CHAPTER VII

SUMMARY

This work was undertaken in two lakes of Kumaun namely, Nainital and Bhimtal. Lake Nainital is situated at an altitude of about 1937 m above sea level between 29° 24' N latitude and 79° 28' E longitude, while Lake Bhimtal lies at an altitude of 1432 m above sea level between 29° 20' N latitude and 79° 36' E longitude in the Kumaun Himalaya. Both lakes contribute significantly to the socio-economic conditions of humans in the region. They are important resources of drinking water, popular recreational and tourists’ spots, and are important for fisheries, boating, etc. During summers, Lake Bhimtal also supplies water to the low lying areas. They are also the resource for living hood of boatmen as hundreds of boatmen are dependent on boating in these lakes. Moreover, they also control the microclimate of the area and are repository of biodiversity. The surface area of the Nainital lake is about 0.48 km$^2$, whereas the surface area of Bhimtal is 0.85 km$^2$.

The research was carried out for a period of three years from April, 2010 to March, 2013. The first one year period was used in standardization of methodology, identification of flora and fauna, selection of sites, etc. The quantitative data were collected for a period of one and half years from April, 2011 to September, 2012 and the remaining 6 months period was used in data synthesis, computation, filling the gaps, etc.

The study was conducted with following main objectives:

(I) to provide a comprehensive information on the periphyton communities, which were unexplored prior to the present investigation in two lakes of Kumaun,

(II) to obtain information on the influence of the substrate types on periphyton communities,

(III) to study the interlacustrine variation, if any in periphyton communities, and

(IV) to determine the influence of certain physico-chemical variables of lakes on periphyton communities.
In order to achieve the objectives of the study, seven physico-chemical variables of the water and various attributes of periphyton communities were analysed. **Standard methods and equipment** were used in analyses.

**Periphyton** are complex assemblages of algae and heterotrophic organisms attached to submerged substrates such as stones, sticks, macrophytes, etc. They are important primary producers and are chief components of aquatic food chain. They also act as pollution indicator. They are exposed to contaminants in the water column and can absorb them into their tissues. They are found mostly in the littoral zone which often serves as the spawning ground for pelagic fish species and provides habitat during larval and juvenile stages of their life cycle. Energy transfer within this zone through periphyton can have an important impact on whole lake processes.

In an annual cycle, the **water temperature** of Nainital lake varied from 10.1 ºC to 24 ºC while that of Lake Bhimtal ranged from 13 ºC to 28 ºC in the littoral zone of the lake. The **hydrogen ion concentration** ranged from 7.9 to 8.5 in Nainital lake and from 7.0 to 8.5 in Bhimtal lake. Thus, the water of both lakes was almost alkaline throughout the year except in few months when the pH was neutral in Bhimtal lake. The concentration of **free CO$_2$** fluctuated from 5.2 mg/l to 15.5 mg/l in Nainital lake and from 0 to 6.5 mg/l in Bhimtal lake. The concentration of dissolved oxygen (DO) varied from 6.5 mg/l to 10.0 mg/l in Nainital lake and from 5.2 mg/l to 8.0 mg/l in Lake Bhimtal. The **biochemical oxygen demand** ranged from a minimum of 7.15 mg/l to a maximum of 10.0 mg/l in Nainital lake and it ranged from 5.5 mg/l to 16.0 mg/l in Bhimtal lake. The **nitrate-nitrogen** concentration fluctuated between 0.42 mg/l and 0.85 mg/l in Nainital lake and from 0 to 0.46 mg/l in Bhimtal. The concentration of **phosphate phosphorus (PO$_4$-P)** varied from 0.25 mg/l to 0.55 mg/l in Lake Nainital and 0.01 mg/l to 0.5 mg/l in Bhimtal lake.

Periphyton community was studied on three substrates (in natural stone and twig substrates and glass slide) in both lakes. In total 54 species of periphyton belonging to two major categories namely **Phytoperiphyton** (Chlorophyceae, Bacillariophyceae and Cyanophyceae) and **Zoopерiphyton** (Cladocera, Copepoda, Diptera and Rotifera) were collected from the two lakes. The number of species found...
in Lake Nainital (49) was slightly greater than that of Bhimtal lake (48). Out of 54 species, 41 were common to both lakes.

**In Nainital lake, on natural stone substrate** the community abundance of periphyton varied from 6.1 ind/cm² to 36.2 ind/cm² with two pronounced peaks during October, 2011 and February, 2012. The seasonality in variation was significant (p<0.05). On annual mean basis, the group Bacillariophyceae was the most significant group of periphyton and contributed as much as 58 % to the total mean periphyton abundance. The two other important groups were: Chlorophyceae and Cyanophyceae which shared 26 % and 8 % of the total community abundance, respectively. The other groups were insignificant and together shared about 8 % of the total community abundance. The dominant species on the basis of Importance Value Index (IVI) were: *Navicula* sp., *Tabellaria* sp., *Philodina roseola*, *Chironomus* sp., *Oedogonium* sp., *Vorticella* sp. and *Scendesmus* sp.

**On the twig substrate**, the periphyton community abundance varied from 13.9 ind/cm² to 28.2 ind/cm². Seasonally in one year cycle, a single pronounced peak with few minor peaks was discernible. At the time of highest peak, the group Bacillariophyceae was maximum and shared about 49 % of the total community abundance. On this substrate also, the group Bacillariophyceae was the most dominant group and it shared 55 % of the total community abundance on annual mean basis. Another important group was Chlorophyceae which contributed 31 % to the total community abundance. The other groups together constituted 14 % to the total mean periphyton standing crop. The dominant species on the basis of IVI on this substrate were: *Navicula* sp., *Tabellaria* sp., *Philodina roseola*, *Oedogonium* sp., *Oocystis irregularis* and *Scendesmus* sp.

**On the glass slide substrate** the periphyton community abundance fluctuated between 1.17 ind/cm² and 39.2 ind/cm² with a pronounced peak in the month of June, 2011. At the time of peak abundance, the group Chlorophyceae was dominant and shared about 58 % of the total. On annual mean basis, the group Chlorophyceae dominated the periphyton community and shared about 58% of the total. Another important group was Bacillariophyceae, which shared 34 % of the total. The
insignificant groups together constituted 8% of the total. Based on IVI, *Navicula* sp., *Pediastrum duplex*, *Tabellaria* sp., *Philodina roseola*, *Chironomus* sp., *Oocystis irregularis* and *Scenedesmus* sp. were found to be dominant.

With regard to distribution pattern of periphyton in Lake Nainital, it was observed that the minimum number of species occurred on stone substrate, while the maximum number of species was recorded on glass slide substrate. The maximum community abundance was found on twig substrate (20.2±4.8 ind/cm²) and the minimum was recorded on glass slide substrate (5.8±8.7 ind/cm²). The group Bacillariophyceae preferred the twig substrate as their concentration was maximum (9.9±6.2 ind/cm²) on this substrate. The Chlorophyceae showed the pattern similar to that of Bacillariophyceae. Here too, the maximum abundance was recorded on twig substrate.

In Bhimtal lake, the community abundance of periphyton on natural stone substrate varied from 11.2 ind/cm² to 90.9 ind/cm² with 4 peaks. The highest peak occurred in September, 2011. At the time of highest peak, group Bacillariophyceae was the most dominant and shared 58% of the total community abundance. On annual mean basis, Bacillariophyceae was the most dominant group and it shared 58% of the total periphyton standing crop. The second dominant group was Chlorophyceae, which contributed 38% to the total community abundance. The remaining groups together contributed 4% to the total. On the basis of IVI, 8 species were found to be dominant. These were: *Navicula* sp., *Closteriopsis longissima*, *Cymbella* sp., *Tabellaria* sp., *Philodina roseola*, *Chironomus* sp., *Gomphoneis* sp. and *Oedogonium* sp.

On twig substrate, the periphyton community abundance varied from 13 ind/cm² to 159.5 ind/cm² with four peaks during a year cycle. During the highest peak, group Bacillariophyceae was most dominant with 92.4% share. On annual mean basis, group Bacillariophyceae was the most significant group and it shared as much as 64% of the total. The second important group was Chlorophyceae with 35% share. All the remaining groups together constituted 1% of the periphyton standing crop. The dominant species on the basis of IVI were: *Navicula* sp., *Cymbella* sp.,

105
Closteriopsis longissima, Tabellaria sp., Chironomus sp., Philodina roseola, Gomphoneis sp., Vorticella sp. and Oedogonium sp.

The community abundance of periphyton colonized on glass slide substrate varied from 1.6 ind/cm² to 22.5 ind/cm² with two peaks of abundance. At the time of highest peak (June, 2011) the group Bacillariophyceae was dominant and shared about 19 % of the total. On annual mean basis, group Chlorophyceae was the most significant group and contributed about 66 % of the community abundance. The next dominant group was Bacillariophyceae with 31 % share. The remaining groups were insignificant and together contributed 3 % to the total. On this substrate, based on IVI, the dominant species were: Navicula sp., Cymbella sp., Closteriopsis longissima, Tabellaria sp., Cosmarium sp. and Chironomus sp.

The distribution pattern of periphyton in Lake Bhimtal revealed that in this lake also, the minimum number of species was recorded on stone substrate and the maximum number was noticed on glass slide substrate. The maximum community abundance was noticed on twig substrate (68±50 ind/cm²), while the minimum was observed on the glass slide substrate (8.5±7.3 ind/cm²). The twig substrate supported the maximum number of all groups, while the glass slide contained the lowest number of individuals of all groups.

Overall, the diversity indices of periphyton across substrates and months ranged from 0.39 to 4.23 in Lake Nainital and from 0.41 to 3.26 in Lake Bhimtal. The concentration of dominance ranged from 0.07 to 0.91 in Nainital lake and from 0.10 to 0.99 in Bhimtal lake.

In Lake Nainital, the simple correlation coefficient curves between community abundance of periphyton and several physico-chemical properties of the water on three substrates indicated that the community abundance of the periphyton on stone substrate was positively related with free CO₂ and BOD and negatively related with pH, temperature, DO, PO₄-P, and NO₃-N. On twig substrate, the community abundance was positively related with free CO₂, BOD and PO₄-P and negatively related with pH, temperature, DO and NO₃-N. On glass slide substrate, it
showed positive relationship with temperature, DO and NO$_3$-N while negative relationship was found with pH, free CO$_2$, BOD and PO$_4$-P concentration. Nevertheless the statistics suggested that the relationship was only significant (p<0.05) with nitrate-nitrogen concentration on stone substrate.

In the Bhimtal lake, the situation was more or less similar. Here too, the community abundance on stone substrate was positively related with free CO$_2$ and BOD and negatively related with pH, temperature, DO, NO$_3$-N and PO$_4$-P. Some of the factors (viz, water temperature and nitrate-nitrogen concentration) showed significant relationship (p<0.05) with community abundance. On twig substrate, the community abundance showed positive relationship with BOD and PO$_4$-P and negative relationship with pH, DO, free CO$_2$ and NO$_3$-N concentration. On this substrate, only one parameter i.e., pH was significantly (p<0.10) correlated with community abundance. The community abundance on glass slide substrate was positively related with temperature, DO and PO$_4$-P concentration, while it was negatively related with pH, free CO$_2$, NO$_3$-N and BOD. On this substrate, two parameters namely pH and phosphate-phosphorus showed significant relationship (p<0.10 for pH, and p<0.05 for phosphate-phosphorus) with community abundance.

In conclusion, the substrate type appeared to have great influence on species richness, community abundance, species preference and diversity indices of periphyton communities. The glass slide substrate supported maximum number of species, while twig substrate harbored maximum community abundance in both lakes. The Qualitative Similarity Indices of periphyton between two lakes suggested that the two lakes were 85% similar. The interlacustrine variation in periphyton communities was not marked. This indicated almost similar trophic state of the two lakes. Some of the physico-chemical variables of lake water appeared to have significant impacts on periphyton communities. Nitrate-nitrogen (NO$_3$-N) in Lake Nainital and pH and phosphate-phosphorus (PO$_4$-P) in Lake Bhimtal, seemed to be driving forces of community abundance of periphyton.

The results of the study are supported by massive data presented in many figures and tables. More than three hundred references are cited in the thesis.
PHOTOGRAPHS OF PERIPHYTON

Fragillaria sp.

Philodina roseola

Closteriopsis longissima

Pediaserum duplex