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

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**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 131species 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

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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]

$$CC_i = \frac{C}{(S_1) + (S_2) - C}$$

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 holly 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.

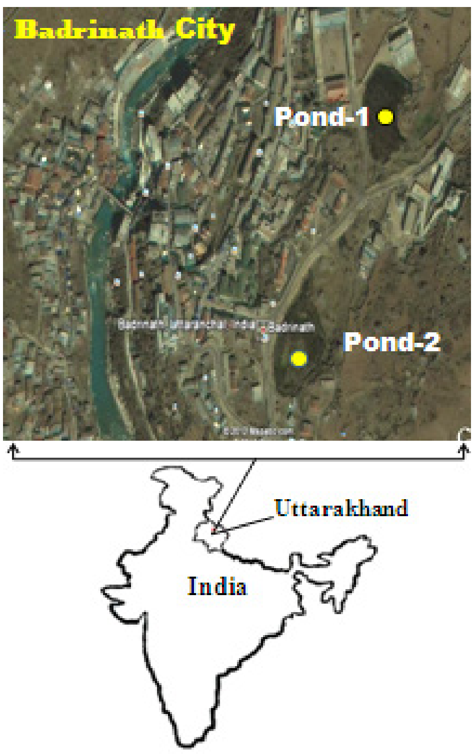


**Figure 1.** Showing sampling sites at both the selected ponds

## 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].

**Table 1.** Some important feature of the selected ponds

| 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) | 3,415 | 3,422 |
| 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 |

**Table 2.** Important physico-chemical characteristics the Ponds

| 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/cm$^2$) | 660 | 650 |
| Free $CO_2$ (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 $CO_2$ 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.

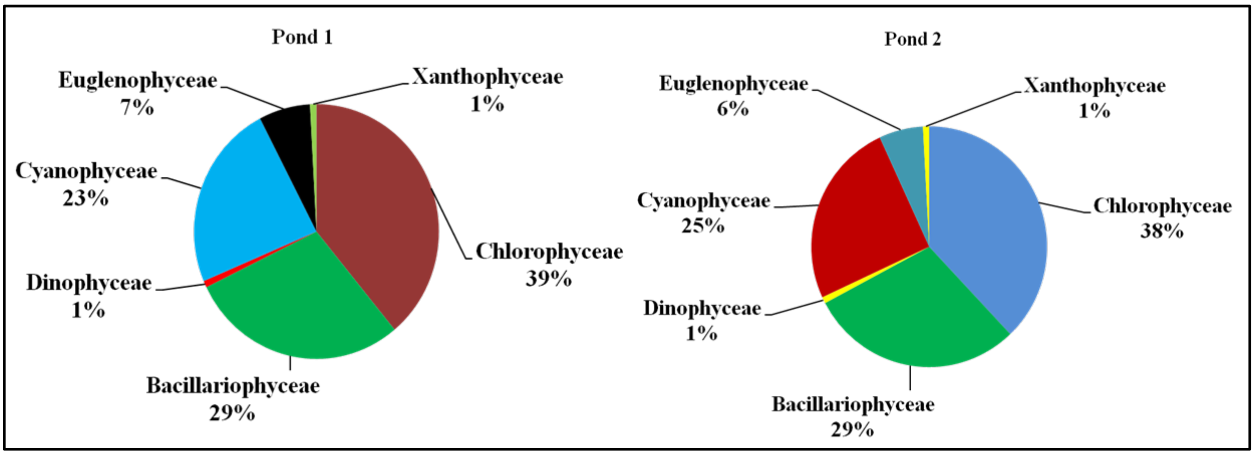


**Figure 2.** Classwise percentage composition of Phytoplankton population in both the ponds

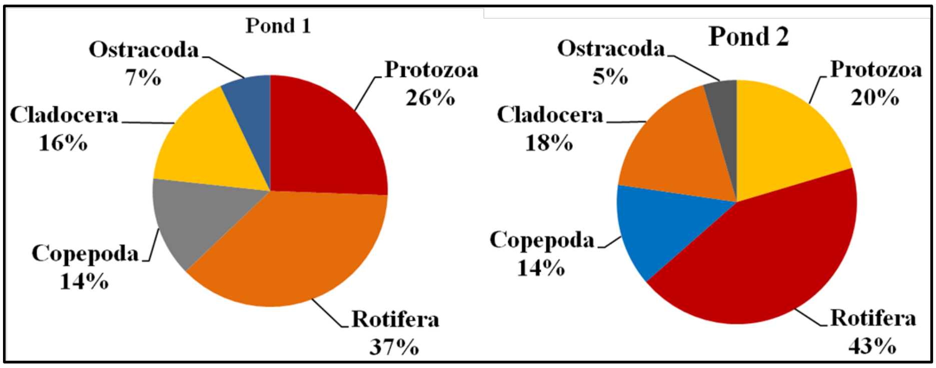


**Figure 3.** Classwise percentage composition of Zooplankton population in both the ponds

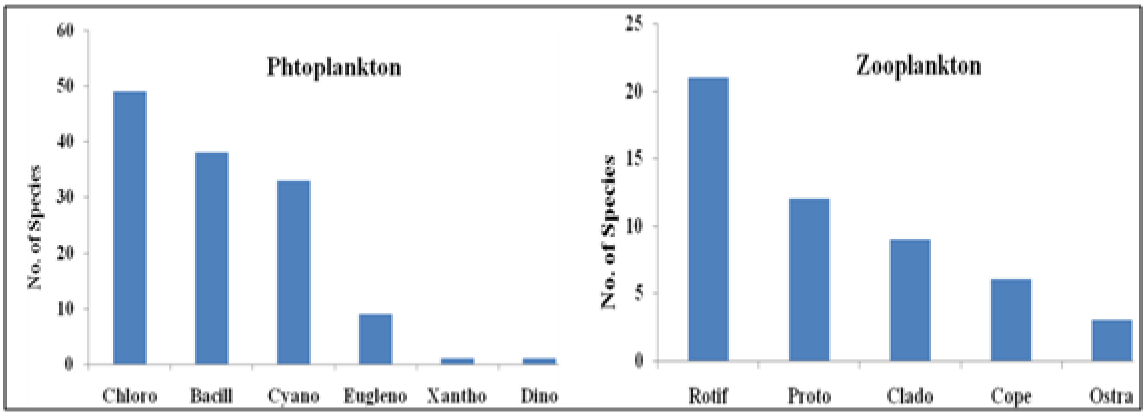


**Figure 4.** Overall species composition of Phytoplankton and Zooplankton recorded from both the ponds

**Table 5.** Species contribution of different planktonic groups in both the selected Pond

| Phytoplankton | Pond 1 | Pond 2 | Zooplankton | Pond 1 | Pond 2 |
|---|---|---|---|---|---|
| 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 1specie (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* | + | + |
| *Chlorococcum* sp. | + | + |
| *Closteriopsis* sp. | + | + |
| *Closterium parvulum* | + | + |
| *Coelastrum microporum* | + | + |
| *Coelastrum* sp. | + | + |
| *Cosmarium bengalicum* | + | + |
| *Cosmarium depressum* | + | + |
| *Cosmarium margaritatum* | + | + |
| *Crucigenia quadrata* | + | + |
| *Elkatothrix* sp. | - | + |
| *Euastrum* sp. | + | + |
| *Gloeocystis* sp. | + | + |
| *Gloeotrichia sp.* | + | + |
| *Gonium* sp. | + | + |
| *Mougeotia* sp. | + | + |
| *Oocystis* sp. | + | + |
| *Oocystis crassa* | + | + |
| *Pandorina cylindricum* | + | - |
| *Pediastrum duplex* | + | + |
| *Pediastrum simplex* | + | + |
| *Pediastrum tetras* | + | + |
| *Scenedesmus abundans* | + | + |
| *Scenedesmus armatus* | + | + |
| *Scenedesmus bijugatus* | + | + |
| *Scenedesmus dimorphos* | + | + |
| *Scenedesmus obliquus* | + | + |
| *Scenedesmus quadricauda* | + | + |
| *Schroderia setigera* | + | - |
| *Selenastrum westii* | + | + |
| *Spirogyra porticalis* | + | + |
| *Staurastrum* sp. | + | + |
| *Stigeoclonium* sp. | + | - |
| *Tetraedron gracile* | + | - |
| *Tetraedron minimum* | + | + |
| *Tetraedron muticum* | - | + |
| *Tetraedron proteforme* | + | + |
| *Tetraedron trigonum* | + | + |
| *Tetraedron trilobatum* | - | + |
| *Ulothrix* sp. | + | + |
| *Ulothrix zonata* | + | + |
| *Westella* sp. | + | + |
| *Westell linearis* | + | + |
| **Bacillariophyceae** | | |
| *Achnanthes lanceolata* | + | + |
| *Achnanthes minutissima* | + | + |

| | | |
|---|---|---|
| *Amphora ovalis* | + | + |
| *Anomoeoneis sphaerophora* | + | + |
| *Ceratonies arcus* | + | + |
| *Cocconeis sp.* | + | + |
| *Cocconeis placentula* | - | + |
| *Cyclotella sp.* | + | + |
| *Cymbella affinis* | + | + |
| *Cymbella ventricosa* | + | + |
| *Cymbella tumida* | + | + |
| *Diploneis sp.* | + | + |
| *Epithemia sp.* | + | - |
| *Eunotia sp.* | + | + |
| *Fragillaria sp.* | + | + |
| *Fragilaria intermedia* | + | + |
| *Gomphonema lanceolatum* | + | + |
| *Gomphonema lucas rankala* | + | - |
| *Gomphonema montanum* | + | + |
| *Gomphonema sphaerophorum* | + | + |
| *Melosira granulata* | + | + |
| *Navicula sp.* | + | + |
| *Navicula cryptocephala* | + | + |
| *Navicula grimmii* | + | - |
| *Navicula rostellata* | + | + |
| *Navicula subrhyncocephalas* | + | + |
| *Navicula subtilissima* | + | + |
| *Navicula tumida* | - | + |
| *Nitzschia sp.* | + | + |
| *Nitzschia capitellata* | - | + |
| *Nitzschia palea* | + | + |
| *Nitzschia sigma* | + | + |
| *Pinnularia sp.* | + | + |
| *Pinnularia interrupta* | + | + |
| *Pleurosigma sp.* | + | + |
| *Synedra ulna* | + | + |
| *Synedra ulna var. biceps* | + | + |
| *Tabillaria sp.* | + | + |
| **Cyanophyceae** | | |
| *Anacystis* sp. | + | + |
| *Anabaena naviculoides* | + | + |
| *Anabaena spiroides* | + | + |
| *Aphanocapsa muscicola* | + | + |
| *Aphanocapsa montana* | - | + |
| *Aphanocapsa koordesii* | + | + |
| *Aphanothece saxicola* | + | + |
| *Aphanizomenon flos-aquae* | + | - |
| *Arthrospira platensis* | + | + |
| *Chroococcus* sp. | + | + |
| *Cylindrospermum* sp. | + | + |
| *Cylindrospermum stagnale* | + | + |
| *Gloeocapsa* sp. | + | + |
| *Gloeocapsa atrata* | - | + |
| *Limnothrix lautebornii* | + | + |
| *Lyngbya martensiana* | + | + |
| *Lyngbya versicolor* | + | - |
| *Merismopedia tenuissima* | - | + |
| *Microcystis aeruginosa* | + | + |
| *Microcystis flos-aquae* | + | + |
| *Nostoc commune* | + | + |
| *Oscillatoria curviceps* | - | + |
| *Oscillatoria limnetica* | + | - |
| *Oscillatoria limosa* | + | + |
| *Oscillatoria peromata* | + | + |
| *Oscillatoria princes* | + | + |
| *Oscillatoria pseudogeminata* | + | + |
| *Oscillatoria rubescens* | + | + |
| *Oscillatoria subbrevis* | + | + |
| *Phormidium tenue* | + | + |
| *Raphidiopsis* sp. | + | + |
| *Spirulina major* | - | + |
| *Spirulina laxissima* | + | + |
| **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]. 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, *Elkatothrix* sp., *Tetraedron muticum* and *Tetraedron trilobatum* of Chlorophyceae; *Cocconies placentula, Navicula tumida, Nitzschia capitellata* of Bacillariophyceae; *Aphanocapsa Montana, Gloeocapsa atrata, Merismopedia tenuissima, Oscillatoria curviceps, Spirulina major* 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* sp., *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, Cephlodella gibba, Cephlodella catelina, 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 discoids* | + | + |
| *Arcella vulgaris* | + | + |
| *Centropyxis ecornis* | + | + |
| *Difflugia cuminata* | + | + |
| *Difflugia* 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. | + | - |
| *Cephlodella gibba* | - | + |
| *Cephlodella catelina* | + | + |
| *Filinia* sp. | + | + |
| *Filinia longiseta* | - | + |
| *Keratella cochlearis* | + | + |
| *Keratella tropica* | + | + |
| *Keratella quadrata* | + | - |
| *Lecane* sp. | + | + |
| *Lecane closterocera* | - | + |
| *Lecane luna* | + | + |
| *Monostyla (Lecane)* | + | + |

| | | |
|---|---|---|
| *Phyllodina sp* | + | + |
| *Polyarthra vulgaris* | + | + |
| *Testudinella* sp | + | + |
| **Copepoda** | | |
| *Arctodiaptomus dorsalis* | + | + |
| *Cyclops* sp. | + | + |
| *Diaptomus* sp. | + | + |
| *Mesocyclops hyalinus* | + | + |
| *Nauplius larvae* | + | + |
| *Thermocylops crassus* | + | + |
| **Cladocera** | | |
| *Alona intermediate* | - | + |
| *Moina branchiata* | + | + |
| *Bosmina longirostris* | + | + |
| *Ceriodaphnia puchella* | + | + |
| *Chydorus sphaericus* | - | + |
| *Macrothrix rosea* | + | + |
| *Daphnia pulex* | + | + |
| *Diaphanosoma excisum* | + | + |
| *Pleuroxus denticulate* | + | - |
| **Ostracoda** | | |
| *Stenocyprismalcomsoni* | + | + |
| *Cyprinotua glaucus* | + | + |
| *Stenocypris* sp. | + | - |

Protozoa recorded as second dominant class in both selected ponds was mostly represented by *Arcella discoids, Arcella vulgaris*, *Centropyxis ecornis*, *Difflugia cuminata*, *Difflugia* 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 Cladoceran, 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 glaucus* and *Stenocypris malcomsoni and Stenocypris* sp. 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 falcatus*, *Cephlodella 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).

**Table 6.** Jaccard similarity index for different planktonic groups of both the ponds

| Phytoplankton | | Zooplankton | |
|---|---|---|---|
| Chlorophyceae | 0.84 | Protozoa | 0.82 |
| Bacillariophyceae | 0.89 | Rotifera | 0.67 |
| Dinophyceae | 1.00 | Copepoda | 1.00 |
| Cyanophyceae | 0.78 | Cladocera | 0.67 |
| Euglenophyceae | 0.67 | Ostracoda | 0.67 |
| Xanthophyceae | 1.00 | | |

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 runoff 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 eutrophic (High productivity) conditions of both the ponds. However, the variation in some planktonic species in these ponds suggest the need of further studies to establish the importance of various environmental factors, their seasonal fluctuations that produce a collective effect on the nature and distribution of freshwater microscopic life at higher altitudes. Present study is first hand work on these two small ponds which will provide the baseline data for the further studies.

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