Plant Diversity in Freshwater Ecosystems of North-West Himalaya

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ABSTRACT

The high altitude valley of Kashmir abounds in a vast array of freshwater bodies of lotic as well as lentic nature. 117 species of macrophytes have been recorded from the various water bodies of the valley, while the number of algal species contributing to phytoplankton, periphyton and phytobenthos exceeds 300. In mountain lakes the bottom sediments are too deep for the growth of attached macrophytes, while three vegetational zones -- emergents, rooted floating-leaf types and submergeds -- are distinguishable in the valley and forest lakes. The total disappearance of *Chara* sp. and *Euryale ferox* and the gradual replacement of clear water species like *Myriophyllum spicatum* and *Potamogeton* spp. by more resistant species, viz., *Elodea sp.* and *Ceratophyllum demersum*, typical of eutrophic habitats, are clear signs of racing eutrophication of the aquatic ecosystems of the valley.

Keywords: Aquatic plants, macrophytes, algae, fungi, Kashmir.

INTRODUCTION

Biodiversity means variability among living organisms from all sources and the ecological complexes of which they are a part which includes diversity within species (genetic diversity), between species (species diversity) and of ecosystems (ecosystem diversity). The high altitude valley of Kashmir, lying in the north-west Himalaya, abounds in a vast array of freshwater bodies - lakes, ponds, wetlands, springs, streams and rivers. Amongst these the lakes and wetlands play an important role in the biodiversity of the region in so far as their potential as resources of both plants and animals is concerned. Further the plants (algae and macrophytes) perform a key role in determining the structure and function of these ecosystems (Pandit, 1980, 84, 92, 99). In view of their ecological dominance, the present paper presents a broad-based critical assessment of the state-of-art in the area of plant biodiversity of freshwater bodies of Kashmir under different environmental conditions.

FRESH WATERBODIES OF KASHMIR

The freshwater bodies of Kashmir can broadly be classified into lotic (running) and lentic (standing) systems. The former includes the River Jhelum and various streams (nallahs) which directly or indirectly join it while the latter includes lakes, ponds, wetlands and similar other aquatic habitats. The lakes of Kashmir are further categorised into three different types: (i) glacial mountain lakes, (ii) pine forest lakes, and (iii) valley lakes, based on their origin, altitudinal situation and nature of biota they contain (Zutshi *et al.*, 1972; Kaul *et al.*, 1978 ; Pandit, 1999). The description of these lakes about 20 in number have been given elsewhere by Pandit (1996,99). The lakes represent the continuum of variation from nutrient poor condition called oligotrophy (e.g., glacial mountain lakes - Alipathar, Tarsar, Marsar, Sheshnag, Kounsernag, Gangabal etc.) through moderate nutrient condition called mesotrophy (e.g. pine forest lakes - Nilnag) to eutrophy also called nutrient rich condition (e.g., valley lakes - Dal, Anchar, Wular, Manasbal etc.). The wetlands almost represent the last stages of eutrophy called dystrophy. Their trophic status is discussed in detail elsewhere (Pandit, 1980, 99; Pandit and Kaul, 1982).

DISTRIBUTION AND PRODUCTION OF MACROPHYTES

The presence and abundance of macrophytes in aquatic habitats is governed by a set of environmental factors. As such the rivers and streams are almost devoid of any macrophytic vegetation which is primarily attributed to the running condition of water. Only certain plants which can anchor better near immovable objects (e.g. *Ranunculus* spp.) grow under such habitats (Pandit, 1984). In contrast, the lakes and wetlands are heavily infested with profuse growth of macrophytes accounting for large amount of photosynthesis. Since macrophytes lock up nutrients in the early growing season from the nutrient sediment pool only very little nutrients are left for the growth of phytoplankton, the former accounting for the major part of primary production in these ecosystems. However, the lakes and wetlands exhibit various kinds of associations of macrophytes and consequently the macrophytic production (biomass) varies among the ecosystems.

Lakes

A comparative study of three series of lakes on the basis of macrophytic production reveals the valley lakes to be eutrophic, the Nilnag, a forest lake, to be mesotrophic and the glacial mountain lakes which are almost devoid of macrophytes to be oligotrophic. In case of mountain lakes the bottom sediments are too deep for the growth of attached macrophytes, besides the low mineral content and low water temperature. In contrast, three vegetational zones, viz. (i) emergents, (ii) rooted floating-leaf types, and (iii) submergeds are distinguishable in the valley and pine forest lakes. In the recent years there has been a growing concern about these lakes getting chocked up by dense growth of macrophytes which is attributed to heavy mineral loading due to cultural eutrophication. Kaul and Zutşhi (1967) have reported a total of 117 species belonging to 69 genera and 42 families in aquatic and marshland habitats of Kashmir. These species have been categorised into 25 different associations spread over six classes viz. (i) Lemnetea, (ii) Utricularietea, (iii) Stratiotatea, (iv) Charetea, (v) Potametea, and (vi) Phragmitetea (Kaul *et al.*, 1973). However, Kaul and Zutshi (1967) have reported only a total of 106 species belonging to 38 families in various basins of Dal Lake (c.f. Pandit, 1992, 96, 99). At present the number of macrophytic species has decreased although the production of a few ones has increased. This is an outcome of accelerating eutrophication of these waterbodies (Pandit, 1980). The macrophytic vegetation of lakes, according to Zutshi *et al.* (1980), does not show any definite relationship with altitude. The hydrological factors represent the chief milieu of conditions governing the occurrence and growth of various macrophytic species and their associations. Water depth and its associated influences are opined to influence the occurrence and extent of individual plant species, while soil type and nutrient composition have little importance in controlling macrophytic distribution. However, for submerged plants the turbidity of water is an additional factor in determining the extent of their colonization. According to Kaul (1971), Lemnids are restricted to water depth of less than 1.5 m; *Myriophyllum spicatum* covers large areas between 0.5 - 2.0 m depth and *Nymphoides peltatum* between 1.0 - 2.5 m. Zutshi and Vass (1982) have estimated 0.5 m as the maximum depth of colonization by emergent forms; floating-leaf forms are reported to be distributed over depth ranges between 0.25 - 1.97 m while maximum amplitude of 0.4 - 3.0 m is recorded for the submerged communities of *Myrophyllum* -

Ceratophyllum. Among the emergents, *Phragmites australis* , *Typha angustata* and *Sparganium ramosum* are the dominant macrophytes occupying the littorals of lakes. Generally the lakes with higher transparency are conducive for the growth of submerged forms and where water is turbid floating forms dominate. This is noted when the macrophytes of Dal and Anchar lakes are compared. Recently Kaul (1984) correlated the development of *Lemna-Salvinia* associations with excessive eutrophication, bringing about a shift in underwater vegetation and resulting in the replacement of *Potamogeton crispus* associations by *Ceratrophyllum demersum*. 15 plant species and 10 plant associations have been reported to be rare while emergent reed-swamp communities are reported to be more resistant to eutrophication. Some macrophytic species namely *Chara fragilis, Nitella acuminata, N. dispersa and Nitellopsis obtusa* in deep waters of Manasbal Lake (Mukerjee, 1926) and *Potamogeton perfoliatus* particularly in Nilnag Lake (Blatter, 1927) reported earlier are no longer existent. The plant species in the Nilnag Lake are divisible into nine life-forms viz. (i) Ceratophyllids, (ii) Myrophyllids, (iii) Parvopotamids, (iv) Magnopotamids, (v) Batrachiids, (vi) Marsileids, (vii) Nymphoids, (viii) Trapids, and (ix) Helophytes (Hogeweg and Brenkert, 1969; c. f. Kaul *et al.*, 1980). Similarly the disappearance of *Chara* sp. and *Euryale ferox* from Dal Lake is attributed to change in environmental complex (Pandit, 1996).

A perusal of data presented by Kaul (1977) showed the total annual dry weight production of Dal Lake to be 30 metric tons ha^{-1} as against 10.1 tons ha^{-1} in the Anchar and 9.7 tons ha^{-1} in the Manasbal Lake during 1970-72. Investigation carried out later during 1972-76 by Zutshi and Vass (1982), however, indicated higher production values of 41.03 t ha^{-1} yr^{-1} for Dal Lake (Table 1). Lately, Trisal (1987) calculated the total macrophytic biomass for the entire Dal Lake including floating zone to be 4,735.05 tonnes. Of the total macrophytic biomass emergents, rooted floating-leaf types and submergeds contribute a total of 3161.94, 247.33 and 1325.78 tonnes respectively. It is evident that submerged forms have maximum coverage but minimal organic matter production. Submergeds like *Myrophyllum spicatum* and *Ceratophyllum demersum* also form monospecific meadows in the Manasbal Lake. As against this, emergents have a low coverage but high rate of production. A high primary productivity of *Typha angustata* (3.2 - 20-9 g m^{-2} d^{-1} ; standing crop being 325 - 10,139 g dry wt m^{-2}) and *Phragmites australis* (5.42 -23.7

$g\ m^{-2}\ d^{-1}$; standing crop being 1,016 – 8,108 g dry wt m^{-2}) has been reported by various investigators. Taking the over all view of submergeds in several lakes from existing data (Pandit, 1999), Dal Lake clearly sustains highly productive macrophytic communities, particularly in comparison to some Russian and Polish lakes (Gerlaczynska, 1973).

Table 1. Macrophytic production in three lake ecosystems of Kashmir.

Lake		Macrophytic production (t/ha)	Source
Dal Lake	Average	30	Kaul : (1977)
	Average	41	Zutshi & Vass (1982)
	Range	30 -150	Vass (1980)
Anchar Lake	Average	10.1	Kaul (1977)
	Range	80 - 100	Vass (1980)
Manasbal Lake	Average	9.7	Kaul (1977)
	Range	40-60	Vass (1980)

Wetlands

In shallow wetlands, unlike lakes, no typical macrophytic zonation is distinguishable; instead several plant species occur together which result in a complex physiognomy. On structural basis, particularly height and position of macrophyes within the wetland, the herbaceous wetlands are dominated by emergents, rooted floating-leaf types and submergeds depending upon water depth and associated factors. The emergent macrophytes have further been classified into three strata: (i) tall growing emergents with shoots more than one metre , (ii) low growing emergents which shoots between 25 and 100 cm tall, and (iii) ground layer species with shoots less than 25 cm in height.

The studies on phytosociology and community architecture in some typical wetlands have been carried out in detail by Handoo and Kaul (1982) and S.Kaul

(1982). Thus, while Handoo and Kaul (1982) reported about 42, 32, 19 and 18 species in Malangpora, Kranchu, Shalabogh and Hokarsar wetlands, Pandit (1991) reported 29, 24, 20,

Table 2. Total number of species and annual primary production* of different wetlands of Kashmir (Pandit, 1999)

S. No	Wetland site	Number of species**	Annual increment of macrophytes (g m^{-2})	Community architecture***
1.	Nowgam	21	845	Dominated by tall growing emergents
2.	Malangpora	42	1790	Dominated by sedge-meadow species
3.	Tullamulla	35	1843	Dominated by sedge[meadow species
4.	Mirgund	20	730	Mainly dominated by tall growing emergents
5.	Shalabogh	19	3073	Mainly dominated by tall growing emergents
6.	Kranchu	32	846	Mainly dominated by tall growing emergents
7.	Malgam	37	312	Dominated by tall growing emergents
8.	Haigam	29	1886	Dominated by low growing emergents and tall gwbing emergents take the position of co dominants
9.	Narkora	18	699	Dominated mainly by rooted floating-leaf types
10.	Homarsar	18	502	Dominated mainly by rooted floating-leaf types

* In all the wetlands sites macrophytes are the main contributors of carbon fixation.

** The species diversity is high in shallow and low in deeper sites.

*** In the shallower wetlands species of tall growing emergents, low growing emergents and ground layer species, all grow together resulting in the economy of space and light within the multitier architecture of the vegetation.

21 and 37 taxa of macrophytes in Haigam, Hokarsar, Mirgund, Nowgam and Malgam wetlands respectively (Table 2). Handoo and Kaul (1982) further noticed a gradual increase in species richness from 1.2 to 4.76 with a decrease in water depth. At Malangpora, the low growing emergents like *Scirpus palustris, Eleocharis palustris* and *Cyperus serotinus* and ground layer species like *Polygonum hydropiper, Myosotis sylvatica, Galium hertifolium* and *Marsilea quadrifolia* were common. They together represented 73.3 -86.8% of the density at the study site (Handoo and Kaul, 1982). In contrast, tall growing emergents like *Phragmites australis, Scirpus lacustris* and *Typha angustata* had high relative frequencies at both Shalabogh and Kranchu wetlands. The tall growing emergents, mainly *T.angustata, P.australis, Phalaris arundinacea* and *Sparganium ramosum*, accounted for 61.5 - 64.6% and 28.8 -49.3% of the total density at these two sites respectively. However, at Kranchu the floating-leaf species (*Nymphoides peltatum* and *Potamogeton natans)* and submerged species *(Myriophyllum spicatum* and *Ranunculus aquatilis)* were almost fairly present. In Haigam, the dominant vegetation comprises low growing emergents like *Scirpus palustris, Carex sp.,* and *Eleochatis palustris* and the tall growing emergents like *P.australis, S. lacu-stris , T. angustata* and *Sparganium erectum* take the position of co-dominant, occurring in somewhat pure or isolated stands (Kaul *et al.,* 1980). However in Nowgam *P.australis, S.erectum, Scirpus lacustris, Acorus calamus* and *Trapa natans* are common. Malgam has a typical prairie look. By intertwining rhizomatous parts of macrophyes, large extensive floating islands are being formed in this wetland. The common macrophytic species comprise *P.australis* (dwarf ecotype), *S.lacustris, Nymphaea candida, Nymphoides peltatum* and *Chara zeylanica*. In deeper wetlands like Hokarsar and Mirgund the increased water depth results in the greater establishment of floating-leaf species (Fig. 1). While in Mirgund floating-leaf types like *Nymphaea alba, Potamogeton natans, Hydrocharis dubia* and *Trapa natans* are the dominant forms, in Hokarsar *Trapa natans* and *Trapa bispinosa* together had 55.2 to 91.7 % relative frequency. *Phragmites australis* (tall ecotype) and *Nymphaea alba* are also the other main colonisers at the latter site. In general, floating-leaf species contributed more at Hokarsar than in other wetlands. *Trapa natans* still claims a good coverage in Wular Lake, a wetland of International Importance (Ramsar Site). In Wular, the growth of submerged vegetation is greatly restricted due to the heavy turbidity brought about by the suspended silt, as is true for

other wetlands also. S.Kaul (1982) while drawing a comparison of some typical wetlands of Kashmir, on the basis of their community architecture, reveals shallower wetlands (Malgan, Nowgam and Haigam) having a water depth of < 0.80 cm to be conducive for the establishment of an association of emergents like *P.australis, T.angustata, S.lacustris, S.erectum* and *Myriophyllum verticillatum* whereas the deeper wetlands (Mirgund and Hokarsar) are colonized by *Trapa -Nymphoides* association. S. Kaul further opined the deeper wetlands, predominantly covered by floating-leaf types, to be structurally less complex compared to other shallow wetlands.

The vegetation of wetlands is specially adapted to survive in different conditions and the Kashmiri wetlands host a number of species found no where else in the country. The most striking feature of the wetlands is the large amount of photosynthesis within the system especially by macrophytes. Their growth increases from minimum in February - April to maximum in August - September. Among the various life-forms, the reed swamps show the maximum biomass ;the standing crop values for *Phragmites australis, Typha angustata, T.latifolia, Scirpus lacustris* and *Sparganium erectum* being between 1,016-3, 216, 866-5, 400, 920-2, 288, 884-1, 280 and 625-1, 838g m^{-2} respectively. Among rooted floating-leaf types *Nelumbium nucifera* (found in Dal, Anchar and Manasbal lakes) and *Trapa natans* accumulates relatively higher biomsss. The biomass values of submergeds and free floating types are quite low as compared to emergents and floating-leaf types (Table 3). In general, some of the most productive wetlands sustained a macrophytic biomass ranging between 58-584 t ha^{-1}. These values are definitely higher than the lakes.

DWINDLING PLANT RESOURCES

The wetlands in Kashmir have remained almost neglected because of the tranditional attitude of the people, who still consider wetlands as "wastelands" serving dumping grounds for waste and "sinks" during floods brining in huge quantities of allochthonous material like silt and domestic refuse. Increasing human pressures, coupled with recurring floods, have brought about a series of changes in the biotic set up of waterbodies. For instance, before the floods of 1952 and 1959, Hokarsar wetland, one of the most imporotant duck shooting sites in Kashmir, was a rich source of some economically important plants like *Trapa natans, Nelumbium* *nucifera* and *Nymphoides peltata*. The thick stands of emergents like *Phragmites australis* (tall ecotype) and *Typha angustata* at this site formed the most suitable breeding sites for mallard, white-eyed pochard and coot untill 1921 (Bates and Lowther, 1952). However, at present the chief colonizers of the wetlands are *Trapa natans, Potamogeton natans* and *Nymphoides peltata. Nelumbium nucifera* has now completely vanished from the wetland and likewise *P.australis* (Fig. 2) is almost getting replaced by *Sparganium erectum* (Fig. 3). Similar situation has reached in Haigam wetland also. Surprisingly, pollution tolelrant species like *Myriophyllum verticillatum* (Fig. 4) and *Hydrocharis dubia* (Fig.5) have come up at certain sites in isolated patches of their own. Above all, the number of macrophytic species has declined considerably from 54 in 1963 to 24 in 1980 (Kaul and Zutshi, 1967; Pandit, 1980,91; Pandit and Qadri, 1990).

MACROPHYTES AND EUTROPHICATION

Macrophytes, through their form, behaviour and resistance, influence pollution in different ways (Lange and Zon, 1973; Rajmankova, 1975; Hejney and Husak, 1978; Clark *et al.*, 1978; Marvan *et al.*, 1978). Besides causing pollution in some ways, they also remove pollutants and purify water to a certain extent. Varshney (1981) and Pandit (1984, 92) used a number of macrophytes as bioindicators of water quality, and their studies were based on the kinds of species present, number of species and the biomass production. Considering the species of macrophytes recorded from Kashmir Himalayan waters, this type of study envisages *Sparganium erectum, Myriophyllum verticillatum, Potamogeton pectinatus* and *P.crispus* as indicators of severe pollution, and *Lemna* spp., *Salvinia natans, Sagittaria sagittifolia, Potamogeton lucens, P.pucillus, Polygonum amphibium, Phalaris arundinacea, Alisma plantago-aquatica* and *Ranunculus sp.* as indicators of eutrophication (Pandit, 1984, 92). The total disappearance of *Chara* sp. and *Euryale ferox* and the gradual replacement of clear water species like *Myriophyllum spicatum* and *Potamogeton* spp. by more resistant species viz. *Elodea sp.* and *Ceratophyllum demersum*, typical of eutrophic habitats, are clear signs of racing eutrophication. The explosive growth of *Lemna-Salvinia* weed complexes, because of their high aggressive capacity, colonize sites rich in organic matter, and also the side-

Fig. 1. Floating leaf species dominate in deeper wetlands.
Fig. 2. Thick stands of *Phragmites australis* in Hokarsar wetlands during 1975

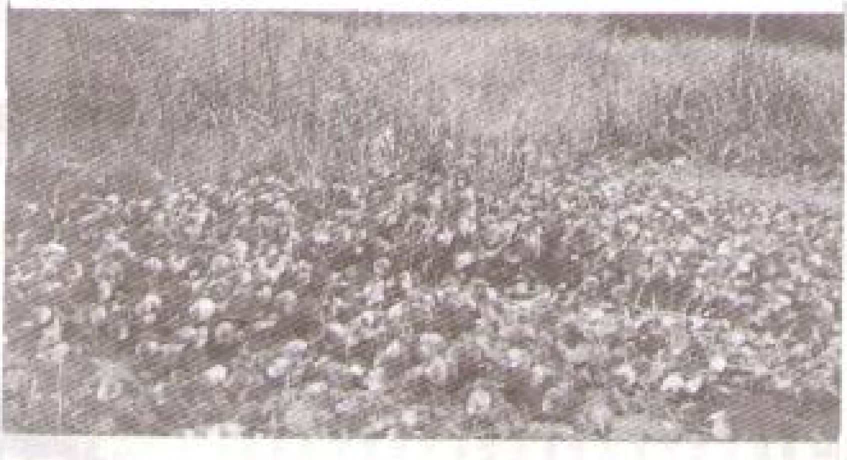

Fig. 3. *Sparganium erectum* forming thick stands during recent years and replacing *P.autralis*
Fig. 4. *Myriophyllum verticillatum*, a pollution tolerant species in Anchar Lake.
Fig. 5. *Hydrocharis dubia*, a pollution tolerant species in Hokarsar.

Table 3. Standing crops (g/m^2) and rates of production ($g/m^2/day$) of some macrophytes growing in various wetlands of Kashmir.

Plant Species	Period	Standing crop (g/m^2) Below ground	Above ground	Total biomass	Productivity ($g/m^2/day$)
A) EMERGENTS					
Tall Emergents					
1. *Acorus calamus*	July - July	312	500-996	812	5.36
2. *Pharagmites australis*	Aug- Sept.	824-3048	265-5280	1089-8328	5.42-23.7
3. *Phalaris arundinacea*	June	-	203-683	-	-
4. *Scripus lacustris*	June	-	196-774	-	-
5. *Sparganium erectum*	August-Sept.	412-634	710-985	1122-1619	-
6. *Typha angustata*	August-Sept.	155-4867	170-5272	325-10.139	3.2-20.9
Low Growing Emergents					
7. *Butomus umbellatus*	June	49	87-94	136	-
8. *Cyperus seratinus*	September	232	78-279	447	1.91
9. *Eleocharis palustris*	June-Sept.	1.49	27-153	302	2.48
10. *Equisetum debile*	June-Sept	60	88-113	148	-
11. *E. diffusum*	September	93	127-142	220	-
12. *Juncus articulatus*	September	9	13	22	-
13. *Lycopus europaeus*	June-Sept	41	76-81	117	-
14. *Myriophyllum verticillatum*	September	310-379	360-580	670-959	-
15. *Rumex maritima*	June	4	25	29	-
16. *Sagittaria sagittifolia*	June-Sept	6-73	14-142	20-191	-
17. *Scripus maritimus*	September	42	59-71	101	-
18. *S. palustris*	September	333	365	624	2.2
19. *Sium latijugum*	September	22	58-62	80	-
Ground Layer Species					
20. *Alisma plantigina*	August	-	-	42	-
21. *Anthroxon lancifolia*	June	16	37	53	-
22. *Cyperus rotundus*	June	8	12	20	-
23. *Echinochloa crusgalli*	June		30	30	-
24. *Epilobium hirsutum*	-	-	-	63	-
25. *Galium hertifolium*	June	21	43-49	64	-

Table 3 continued

26. *Marsilea quadrifolia*	Sept-June	-	-	12-44	-
27. *Myosotis sylvatica*	June	-	-	125	-
28. *Polygonum hydropiper*	June-Sept	67	98-116	183	1.44
29. *Potentilla reptans*	June-Sept	-	-	68-101	-
30. *Ranunculus sceleratus*	April	15	46	61	-
31. *Veronica anagallis*	April-June	11	10-23	34	-
B) FREE FLOATING TYPES					
32. *Lemna* spp.	July	-	-	75-295	0.75-1.19
33. *Salvinia natans*	May & Sept.	-	-	266-393.7	2.0-2.5
34. *Spirodela polyrhiza*	July	-	-	43-190	0.4-1.1
C) ROOTED FLOATING LEAF TYPES					
35. *Hydrocharis morsus ranae*	August	-	36	141-231	0.9-1.5
36. *Nelumbium nucifera*	September	-	549-813	-	4.5-5.4
37. *Nymphaea alba*	September	-	101-246	210	1.36-1.6
38. *N.stellata*	August-Sept.	-	18-319	262	1.75
39. *Nymphoides peltatum*	May-August	-	8-39	62-231	0.45-2.20
40. *Potamogeton natans*	August	-	61.89	70-298	0.34-1.89
41. *Ranunculus aquatilis*	April	-	12	-	-
42. *Trapa bispinosa*	September	-	545	-	-
43. *Trapa natans*	August-Sept.	-	-	10-490	2.9-3.78
D) SUBMERGED TYPES					
44. *Ceratophyllum demersum*	August-Sept.	-	-	16-480	1.04
45. *Hydrilla verticillata*	August-Sept.	-	-	104-533	0.74-2.6
46. *Myriophyllum spicatum*	May-Sept.	-	-	288-640	0.8-5.3
47. *Najas graminea*	February	-	-	130-555	0.94-3.5
48. *Potamogeton crispus*	February	-	-	92-276	1.0-1.3
49. *P.lucens*	August	-	-	131-380	1.1-2.4
50. *P.pusillus*	September	-	-	198-279	1.18-1.53

water channels and lake littorals (Kaul and Bakaya, 1973; Pandit *et al.*, 1978). Kaul (1984) correlated the development of *Lemna-Salvinia* associations of *Ricciocarpus-Lemnetum, Spirodela-Lemneum gibbae, Lemnetum trisulcale-Salvinietum natantis* with excessive eutrophication bringing about a shift in under-water vegetation and resulting in the replacement of *Potamogeton lucens* by more eutrophic *Ceratophyllum demersum*. The author further opined 15 plant species and 10 plant associations to be rare in Kashmir waters and further believed emergent reed-swamp communities to be more resistant to eutrophication. The thick mats of *lemna minor, L.gibba, L.trisulca* and *Spirodela polyrhiza* (duckweeds) and the extensive growth of water fern (*Salvinia natans*) dispersed through wind, water curents and boating, the latter encroaching even upon the lotus (*Nelumbium nucifera*) zone during the recent years in Dal and other eutrophic waterbodies are the positive signs of increasing eutrophication of Kashmir freshwaters (Kaloo *et al.*, 1995).

ALGAL BIODIVERSITY

The algae can be classifed, on the basis of their ecological distribution, into phytoplankton, periphyton and phytobenthos (epipelic algae), and comprise a multitudinous number of about 300 algal species belonging to Cyanophyceae, Chlorophyceae, Bacillariophyceae, Euglenophyceae, Xanthophyceae, Chryso-phyceae and Dinophyceae. The extent of their occurrence and growth is, however, determined by a number of environmental factors, the physico-chemical characters of water being the chief milleu of conditions governing their distribution and production. Although a number of studies have been carried on the qualitative and quantitative aspects of phytoplankton, yet there is no comparability of the data presented by various investigators. There is enough evidence in literature to show that the difference in the dominant phytoplankton assemblages of the lakes reflect differences in their tropic levels. Kaul *et al.* (1978) opined that Dal Lake waters, in general, are low in available phosphorus which possibly is a limiting factor for phytoplankton blooms in the lake. Overall 117 species of phytoplankton belonging to 71 genera have been identified by Trisal (1987), the dominance pattern being Chlorophyceae followed by Bacillariophyceae, Cyanophyceae and Eugleno-phyceae. In contrast to the findings of Trisal (1987), Kant and Kachroo (1977) reported a much greater number of phytoplankton species encompassing 150 species of Chlorophyceae and 86 species of Bacillariophyceae which point out to the fact that the number of phytoplankton species is exceptionally great in this biotope. The latter studies are further corroborated by the findings of Pandit and Pandit (1996) who reported the periphytic flora of Dal Lake to be composed of 264 species and subspecies spread over 84 genera on *Potamogeton lucens* and 239 taxa belonging to 77 genera on *Myriophyllum spicatum*, with the pattern of dominance among various algal groups being Chlorophyceae > Bacillariophyceae> Cyanophyceae > Euglenophyceae > Dinophyceae > Chrysophyceae > Xanthophyceae. However, on the basis of biomass, the pattern of dominance among various periphytic algae is Bacillariophyceae > Chlorophyceae > Cyanophyceae > Euglenophyceae > other groups. In other study, Sarwar and Zutshi (1987) could record only 178 species of algae, composed of Bacillariophyceae (78), Chlorophyceae (77), Cyanophyceae (19), Dinophyceae (2), Chrysophyceae (1) and Cryptophyceae (1), associated with both artificial and natural substrates. In the enriched Trigam Lake, the phytoplankton population is mainly represented by Cyanophyceae (blue-greeen algae) followed by Bacillariophyceae (diatoms). Zutshi *et al.* (1980), on the basis of relative dominance of algal groups, place this lake at the highest level of pollution. But in the mesotrophic lakes e.g., Manasbal and Naranbagh diatoms and Chlorophyceae (green algae) dominate. Wanganeo (1984) and Zutshi and Wanganeo (1984) reported 75.80 - 82.51 % Bacillariophyceae, 8.26 - 15.69 % Cyanophyceae, 3.69 - 6.78 % Chlorophyceae, 1.36 - 3.67 % Chrysophyceae and 0.58 - 0.98 % Dinophyceae in such of the lakes as Manasbal. In this lake 125 species of phytoplankton have been recorded out of which 55 were Chlorophyceae, 45 Bacillariophyceae and 17 Cyanophyceae. Pandit (1980), Pandit and Kaul (1982) and Pandit (1999) recorded a total of 190 species of phytoplankton in five wetlands (Nowgam, Malgam, Haigam, Mirgund and Hokarsar) of Kashmir of which 20 belong to Cyanophyceae, 72 to Chlorophyceae, 60 to Bacillariophyceae, 3 each to Xanthophyceae, Chrysophyceae and Dinophyceae. The maximum number of species is, however, recorded in Nowgam (189), followed by Haigam (183), Mirgund (179), Malgam (177) and decreasing to minimum in Hokarsar (156). The phytoplankton community reaches its maximum development in spring and autumn when the number of component species is also the highest (Pandit, 1998). Although, the mean number of species in wetlands, in general, is high yet only a compatatively small number of species contribute appreciably to the total density and biomass, presumably owing to the state of dynamic balance of plankton community; the species competing for the same materials in fairly uniform environment. In such a process some species profit more than others and hence dominate the scene (Pandit, 1998, 99).

Kaul *et al.* (1978) obtained a higher number of phytoplankton species in wetlands as compared to that in the sewage ponds and lakes in that order, the rich assemblages in wetlands being attributed to macrophytic cover, floods and availability of nutrients favouring many heterogenous niches, both spatial and temporal. The filamentous green algae are favoured by higher transparency and temperature conditions. In Alipahter, a high altitude mountain lake, the dominance pattern and seasonal dynamics of phytoplankton are both not clear as only 16 species of Chlorophyceae and diatoms have been recorded (Kaul *et al.*, 1978; Zutshi *et al.*, 1980), probably due to only a brief ice-free period in summer. Although no systematic survey of epipelic algae growing in the lake sediments has been carreid out, yet it has been conducted for the wetlands by Pandit (1980). The author registered a total of 155 species of sediment algae spreading over the various taxonomic groups with the following break up: Cyanophyceae -18, Chlorophyceae -37, Bacillariophyceae -61, Xanthophyceae -1, Chrysophyceae -2, Dinophyceae -5, Cryptophyceae -4 and Euglenophyceae -27. Due to only little depth and hence a close proximity of bottom to the surface water in wetlands, a large number of phytoplankton species are regularly present in the bottom flora as well (Pandit 1980).

SOIL FUNGI

Pandit (1980) recorded only 14 species of aquatic soil fungi, playing a considerable role in the decomposition process of wetlands, in the bottom sediments. And these are sparsely distributed in the water column.

CONCLUSIONS

The present review represents a broad-based critical assessment of the state-of-art in the area of plant (microphytic and macrophytic) biodiversity in freshwater ecosystems of Kashmir under different environmental conditions. The hydrological factors represent the chief milleu of conditions governing the occurrence and growth of various macrophytic species and their associations. Water depth and its associated influences are opined to influence the occurrence and extent of individual plant species while soil type and nutrient compostion have little importance in controlling macrophytic distribution. A comparative study of the three series of lakes reveals the valley lakes (e.g., Dal, Anchar, Manasbal, Wular etc), being nutrient rich and shallow, to be highly productive and therefore, eutrophic; the forest lakes (e.g., Nilnag) to be moderately productive as compared to valley lakes and, therefore, mesotrophic and the mountain glacial lakes (e.g., Alipathar, Tarsar, Marsar, Gangabal, Sheshnag, Kounsernag etc.), being nutrient poor and too deep for the growth of attached macrophytes and consequently devoid of any macrophytic vegetation , to be almost biologically sterile (except for algal growth) and, therefore, categorized as oligotrophic systems. Wetlands represent the last stages of plant succession where, unlike lakes, no typical macrophytic zonation into emergents , rooted floating-leaf types, free floating types and submergeds is distinguishable; instead several plant species occur together resutling in complex physiognomy. In all 117 species belonging to 69 genera and 42 families have been recorded in the aquatic and marshland vegetation of Kashmir. Similarly a multitudinous number of more than 300 algal species belonging to phytoplankton, periphyton and phytobenthic communities and spread over to various taxonomic groups (Cyanophyceae, Chlorophyceae, Bacillario-phyceae, Euglenophyceae, Xanthophyceae, Chrysophyceae, Cryptophyceae and Dinophyceae) have been registered from various aquatic biotopes, the extent of their occurrence and growth being determined by a number of environmental factors. However, due to accelerated eutrophication the total number of plant species has declined during the recent years and instead a few eutrophic or pollution tolerant species are showing exponential growth in different lakes and wetlands exhibiting varying degree of eutrophication. In comparison to lentic systems, a very small number of algal populations and species have been registered in the lotic systems (River Jhelum).

ACKNOWLEDGEMENTS

The author wishes to thank various investigators for providing the relevant literature.

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