Phytoplankton community response to changing physico-chemical environment of subtropical Lake Mansar, India

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Abstract

This paper describes the diversity and community dynamics of phytoplankton group in lake Mansar. A total of 33 phytoplankton taxa were recorded during a period of one year (March-2009 to February-2010) which belonged to three groups i.e. chlorophyceae, bacillariophyceae and cyanophyceae. Members of cyanophyceae dominated phytoplankton population throughout the study with predominance of 3 species of Microcystis i.e. M. elabens, M. pulvera and M. aeruginosa. Bacillariophyceae was dominated by genus Navicula. Overall phytoplankton population peaked in summer while decline was recorded during monsoon season. However, individual phytoplankton groups except cyanophyceae were observed to show maxima in spring season. Maximum value for Shannon diversity (H’ =2.9) was observed in spring season with high values of evenness. Shannon’s diversity and Pielou’s evenness values were observed to be negatively related to both total nitrogen and total phosphorus levels. Thus, with increasing nutrient enrichment due to anthropogenic activities around lake Mansar, not only its water quality is deteriorating but negative impacts may also be inflicted on phytoplankton population and its diversity.

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Introduction

Lake Mansar is one among several Himalayan freshwater lakes in India, which act as a source of water for drinking, irrigation and domestic purposes (Kumar et al., 2006; Chandrakiran & Sharma 2013; Zubair & Ahrar, 2013) and also add in the local economy by attracting tourists from all over the country (Kumar et al., 2006; Rai et al., 2007). But, in past few decades this lake has been facing adverse impacts due to increasing anthropogenic activities like influx of domestic sewage, detergents, animal excrement, fertilizers & pesticides from agricultural land and increased tourist & religious activities. Due to this increased cultural eutrophication, water quality of Lake Mansar has depreciated a lot over last few years (Kumar et al., 2006; Zubair & Ahrar, 2013). Such changes in the water quality are often manifested as change in the biological community of the aquatic environment (Ramo & Villena, 2005; Kucuksezgin et al., 2008; Laskar & Gupta, 2013).

Phytoplankton are the most important floral component of the aquatic environment, which comprised of several groups of algae and bacteria (Reynolds, 1984). Majority of these primary producers form the base of aquatic food chain (Steeman, 1964; Wetzel, 2001) while some actively participate in various chemical / biogeochemical processes (Reynolds, 1984). Being highly heterogeneous (both spatially and temporally), aquatic environment tend to inhabit diverse phytoplanktonic groups at same time and space (Reynolds, 1984). Although the study of abundance and population dynamics of individual taxa or group is important but sometimes this information prove insufficient or complex to study whole community response to various habitat changes like physico-chemical health of water body. Under such circumstances, various diversity indices (Shannon’s, Pielou’s & Simpson’s) can be used as a tool to explain the variability in phytoplankton community with respect to various water quality changes induced either by climate and/or human inflicted (Magurran, 1988; Reynolds, 1998; Sommer et al., 1993; Barnese & Schelske, 1994; Figueredo & Giani, 2001, Kumar et al., 2012). The aim of present study is to investigate seasonal variations in phytoplankton community and its relationship to physico-chemical environment of Lake Mansar. Such assessment can be a great value for understanding the phytoplankton community behavior of other Himalayan lakes which are exposed to similar anthropogenic pressures.

Material and methods

Study area

Lake Mansar is a rural subtropical lake situated in the lower Shivalik Himalayan region (75°5’11.5” to 75°5’12.5”E and 32°40’58.5” to 32°40’59.2” N) at an altitude of 666m above MSL (Fig. 1). It is an important Ramsar site in India with religious and cultural importance due to its historical background. The lake is closed and non-drainage type having a shoreline of 3.4 km and maximum depth of 38 m. It received water from monsoon rains and ground water springs (Goyal et al., 2002; Kumar et al., 2006). Its 2000 ha catchment area is comprised of hills and plains which was utilized for agricultural, wild life sanctuary and human habitation. Lake is facing anthropogenic stress due to continuous upwelling of water (domestic and commercial purposes), dumping of domestic & religious waste, runoff from agricultural land, wild life sanctuary and cremation ground.

Field sampling and analysis of phytoplankton and water samples

The study was conducted from March, 2009 to February, 2010. Qualitative and quantitative analysis
of phytoplankton sample was done by adopting Sedgwick rafter counting cell method and identified using pertinent literature (ICAR, 1959; Edmondson, 1963; Hutchinson, 1975; Anand, 1998). Water samples were collected using van-dorn bottle from the epilimnetic zone of lake and analyzed for physico-chemical parameters including Water temperature, Dissolved oxygen (DO), Free carbon dioxide (FCO₂) Secchi depth transparency, pH, Total Nitrogen (TN) and Total Phosphorus (TP) following standards methods (ISI, 1973; APHA, 2005).

Statistical analysis of data

Various biological indices were calculated including Shannon’s diversity (H’) (Shannon & Weaver, 1949), Pielou’s evenness (J’) (Pielou, 1969) and Simpson’s dominance (Ds) (Stone & Pence, 1978) for analysis of phytoplankton community. Relationship between various physico-chemical variables and diversity indices were analyzed by linear regression models using the statistical software program R 2.13.1 (R Development Core Team 2011).

Results and discussion

Water quality parameters

Physico-chemical properties of water like DO, pH, temperature and nutrients are highly important in determining flora and fauna of a water body (Wetzel, 2001; Kucuksezgin et al., 2008; Kumar et al., 2012; Laskar & Gupta, 2013). All the physico-chemical parameters except DO and pH varied to a large extent during the period of study (Fig. 2 & Table 1). Water temperature was above 20°C from the month of March till September with lowest of ~15°C in December and January. Overall seasonal difference in water temperature is directly related to the duration of photoperiod and intensity of solar radiations. pH remained moderately alkaline mostly above 8.2 during July to October. High pH during monsoon was attributed to the agitation and dilution of lake water with rains (Wetzel 2001; Ahmed 2004; Sharma et al., 2013) and leaching of carbonates from lake catchment area into the lacustrine ecosystem (Kumar et al., 2006 and Zuber & Ahrar, 2013). Free carbon dioxide remained low during spring but attained as high as 19 mg/L during winter season. Low FCO₂ in spring was perhaps a consequence of the increased photosynthetic uptake of carbon dioxide by the increased biomass of phytoplankton and macrophytes (Wetzel, 2001; Sharma et al., 2013). Water remained oxic throughout the season ranging from 3.7 mg/l to 5.8 mg/l. Total phosphorus (TP) ranged from 0.06mg/l to 0.48 mg/l while total nitrogen (TN) from 0.17mg/l to 0.68 mg/l. Both nutrients showed peaks in monsoon and winter seasons. Higher values of total phosphorus in lake Mansar indicated its eutrophic to hyper eutrophic status. A similar finding about its trophic status was also reported by Kumar et al. (2006).

Table 1. Summary statistics for diversity indices and water quality variables for Lake Mansar.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Max</th>
<th>Min</th>
<th>Mean</th>
<th>SD</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shannon’s diversity (H‘)</td>
<td>2.95</td>
<td>2.14</td>
<td>2.48</td>
<td>0.27</td>
<td>10.8</td>
</tr>
<tr>
<td>Evenness Index (J’)</td>
<td>0.91</td>
<td>0.78</td>
<td>0.87</td>
<td>0.05</td>
<td>5.74</td>
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<tr>
<td>Dominance Index (Ds)</td>
<td>0.18</td>
<td>0.07</td>
<td>0.12</td>
<td>0.03</td>
<td>25</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>30.75</td>
<td>15.25</td>
<td>22.90</td>
<td>5.56</td>
<td>24.27</td>
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<tr>
<td>Secchi transparency (cm)</td>
<td>56.88</td>
<td>25.00</td>
<td>34.41</td>
<td>10.49</td>
<td>30.48</td>
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<tr>
<td>DO (mg/L)</td>
<td>5.80</td>
<td>3.70</td>
<td>4.63</td>
<td>0.76</td>
<td>16.4</td>
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<tr>
<td>FCO₂ (mg/L)</td>
<td>19.00</td>
<td>0.00</td>
<td>5.17</td>
<td>6.11</td>
<td>118.1</td>
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<tr>
<td>pH</td>
<td>8.68</td>
<td>7.75</td>
<td>8.14</td>
<td>0.38</td>
<td>4.66</td>
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<tr>
<td>Total Nitrogen (mg/L)</td>
<td>0.68</td>
<td>0.17</td>
<td>0.36</td>
<td>0.15</td>
<td>41.66</td>
</tr>
<tr>
<td>Total Phosphorus (mg/L)</td>
<td>0.48</td>
<td>0.06</td>
<td>0.22</td>
<td>0.13</td>
<td>59.09</td>
</tr>
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</table>

Phytoplankton community composition, diversity indices and its relation to water quality

Phytoplankton community of Lake Mansar comprised of 33 taxa, of which 13 belong to chlorophyceae, 11 to cyanophyceae and 9 to bacillariophyceae (Table 2). Qualitatively, chlorophyceae was most abundant group with 4 representing orders viz. volvocales (1),
chlorococcales (7), oedogoniales (1) and zygnematales (4) while bacillariophyceae and cyanophyceae were represented by 1 order each (Table 2). Phytoplankton population dynamics indicated bimodal peaks during summer and autumn season. A most common cyanophyceae genus was *Microcystis* while few nitrogen fixing nostocales were also recorded. However, bacillariophyceae was dominated by genus *Navicula*. Individual phytoplankton population dynamics clearly indicated that both chlorophyceae and bacillariophyceae groups showed maxima in spring season while with increasing temperature in summer months, the community shifted to cyanophyceae abundance. Analysis of relative percentages of three phytoplankton groups to the total population clearly suggested the dominance of cyanophyceae (more than 50%) throughout the study period (Fig. 3).

**Table 2.** List of phytoplankton taxa present in Lake Mansar during the period of study (March-2009 to February-2010).

<table>
<thead>
<tr>
<th>Phytoplankton Taxa</th>
<th>Mar, 09</th>
<th>Apr, 09</th>
<th>May, 09</th>
<th>Jun, 09</th>
<th>Jul, 09</th>
<th>Aug, 09</th>
<th>Sep, 09</th>
<th>Oct, 09</th>
<th>Nov, 09</th>
<th>Dec, 09</th>
<th>Jan, 10</th>
<th>Feb, 10</th>
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<tr>
<td><strong>CLASS: CHLOROPHYCEAE</strong></td>
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<tr>
<td>Order - Volvocales</td>
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<td>Order - Chlorococcales</td>
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<td>Order - Oedogoniales</td>
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<td>Order - Zygnematales</td>
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<td><strong>CLASS: BACILLARIOPHYCEAE</strong></td>
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<td>Order - Centrales</td>
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<td>Order - Famiilies</td>
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<td><strong>CLASS: CYANOPHYCEAE</strong></td>
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<td>Order - Bacillariaceae</td>
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<tr>
<td><strong>Total no. of species</strong></td>
<td>31</td>
<td>33</td>
<td>33</td>
<td>29</td>
<td>28</td>
<td>24</td>
<td>22</td>
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</table>
Temporal variation in phytoplankton community composition suggested that different algal groups registered its peaks in different seasons. Such variations in the peaks in the populations of different algal groups in relation to total density suggest that different species require different optimal conditions for their presence, survival and multiplication/growth (Reynolds, 1984; Palmer, 1980; Watson et al., 1997; Litchman et al., 2007). Summer peak in total phytoplankton population (mainly contributed by cyanophyceae) was due to higher temperature, alkaline pH and increased phosphorus content in water. Several workers were of the opinion that higher temperature, nitrate, phosphate and pH are some of the favorable factors for cyanophycean growth (Fritsch, 1907; Prescott, 1948; Singh & Swarup, 1980; Tripathi & Pandey, 1990, Neil et al., 2012). Moreover, various other workers emphasized that the elevation in water temperature (greater than 20°C) trigger the growth of bloom forming Cyanophyceae taxa which has competitive advantage over other phytoplankton groups (Paerl & Huisman, 2009; Paerl et al., 2011; Neil et al., 2012). Decline in phytoplankton population in monsoon was a result of flushing due to incessant rain in regions which also hamper light penetration decreasing photosynthesis. Similar opinion was also proposed by various workers who suggested that heavy rainfall, over flooding, dilution and turbidity are the factors responsible for the reduced population of phytoplankton during monsoon season despite of increased nutrient levels during the period (Tripathi & Pandey, 1990; Kumar & Gupta, 2002; Laskar & Gupta, 2013).

Fig. 2. Seasonal variation in Temperature (°C), Secchi (cm), pH, FCO2 (mg/l), DO (mg/l), TN (mg/l) and TP (mg/l) in Lake Mansar (March-2009 to February-2010).

Fig. 3. Seasonal variation in (A) population dynamics and (B) relative percentage of different phytoplankton groups in Lake Mansar (March-2009 to February-2010).

Fig. 4. Seasonal variation in the phytoplankton community indices in Lake Mansar (March-2009 to February-2010).

Fig. 5. Seasonal variations in Shannon’s diversity index ($H'$), Pielou’s evenness ($J'$) and Simpson’s dominance index (D) over entire study period was illustrated in Fig. 4. Maximum values for Shannon diversity and Pielou’s evenness were observed in spring season recorded by decline during early monsoon season. However, values of Simpson’s dominance (Ds) remained low throughout the study. Results for the
relationship between nutrients and the phytoplankton community indices are indicated in Fig. 5. Significant negative relationships were recorded between Shannon’s diversity index and both TN ($R^2 = -0.78$) & TP ($R^2 = -0.42$). Similarly, Pielou’s evenness was also negatively related to both TN ($R^2 = -0.73$) and TP ($R^2 = -0.53$) (Fig. 5b). Maximum Shannon’s diversity and Pielou’s evenness in spring were perhaps due to the presence of most of phytoplankton taxa during spring and early summer season (Laskar and Gupta, 2009) but community later shifted to abundance of cyanophyceae members thereby reducing the diversity. Gerritsen et al. (1998) suggested that the higher the number and distribution of species in a community, greater is values for shannon’s diversity. Also, shannon’s diversity is more sensitive to rare species rather than the abundance of some common species among community (Mukhopadhyay et al., 2006). Ramo and Villena (2005) also observed that both diversity and richness tended to decrease with the increasing nutrient concentration in Mediterranean lakes.

**Conclusion**

Thus, present study revealed that the phytoplankton community in lake Mansar mainly dominated by members of cyanophyceae throughout the period of investigation. With the increased eutrophication, the phytoplankton population has shifted to cyanophyceae abundance thereby reducing the diversity and evenness in the community. Thus, this study emphasizes on restoring the lake trophic status in terms of water quality and its plankton richness by reducing the external loading of nutrient from the catchment.

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