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ON THE TROPHIC STATUS AND CONSERVATION OF KASHMIR LAKES

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Abstract

The lakes of the Kashmir Valley are generally shallow and situated in the flood plain of the river Jhelum. Thermal stratification is fairly uncommon, and stable stratification occurs in deeper lakes (12 metres, Manasbal lake). The waters are mostly low in dissolved solids, medium hard and slight to highly alkaline.

The eutrophic typology of the lakes has been developed by using various physico-chemical and biological parameters. Greater habitational influence and tourist traffic seems to be a major factor contributing towards higher trophic levels of these lakes. Certain methods for conservation of these lakes have been suggested.

Introduction

Limnological investigations of the inumerable lakes in Kashmir (Kaul *et al.*, 1971) have been few and preliminary. Hutchinson (1937) reported on some aspects of zooplankton of the lakes of Indian Tibet. His studies pertained more to fish than to methodical limnology. Studies on the physical, chemical and biological characteristics of some of the valley lakes include those made by Kaul & Zutshi (1966, 1967); Kaul & Vass (1970, 1972); Kaul *et al.* (1971); Zutshi & Vass (1971 a, b, 1972) and Vass (1976). Studies on their typology have been made (Vass, 1976) to form a base for future research and in studies on the conservation of these lakes.

The threat to the recreational assets of Kashmir lakes by habitional enroachment and consequent nutrient enrichment warranted the present studies on these lakes with the following objectives (i) to determine the basic limnological features of lakes in the region; (ii) to assess the present water quality (trophic status) characteristics of the lakes and (iii) to provide background information for future studies. This paper describes some of the more general results of investigations with particular reference to trophic features.

Methods

For this study, three accessible and potentially important recreational lakes in the valley, namely the multiple basined Dal lake (consisting of three different bains - Nagin, Hazratbal and Gagribal), Anchar lake and Manasbal lake, exhibiting considerable diversity in topography, were selected. A sampling schedule was designed to provide information on the average chemical, biological and physical characteristics of the lakes round the year.

Water samples for chemical and biological analyses were composites of various stations in shallow lakes while deeper lakes ($Zm > 4m$) were sampled at different depths.

The chemical parameters studied include inorganic phosphates, nitrates and standard limnological measurements (dissolved oxygen, pH, and specific conductance). Biological parameters included the algal flora and primary production. Temperature and Secchi disc visibility were the physical parameters. Basic morphometric parameters were computed from bathymetric maps (Hutchinson, 1957).

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Results and discussion

Morphometric and physical features

Geologically the valley may be considered as an oval 'dun' in the middle Himalayas composed of highly compressed and altered rocks of various geological age from Purana Carboniferous to Eocene. This synclinal basin of the valley rises at places in the north and north-east as high as 3,900 metres above sea level.

The pleistocene and recent deposits such as lacustrine, fluviatile and glacial, spread horizontally over most of the areas in the state, whereas the slopy 'Karewas' are attractive beds of fine material carrying gravelly conglomerate in lenticellular bands. Glaciation is still another feature that has left a remarkable impact on the valley of Kashmir.

Kashmir lakes lie in the flood plain of the river Jhelum, whose broad meanders have cut swampy low lands out of the Karewas terraces (De-Terra & Paterson, 1939). According to them the position of the lakes shows that they are derived from enlarged oxbows and abandoned flood channels rather than from progressive shrinkage of a glacial lake. Wadia (1947) is of the opinion that the lakes have been formed from inundated parts of the Jhelum river which have alluvial dams and marshy borders. Several tributaries of the Jhelum drop their silt into the lakes.

The general morphometric features of the lakes are presented in Table I. In general the lakes are shallow; maximum depths of more than 12 metres are uncommon. Mean depths for all the lakes range from about 0.6 to 3.0 metres and maximum depths from about 2.0 to 12.0 metres. The ratio of mean and maximum depth ranges between 0.20 to 0.25 which, coupled with the DL values, indicates the gentle slope of the lake basins.

Table I. Morphometric features of selected Kashmir Lakes.

Lake	Surface area (km^2)	Depth (m) Maximum	Mean	DV	DL
Dal	11.45	6.0	1.0	0.785	1.840
Anchar	6.6	3.0	0.6	0.6	0.958
Manasbal	2.80	12.0	3.0	0.752	1.5

The DV values indicate that the lake basins are convex towards the water surface (Hutchinson, 1957; Zafar, 1956).

The shallowness of the valley-lake suggests that thermal stratification should be unimportant, although the pattern of water inflow influences the thermal behaviour of some very shallow lakes. Anchar lake and most of the basins of Dal lake do not exhibit classicial Birgean thermoclines with stagnant hypolimnia. While Manasbal lake, being sufficiently deep with a narrow outflow system, develops stable stratification and oxygen deficient bottom waters (Vass, 1976).

Thermal structure in the different basins of Dal lake differs markedly (Fig. 1). This is due to varying depths of the various basins and also on account of the feeding channel coming into the Hazratbal basin of the lake. Considering the annual changes in the temperature of the basins, a thermal gradient develops in the Nagin and the Hazrathal basins, while the Gagribal basin remains isothermal throughout. In the Hazratbal basin a maximum thermal amplitude of 5°C was recorded in March-April while in succeeding months it ranged between 1-2°C. In the Nagin basin, on the other hand, a maximum amplitude of 4-5°C obtained from April-July and a minimal one of 2°C during early spring (March) and autumn (September). The thermal gradient observed in the Anchar lake is also due to the cold water brought in by the feeding channel of the river Sindh.

Thermal stratification is quite marked in Manasbal lake (Fig. 2). The stratification set in by early March lasts throughout the succeeding summer and autumn. The stagnation period was of eight months while isothermy prevailed from the last week of November to February. The lake may show inverse stratification in severe winters but this was not observed in moderately cold winters. The thickness of the thermocline varied from month to month, a maximum thickness of 5.50 metres being observed in August which dropped to 2.0 metres in October.

General chemical characteristics

The dissolved oxygen pattern in these lakes showed marked variations (Fig. 3). In the Gagribal basin of Dal lake the water remained mixed throughout the year and the oxygen content was consequently almost the same from surface to bottom, all the year round. In the Hazratbal basin, on the other hand, the development of a thermal gradient resulted in the development of an oxygen gradient as well, the surface water containing more oxygen than the lower layer. In Ancher lake the oxygen concentration from surface to bottom was the same till April, whereafter till October an oxygen gradient of the 2-3 mg/l developed.

Oxygen profiles in the Nagin basin of Dal lake and

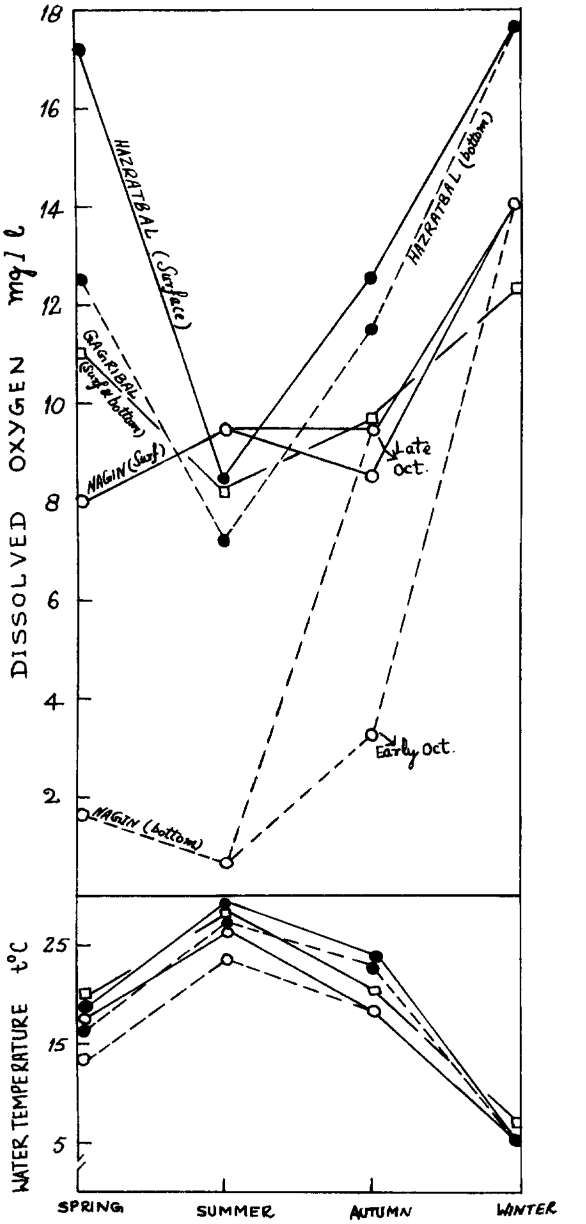

Fig. 1. Seasonal variation in temperature and dissolved oxygen of different basins of Dal Lake.

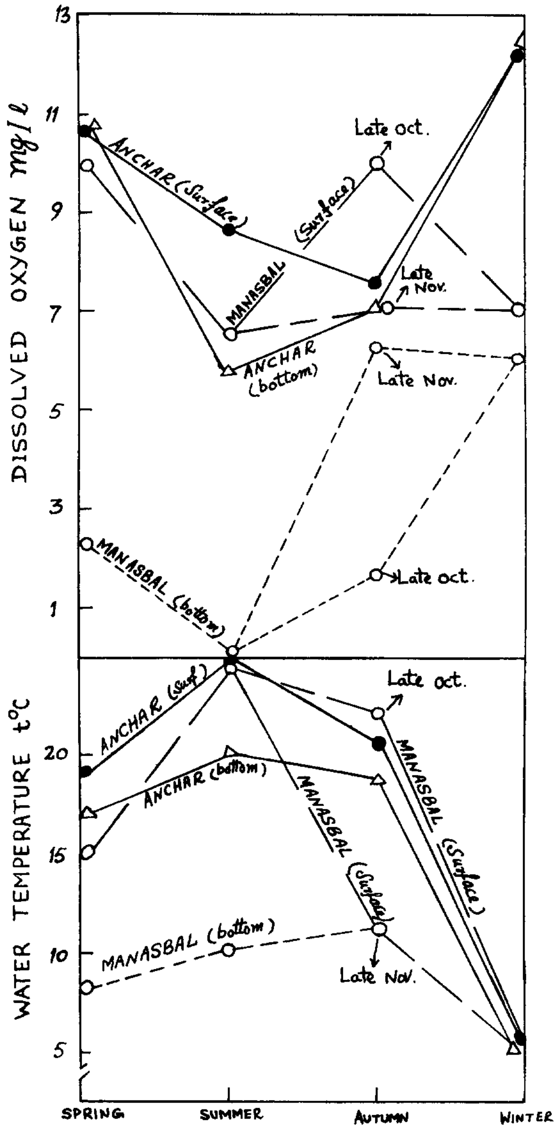

Fig. 2. Seasonal variation in temperature and dissolved oxygen of Anchar and Manasbal Lakes.

Manasbal lakes showed certain distinctive features, with a clinograde type of oxygen curve, being markedly obtained for both lakes. While the Nagin basin showed a positive heterograde along with a clinograde type, no positive heterograde type of curve was obtained for Manasbal lake. The positive heterograde oxygen curve in the Nagin basin of Dal lake was biogenic. The lower layers of the Nagin basin and the Manasbal lakes got depleted of oxygen during the summer stagnation period, although the intensity of depletion in the two differed. This summer depletion of oxygen in these lakes is characteristic and indicative of a tendency towards eutrophication (Fig. 3).

The hypolimnetic oxygen deficit calculated for the Nagin basin and Manasbal lake was 0.0129 and 0.068 mg cm^{-2} day^{-1}, respectively. Applying Hutchinson's (1938) concept of correlating the rate of hypolimnetic oxygen dificit with lake typology, the Nagin basin of Dal lake falls

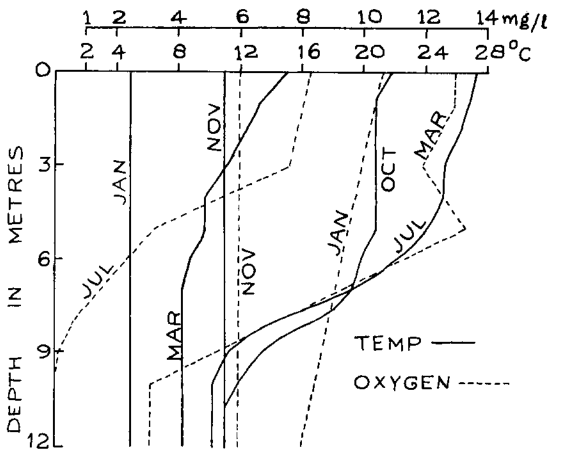

Fig. 3. Column-wise distribution of temperature and dissolved oxygen in the Manasbal Lake.

in the oligotrophic series while Manasbal lake in that of eutrophic lakes.

The conductivity values of the lake waters evidenced a definite seasonal trend, being higher in winter, spring, autumn and lower in summer months (Fig. 4 & 5). Stratifications in conductivity values were recorded in Nagin basin and Manasbal lake, (Fig. 4 & 5). The conductivity values ranged between 200-500 μs/25°C. On the whole, increased conductivity values have been suggested as an indication of a higher trophic level (Berg *et al.,* 1958).

Both inorganic phosphorus and inorganic nitrogen were low in the waters of these lakes. The phosphate ranged between 5-10 μg/l whereas the nitrate nitrogen ranged from 20-25 μg/l, which indicates the lakes to be of low trophic level. Both being subject to a great habitation influence, besides, being the receivers of sewage and other effluents, the lakes should surely have shown higher values for phosphate and nitrates. However, no such high values were found. The low content of phosphates and nitrates in these lakes can be attributed to (i) the formation of an insoluble calcium phosphate complex, because the waters· are basically marl lakes and hence rich in calcium and (ii) the locking up of phosphates and nitrates in the dense macrophytic vegetation that abounds in these lakes round the year. A sharp competition for these radicals between plankton population and macrophytes is bound to occur. Similar conclusions have earlier been drawn by Goulder (1969) in regard to a gravel pit in England and by Boyd (1969) in regard to the production of *Justicia americana* and *Alternanthera philoxerodis.*

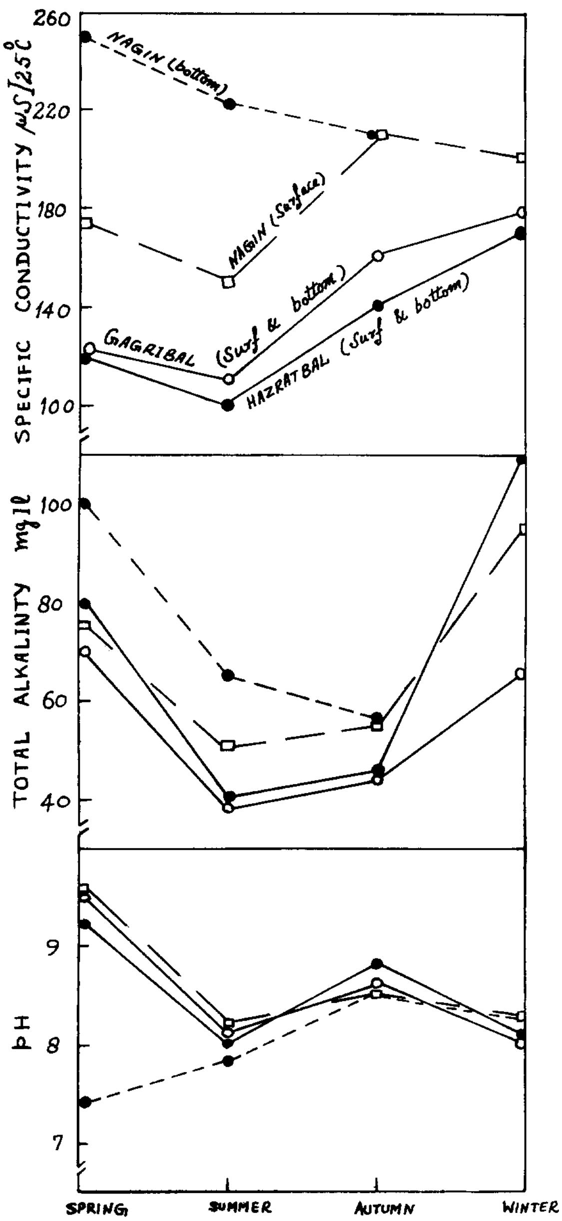

Fig. 4. Seasonal variation in some chemical characteristics of different basins of Dal Lake.

General biological characteristics

A) Micro- and Macrophytes

The main dominant forms of phytoplankton, zooplankton and macrophytes recorded from these lakes are listed below in a tabulated form.

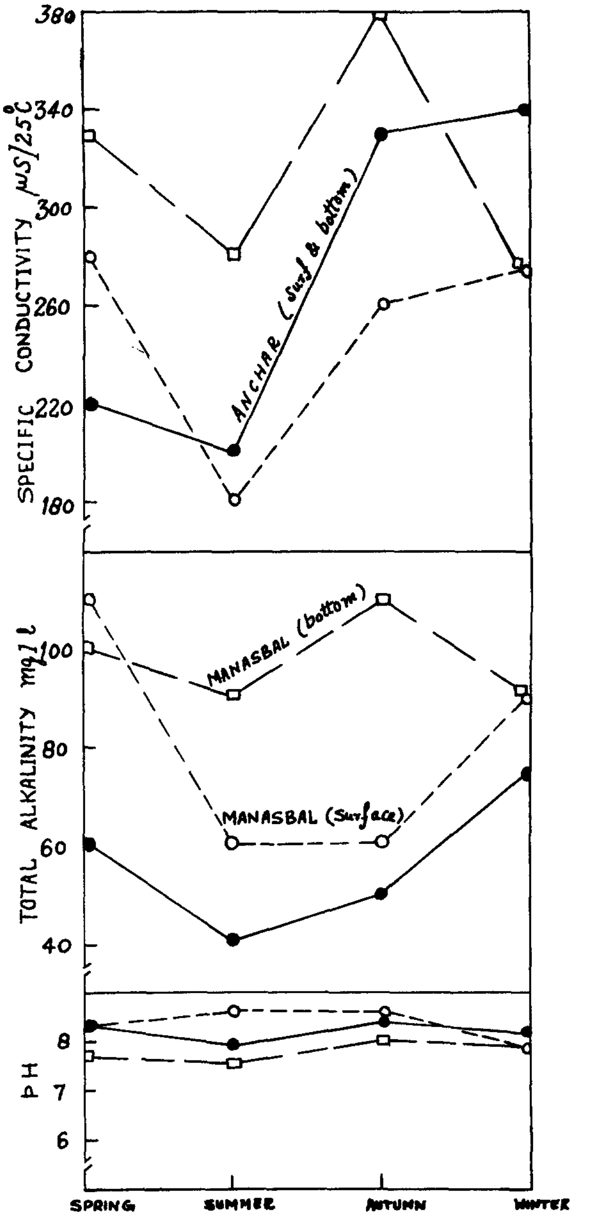

Fig. 5. Seasonal variations in some chemical characteristics of Anchar and Manasbal Lakes.

B) Primary Productivity

The dominant primary producers in valley lakes are not phytoplankton but macrophytic vegetation. In Dal lake alone, submerged macrophytes cover as much as 40 percent of the total area during the optimum growth period. The total estimated macrophytic production (biomass dry weight) in this lake ranged between 130 to 150 m. tons per hectare, against 80 to 100 m. tons in Anchar lake and 40 to 60 m. tons in Manasbal lake. Rodhe (1969) gave approximate ranges of phytoplankton production during the growing season as 30 to 100 mg C $m^{-2}day^{-1}$ for oligotrophic lakes, 300 to 1,000 mb C $m^{-2}day^{-1}$ for natural eutrophic lakes, and 1,500 to 3,000 mg C $m^{-2}day^{-1}$ for polluted eutrophic lakes. In the present study the plankton production ranged between 350 to 600 mg C $m^{-2}day^{-1}$ for Dal lake, between 240 to 475 mg C $m^{-2}day^{-1}$ for Manasbal lake and between 185 to 320 mg C $m^{-2}day^{-1}$ for Anchar lake. By applying Rodhe's (1969) ranges it is clearly shown that the valley lakes are getting eutrophied. Further, the phytoplankton assimilation curves for the Nagin basin of Dal lake and for Manasbal lake showed the typical metalimnic maxima characteristic of Findenegg's (1964) type III assimilation curves, this also further supports the view that there is a definite trend towards eutrophication in these lakes.

Conclusions

On consideration of the various parameters, the lakes in Kashmir valley show certain indices towards eutrophication. The parameters of positive significance being (i) morphometric features, (ii) increased oxygen content in the surface layer, (iii) hypolimnetic oxygen deficit, (iv) increased specific conductivity, (v) the pattern of assimilation curve and (vi) increased values of phytoplankton production. While (i) low concentration of inorganic phosphates and nitrates in lake waters (ii) lack of planktonic blooms and (iii) lower plankton density, are of a negative significance. The chief causative factor for this change being enrichment due to runoff from floating gardens and habitation coming up on the sides of these lakes.

Conservation

The Kashmir valley lakes are not derelict at the moment to cause any alarm but some indications are there that they are deteriorating. So it is better to plan for their conservation well in advance. Some of the conservation practices that can be resorted to are:

A. *Land use control:* The zoning/development of residential, industrial and recreational areas should be avoided as far as possible around the lakes. The most

Table II. Showing the general biological spectrum of three lakes.

Lake	Forms available – General	Dominant forms
Dal lake	a) Phytoplankton:	
	i) Cyanophyta: *Microcystis flos aquae, M. aeruginosa, Oscillatoria rubescens,*	*Microcystis aeruginosa, Oscillatoria rubescens.*
	ii) Pyrrophyta: *Ceratium hirundinella.*	
	iii) Chlorophyta: *Sphaerocystis schroeteri, Pediastrum boryanum, Scenedesmus protuberans*	*Pediastrum boryanum, Scenedesmus protuberans*
	iv) Chrysophyta: *Cocconeis placentula, Gomphonema constrictum, Cymbella cymbiformis*	*Cymbella cymbiformis*
	b) Zooplankton: *Asplanchna, Brachionus, Polyarthra, Chydorus, Centrophyxis, Alonia, Cyclops* and nauplii of Copepods.	*Brachionus, Centropyxis, Cyclops,* nauplii of Copepods and *Alonia.*
	c) Macrophytes: *Myriophyllum spicatum, Potamogeton lucens, P. pectinatus, P. natans, Ceratophyllum, demersum, Typha angustifolia* and *Phragmites Communis.*	*Myriophyllum spicatum, Ceratophyllum demersum Potamogeton lucens.*
Anchar lake	a) Phytoplankton:	
	i) Cyanophyta: *Oscillatoria proteus,*	*Oscillatoria proteus*
	ii) Pyrrophyta: *Peridinium* sp.	
	iii) Chlorophyta: *Ulothrix variabilis Sphaerocystis schroeteri, Scenedesmus longus,*	*Ulothrix variabilis, Scenedesmus longus,*
	iv) Chrysophyta: *Cymbella prostrata, Tabellaria fenestrata, Cocconeis, placentula, Navicula radiosa*	*Navicula radiosa, Cymbella prostrata*
	b) Zooplankton: *Keratella, Ascomorpha, Philodina, Bosmina, Diaptomus, Cyclops*	*Keratella, Philodina, Cyclops* and *Diaptomus*
	c) Macrophytes: *Myriophyllum spicatum, Potamogeton crispus, P. natans, Nymphoides peltata, Ranunculus lingua, Sparganium ramosum,* and *Butomus umbellatus*	*Myriophyllum spicatum, Potamogeton natans* and *Nymphoides peltata*
Manasbal lake	a) Phytoplankton:	
	i) Cyanophyta: *Spirulina jenneri, Oscillatoria proteus, O. tenuis Microcystis aeruginosa, Lyngbya*	*Oscillatoria proteus, Spirulina jeneri,*
	ii) Chlorophyta: *Pediastrum duplex, Gonium* sp. *Euastrum pulchellum*	*Pediastrum duplex*
	iii) Pyrrophyta: *Ceratium hirundinella, Peridinium* sp.	*Ceratium hirundinella,*
	iv) Chrysophyta: *Navicula radiosa, Asterionella formosa, Cymbella* sp. *Cocconeis placentula* and *Tabellaria* sp.	*Navicula radiosa, Cymbella, Tabellaria*
	b) Zooplankton: *Bosmina, Ceriodaphnia, Diaptomus, Mesocyclops, Philodina* and nauplii of Copepods.	*Ceriodaphnia, Mesocyclops,* and nauplii of Copepods
	c) Macrophytes: *Ceratophyllum demersum, Myrophyllum spicatum, Najas, graminea, Potamogeton pectinatus* and *Nelumbo nucifera*	*Ceratophyllum demersum*

urgent thought should be given to the diversion of the sewage disposal of house-boats in the Gagribal basin of Dal lake.

B. *Diversion of Effluents:* Since the influence of sewage and other sources of nutrients has affected and is going to affect further the water quality of these lakes, the course open is to find out ways to divert the sewage of villages around the lakes.

C. *Dredging:* Substantial quantities of nutrients are tied up in either the sediments or the plant material in these lakes. Therefore considerations should be given to dredging, in an effort to remove this concentrated source of nutrients. This practice is followed to some extent in Dal and Anchar lakes but that should be taken up on more scientific lines, keeping in view the general ecological features of these macrophytes.

D. *Harvesting of weeds and algae:* The harvesting in this sense is concerned with the complete removal of weeds and algae and not just their temporary control by chemicals and algicides. Sawyer *et all.* (1952) warned against merely cutting under water weeds and then letting them manure the water as they die and undergo decay. Efforts should be made to find natural predators for control of weeds. Allsopp (1960) found manatees to be very effective for controlling the weeds. In Kashmir lakes, Grass carp *(Ctenopharyngodon idella)* could be introduced under observations for controlling the aquatic vegetation especially the submerged ones, which incidentaly shows 40% of infestation of the water area.

E. *Nutrient removal from waste waters:* Physical, chemical and biological methods should be used in removing the nutrients from waste water before discharging them into a particular water body.

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