7.1 Summary

Wetlands are often described as “nature’s kidneys” for their ability to filter waste and pollutants, as well as “nature’s supermarket” for their high productivity and ability to act as a source of food to many organisms. The ecological significant services provided by the wetlands include climate regulation, turnover of organic matter, biomass accumulation, as well as substrate for phytophilous organisms and a source of food for aquatic as well as terrestrial organisms. These ecological services are often considered in anthropocentric terms, because of their ability to ameliorate floods, stabilize shoreline, prevent erosion, as well as removal of contaminants from the water. Wetlands also play significant role in the biogeochemical cycling of nutrients by acting as nutrient source, as well as sink of nutrients.

Macrophytes, as a component of shallow lakes and wetlands, have diverse roles to play in the functioning of these ecosystems. The macrophytes serve as a base of aquatic food-chains, besides they also actively contribute to the promotion and maintenance of food webs and services in freshwater ecosystems especially the macrophyte dominated ones. Aquatic macrophytes also act as important bioindicators of environmental conditions and long-term ecological changes in water quality. The function of macrophytes in these ecosystems is related to their structural attributes like species composition, distribution, abundance and diversity which in turn depend on various environmental factors. Because of their high rate of biomass production, macrophytes act as an important primary food resource for aquatic organisms. The complex tropic dynamics and primary productivity of wetlands is greatly influenced by the higher diversity and biomass of macrophytes. For the assessment of nutritional value and evaluation of food potential of aquatic plants, the knowledge of their ecological significance and chemical composition is essential. It is well known that seasonal variations in certain abiotic factors such as light, temperature, sediment composition and water chemistry can influence photosynthetic rates and biochemical
composition of macrophytes, thus necessitating the determination of their biochemical composition.

Among the fresh water bodies of the valley Wular lake enjoys special status for being the largest freshwater body within Indian sub-continent and a designated Ramsar Site (a Wetland of International Importance). It is spread over an area of 48-54 km², being situated at a surface elevation of 1580 m (a.m.s.l) and positioned between geographical coordinates of 34° 16′ 24.67″ N latitude and 74° 33′ 41.42″ longitude. It plays a major role in the hydrological regime of the Kashmir valley by acting as a huge absorption basin for floodwaters of Jhelum floodplain. Wular lake and its associated wetlands act as an important habitat for migratory water birds within Central Asian Flyway and supports rich biodiversity. It also supports a large population living along its fringes owing to its huge fishery potential.

Since the wetland is dominated by macrophytes, considerable efforts have gone into the field studies to correlate the spatial distribution pattern of aquatic plants with major physico-chemical environment of their habitat. There are only few reports regarding the distribution patterns and community characteristics of macrophytes including the studies pertaining to physiognomy of wetland vegetation in Kashmir. It is only very recently some work, yet to be published, has been conducted on the production and nutrient dynamics of macrophytes in Hokersar wetland which as such has remained untouched as far as the distribution patterns and biochemical composition of macrophytes is concerned (Kumar, 2009). In this backdrop the present study on “Distribution, production and biochemical status of dominant macrophytes in Wular lake, a Ramsar Site in Kashmir Himalaya” has been undertaken to work out a generalized relation between water and macro-vegetation distribution, production and biochemical composition. This study can latter on in future help in determining the pattern in which distribution, production and biochemical composition of macrophytes change as the water quality deteriorates.

Water depth in the Wular lake showed slight significant spatial as well as temporal variations. The maximum depth of water was recorded during spring as against the minimum being recorded during winter. The secchi disc transparency in the Wular waters revealed slight insignificant spatial as well as temporal variations. Wular waters, having the permanence of water all through the year remained, least turbid except during spring and early summer season when least transparency on
account of increased silt laden inflows was noticed. Water temperature in Wular lake followed the general thermal cycle of the region with peak temperatures being recorded during summer and the lowest temperature registered in winter.

Total dissolved solids followed the same trend as that of specific conductivity, witnessing its peak amount during winter and then following a decline to reach the lowest value during summer where after an increasing trend was evinced towards the autumn. The overall absolute values for total dissolved solids fluctuated between a low of 64 mg/L (August) and a high of 320 mg/L (January). Water conductivity, reflecting total ionic concentration of salts, witnessed a seasonal trend and depicted comparatively higher values. Maximum specific conductivity (508.7±17.0 µScm⁻¹ at 25 °C) was recorded during winter as against the minimum (115±10.0 µScm⁻¹ at 25 °C), being recorded during summer.

Dissolved free carbon dioxide in Wular waters depicted an inverse trend to that of pH registering its higher concentration during winter and lowest during summer. The maximum and minimum concentrations of free carbon dioxide in water were 28 mg/L (December) and 5 mg/L (August) respectively. Dissolved oxygen, showing inverse relationship with temperature, witnessed a summer fall recording its maximum values in winter. The maximum amounts of dissolved oxygen (11 mg/L) were registered in November while as the minimum amounts (6.4 mg/L) were recorded during July, August and September respectively.

The alkaline waters of Wular lake registered the pH ranging between a low of 7.1 (December) and a high of 8.5 (June). Chloride content of water did not depict noticeable seasonal trend. However, the absolute values ranged between 6.0 mg/L (December and February) and 28.0 mg/L (April).

Total hardness recorded very noticeable temporal variations with greater amounts being recorded during winters as against the least being recorded during summers. The highest amount of total hardness (290 mg/L) was recorded in February as against the lowest of 55 mg/L being recorded during August and September. Calcium and magnesium concentrations in the lake waters revealed comparatively harder waters during winter and spring. The seasonal values of calcium ranged from a low of 34.6±4.9 mg/L (summer) to a high of 106.4±1.2 mg/L (winter) and that of magnesium content from 5.9±1.4 mg/L (summer) to 43.1±1.9 mg/L (winter). The alkalinity of Wular waters varied greatly with regard to time but experienced least
spatial variations. The alkalinity of water was solely due to bicarbonates as the carbonates, were not recorded at any of the sites throughout the study. The highest value of bicarbonate alkalinity (245 mg/L) was recorded during January as against the lowest value of 55 mg/L, being recorded during August.

Greater amounts of dissolved silica were recorded during spring, followed by summer and autumn and decreasing to the lowest during the winter. The maximum amounts of silicate (18.4 mg/L) were noticed in April while as the minimum amounts (3.8 mg/L) were recorded during December. The amounts of orthophosphate-phosphorus in Wular waters depicted a peak concentration in winter, moderate in autumn and further experienced a fall in the concentration during summer. The minimum and maximum concentrations of orthophosphate-phosphorus in water were 9 µg/L (June) and 118 µg/L (January) respectively. Same was true for total phosphorus, depicting peak values in winter. The ranges of total phosphorus over the whole period of investigation were much wider and thus fluctuated from the lowest value (60 µg/L) during September 2011 to the highest value (393 µg/L) during February.

Ammonical-nitrogen and nitrate-nitrogen in water depicted the same trend as that of phosphorus registering their higher concentrations during winters and lowest during summers. The maximum and minimum seasonal amounts of 290.0±20.0 µg/L (winter) and 48.5±9.2 µg/L (summer) were obtained for ammonical-nitrogen and for nitrate-nitrogen such values were 1416.7±336.1 µg/L (winter) and 178.7±22.7 µg/L (summer) respectively.

Lake waters recorded the maximum amounts of iron in winter, moderate amounts in autumn and spring and the lowest amounts in summer. The overall absolute values for iron ranged from a low of 189 µg/L (August) to a high of 413 µg/L (February).

Wular lake, harbouring a complex physiognomy of macrophytes, was represented by 55 species belonging to 38 genera that are spread over 27 families. Greater variations in macrophytic distribution with regard to time and space were registered in the wetland. The first half of the growing season recorded the significant fluctuations but the later half did not reflect much change in the species make up. During the entire growing period the highest number of 24 species was recorded at Site I during summer, 2012. Spatially the highest number of species (35) was
recorded at Site I with 25 species of emergents, 06 rooted floating-leaf type, 01
submergeds and 03 free floating type as against the lowest number of 18 species being
registered at Site IV. However, among the various life-form classes the greater
fluctuations were witnessed in the number of emergents. The macrophytic community
of Wular lake was represented by all the four life-form classes belonging to emergents
(42.6 %), rooted floating leaf type (24.7 %), submerged (15.4 %) and free floating
(17.3 %) and each life-form class embraced a distinct assemblage of plant species.
However, the rooted floating-leaf type macrophytes cover significant area of the lake,
while as submergeds cover least area of the wetland. *Typha angustata* and *Phragmites
australis*, the chief occupants of littoral zone, extend all along the eastern, north-
western and parts of south-eastern side of the lake up to a depth of 2.0 m accompanied
by widespread stands of rooted floating-leaf type species (*Nymphoides peltatum,
Potamogetan natans* and *Trapa natans*). The maximum area under emergents was
seen at Site I where large aggregations of these plant species were found distributed
throughout. Rooted floating-leaf type macrophytes formed widespread dense beds in
Wular lake. *Trapa natans* was the chief constituent species among these macrophytes
and formed large beds at sites V, VII and III. The free-floating species being
dispersed were confined mostly towards littorals and side water channels. Amongst,
the free floating species, *Azolla* sp., *Salvinia natans*, and *Lemna minor* formed thick
dense mats over extensive areas in the littorals at sites II, V and VI. Submerged
macrophytes, due to their high aggressive capacity, covered the maximum area all
along the western side of the Wular lake. This life-form class dominated by
*Ceratophyllum demersum, Potamogeton crispus* and *Potamogeton lucens* association
formed dense meadows in the open water areas at sites VII, VIII and IV. Certain
species of macrophytes showed restricted distribution to a particular site. These were
*Scirpus lacustris* (Site I), *Nelumbo nucifera* (Site V), *Rununculus lingua* (Site VI) and
*Batrachium trichophyllum* (Site VIII).

Various community characteristics again depicted noticeable variations in
Wular lake. The Sorenson’s similarity index based on species composition indicate
that Site I had high degree of similarity with Site VI (81.3 %) which may be due to
their littoral nature and similarity in their water characteristics as was observed during
the present study. The study of IVI values revealed that *Lemna-Salvinia* complex
dominated all the sites and was co-dominant at Site II indicating its absolute
dominance over other species in the Wular lake. The Shannon’s Diversity Index showed high diversity of macrophytes at Site VII (3.06) and lowest at Site IX (2.38). On the other hand, Simpson’s diversity index revealed its maximum value of 0.989 at Site V as against the minimum value of 0.939 being recorded at Site I on the basis of occurrence of macrophytes. Bray-Curtis cluster analysis revealed that the sites III, V and IX are very much similar in terms of their macrophytic composition.

Production estimates in Wular lake were undertaken for a total of 16 species of macrophytes comprising 05 emergents, 06 rooted floating-leaf types, 03 free-floating type and 02 submergeds. Among the emergents Typha angustata registered the maximum primary productivity (1,800 g dwt. m$^{-2}$), followed by Phragmites australis (1,450 g dwt. m$^{-2}$). Among the rooted floating-leaf types, Trapa natans with a production value of 450 g dwt. m$^{-2}$ was the most productive species. Salvinia natans depicted the maximum productivity (33 g dwt. m$^{-2}$) among the free-floating class. Among submergeds, Ceratophyllum demersum registered the highest productivity with a value of 170 g dwt. m$^{-2}$ against the lowest value of 83 g dwt. m$^{-2}$, being recorded for Potamogetan crispus. On the other hand, net primary productivity fluctuated between a minimum of 0.09 g dwt. m$^{-2}$ day$^{-1}$ for Lemna minor and a maximum of 6.94 g dwt. m$^{-2}$ day$^{-1}$ for Typha angustata. Phragmites australis was the second most productive species with net primary productivity of 5.59 g dwt. m$^{-2}$ day$^{-1}$.

In general, among the dominant species of macrophytes estimated for the primary production in Wular lake, Typha angustata depicted the maximum productivity, followed by Phragmites australis and Trapa natans in a decreasing order. The lowest production was recorded for free floating Lemna minor. Emergents, contributing a maximum of about 69 % to the overall primary productivity, were followed by rooted floating-leaf type class (24.5 %), submergeds (5 %) and free-floating type (1.5 %).

In all, sixteen macrophytic species, including 05 emergent, 06 rooted floating-leaf type species, 03 free-floating and 02 submergded species, were analysed, on seasonal basis, for various biochemical constituents viz. total lipids, carbohydrate, protein and chlorophyll contents. Different macrophytic species besides showing considerable temporal variations were observed to exhibit interspecies and interclass variations in their biochemical compositions. Total lipids (on % fresh wt. basis) depicted the maximum concentrations in various plant tissues during autumn, followed by summer and spring and decreasing to the minimum in winter. For
emergents, *Myriophyllum verticillatum* registered the maximum concentration of total lipids (4.8±2.6 %), followed by *Phragmites australis* (4.3±2.5 %) and *Typha angustata* (3.9±2.3 %). However, among the rooted floating-leaf type species, the maximum concentration of total lipids (4.5±2.2 %) was recorded for *Trapa natans*, followed by *Marsilea quadrifolia* (3.3±1.9 %). Among free-floating species, the maximum concentration of total lipids (3.4±1.9 %) was noted for *Azolla* sp. as against the minimum of 2.8±1.4 %, being recorded for *Salvinia natans*. *Potamogeton crispus* depicted the maximum concentration of total lipids (3.5±2.9 %) among the submersed. The concentration of total lipids depicted greater variations in different periods, though significant increases for *Ceratophyllum demersum* and *Potamogeton crispus* (about 4 times each) were evinced in the early autumn season.

Maximum concentrations of carbohydrates in various plant tissues were recorded during summer, followed by spring and autumn and decreasing to the minimum in winter. Among all the four life-form classes, the rooted floating-leaf type macrophytes registered the highest concentration of carbohydrates as evinced by *Marsilea quadrifolia* (14.9±6.3 %), *Nymphaea mexicana* (14.7±5.4 %), *Potamogeton natans* (14.0±8.8 %) and *Hydrocharis dubia* (10.8±5.6 %). The submerseds registered the lowest concentration of carbohydrates with *Potamogeton crispus* recording a highest of 6.4±2.6 %) as against the lowest of 3.6±2.9 %), being recorded for *Ceratophyllum demersum*.

Like lipids, the maximum concentration of proteins in various plant tissues were recorded during autumn, followed by summer and spring and decreasing to the minimum in winter. The free-floating species registered the highest concentrations of proteins with *Azolla* sp. recording a highest of 17.2±6.2 % as against the lowest of 9.1±2.7 %, being recorded for *Salvinia natans*. On the other hand, emergents recorded the lowest concentration of proteins as evinced by *Phragmites australis* (6.4±4.0 %), *Polygonum amphibium* (6.0±4.0 %), *Polygonum hydropiper* (5.3±2.8 %) and *Myriophyllum verticillatum* (5.1±1.8 %) in a decreasing order.

The maximum pigment content in different species of macrophytes was recorded during the period of active growth in summer. The autumn and spring season registered almost equal concentration of Chlorophyll-a and Chlorophyll-b and the values peaked during summer. However, relative content of Total Chlorophyll in the macrophytes was notably lower in spring season than in autumn. The concentration of
Chlorophyll-a in different species of macrophytes fluctuated between a minimum of 0.8 mg/g for *Azolla* sp. and a maximum of 4.3 mg/g for *Ceratophyllum demersum*. The Chlorophyll-b content recorded its highest concentration in *Ceratophyllum demersum* (2.5 mg/g), followed closely by *Potamogeton crispus* (2.2 mg/g). The lowest Chlorophyll-b values were obtained in *Azolla* sp. (0.1 mg/g). Total Chlorophyll content recorded its highest concentration in *Polygonum amphibium* (5.0 mg/g), followed by *Nymphaea mexicana* having a value of 4.9 mg/g and decreasing to a lowest of 0.4 mg/g in *Azolla* sp. In general, among the different life-form classes of macrophytes, submergeds accumulated greater pigment content.