Limnological Study on two High Altitude Himalayan Ponds, Badrinath, Uttarakhand

Pramod Kumar¹*, Ashwani Wanganeo¹, Fozia Sonaullah¹, Rajni Wanganeo²

¹Department of Environmental Sciences and Limnology, Barkatullah University, Bhopal, 462026, India
²Department of Zoology, Jayawanti Haksar Govt. P.G. College, Betul, M.P., India

Abstract Present study has been done on two high altitude Himalayan ponds situated near the Badrinath temple, Uttarakhand (India). During the investigation physico-chemical and biological analysis (Phytoplankton & Zooplankton) were carried out at two selected sites one in each pond. A total 131 species of phytoplankton and 51 species of zooplankton were encountered from both the ponds. Among phytoplankton, class Cyanophyceae was the most dominant whereas, among zooplankton Rotifera was the dominant class during the study period. Most of the phytoplankton and zooplankton species recorded from both the water bodies are indicators of higher trophic status. Physico-chemical features of ponds showed the nutrient rich water of both the ponds. Presence of various planktonic species and higher trophic status of both the ponds at high altitude showed the impact of high anthropogenic pressure as well as favourable environmental factors like temperature. Also, the impact of global warming on micro flora and fauna present in water bodies situated at high altitude has been discussed. Present study is preliminary work on these two ponds which will provide the baseline data for the further studies. Some further studies required to establish the importance of various environmental factors which are responsible for the growth of more planktonic species at higher altitudes.

Keywords Himalayan Ponds, Water Quality, Plankton Population, Trophic Status

1. Introduction

The aquatic habitats situated in mountains are some of the most sensitive indicators of environmental change[1]. Their high elevation leads to increased exposure to ultraviolet radiation as well as a shortened growing season that aggravates plankton populations due to both temperature and light limitations[2].

In order to assess the various limnological characteristics of the ponds, their physico-chemical and planktonological analysis was carried out. Study of planktonic population in relation to water chemistry provides the basic information of entire ecology of the pond.

Plankton are considered indicators of the different trophic status of a water body because of their specific qualitative features and their capacity to reproduce in large number under environmental conditions that are favourable to them[3] and they used for pollution surveillance[4,5-6].

Plankton are important part of aquatic life and good indicator of changes in water quality because they are strongly affected by environmental conditions and responds quickly to changes in environmental quality. Apart from primary production, phytoplankton play an important role as food for herbivorous animals and act as biological indicators of water quality in pollution studies while, zooplankton occupy a vital role in the trophic structure of an aquatic ecosystem and play a key role in the energy transfer. Hence qualitative and quantitative assessments of plankton are of great importance.

The ponds are infested with macrophytic vegetation. The ponds receive glacial melt water besides runoff from the surrounding areas. These ponds are subject to high anthropogenic pressure by both local and tourists. The aim of this paper is to determine the overall role of anthropogenic pressure on these glacial fed ponds.

2. Material and Methods

Physico-chemical analysis of water samples was carried out following the standard methods as given in[7-8]. Water samples were directly collected from the surface of the pond for physico-chemical analysis and for the qualitative enumeration of planktonic population surface water samples were collected from different locations mainly from central part of the ponds. Plankton samples were filtered with the help of plankton net made of bolting silk of mesh size 20μ and concentrated samples were preserved with 1ml of Lugol’s solution simultaneously in 100ml vials. The concentrated samples were examined under the inverted
microscope and identification of plankton was done using the following taxonomic references [9-21].

The inter-relationships between the different planktonic communities present in both the ponds were calculated by Jaccard’s similarity index [22]

\[ CC_i = \frac{C}{\left(S_1 + S_2 - C\right)} \]

Where,
- \( CC_i \) = Jaccard coefficient of community similarity
- \( S_1 \) = Number of species present in community 1
- \( S_2 \) = Number of species present in community 2
- \( C \) = Number of species common in both the communities

3. Study Area

Both the selected ponds are situated at high altitude Himalayan region near Indo-Tibet boarder in Chamoli district of Uttarakhand. The place is popularly known as Badrinath (an important holy place of India). The Badrinath town is situated in the cold climatic condition of Garhwal hills, on the banks of the Alaknanda River at an elevation of 415 meters. The town lies between the Nar and Narayana mountain ranges and in the shadow of Nilkantha peak, most of the period it was covered by snow. The location and important features of both the ponds have been mentioned in Table 1 and Figure 1.

4. Results and Discussion

The physico-chemical environment mainly controls the biological diversity [23, 24-25]. Physico-chemical features of the ponds are given in table 2 and planktonic flora and fauna are enlisted in tables 3 and 4 respectively.

During the present study air temperature of 22°C and water temperature of 18°C was observed at both the sampling sites. This optimum water temperature in both the ponds supports high biological population. The water colour of both the ponds was observed to be dark green due to the good growth of various algal species. The low transparency values of 36 cm and 40 cm was recorded in pond 1 and pond 2 respectively due to the dominance of green algae (table 2). Low transparency also indicates the eutrophic nature of pond waters [26-27]. The low transparency value in some of the high altitude Kashmir Himalayan water bodies has been attributed to the incoming silt from the catchment [28-29].

| Features         | Pond-1                | Pond-2                |
|------------------|-----------------------|-----------------------|
| Location         | Badrinath             | Badrinath             |
| Type             | Natural               | Natural               |
| Latitude         | 79°29'39.19''E        | 79°29'43.25''E        |
| Longitude        | 30°44'35.54''N        | 30°44'42.30''N        |
| Altitude (m)     | 3.45                  | 3.42                  |
| Maximum length (m) | 144                  | 92                    |
| Minimum width (m) | 62                   | 85                    |
| Maximum depth (m) | 1                    | 1.5                   |
| Average depth (m) | 0.5                  | 0.5                   |
| Source of water  | Rain water, Ice melts | Rain water, Ice melts |

| Parameters                  | Pond-1 | Pond-2 |
|-----------------------------|--------|--------|
| Air temperature (°C)        | 22     | 22     |
| Water temperature (°C)      | 18     | 18     |
| Depth (m)                   | 1      | 1.5    |
| Transparency (cm)           | 36     | 40     |
| pH                          | 8.1    | 7.9    |
| TDS (ppm)                   | 470    | 510    |
| Conductivity (µS/cm²)       | 660    | 650    |
| Free CO₂ (mg/l)             | 4.6    | 5.2    |
| Dissolved oxygen (mg/l)     | 8.4    | 8.8    |
| Ph. alkalinity (mg/l)        | Absent | Absent |
| Total alkalinity (mg/l)      | 116    | 120    |
| Chloride (mg/l)             | 212    | 232    |
| Total hardness (mg/l)        | 130    | 168    |
| Calcium hardness (mg/l)      | 44     | 56     |
| Mg. content (mg/l)          | 20.8   | 27     |
| Orthophosphate (mg/l)       | 0.056  | 0.049  |
| Nitrate (mg/l)              | 0.38   | 0.43   |

Alkaline pH of 8.1 units (pond 1) and 7.9 units (pond 2) indicating productive nature of pond waters. Free CO₂ recorded a value of 4.6 mg/l to 5.2 mg/l in pond 1 and pond 2 respectively. Phenolphthalein alkalinity was absent in both the ponds. Total alkalinity of 116 mg/l and 120 mg/l was recorded for pond 1 and pond 2 respectively. Water bodies having total alkalinity above 50 mg/l can be considered productive in nature [30] (table 2). TDS value of 470 ppm and 510 ppm for pond 1 and 2 respectively, indicate regular interference from respective catchment area. The high specific conductivity values of 660 µS/cm and 650 µS/cm signify high amount of anthropogenic pressure [31-27].
Water bodies having conductivity values greater than 500 μS/cm are considered as eutrophic in nature[32]. Chloride content of 212 mg/l and 232 mg/l respectively again signify the impact of anthropogenic pressure (table 2). A value of 8.4 mg/l and 8.8 mg/l of Dissolved oxygen in surface waters of both the ponds suggested good growth of autotrophs.

![Figure 2. Classwise percentage composition of Phytoplankton population in both the ponds](image1)

![Figure 3. Classwise percentage composition of Zooplankton population in both the ponds](image2)

![Figure 4. Overall species composition of Phytoplankton and Zooplankton recorded from both the ponds](image3)

| Table 5. Species contribution of different planktonic groups in both the selected Pond |
|------------------------------------------|----------|----------|-----------------|----------|----------|
| Phytoplankton                           |          |          | Zooplankton     |          |          |
| Chlorophyceae                           | 46       | 44       | Rotifera        | 16       | 19       |
| Bacillariophyceae                       | 34       | 34       | Protozoa        | 11       | 9        |
| Cyanophyceae                            | 28       | 29       | Cladocera       | 7        | 8        |
| Euglenophyceae                          | 8        | 7        | Copepoda        | 6        | 6        |
| Dinophyceae                             | 1        | 1        | Ostracoda       | 3        | 2        |
| Xanthophyceae                           | 1        | 1        |                 |          |          |
| **Total**                               | **118**  | **116**  | **Total**       | **43**   | **44**   |
Total hardness values of 130 mg/l and 168 mg/l was observed in pond 1 and pond 2 respectively. On the basis of hardness values water of both the ponds is of hard water type. Calcium hardness of 44mg/l and 56 mg/l and Magnesium contents 20.8 mg/l and 27 mg/l recorded for pond 1 and pond 2 respectively suggest that both the ponds are Calcium rich. The water bodies rich in Calcium and Magnesium ions have thick population of algae[33]. In the present study 0.056 mg/l (pond 1) and 0.049 mg/l (pond 2) of Orthophosphate; and 0.38 mg/l (pond 1) and 0.43 mg/l (pond 2) of Nitrate values were recorded (table 2). These values of Orthophosphate and Nitrate indicated the healthy mesotrophic status of pond waters[34].

Besides physico-chemical features, observations on changes in planktonic diversity are generally considered a necessity in evaluating the impact of environmental changes on an aquatic system, especially phytoplankton that show changes with the changes in the environmental factors[35]. Plankton are very significant tool for observing the continuous changes in the environmental conditions at higher altitudes. They are the most sensitive micro organisms that respond quickly to any change in the ecological condition. Hence, they can be used as ecological indicators. They are able to grow at higher altitudes as compared to other macro flora and fauna.

During the present period of investigation, a total of 118 and 116 phytoplankton species have been recorded from pond 1 and pond 2 respectively (table 3).

From the pond 1, 46 species (39%) of Chlorophyceae; 34 (29%) species of Bacillariophyceae; 28 (23%) species of Cyanophyceae; 8 (7%) species of Euglenophyceae and 1 (1%) specie each of Dinophyceae and Xanthophyceae were recorded (table 5 & figure 2).

In the pond 2, Chlorophyceae contributed 44 species (38%) of the total phytoplankton population followed by Bacillariophyceae 34 species (29%); Cyanophyceae 29 species (25%) and Euglenophyceae 7 species (6%) respectively. Class Dinophyceae and Xanthophyceae contributed Ispecie (1%) each towards the total phytoplankton respectively (table 5 & figure 2).

### Table 3. Composition of Phytoplankton Population of Badrinath pond

| Chlorophyceae | Pond-1 | Pond-2 |
|---------------|--------|--------|
| Botryococcus braunii | + | + |
| Actinastrum hantzschii | + | + |
| Ankistrodesmus falcatus | + | + |
| Ankistrodesmus sp. | + | - |
| Calothrix sp | + | + |
| Chlorella sp. | + | + |
| Chlorella vulgaris | + | + |
| Chlorococcus sp. | + | + |
| Closteriopsis sp. | + | + |
| Closterium parvulum | + | + |

| Bacillariophyceae | |
|------------------|---|
| Achnanthus lanceolata | + | + |
| Achnanthes minutissima | + | + |
| Amphora ovalis            | + | + |
|--------------------------|---|---|
| Anomooneis sphaerophora  | + | + |
| Ceratonia arcus          | + | + |
| Cocconeis sp.            | + | + |
| Cocconeis placenta       | + | - |
| Cyclotella sp.           | + | + |
| Cymbella affinis         | + | + |
| Cymbella ventricosa      | + | + |
| Cymbella tumida          | + | + |
| Diploneis sp.            | + | + |
| Epithemia sp.            | + | - |
| Eunotia sp.              | + | + |
| Fragilaria sp.           | + | + |
| Fragilaria intermedia    | + | + |
| Gomphorema lanceolatum   | + | + |
| Gomphorema lucas rankala | + | - |
| Gomphorema montanum      | + | + |
| Gomphorema sphaerophonum | + | + |
| Melosira granulata       | + | + |
| Navicula sp.             | + | + |
| Navicula cryptocophala   | + | + |
| Navicula grimmii         | + | - |
| Navicula rostellata      | + | + |
| Navicula subrhyncocephala| + | + |
| Navicula subtilissima    | + | + |
| Navicula tumida          | + | + |
| Nitzschia sp.            | + | + |
| Nitzschia capelliata     | - | + |
| Nitzschia palea          | + | + |
| Nitzschia sigma          | + | + |
| Pinnularia sp.           | + | + |
| Pinnularia interrupta    | + | + |
| Pleurosigma sp.          | + | + |
| Synedra ulna             | + | + |
| Synedra ulna var. biceps | + | + |
| Tabilaria sp.            | + | + |
| Cyanophyceae             |    |    |
| Anacystis sp.            | + | + |
| Anabaena navicoloides    | + | + |
| Anabaena spiroides       | + | + |
| Aphanocapsa muscoscola   | + | + |
| Aphanocapsa montana     | - | + |
| Aphanocapsa koordesii    | + | + |
| Aphanotheca saxicola     | + | + |
| Aphanizomenon flos-aquae | + | - |
| Arthospira platensis     | + | + |
| Ceroococcus sp.          | + | + |
| Cylindrospum sp.         | + | + |
| Cylindrospum stagnale    | + | + |
| Gloeocapsa sp.           | + | + |
| Gloeocapsa atrata        | - | + |
| Limnothrix kaehbornii     | + | + |
| Lyngbya martensiana      | + | + |
| Lyngbya versicolor       | + | - |
| Merismopedia tenuissima  | - | + |
| Microcystis aenginosa    | + | + |
| Microcystis flos-aquae   | + | + |
| Nostoc commune           | + | + |
| Oscillatoria curvipes    | - | + |
| Oscillatoria limnetica   | + | - |
| Oscillatoria limosa      | + | + |
| Oscillatoria peronata    | + | + |
| Oscillatoria princeps    | + | + |
| Oscillatoria pseudogeminata | + | + |
| Oscillatoria rubescens   | + | + |
| Oscillatoria subbreviis  | + | + |
| Phormidium tenue         | + | + |
| Raphidopsis sp.          | + | + |
| Spinulina major          | + | - |
| Spinulina lacissima      | + | + |
| Euglenophyceae           |    |    |
| Euglena sp.              | + | + |
| Euglena acus             | + | + |
| Euglena vagans           | + | - |
| Euglena proxima          | + | + |
| Euglenomorpha sp.        | + | + |
| Lepocinclis sp.          | + | + |
| Trachelomonas armata     | + | + |
| Trachelomonas playfairii | - | + |
| Trachelomonas oblonga    | + | - |
| Dinophyceae              |    |    |
| Ceratium sp.             | + | + |
| Xanthophyceae            |    |    |
| Tribonema sp.            | + | + |
The class wise dominance of phytoplankton population in both the ponds was same. Among phytoplankton, class Chlorophyceae showed its maximum dominance in both the selected ponds followed by Bacillariophyceae, Cyanophyceae, Euglenophyceae, Dinophyceae and Xanthophyceae (table 5). During the investigation it was observed that both the ponds were infested with macrophytic vegetation besides algal blooms in the surface waters. Maximum planktonic diversity was observed nearby macrophytic vegetation in the Himalayan water bodies [36].

Maxim um planktonic diversity was observed nearby vegetation besides algal bloom s in the surface waters. Observed that both the ponds were infested with macrophytic vegetation in the Himalayan water bodies [36]. The species recorded from the Badrinath ponds reflected higher anthropogenic impact supporting good growth of planktonic flora and fauna.

Generally, Bacillariophyceae are found as dominant group in temperate water bodies because diatoms are able to grow under the conditions of weak light and low temperature which are less suitable for the other phytoplankton groups [35-37]. But, during the present investigation Chlorophyceae was recorded as dominant among all the phytoplankton groups on account of relatively high temperature and nutrient condition.

Most dominant genus of phytoplankton encountered from both the ponds was Scenedesmus, Tetraedron, Cymbella, Gomphonema, Navicula, Nitzschia, Oscillatoria, Aphanocapsa, Euglena and Trachelomonas (table 3). Each of these genus are known to indicate polluted waters [38].

Among Phytoplankton, Elkatotrix sp., Tetraedron muticum and Tetraedron trilobatum of Chlorophyceae; Cocconies placentula, Navicula tumida, Nitzschia capitellata of Bacillariophyceae; Aphanocapsa Montana, Gloeocapsa atrata, Merismopedia temuissima, Oscillatoria curviceps, Spirulina of Cyanophyceae; Trachelomonas playfairii of Euglenophyceae were not recorded from pond 1 whereas, Ankistrodesmus sp., Pandorina cylindricum, Schroderia setigera, Staurastrum sp., Tetraedron gracile of Chlorophyceae; Epithemia, Gomphonema lucas rankala, Navicula grimmii of Bacillariophyceae; Aphanizomenonflosaquae, Lyngbya versicolor, Oscillatoria limnetica of Cyanophyceae and Trachelomonas oblonga of Euglenophyceae were absent in pond 2 (table 3).

During the present study a total of 39 and 40 zooplankton species were recorded from pond 1 and pond 2 respectively. During the present investigation Rotifera contributed 16 species (37%) of the total zooplankton population in the pond 1 followed by Protozoa 11 species (26%); Cladocera 7 species (6%); Copepoda 5 species (14%) and Ostracoda 3 species (7%) respectively (figure 3 and table 4). In pond 2 Rotifera again dominated the group with 19 species (43%) followed by Protozoa 9 species (20%); Cladocera 8 species (18%); Copepoda 5 species (14%) and Ostracoda 2 species (5%) (figure 3 and table 4).

An overall dominance of Rotifera in both the ponds under present investigation indicates that the ponds are under the influence of eutrophication. In various temperate water bodies predominance of Rotifera has been reported by various workers [39-46].

Rotifer species viz., Asplanchna brightwelli, Brachionus angularis, Brachionus bidentata, Brachionus calyciflorus, Brachionus caudatus, Brachionus forficula, Brachionus falcatus, Cephalodella gibba, Cephalodella catelia, Filinia longiseta, Keratella cochlearis, Keratella tropica, Keratella quadrata, Lecane sp., Lecane closterocera, Lecane luna and Polyarthra vulgaris recorded in the present investigation have also been reported from a highly eutrophic pond [27] and most of these species have been considered as indicators of eutrophication [29, 36, 42-46].

Table 4. Composition of Zooplankton Population of Badrinath pond

| Name of the Taxa       | Pond 1 | Pond 2 |
|------------------------|--------|--------|
| **Protozoa**           |        |        |
| Arcella discaoides     | +      | -      |
| Arcella vulgaris       | +      | +      |
| Centropyxis ecornis    | +      | +      |
| Diffugia cuminata      | +      | +      |
| Diffugia sp.           | +      | +      |
| Glenodinium sp.        | +      | +      |
| Oxytricha sp.          |        | +      |
| Paramoecium sp.        | +      | -      |
| Tardigrade sp.         | +      | +      |
| Vampyrella sp.         | +      | -      |
| Vorticella sp.         |        | -      |
| **Rotifera**           |        |        |
| Asplanchna brightwelli | +      | +      |
| Brachionus angularis   | +      | +      |
| Brachionus bidentata   |        | -      |
| Brachionus calyciflorus| -      | +      |
| Brachionus caudatus    | +      | +      |
| Brachionus forficula   | +      | +      |
| Brachionus falcatus    | -      | +      |
| Bosmina sp.            | +      | -      |
| Cephalodella gibba     | -      | -      |
| Cephalodella catelia   | +      | +      |
| Filinia sp.            | -      | +      |
| Filinia longiseta      | -      | +      |
| Keratella cochlearis   | +      | +      |
| Keratella tropica      | +      | +      |
| Keratella quadrata     | -      | +      |
| Lecane sp.             | +      | +      |
| Lecane closterocera    | -      | +      |
| Lecane luna            | +      | +      |
| Monostyla (Lecane)     | +      | +      |
Protozoa recorded as second dominant class in both selected ponds was mostly represented by Arcella discoids, Arcella vulgaris, Centropyx ecornis, Diffugia cuminata, Diffugia sp., Paramoecium sp. and Tardigrade sp. These species are indicators of higher trophic status by [24, 27, 47-49].

In general low Cladocera and Copepod species were recorded in both the ponds. Among Cladocera, all the species listed in table 5 grow well in nutrient rich waters [7, 24-27, 36, 46]. All the species belonging to Copepods namely Arctodiaptomus dorsalis, Cyclops sp., Diaptomus sp., Mesocyclops hyalinus, Nauplius larvae, Thermocylops crassus; and three species of Ostracoda viz., Cyprinotus glaucescens, Theromyctops crassus, Mesocyclops hyalinus were reported as pollution indicators [24-27,46,50-52]. Arctodiaptomus dorsalis dominates the crustacean zooplankton in moderately productive water bodies [53] and cannot survive under conditions of low food concentrations [54]. In water bodies at higher latitudes and altitudes, Arctodiaptomus dorsalis may appear mainly in the warmer seasons. It is often dominant in eutrophic water bodies [55-56].

Among Zooplankton, Brachionus calyciflorus, Brachionus plicatilis, Cephotodella gibba, Filinia longiseta, Lecane closterocera of Rotifera; and Alona intermediate and Chydorus sphaericus of Cladocera were not recorded in pond 1, whereas, Vorticella sp., Paramoecium sp. of Protozoa; Brachionus bidentata, Bosmina sp., Keratella quadrata of Rotifera; Pleuroxus denticulate of Cladocera and Stenocypris sp., of Ostracoda was not recorded from pond 2 (table 4).

Jaccard’s similarity index showed that the species belongs to Dinophyceae and Xanthophyceae are 100% similar at both the sites while the species belonged to Bacillariophyceae showed 89% similarity followed by Chlorophyceae 84%, Cyanophyceae 78% and Euglenophyceae 67% between both the ponds. Among zooplankton Copepoda showed 100% similarity followed by 82% of Protozoa and 67% each of Rotifera, Cladocera and Ostracoda between both the ponds (table 6).

The overall qualitative class wise species contribution of phytoplankton and zooplankton of both ponds have been shown in figure 4. The maximum contribution was made by Chlorophyceae and minimum by Dinophyceae among phytoplankton while Rotifera contributed maximum and Ostracoda minimum among zooplankton population.

The presence of more diversity of planktonic flora and fauna at high altitudes showed the favourable environmental conditions for their growth. Both the ponds are situated at base of high mountains and during the high precipitation the nutrient rich run off settled in the ponds and increased the trophic levels and creates the favourable conditions for the growth of planktonic population. The changes in physico-chemical parameters led to increase in diversity of planktonic flora and fauna in high altitude Himalayan water bodies [57]. Besides the anthropogenic pressure, impact of global climate changes also supports the microscopic life to grow in aquatic systems situated at higher altitude.

5. Conclusions

The biological as well as physico-chemical result of both the ponds indicate the significant role of anthropogenic activity for growth of planktonic diversity and their distribution. Generally, water bodies situated at higher altitudes are oligotrophic and do not support the diverse groups of planktonic flora and fauna. But species recorded during present investigation are the classic indicators of a shift from oligotrophic (Low productivity) conditions to...
which will provide the baseline data for the further studies.

REFERENCES

[1] Williamson C. E., Dodds W., Kratz T. K. & Palmer M. A. Lakes and streams as sentinels of environmental change in terrestrial and atmospheric processes. Frontiers in Ecology and the Environment, 2008, 6: 247-254.

[2] Sommaruga R. The role of solar UV radiation in the ecology of alpine lakes. Journal of Photochemistry and Photobiology, 2001, B: Biology 62: 35-42.

[3] Vollenweider, R.A. Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication OECD. Paris. Tech Report DA 515C116827, 1968, 250 p.

[4] Prescott, G.W. Some relationship of phytoplankton to limnology and aquatic biology. Publ. Amer. Assoc. Adv. Sci. publ., 1939, 10, 65-78.

[5] Lund, J.W.G. Phytoplankton from some lakes of northern Saskatchewan and from Great Slave Lake. Can. J. Botany, 1962, 40: 1499-1514.

[6] Brook, A.J. Planktonic algae as indicators of lake type with special reference to the Desmidia ceae. Limnol. Oceanogr. (1965), 10, 403-211.

[7] Adoni A. D. Work book on limnology. Pratibha Publishers, Sagar, (1985), 1-126.

[8] APHA. Standard methods for the examination of the water and waste water. 20th addition. American Public Health (1998).

[9] Ward H.B. and Whipple G.C. Freshwater biology. (2nd Ed) John Willey and Sons Inc. New York, 1959.

[10] Desikacharya T.V. Book of Cyanophyta. ICAR, New Delhi, Publication, 1958.

[11] Needham J.G. and Needham P.R. A guide to the study of fresh water biology. Publishers-Holden -Day, Inc., San Francisco, U.S.A., 1962, pp: 107.

[12] G.W. The Fresh Water Algae. Brown Company Publishers, Dubuque, Iowa, 1973.

[13] Pennak, R. W. Freshwater invertebrates of United States 2nd Edn. John Willey Sons Inc., New York, 1978.

[14] Victor, R. and Fernando, C. H. The fresh water Ostracoda (Crustacea: Ostracoda) of India. Records of the zoological survey of India, 1979, 74(2) 147-242.

[15] Michael, R.G. & Sharma, B.K. INDIAN CLADOCERA. (Crustacea: Branchiopoda: Cladacea). Fauna of India and adjacent countries. Zool. Sur. India, 1988, p 261.

[16] Edmondson, W. T. Freshwater biology. 2nd Ed. John Wiley & Sons, New York, U.S.A., 1959.

[17] Battish, S.K. Freshwater zooplankton of India. Oxford and IBH Publishing Co. Ltd. New Delhi, 1992.

[18] Reddy, Y.R. Corepoda: Calanoida: Diaptomidae: Guide to the identification of the mio-inverte -brates of the continental waters of the world, 1994, Vol.5 SPB Publishers, The Hague, Netherlands.

[19] Sinha S. and Naik M.L. Phytoplankton and Macrophytes in the ponds of Raipur city area, M.P. Pub. Ravi shanker Shucla University, Raipur, M.P., 1997, pp-164.

[20] Sharma, B. K. Freshwater Rotifers (Rotifera: Eurotatoria) Zoological Survey of India. State Fauna Series 3, Fauna of West Bengal, 1999, Part 11: 341-468.

[21] Dhanapathi, M.V.S.S.S.. Rotifers from Andhra Pradesh, India–III. Hydobiologia, 2003, 48(1): 9-16.

[22] Jaccard, P. "Étude comparative de la distribution florale dans une portion des Alpes et des Jura". Bulletin de la Société Vaudoise des Sciences Naturelles, 1901, 37: 547–579

[23] S. K., George M.P., Saxena R., Johri M. and Shrivsatava M. Seasonal variation in the limno chemical characteristics of Mansarovar reservoir of Bhopal. In: S.R. Mishra and Saxena, D.N.(eds), Aquatic Ecology, 1992, Ashish Publishing House, New Delhi, pp 275-292.

[24] Agarkar M.S., Goswami H.K., Kaushik S., Mishra S. N., Bajpai A.K. and Sharma U.S.. Biology, conservation and management of Bhog Wat erl 1. Upper Lake Ecosystem in Bhopal. Bionature, 1994, 14 (2), pp 1-119.

[25] Wanganeo A., Wanganeo R. and Pani S. Summer dissolved oxygen regimes in tropical Vindhyan Lake in relation to its conservation strategy. Strategy Bionature, 1997, 17(1): 7-11.

[26] Lee G.F., Jones R. A., and Rast W. Alternative approach to trophic status classification for water quality management. Occasional paper no. 66. Dept. of Civil Eng. Env. Eng. Progress. Colorado, State University fort Collins Co., 1981.

[27] Kumar P., Wanganeo A. and Sonaullah F. A Preliminary Limnological Study on Shershah Suri Pond, Sasaram, Bihar. Asian J. Exp. Sci. 2010, Vol. 24, No. 2, 219-226.

[28] Bamforth S. Ecological studies on the planktonic Protozoa of a small artificial pond. Limnology of Oceanography, 1958, Vol. 3, pp. 398-412.

[29] Wanganeo A., Raina R. and Zutshi D.P. Limnological studies on dimictic Himalayan Lake. Rec. Adv. Fish Ecol. Lim. Eco-conserv. 1996, IV: 37-54

[30] Moyle J.B. Some indices of lake productivity trends. American Fisheries Society, 1946, 76, pp. 322-334.

[31] Raina R., Wanganeo, A., Fozia S. and Pramod K. Variation in summer Limnological characteristics of Bodsar wetland over a period of more than two decades. J. Himalayan Ecol. Sustian. Dev., 2009, Vol 4.
[32] Olsen S. Aquatic plants and hydrospheric factor. I. Aquatic plants in Switzerland, Arizona. J. Sevensk. Botanik Tidskriff, 1950, 44: 1-34.

[33] Kaul V., Trisal C. L. and Handoo J. K. Distribution and production of macrophytes in some water bodies of Kashmir. In Glimpses of Ecology, 1978, Eds. J.S. Singh & B. Gopal. Praksh Publ. Jaipur. 592 pp.

[34] Wetzel R.G. Limnology. W.B. Saunders Co. Philadelphia, 1975, pp: 743.

[35] Mir A. R., Wanganeo A., Yousuf A. R. and Wanganeo R. Plankton dynamics in relation to fish in Wular lake of Kashmir. Poll. Res. 2007, 26 (4): 733-743.

[36] Wanganeo A. and Wanganeo R. Variation in Zooplankton population in two morphologically dissimilar rural lakes in Kashmir Himalaya. Nat. Acad. Sci. 2006, 76 (B) III. 222-239.

[37] Wanganeo A. and Wanganeo R. Algal population in valley lakes of Kashmir Himalaya. Arch. Hydrobiol., 1991, 131(2): 219-233.

[38] Raina R., Subla B. A. and Zutshi D.P. Water quality and plankton of Jhelum River. Int. J. Ecol. Environ. Sci. 1982, 8: 11-17.

[39] Vass K.K., Wanganeo A., Raina H.S., Zutshi D.P. and Wanganeo R. Summer limnology and fisheries of high mountain lakes of Kashmir Himalayas. Arch. Hydrobiol., (1989): 114-4, 606-619.

[40] Wanganeo A. Phytoplankton photosynthesis, nutrient dynamics & trophic status of Manasbal Lake, Kashmir. 1980, Ph.D. Thesis, Kashmir University (Unpublished).

[41] Raina, R. Plankton dynamics and Hydrobiology of Bod-Sar Lake, Kashmir. 1981, Ph. D. Thesis. Kashmir University, Kashmir, (Unpublished).

[42] Thunmark S. Die Abwasserfrage der vaxijaseen in hydrobiologischer Beleuchtung. Grundzuge in der regnation planktologie van sudschweden. Medd. Lunds. Univ. Limnol. Inst., 1945, 4, 239.

[43] Berzins B. Zye limnologie der seen sudosttettlands. Schweiz. Z. Hydrol.1949, 11: 583-607.

[44] Arora H.C. Rotifers as indicators of trophic nature of environments. Hydrobiol. 1966, 27: 46-49.

[45] Sharma B. K. Assessment of pollution indicators in Indian rotatoria. J. Meghalaya Sci. 1986, X., 47-49.

[46] Kulshrestha S. K., Adhola U.N., Bhatnagar A., Khan A.A., Saxena M. and Baghalf M. Studies on pollution on river Kshipra: Zooplankton in relation to water quality. Int. J. Ecol. Env. Sci. 1989, 15:27-36.

[47] David A. and Roy S. Studies on the pollution of the river Dana, North Bihar by Sugar and Distillery wastes. Environ. Hlth. 1966, 8: 6-35.

[48] Sharma B. K. The Indian species of the genus Brachionus (Eurotatoria: Monogononta: Brachionidae). Hydrobiologia, 1983, 104, pp 3139.

[49] Kumar Pramod, Wanganeo A., Wangaeno R. and Sonaullah Foizia. Seasonal variations in Zooplankton Diversity of Railway Pond, Sasaram, Bihar. International Journal of Environmental Sciences. 2011, Vol. 2, No 2.

[50] Saxena D.N. and Sharma S.P. Zooplankton fauna of some lentic water bodies of Gwalior I, Govind sagar, Ehanatri tank, Sawarkar sarover and Matsya sarover. Env. India. 1981, 4:13-17.

[51] Subbamma D. V. Plankton of a temple pond near Machili Patnam, Andhra Pradesh. J. Aqua. Biol., 1992, 7(1 & 2):17-21.

[52] Pejaver M. K. and Somani V. Crustacean Zooplankton of Lake Masunda, Thane. Journal of Aquatic Biology, 2004, 19 (1): 57-60.

[53] Deevey E. S., Deevey Jr. G. B. and M. Brenner. Structure of zooplankton communities in the Peten Lake, District Guatemala. In W. C. Kerfoot (ed.), Evolution and Ecology of Zooplankton Communities. 1980, Pp. 669-678. University Press of New England, Hanover, NH.

[54] Elmore J. L. Factors influencing Diaptomus distributions: An experimental study in subtropical Florida. Limnology and Oceanoography, 1983, 28: 522-532.

[55] Lee C. E. and Bell M. A. Causes and consequences of recent freshwater invasions by saltwater animals. Trends in Ecology & Evolution, 1999, 14: 284-288.

[56] Reid J. W. Arctodiaptomus dorsalis (Marsh): A Case History of Copepod Dispersal. Banisteria, 2007, Number 30, pp 3-18.

[57] Ayoade A. A., Agarwal N. K. and Chandola- Saklani A. Changes in Physicochemical Features and Plankton of Two Regulated High Altitude Rivers Garhwal Himalaya, India. European Journal of Scientific Research. 2009.