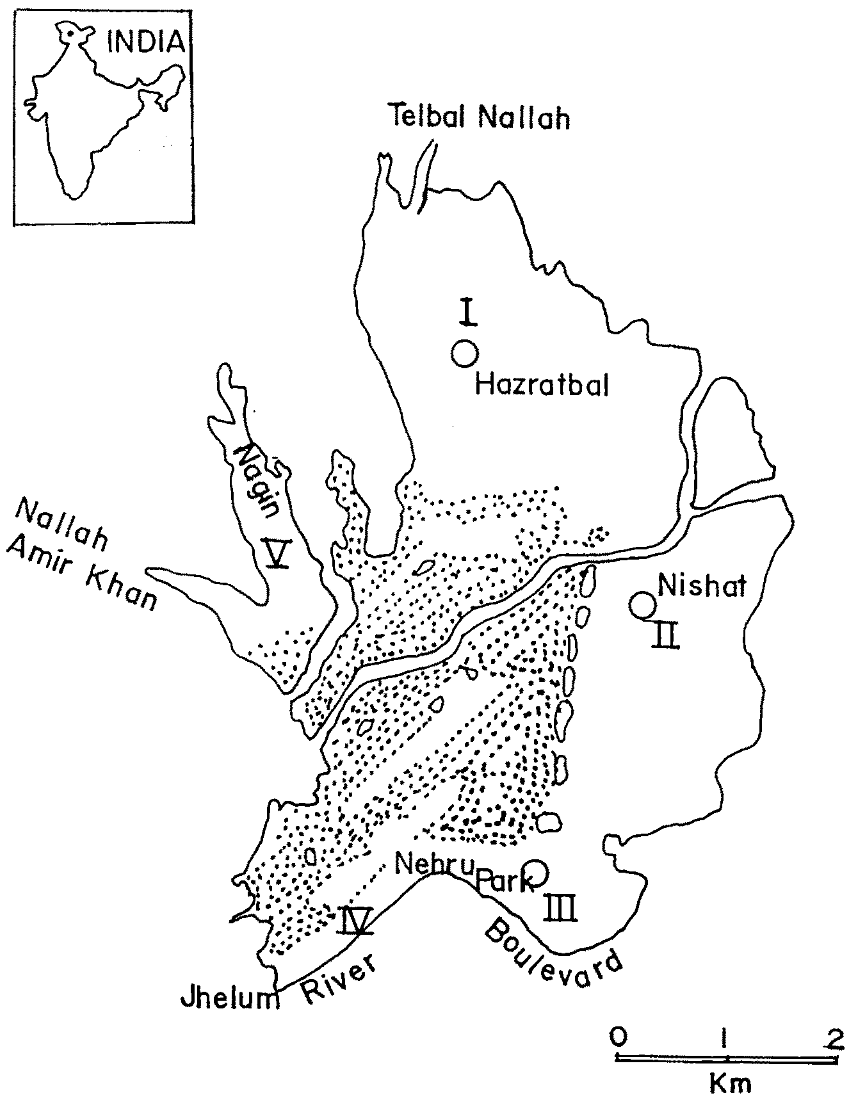

Fig. 1. Site map of Dal lake, Srinagar, India.

Table 1. Morphometry of Dal lake.

	Hazratbal	Bod Dal	Gagribal	Nagin	Boulevard
Maximum water depth (m)	3.5	3.0	2.5	6.0	2.0
Open water area (Km^2)	3.54	5.72	1.3	0.89	3.0
Volume ($\times 10^6$ m^3)	2.8	4.9	0.9	1.2	6.0

33% is forested area and mainly concentrated in Dachigam National Park.

According to Zutshi & Vass (1982) about 6.8 km^2, i.e. 55–65% of the total area, is under submerged vegetation. The contribution of organic matter production by submerged species is 4.62 tons ha^{-1} y^{-1}. The most common macrophytes in the lake are *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Potamogeton lucens*, *P. crispus*, *P. pectinatus* and *Hydrilla verticillata*.

Material and methods

The first phase of survey was carried out from September, 1986 to August, 1987 using three sites, viz. Nehrupark, Nishat and Hazratbal (Fig. 1) for sample collection and field observations. These sites were visited every month to obtain data for long term (i.e. for 12 months) basis. Short-term data were collected from Nehrupark basin between July and August 1987 to assess the immediate consequences of harvesting. Samples were obtained prior to harvesting and then again after the area was deweeded. During the second phase of the survey, from September, 1987 to May, 1989, additional study sites were selected (Fig. 1).

Data on water temperature and Secchi-disc visibility were recorded in the field. The initial fixation of dissolved oxygen was also done in the field using unmodified Winkler's method. The samples from bottom waters were collected using Ruttner Sampler. For plankton analysis 3 litres of lake water were filtered through a plankton net with a mesh size 64 mμ. The filtered plankton samples were preserved with 1% acidified Lugol's solution. Plankton was counted in 1 ml Sedgewick Rafter Cell, as the entire cell contents. The entangled fish were removed and sorted out from 100 kg of harvested weed. The fish were identified, counted and weighed individually in the laboratory. Water samples were analyzed using the methods as given in APHA (1970), Golterman & Clymo (1969) and Mackereth (1963). The data were statistically analysed.

Results and discussion

No significant variations in surface and bottom water temperature before and after the deweeding operations were observed. The temperature either fluctuated marginally or remained constant. Gasith (1975) and Carpenter (1976) also observed that temperature of the cut and control plots usually differed by 1 °C. The Secchi visibility of the lake water varied both temporally and spatially. The highest transparency of 2.50 m was recorded in Nehrupark and of 2.75 m in Nishat during August. Hazratbal basin recorded 2.35 m. After weed harvesting the transparency decreased considerably at all the sites, exhibiting maximum reduction of about 50% at Nehrupark. The increase in turbidity of the lake water may be caused by the suspension of sediment due to the impact of harvesters. Since the lake is shallow with soft bottom overlaid with marl, a little disturbance in the water column would result in increased turbidity. However, this effect was short-lived and the suspended material apparently settled from the water column on cessation of cutting and completion of sampling. But frequent harvesting would disturb the extent of light penetration in the lake and thus interfere with photosynthesis.

Dal Lake water is alkaline in nature with average pH values ranging from 8 to 9.5. Hydrogen ion-concentration during long term basis showed significant temporal and spatial variations but no change was observed between surface and bottom samples (Table 2) and before and after deweeding (Table 3). It seems that mechanical deweeding does not affect the buffering potential of the lake water.

The electrical conductivity (EC_{25}) of lake water varied between various sites but no change between months and between surface and bottom was registered (Table 2). It is quite interesting to note that during short term basis of the present study there was significant increase (31%) in conductivity values after deweeding (Table 3). But this increase was short-lived. The high electrical conductivity values indicate high ionic concentration (Young *et al.*, 1972). Therefore, deweeding does change the overall nutrient concentration of the lake water. Subsequently in 1987–89 no such increase could be noted and the conductivity remained almost same before and after deweeding. This is difficult to explain, but is likely that the harvesters disturbed the lake bottom to a large extent, thus increasing ionic concentration of water. In their studies on the impact of mechanical deweeding, Gasith (1975) and Carpenter (1976) observed that the mean conductivities

Table 2. Analysis of Variance (Long term); * Significant at 5% level; S/B: surface and bottom.

Parameter	Variation	d.f.	Sum of squares (s)	Variances V = s/d.f.	F = V/VR
	Between months	11	18.3	1.66	6.15*
	Between sites	2	3.39	1.70	6.30*
pH	Between S/B	1	0.05	0.05	0.19
	Residual (R)	57	15.64	0.27	–
	Total	71	37.38	–	–
	Between months	11	10094.43	917.68	0.85
	Between sites	2	9244.43	4622.22	4.30*
$EC_{(25)}$	Between S/B	1	1422.21	1422.21	1.32
	Residual (R)	57	61300.03	1075.44	–
	Total	71	82061.01	–	–
	Between months	11	1177.72	107.07	4.47*
	Between sites	2	94.17	47.09	1.97
DO	Between S/B	1	14.94	14.94	0.62
	Residual (R)	57	1364.50	23.94	–
	Total	71	2651.33	–	–
	Between months	11	66.37	6.03	2.60*
	Between sites	2	39.00	19.5	8.41*
TP	Between S/B	1	28.12	28.12	12.12*
	Residual (R)	57	132.38	2.32	–
	Total	71	265.87	–	–
	Between months	11	19612.20	1782.93	2.17*
	Between sites	2	4998.16	2499.08	3.05*
NO_3-N	Between S/B	1	1020.06	1020.06	1.24
	Residual (R)	57	46776.28	820.64	–
	Total	71	72406.7	–	–

Table 3. Analysis of Variance (Short term); * significant at 5% level, between operations: before and after deweeding.

Parameter	Variatins	d.f.	Sum of squares (s)		Variance V = s/d.f.		F = V/VR	
			Surface	Bottom	Surface	Bottom	Surface	Bottom
pH	Between operations	1	0.07	0.84	0.07	0.84	0.21	2.40
	Between samples	11	6.38	10.33	0.58	0.94	1.76	2.69
	Residual (R)	11	3.66	3.89	0.33	0.35	–	–
	Total	23	10.11	15.06	–	–	–	–
$EC_{(25)}$	Between operations	1	8066.67	4.16	8066.67	4.16	9.41*	0.008
	Between samples	11	7683.33	5645.83	698.48	513.26	0.81	1.09
	Residual (R)	11	9433.34	5145.84	857.58	467.80	–	–
	Total	23	25183.34	10795.83	–	–	–	–
DO	Between operations	1	5.84	14.21	5.84	14.21	3.38	8.17*
	Between samples	11	52.00	53.77	4.73	4.89	2.73	2.81
	Residual (R)	11	19.02	19.11	1.75	1.74	–	–
	Total	23	76.86	87.09	–	–	–	–
TP	Between operations	1	130.66	198.37	130.66	198.37	35.60*	36.27*
	Between samples	11	94.83	146.12	8.621	13.28	2.35	2.43
	Residual (R)	11	40.33	60.13	3.67	5.47	–	–
	Total	23	265.82	404.62	–	–	–	–
NO_3-N	Between operations	1	27337.47	23562.63	27337.47	23562.63	17.54*	108.0*
	Between samples	11	10924.30	2995.30	993.12	272.30	0.64	1.2
	Residual (R)	11	17141.53	2397.37	1558.32	217.94	–	–
	Total	23	55403.30	28955.30	–	–	–	–

between the cut and uncut plots differed by less than 10 μmhos.

The differences in dissolved oxygen concentration at the three sites as also between surface and bottom water were not significant at 5% level. However, the temporal differences were significant (Table 2). During summer there was moderate reduction in oxygen concentration in bottom waters but at no time were these completely anoxic. The concentration of dissolved oxygen increased by 23% in the surface and by 36% in bottom waters after deweeding on short-term basis (Table 3). The increase may be attributed to mechanical aeration.

Total phosphorus concentrations did not show any major temporal variations but site variations were quite significant. There was only a slight difference in phosphorus concentrations of surface and bottom water (Table 2). Short-term observations show that phosphorus concentration increased from 9% to 11% after deweeding (Table 3). But in the subsequent year no such increase was detected. The exact cause for this discrepancy is not known. In a study conducted in Lake Sallie, Minnesota (USA), Peterson *et al.* (1974) reported that aquatic plant harvesting operations resulted in the removal of only 1.4% of the total phosphorus inputs to the lake. They concluded that weed harvesting was not an effective method of reducing nutrient supplies in the lakes that receive cultural enrichment. According to Breck *et al.* (1979) harvesting macrophyte biomass decreases phosphorus recycling from sediment and also decreases cover for fish.

The nitrate-nitrogen concentration on long-term basis depicted significant temporal change but horizontal and vertical differences were little (Table 2). Increase in nitrate-nitrogen concentration by 35% was observed in water after deweeding (Table 3).

Deweeding had significant impact on the plankton densities. In Nishat and Hazratbal basin the diatom populations increased from 17% to 38% which is a significant shift. This substantial increase of diatoms after deweeding was perhaps due to vigorous shaking of macrophytes by harvesters. The periphytic forms attached to the submerged vegetation got dislodged in the process, remained suspended and added to the overall numerical abundance of Bacillariophyceae. The species that increased in densities on deweeding were: *Asterionella formosa*, *Cymbella cistula* (Nehrupark), *Eunotia sp.*, *Rhopalodia gibba* and *Cymbella cistula* (Nishat), and *Amphora ovalis*, *Navicula radiosa* and *Synedra ulna* (Hazratbal).

The numerical increase at Nishat and Hazratbal sites in green-algae was 15%–19%, which may be also due to vigorous shaking of macrophytes by harvesters. The species which increased in numbers were: *Closterium setaceum*, *Coelastrum sphaericum*, *Euastrum insulare*, *Pediastrum biradiatum*, *P. simplex*, *Cosmarium sp.* and *Cosmarium galiretum*.

Blue-green algae increased only marginally (about 7%) after deweeding. The increasing trend in algal population as a result of deweeding was also observed during the subsequent years of investigation. The reason being that during harvesting stems are cut and the plants floating on the surface are collected and removed, due to which 'Aufuches' get dislodged and are temporarily suspended in water column (Carpenter & Gasith, 1975). According to Wile & Hitchin (1977) in lakes in which phytoplankton production is inhibited by competition for nutrients, removal of vegetation could result in increased algal densities. Presence of denser phytoplankton population were observed after the first year of harvesting in lake Sallie, USA by Neel *et al.* (1973). The overall behaviour of phytoplankton before and after deweeding in Dal lake on short-term basis has been shown in Fig. 2.

Zooplankton community also reflected numerical increase after the weeds were removed by the harvesters. The extent of overall rotifer increase was about 16%. The main species increasing in numbers were: *Anuraeopsis fissa*, *Brachionus bidentata*, *Keratella cochlearis*, *K. serrulata*, *K. quadrata*, *Lacene luna* and *Trichocerca longiseta*. The overall behaviour of zooplankton on short-term basis has been shown in Fig. 3. Our

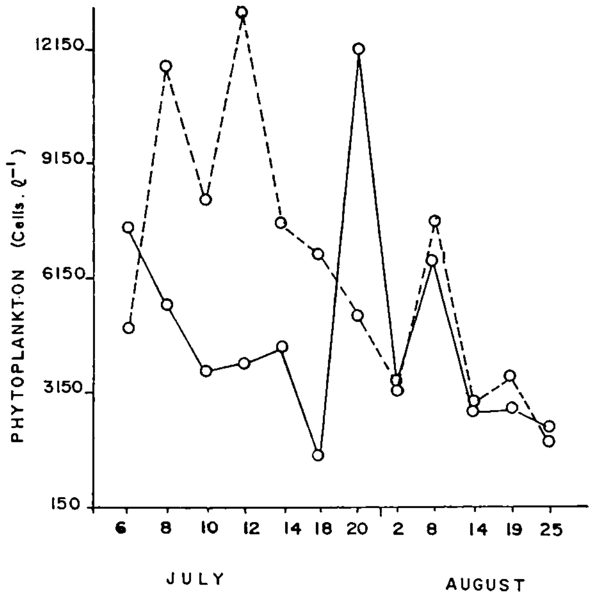

Fig. 2. Impact of deweeding on phytoplankton of Dal lake. Continuous lines represent population before the deweeding and the broken lines after deweeding (July–August).

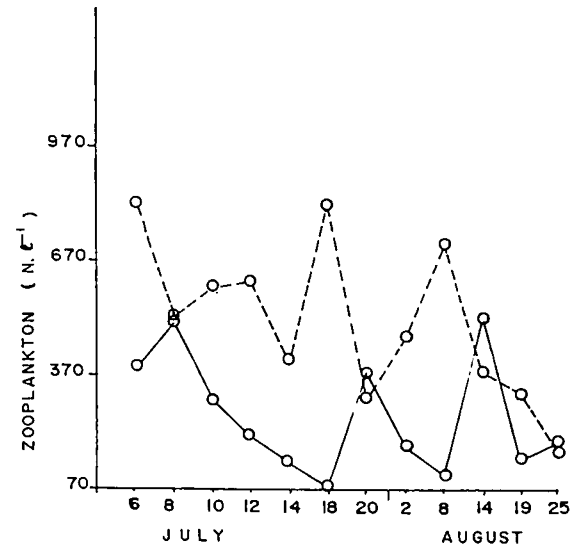

Fig. 3. Impact of deweeding on zooplankton of Dal lake. Continuous lines represent population before the deweeding and the broken lines after deweeding (July–August).

results are in contrast to the observations of Wile and Hitchin (1977), who found that harvesting had no significant effect on the density of zooplankton population. It is probable that in Dal lake because of preponderance of periphytic zooplankton the population shows increases due to harvesting.

The field observations revealed that after harvesting it takes about 3–4 weeks for the weeds to re-vegetate and cover the entire area. Carpenter (1975) also observed that the plant beds in the cut area were restored within three to four weeks after cutting. The preliminary observations indicated that the macrophytes have not so far developed fan-shaped appearance but because of harvesting pressures they do spread horizontally. Blooms of filamentous algae were observed in Nehrupark basin. The important taxa were: *Spirogyra*, *Cladophora*, *Oedogonium*, and *Pithophora*. This may be due to the release of competition for nutrients after macrophyte removal.

The maximum capacity of the harvester is about 120 tons of plant material removal per day. However, the actual estimates of biomass removal have not been possible because there is no regular schedule for the use of these harvesters.

The preliminary estimates indicated, the direct loss of fish which gets entrapped in the vegetation and removed during harvesting process. The data presented in Table 4 shows that it was 372, 44 and 139 g in 100 kg. of plant material constituting 67%, 8% and 25% in respect of species *Nemachilus latius*, *Barbus* sp. and *Cyprinus carpio-communis*, respectively.

Table 4. Data on fish loss during harvesting (per 100 Kg of weed).

Species	Average wt. (g)	%
Nemachilus latius	372	67
Barbus sp.	44	8
Cyprinus carpio-communis	139	25
	555	100

Conclusions

No visible improvements in the Dal Lake environment were observed although mechanical harvesting has been in operation for the last three years. This is mainly because harvesting operations are not being carried out under a definite schedule and time frame. There are ample indications that harvesting does affect the overall stability of the system. There is need to continue only with selective deweeding and that too during the high tourist season. The possibility of introducing biological control measures should be assessed.

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References

A.P.H.A., 1970. Standard methods for the examination of waters, sewage and industrial wastes, New York, 174 pp.

Breck, J. E., R. T. Prentki & O. L. Loucks, 1979. Aquatic plants, lake management and ecosystem consequences of lake harvesting. Inst. Envir. Studies, Madison, WI, 435 pp.

Carpenter, S. R., 1976. Some environmental impacts of mechanical harvesting of nuisance submerged vascular plants. M.S. thesis. Univ. of Wisconsin, Madison, 95 pp.

Carpenter, S. R., A. Gasith, 1975. Mechanical cutting of submerged macrophytes: immediate effects on littoral water chemistry and metabolism. Water Research. 12: 55–57.

Enex, 1978. Pollution of Dal lake. Enex of New Zealand Inc, 140 pp.

Gasith, A., 1975. Tripton sedimentation in eutrophic lakes – simple corrections for the resuspended matter. Verh. int. Ver. Limnol. 19: 166–122.

Golterman, H. L. & R. S. Clymo, 1969. Methods for chemi-

cal analysis of fresh water. IBP Hand Book No. 5. Blackwell Scientific Publication, Oxford, 172 pp.
Mackereth, F. J. M., 1963. Water analysis for Limnologists. Fresh. Wat. Biol. Assoc. 21: 1–70.
Neel, J. K., S. A. Peterson & W. L. Smith, 1973. Weed harvest and lake nutrient dynamics. EPA-660/3-73-001.
Peterson, S. A., W. L. Smith & K. W. Malueg, 1974. Full scale harvest of aquatic plants: nutrient removal from a eutrophic lake. J. Wat. Pollut. Cont. Fed. 46: 697–707.
Wile, I. & G. Hitchin, 1977. An assessment of the practical and environmental implications of mechanical harvesting of aquatic vegetation in Southern Chemung Lake. Ontario Ministry of the Environment, Canada, 180 pp.
Young, W. C., H. H. Hannan & J. W. Tatune, 1972. The physicochemical limnology of a stretch of the Guadalupa River Taxas, with main stream impoundments. Hydrobiologia 40: 297–319.
Zutshi, D. P. & K. K. Vass, 1982. Limnological studies on Dal lake, Srinagar III. Biological features. Proc. Indian natn. Sci. Acad. 48: 234–241.