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Habitat ecology and diversity of freshwater zooplankton of Uttarakhand Himalaya, India

Abstract

The present contribution is a comprehensive review of the status of biodiversity of freshwater zooplankton of Uttarakhand Himalaya. Uttarakhand harbours a wide diversity in freshwater habitats in terms of rapids, riffles, runs, cascades of falls and pools of rivers and streams and the shallow and swift water of springs and lentic waters of lakes, ponds and reservoirs with varied physico-chemical environmental variables. Freshwater zooplankton of Uttarakhand are composed of the taxa of Protozoa, Rotifera, Copepoda, Cladocera and Ostrocoda. Ritifera contributes maximum (40.50%) with thirty two species followed by Protozoa (22.78%) with eighteen species and Cladocera (22.78%) with eighteen species to the total zooplankton taxa of Uttarakhand. Copepoda contributes 8.86% with seven species, while minimum contribution (5.08%) with only four species is made by Ostracoda to the total zooplankton taxa of Uttarakhand. Seasonal variation in the abundance of zooplankton in addition to diurnal vertical migration in diverse freshwater habitats of Uttarakhand Himalayahas also been reported.

Keywords: zooplankton, Uttarakhand, Himalaya, freshwater, river, lakes

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Introduction

India is blessed with rich biodiversity due to its specific biogeographic location, vast climatic variations and diverse habitats. Occupying only two percent of the world's total landmass, India harbours about 89,500 animal species comprising a little more than seven percent of the world's known animal species.[1] Uttarakhand, the important part of the Indian Himalaya harbours the rich biodiversity due to gradients in temperature and altitude in addition to enormous diversity in habitats. Freshwater biodiversity of Uttarakhand is also very rich due to its wide diversity in terms of its freshwater habitats, rapids, riffles, runs and pools of rivers and streams and the shallow and swift water of springs and lentic waters of lakes, ponds and reservoirs.

Zooplankton are an important constituent of the food chain in aquatic ecosystem. Zooplankton feed on the phytoplankton, bacteria, aggregates of detritus and micro-organisms as well as other zooplankton species. Almost all freshwater fish feed on zooplankton at some stage in their life history.[2,3] Zooplankton are heterotrophic planktonic animals. These are suspended in water with limited power of locomotion. Like phytoplankton, they are usually defused in water. Freshwater zooplankton are dominated by four major groups of animals Protozoa, Rotifera and two sub-classes of Crustacea-Cladocera and Copepoda. The zooplankton feed on phytoplankton and facilitate the conversion of plant material into animal tissue and in turn constitute the basic food for higher animals including fishes, particularly their larve.[4] The stability of zooplankton community in any aquatic body of water is of profound importance, because they represent important and sometimes unique food source for fish and many other aquatic vertebrates.[5]

A considerable work on the biodiversity of freshwater zooplankton of the Indian Himalaya has been done from different parts. A detailed analysis of the diversity of Rotifera from North East Himalaya has been made by Sharma[6–12] and Sharma and Sharma.[13–17] Contribution on biodiversity of Cladocera of North East Himalaya has also been made by Sharma and Sharma.[18–22] Few reports on the zooplankton of Western Himalaya are also available.[23–29] However, the scattered reports on the of lentic and lotic environments of Uttarakhand are available and no sincere attempt has been made so far on the comprehensive review the status of the biodiversity of freshwater zooplankton of Uttarakhand. Therefore, it was felt desirable to contribute on the review of the biodiversity of freshwater zooplankton of Uttarakhand.

Materials and methods

Physiography of the study area

The Uttarakhand is an important part of the Western Himalaya. The state of Uttaranchal, the 27th state of India was carved out of Uttar Pradesh on November 09, 2000. In January 2007, the new state changed its name to Uttarakhand, meaning "northern region", which was the traditional name for the area of 51,125 km^2 with the population of 1,00,86,292 (2011 census). Uttarakhand has a highly varied topography, with snow covered peaks, glaciers, major rivers and tributaries of the Ganga, Yamuna, Ramganga and the Kali in addition to beautiful lakes located at different altitudes. It is located in the northwestern part of the country. It is bordered to the north west by Himachal Pradesh, to the northeast by the Tibet, to the southeast by Nepal, to the south and southwest by Uttar Pradesh and to the west by Haryana (Figure 1).

Uttarakhand can be divided into several physiographic zones, all running parallel to each other from north west to south east. The northern zone, popularly known as the *Himadri,* contains segments of the Zaskar and the Great Himalaya ranges, with elevations ranging from 3,000 to 7,600 m above m.s.l. Adjacent to and south of the Great Himalaya is a zone containing the Lesser Himalaya with elevations between 2,000- 3,000 m above m.s.l. To the south of the Lesser Himalaya, is a stretch of the Siwalik range. The south end of Siwalik merges with a thin strip of gravel and alluvium called Bhabar, which interfaces to the southeast with marshy landscape of Terai. The combined Siwalik-Bhabar-Tarai area ranges in elevation from 300-3,000 m above m.s.l. South of the Siwalik are found flat-floored depressions, locally known as duns, such as Dehradun.

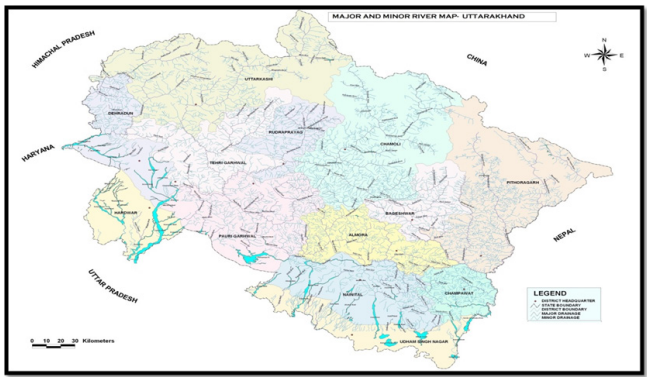

Figure 1 Geographical map of Uttarakhand showing major and minor rivers.

The state is drained by various rivers of the Ganga system. The western most water shed is formed by the Yamuna River and its major tributary, the Tons. The land to the east of the basin is drained by the Bhagirathi and the Alaknanda and they join to form the Ganges (Ganga) at Devprayag- The Mandakini, Pindar and Dhauliganga all principal tributaries of the Alaknanda. The eastern part of Uttarakhand is drained by Ramganga, Kosi, Sarju and Kali rivers. Kali river makes the Uttarakhand's border with Nepal.

The climate of Uttarakhand is mainly temperate, but influenced by tropical monsoons. It is characterized by marked seasonal fluctuations in temperature. January is the coldest month, with daily high temperature averaging below freezing in the north and near 21^{0}C in the southeast. In the north, July is the hottest month, with temperature rising from 7^{0}C to 21^{0}C daily. In the southeast, May is the warmest month, with daily temperatures normally reaching from 27^{0}C to 38^{0}C. An average of 1,500 mm of annual precipitation is brought by the southwest monsoon in most area of Uttarakhand. Southwest monsoon blows from mid June through September. Floods and landslides are common during monsoon season in the lower stretches of the valleys. In the northern parts of the state, 3 to 5m of snowfall is common between December and March.

Methodology

The diverse habitats of freshwater (rivers, streams, springs, lakes, ponds, reservoirs) of Uttarakhand were taken into consideration for representing the diversity of zooplankton. Physico- chemical parameters were analyzed following the methods outlined in Wetzel and Likens[30] and APHA.[31]

Collection of zooplankton were made by towing plankton net (mesh size 50µm) in the waterand were preserved in 5% formalin and Lugol's solution and alcohol.[32] Counting of zooplankton was made by Sedgewick Rafter Cell. Identification of zooplankton was made following the methods outlined in APHA,[31] Pennak,[33] Tonapi[34] Ward and Whipple,[35] Korovchiasky,[36] Simirnov,[37] Battish,[32] Segers,[38,39] Sharma,[7] Fernando,[40] Orlova-Biekowskaja,[41] Korinek,[42] Jersabek Lietner.[43]

Results and discussion

Biodiversity is the variability among living organisms from all sources including the diversity in habitats and the ecological complexes of which they are the part. Thus, for reviewing the biodiversity of freshwater zooplankton of Uttarakhand, it is necessary to provide information on habitat diversity and diversity in the various components of zooplankton.

Habitat diversity

Fresh water zooplankton community of Uttarakhand dwells the diverse habitats of fresh water ecosystems – rivers, streams, springs, ponds, lakes and reservoirs. A rich diversity in lotic environments in the form of fast water current of rapids, riffles and runs of high altitude cold water streams and moderate to slow water current of deep pools of wide and low altitude big rivers are available in Uttarakhand. In addition to it, a diverse group of habitats of lentic waters in the form of high altitude coldwater lakes, ponds in the foothills and few big reservoirs created by the construction of dams are available in Uttarakhand, which provide suitable habitats for the zooplankton.

Riverine habitats

The riverine habitat in Uttarakhand has broadly three kinds of habitats (Table1). The upper most stretches are located in the high altitude regions with torrential water velocity, coldwater, rockyriver beds with dominance of boulders, cobbles, pebbles and gravel. Geomorphologically, this streach has dominant rapids, riffles, runs and cascades of falls with very few shallow pools. This zone of river is "No fish zone" or epirhithron.[44]

Table 1 Physical and ecological attributes of epirhithron, metarhithron and hyporhithron zones of the major rivers of Uttarakhand Himalaya

Zone	Alitude(m above msl)	Bottom substrates	Habitat type
Epirhithron	>2,500m	Rocky bed with boulders, cobbles, pebbles, gravels and coarse sand	Dominant rapids, runs, riffles, waterfalls, cascades with few shallow pools
Metarhithron	500-2,500m	Hard river bed with cobbles, pebbles, gravels and sand	Mixed number of rapids, runs, riffles and deep pools
Hyporhithron	250-500m	Deep river bed with pebbles, gravels and fine sand	Dominated deep pools with few rapids and riffles

The mid stretches of the rivers in the Uttarakhand are located in mid altitude in the Himalayan region with moderate water velocity and temperature, hard river bed with cobbles, pebbles, gravel and coarse sand. Geomorphologically, this stretch has mixed number of rapids, runs, riffles and deep pools. This zone of river is known as 'Snow trout Zone' or metarhithron, as the species of *Schizothorax*(Snow trout) thrive best in this zone. The lower most stretches of the river in Uttarakhand are located in the lower altitude/foot hills or Tarai region with deep river bed with few pebbles, gravels and fine sand silt. Geomorphologically, this stretch is dominated by deep pools with few rapids and riffles. This zone of river in Uttarakhand can be called as hyporhithron or "Mahseer zone" as Mahseer the famous sport fish thrive well in these stretches.

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Physico-chemical environmental variables

The physical parameters (water temperature, water velocity, hydromedian depth, turbidity, transparency, conductivity and total dissolved solids) are different in all the three strechesepirhithron, metarhithron and hyporhithron of the reverine habitats of Uttarakhand (Table 2). Water temperature, hydromedian depth, turbidity, conductivity and TDS increased from epirhithron to hyporhithron. However, the water velocity and transparency decreased from higher stretches to lower stretches.

The chemical environmental variables (dissolved oxygen, free carbon dioxide, pH, BOD, phosphates, nitrates, Sodium and Potassium) are also different in all the three stretches of river in habitats of Uttarakhand. Free carbon dioxide, pH, BOD, phosphhtes, nitrates, Sodium and Potassium have increasing trends from epirhithron to hyporhitron. However, the dissolved oxygen concentration has shown decreasing trend from epirhithron to hyporhitron.

Lacustrine habitats

The lentic environment of Uttarakhand has also diverse habitats in the form of high altitude lakes (>2,500 above m.s.l.), mid altitude (500-2,500 m) and lower altitude (250–500 m) lakes. High altitude lakes have pristine environment with very low trophic status (extremely oligotrophic) with the exception of Nanital lake, which is passing through eutrophic status. Mid altitude (500-2,500 m above m.s.l.) lakes of Uttarakhand are oligotrophic to oligo-mesotrophic status with moderate biodiversity. In addition to it, few lakes and ponds are also available in the foothills or lower altitude of the Uttarakhand. These lakes have mesotrophic status with rich biodiversity. Few big reservoir have also come up in Uttarakhand after the construction of dams. These reservoirs are the Nanak Sagar, the Tehri Dam reservoir and the Assan wetland in Uttarakhand. (Table 3).

Table 2 Annual mean of physico-chemical environmental variables (± S.D) recorded in epirhithron, metarhithron and hyporhithron stretches of the major rivers of Uttarakhand Himalaya

S.N.	Environmental Variable	Epirhithron	Metarhithron	Hyporhithron
1	Ait temp (^{0}C)	10.65 ± 3.4	17.7 ± 4.25	21.78 ± 2.75
2	Water temp. (^{0}C)	7.30 ± 2.85	12.9 ± 3.15	18.12 ± 2.12
3	Water velocity (m sec^{-1})	2.75 ± 0.75	1.74 ± 0.38	1.32 ± 0.167
4	HMD (m)	1.21 ± 0.71	2.21 ± 1.72	2.64 ± 1.74
5	Turbidity (NTU)	65.25 ± 109.6	138.13 ± 244.75	156.32 ± 160.02
6	Transparency (m)	0.98 ± 0.81	0.35 ± 0.01	0.25 ± 0.12
7	Conductivity (µScm^{-1})	0.13 ± 0.34	0.15 ± 0.52	0.17 ± 0.54
8	TDS (mg l^{-1})	14.1 ± 12.24	34.0 ± 33.39	96.17 ± 39.12
9	Dissolved oxygen (mg.l^{-1})	11.44 ± 2.60	10.55 ± 0.84	8.65 ± 0.42
10	Free CO_2 (mg l^{-1})	0.62 ± 0.12	1.02 ± 0.32	1.32 ± 0.42
11	pH	7.32 ± 0.17	7.56 ± 0.19	8.083 ± 0.37
12	BOD (mg.l^{-1})	0.24 ±0.5	1.29 ± 0.28	2.45 ± 0.32
13	Phosphate (mg.l^{-1})	0.102 ±0.10	0.150 ± 0.12	0.175 ± 0.15
14	Nitrate (mg.l^{-1})	0.101 ± 0.01	0.140 ± 0.10	0.162 ± 0.13
15	Sodium (mg.l^{-1})	5.19 ± 1.72	7.85 ± 1.85	8.95 ± 1.95
16	Potassium (mg.l^{-1})	3.62 ± 0.50	6.23 ± 0.65	7.25 ± 0.72

Table 3 Physico-chemical environmental variables (± S.D) in high altitude, mid altitude and lower altitude lakes of the Uttarakhand Himalaya

S.N.	Environmental Variable	High altitude* (2,500m)	Mid altitude (500-2,500m)	Lower altitude (250-500m)
1.	Air temperature (^{0}C)	9.56 ±4.12	13.51±5.168	26.38±7.256
2.	Water temperature (^{0}C)	7.18 ±5.539	14.78±5.539	16.82 ± 0.22
3.	Turbidity (NTU)	2.11 ± 2.40	5.69±7.930	77.81 ± 9.04
4.	Transparency (m)	0.232±0.145	0.859±0.259	0. 785± 0.516
5.	Conductivity (µScm^{-1})	0.850±0.002	0.142±0.003	0.199 ± 0.010
6.	TDS (mg l^{-1})	10.25±4.35	48.41±15.011	96.17 ± 39.12
7.	Dissolved Oxygen (mg.l^{-1})	5.12±0.432	6.87±0.638	7.92 ± 0.12
8.	Free CO_2 (mg l^{-1})	0.131±0.074	0.491±0.194	0.68 ± 0.27
9.	pH	6.42±0.305	6.52±0.705	7.90 ± 0.05
10.	BOD (mg.l^{-1})	0.120±0.114	0.47± 0.21	1.31 ± 0.46

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Table continue

S.N.	Environmental Variable	High altitude* (2,500m)	Mid altitude (500-2,500m)	Lower altitude (250-500m)
11.	Phosphates ($mg.l^{-1}$)	0.004±0.003	0.015±0.007	0.050 ± 0.001
12.	Nitrates ($mg.l^{-1}$)	0.016±0.007	0.052±0.019	0.099 ± 0.003
13.	Sodium ($mg.l^{-1}$)	6.210±1.120	8.150±1.830	15.725±2.648
14.	Potassium ($mg.l^{-1}$)	1.247±0.670	1.950±0.643	2.695±0.947

*The lakes were snow covered during mid December to mid March.

Biodiversity of zooplankton

Zooplanktonic community is an important component of freshwater biodiversity and plays a pivotal role in food chains of freshwater ecosystems of Uttarakhand Himalaya. Zooplankton are an important food sources of fishes. Zooplankton are able to consume great quantities of phytoplankton from the open water zone, thereby influencing the primary production. These planktonic organisms also act as bio indicator for assessing the health of the aquatic ecosystems. The review of the biodiversity of freshwater zooplankton of Uttarakhand is very extensive and complicated due to environmental, physical, geographical and chemical variations involving ecological, extrinsic and intrinsic factors.

Freshwater zooplankton of Uttarakhand are composed of the taxa of Protozoa, Rotifera, Copepoda, Cladocera and Ostrocoda. If, we are looking at general composition of zooplankton of Uttarakhand, Rotifera contributes maximum (40.50%) with 32 species followed by Protozoa (22.78%) with 18 species and Cladocera (22.78%) with 18 species. Copepoda contributes 8.86% with seven species to the total zooplankton taxa of Uttarakhand. Minimum contribution (5.08%) with only four species is made by Ostracoda (Figure 2).

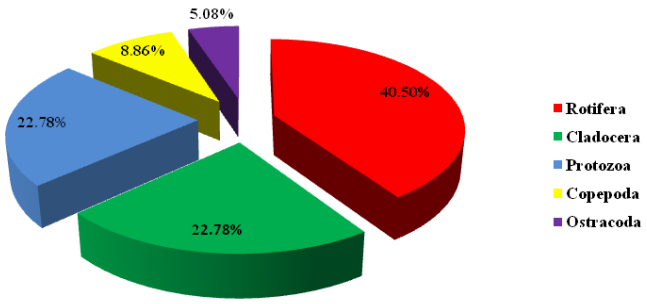

Figure 2 Percentage composition of zooplankton of Uttarakhand.

a. Rotifera

Rotifera, an important component of zooplankton occur widely in diverse freshwater habitats and plays an important role in functioning of freshwater ecosystems. The members of Rotifera serve as indicators of water quality, test organisms in environmental toxicology and fish food in aquaculture practices.[45–48]

A total of 32 species belonging to18genera and 13 families of Rotifera have been reported from the diverse habitats of Uttarakhand

Phylum: Rotifera Cuvier, 1817

Class: Eurotoria De Reidder, 1957

Sub class: Monogononta Plate, 1889

Order: Ploima Hudson & Goose, 1886

Family:Brachionidae

1. *Anuraeopsisfissa* Goose,1851
2. *Brachionus angularis* Goose, 1851
3. *Brachionusquadridentatus*Hermann 1783
4. *Keratellacochlearis*Goose, 1851
5. *Keratellatropica*Apstein, 1907

Family:Mytinidae

1. *Mytilinaacanthophora* Hauer, 1938
2. *Mytilinaventralis* Ehrenberg, 1830

Family:Lecanidae

1. *Lacaneacanthinula*Hauer, 1938
2. *L.arcula*Harring, 1914
3. *L.blachei*Berzins, 1973
4. *L. curvicornis* Murray, 1913
5. *L. leontina* Turner, 1892
6. *L. lunaris*Ehrenberg, 1982
7. *L. papuna* Murray, 1913
8. *L. ungulata*Hauaen, 1938

Family:Notomanatidae

1. *Cephalodellaforficula* Ehrenberg, 1830

Family:Gastropodidae

1. *Ascomorpha ovalis*Bergendal, 1892

Family:Asplanchnidae

1. *Asplanchnapridonata* Goose, 1850

Family:Synchaetidae

1. *Ploesmalenticulare* Herrick, 1885
2. *Polyarthra vulgaris* Carlin, 1943

Family:Testudinellidae

1. *Testudinellatridentata*Smimov, 1931
2. *Testudinella patina* Hermann, 1783

Family:Trichocercidae

1. Trichocerabidens Lucks 1912
2. Trichocerarattus O.F Muller, 1776
3. TrichocerasimilisWierzesiski, 1893

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Family: Trochosphaeridae

1. *Filiniabrachiata*Rousselet, 1901

Family: Euchlanidae

1. *Euchlarisdilatata* Ehrenberg, 1832

Family: Lepadellidae

1. *Colurellaadritica* Ehrenberg, 1831
2. *Lepadellabicornis*VashishtandBattish, 1971
3. *L. ovalis* O.F Muller, 1786

Sub Class:Dignononta

Order:Bdelloidea

Family:Philodinidae

1. *Rotatoriamacroceros* Goose, 1851
2. *Philodinacitrina* Ehrenberg, 1832

b. Cladocera

Cladocera, commonly known as 'water flees' form an integral link in food web of freshwater ecosystems of Uttrakhand. The members of Cladocera contribute significantly to biological production at the second trophic level and energy flow in aquatic ecosystems due to their rapid turnover rates. Contribution on Indian freshwater Cladocera was initiated by Baird.[49] After that many contribution were made on the diversity of Cladocera.

A total of 18species belonging to 13genera and 07families of Cladocera have been reported from the diverse habitats of Uttarakhand

Super Class: Crustacea

Class: Branchiopoda

Sub Class: Cladocera

Order: Ctenopoda

Family: Sididae

1. *Diaphanosomaexcisum*Sars, 1885
2. *Diaphanosomasarsi* Richard, 1895
3. *Diaphanosomatropicum*Korovchinsky, 1998

Order: Anomopoda

Family: Daphniidae

Sub Family: Daphniinae

1. *Ceriodaphniacormuta*Sars, 1885
2. *Daphnia lumholtzi*Sars,1885
3. *D. pulex Leydig* 1860 emend. Scourfield, 1942
4. *Simocephalusmixtus*Sars, 1903

Family: Bosminidae

1. *Bosminopsisdeitersi* Richard, 1895
2. *Bosminalongirostris* O.F. Muller, 1776

Family: Moimnidae

1. *Moinamicrura*Kurz, 1874

Family: Chydoridae

Sub family: Chydoridae

1. *Alonellaexcisa* Fisher, 1854
2. *Chydorussphaericus* O.F. Muller, 1776
3. *Chydorusangustirostris* Frey, 1987
4. *Pleuroxus (Picripleuroxus) laevis,* Sars, 1862

Sub Family: Aloninae

1. *Alonacheni*Sinev, 1999
2. *Alonaguttata*Sars, 1862

Family: Leptodoridae

1. *LeptodorarichardiiKorovchinsky, 2009*

Family: Macrothricidae

1. *Macrothrixtriserialis* Brady,1886

c. Copepoda

Copepods have adapted themselves to live in diverse habitats. They dwell in temporary rainwater pools to perennial rivers, lakes and reservoir of Uttarakhand. A total of 07 species belonging to 07 genera and 02 families of Copepodahave been reported from the diverse habitats of Uttarakhand.

Super Class: Crustacea

Class: Branchiopoda

SubClass: Copepoda

Family:Diaptomidae

1. *Arctodiaptomus dorsalis* Kiefer, 1932
2. *Diaptomusvirdus*Gueney, 1916

Family: **Cyclopidae**

1. *Cyclops affinis*Sars, 1863
2. *Eucylopsserrulatus* Fischer, 1851
3. *Macrocyclopsalbidus*Jurine, 1820
4. *Mesocyclopslecukarti* Claus, 1857
5. *Thermocyclopsdumonti*Baribwegure and Meirabdullaya 2003

d. Ostracoda

Ostracoda are small bivalve crustaceans which colonize in a wide variety of aquatic habitats including the diverse freshwater habitats of Uttarakhand. Various taxa of Ostracoda have successfully adapted to a large variety of ecological conditions. A total of 04species belonging to 04 genera and 02families of Ostracoda have been reported from the diverse habitats of Uttarakhand.

Super Class: Crustacea

Class: Ostracoda latreille 1806

Order:Podocopida Muller 1894

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Sub Order: PodocopinaSars 1866

Family:Cyprididae Baird 1854

1. *Cypris globosa* Deb 1983
2. *Psychrodromusolivaceus* Brady and Norman 1889
3. *Potamocyprisvilosa*Sars 1890

Family:IlyocypridideaeKaufman 1900

Sub Family: Ilyocypridinae Kaufman 1900

1. *Ilyocyprisgibba*Ramdohr 1808

e. Protozoa

Protozoa are found in every kind of freshwater ecosystem of Uttarakhand. Free living Protozoa are cosmopolitan in distribution and available in all natural conditions throughout Uttarakhand, where little moisture is found. Planktonic Protozoa (mainly flagellate and ciliates) play a significant role in food web as primary consumer in aquatic ecosystems. Soil inhabiting Protozoa (mainly Rhizopods and Ciliates) help in humification and mineralization of leaf litter on the forest floor in association with other micro-organism. Protozoa are also conveniently used for environmental biomonitoring for assessing the water quality.

A total of 18 species belonging to 17 genera and 12 families have been reported from the diverse habitats of Uttarakhand.

Kingdom: Protista (Protozoa)

Phylum: Protozoa

Class: Heliozoa

Family: Actinophyridae

1. *Actinophrys sol* Ehrenberg, 1830
2. *Actinospheriumeichhornii* Ehrenberg, 1840

Family: Arcellidae

1. *Arcelladiscoides* Ehrenberg, 1843
2. *Arcellavulgaris*Ehrenberg, 1830

Family:Amoebidae

1. *Amoeba proteus*Palles 1766
2. *Centropyxisaculeata* Ehrenberg, 1838
3. *Chaos (Pelomyxa) cerolinensis* Linnaeus 1767

Family:Epistylididae

1. *Campanella umbellaria*Linnaeus, 1758
2. *Epistylisniagarae*Kelliocolt, 1883

Family:Difflugididae

1. *Difflugiaacuminanta* Ehrenberg, 1838

Family:Euglenaceae

1. *Euglena pedunculata*Gijdico 1953
2. *Phacuslongicauda* Ehrenberg 1841

Family:Thecamoebidae

1. *Thecamoebastriata*Penard 1890

Family:Parameciidae

1. *Paramecium caudatum* Ehrenberg, 1838

Family:Peridiniaceae

1. *Peridiniumcinctum* Ehrenberg, 1830

Family:Glenodiniaceae

1. *Glenodiniumpulvisculus*(Ehrenberg) F. Stein 1883

Family:Oxytrichidae

1. *Oxytrichafallax* Stein, 1859

Family:Vampyrellidae

1. *Vampyrellalateritia* (Fresenius, 1856) Leidy 1879

Scattered reports on the -freshwater zooplankton of Uttarakhand are available.Sharma reported zooplankton from the Bhagirathi river. He reported that rotifers (*Brachinous*sp., *Philodina*sp. and *Mytilina* sp.) were common in the Bhagirathi river. However, few crustacean (*Cyclops* sp., *Cypris* sp., *Daphnia* sp.,*Diaptomus*) were also reported from the Bhagirathi River.[28] Bhatt et.al. reported Protozoa (*Diffugia* sp., *Arcella* sp., *Vorticella* sp.), Rotatoria (*Asplanchna* sp.,*Polyarthra*sp., *Filina* sp., *Anuraeopsis*) and few species of crustacea (*Cyclops* sp., *Daphnia* sp., *Bosmina* sp., *Ceriodaphnia*) as zooplankton from the Kosi river of Kumaon region of Uttarakhand Himalaya.[50]

Johal[51] reported forty five genera of zooplankton from the hill streams of Western Himalaya including Uttarakhand. Protozoans constituted the major zooplanktonic diversity. The protozoan were observed during the months of February- May and September - December. They abode in the side pools, having stones of variable size, low water current and high transparency. majority of Rhizopods grow on stones with their pseudopodia.

Out of eleven genera of Rotifers *Keratella*spp., *Branchionus*spp. and *Asplanchna*spp. occurred in most of the streams, whereas rest of the genera were restricted to a few streams. Their abundance has been recorded during the months March-June i.e. during pre-monsoon period which is in accordance with the development of the members of Cyanophyceae.

Pathani and Upadhyay[52] recorded 17 taxa of zooplankton from the Ramganga river. The Protozoa were represented by species of *Diffugia*and *Centropyxis.* Rotifera were represented by the species of *Philodina, Trichocera, Asplanchna, Polyarthra*and *Brachionus*. Crustaceans were represented by the species of *Daphnia, Cyclops, Bosmina*and *Ceriodaphnia.* They also reported that the zooplankton fluctuated seasonally and altitudinally in the river Ramganga.

Bahuguna[53] studied the zooplankton of Bhagirathi River and observed that the zooplankton were contributed by Cladocera (2 genera), Protozoa (2 genera), Copepoda (2 genera) and Rotifera (3 genera). Ayoade et al.,[54] reported only few rotifera (*Testudinella*sp.) and Crustacean (*Daphnia, Cyclops* and *Diaptomus*) in the lentic water of Tehri Dam Reservoir. Sharma[10] undertook a comprehensive study on the response of biomass and production of zooplankton community (Protozoa, Rotifera, Copepoda, Cladocera) in Upper Ganges to Tehri Dam constructed in the Garhwal Himalaya. No major changes in the biomass and net secondary production were observed at the impacted site caused by construction activities of the dam. Arambam[55] reported 12 genera of zooplankton belonging to Rotifera (6 genera),Cladocera (4 genera) and Copepoda(02 genera) from Tons River, a major tributary of the Yamuna River.

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Negi and Negi[56] studied the zooplankton diversity of Hinval stream at Shivpuri near Rishikesh, Uttarakhand and reported a total of 16 genera belonging to Rotifera (07 genera), Protozoa (04 genera) and Cladocera (04 genera). Joshi and Tripathi[57] reported zooplankton from the Nanak Sagar reservoir of Uttarakhand. 10 species of Rotifera (*Lepadella, Lecane, Philodina, Asplanchna, Filina, Polyarthra, Ascomorpha, Ploesma, Brachionus* and *Keratella*) were reported from the Nanak Sagar reservoir. Few species of Cladocera and Copepoda were also repoted from the reservoir.

Kanwal and Pathani[58] reported many taxa of Protozoa (*Centropyxis, Diffugia, Paramecium, Phacus, Thecamoeba*) and six taxa of Rotifera (*Filinia, Colurella, Philodina, Lecane, Cephallodella, Lepadela*) from spring fed river Suyal of Kumaun region of Uttarakhand. Minimum occurrence was recorded in summer and maximum in winter season. It was also reported that the population of phytoplankton supports the growth of zooplankton with qualitative and quantitative seasonal variations.

Kumar et al.,[59] reported 39 species of zooplankton represented by Protozoa (11 species), Rotifera (22 species), Copepoda (06 species) Cladocera (09 species) and Ostracoda (03 species) from two high altitude ponds near Badrinath from Uttarakhand. Overall the dominance of Rotifera followed by Protozoa was recorded from these shallow ponds.

Negi and Mamgain[60] reported zooplankton diversity from Tons river of Uttarakhand. A total of 23 genera belonging to seven major groups: Ciliophora (05 genera), Cladocera (05 genera), Copepoda (01 genera), Porifera (02 genera), Rotifera (07genera) Ostracoda (01 genera) and Zooflagellata (02 genera) have been reported from this river, an important tributary of river Yamuna.

Kotlia et al.,[61] reported Ostracoda species of the family Ilyocyprididae of Cyprinidiae and Candonidae of freshwater Ostrocoda from a small pond created by a small tributary of the glacier fed Tinker river near India- Nepal border. Sharma[62,63] reported genera of zooplankton from the erosional zone of epirhithron and 18 genera from the deposition zone of pools and back waters of metarhithron and hyporhithron stretches of the upper Ganga flowing in Uttarakhand.

Malik and Panwar[64] reported 26 species of zooplankton including 16 species of Rotifera, 6 species of Cladocera and 5 species of Copepoda from Bhimtal lake of Kumaun region of Utttarakhand. Kumar et al.,[65] reported 18 genera of zooplankton from the Nanak Sagar Reservoir of Uttarakhand. Singh and Goswami[66] reported 8 genera of zooplankton belonging to Protozoa (2 genera), Rotifera (5 genera) and Copepoda (one genera) from the Mandakini, a major tributary of Alaknanda River after the impact of a major flood caused by Kedernathecodisaster of June 2013.

Prevailing physico-chemical parameters affect the life in all ecosystems. The abundance and quality of life and species richness appeared to be influenced by high turbidity, water velocity, fluctuating water levels and age of water.[67] Inaotombi & Gupta[68] observed that Nitrogen nutrients, total organic matter (TOM) and clay particles influence the distribution pattern of zooplankton dwelling high altitude lake of Uttarakhand. Physico-chemical factors such as turbidity, water velocity and dissolved oxygen depicted subtle seasonal variations and were found to alter the biological balance of the river water.[50] Most of the zooplankton were available during the period of minimum velocity (December to April) and did not seem to undergo cyclomorphosis. A pronounced cyclic periodicity of zooplankton community in the lower stretches of Kosi river with slow water was observed during winter season. This seasonal cycle in the river may be correlated with the seasonal pattern of phytoplankton production. This shows the existence of high ecological efficiency of zooplankton in the river water during winter season.[69]

Cairns[70] postulated that the exact role of protozoan, plankton in stream ecology is poorly understood. He considered that the temperature, dissolved oxygen and the characteristics of substratum influence the distribution and productivity of the protozoans. He also observed that the cilliate protozoans are important in the metabolism of dissolved and particulate organic matter of sewage treatment facilities and organically polluted streams. Bisht[71] reported maximum zooplankton diversity in the month of September and minimum in the month of January during his investigation on the Pindar river of Uttarakhand. Dobriyal et al.,[72] reported that the highest planktonic diversity was observed in the winter months when the water temperature and water velocity were low and the water was clear without turbidity. Bhatt et al.,[50,73] reported highest biomass in winter-summer interphase depression in the rainy seasons and production is directly affected by food supply, phytoplankton production, water temperature and water current. Zooplankton distribution depends on food availability and avoidance of predators. Arambam[55] reported maximum density of zooplankton in February (38 ind.l^{-1}) and minimum in August (6 ind.l^{-1}). Seasonally, it was found to be maximum in spring and minimum in monsoon season.

Maximum abundance of zooplankton (39.9-41.0%) in the Nanak Sagar reservoir of Uttarakhand was reported in the winter season. While, minimum abundance in summer (28.9- 29.9%) and monsoon(28.7-31.8%) seasons was recorded in the reservoir.[57] The seasonal fluctuations of the zooplankton population are a well known phenomenon and they exhibit a bimodal oscillation with a spring and autumn in the temperate lakes and reservoirs.[72] This fluctuation is greatly influenced by the variations in temperature along with many other factors. Among several factors, temperature seems to exhibit the greatest influence on the periodicity of zooplankton.[74] Water temperatures between 10-29^{0}C are suitable for zooplankton development.[75] Zooplankton in general showed up migration during night hours and down migration during daytime. This vertical migration has been reported by many workers in their studies.[76–79] It is considered that temperature, dissolved oxygen and the characteristics of the substratum influence the distribution and productivity of protozoans. Most of the rhizopods need slimy substrate. Ciliate[69] protozoans are important in the metabolism of dissolved and particulate organic matter of sewage-treatment facilities and organically polluted streams.

The seasonal occurrence of Cladocera is quite variable, both among species and within a species living in different lake conditions. It is very difficult to assign the peak population periods especially in temperate regions.[72]

Thus, it is clearly understood that the Uttarakhand Himalaya provides a diverse array of freshwater habitats and their ecology. Thus, presence, diversity and seasonal abundance of various components of zooplankton- Rotifera, Cladocera, Copepoda, Protozoa and Ostracoda in Uttarakhand Himalaya is different in diverse habitats.

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Conflicts of interest

Author has no conflict of interest in any form related with the present contribution.

References

1. Alfred JRB. Faunal diversity in India: An overview. In: Alfred JRB, Das AK, et al. editors. *Faunal diversity in India:* Zoological Society of India Kolkatta. 1998:1–9.
2. Moss B. *Ecology of Freshwater*. Wiley–Blackwell, New Jersy, USA. 1988:1–352.
3. Lampert W, SommerU. Limnoecology: The Ecology of Lakes and Streams. Oxford University Press, Canada. 1997:1–400.
4. Dhargalkar VK, Verlecar XN. Zooplankton Methodology Collection and Identification: A Field Manual, National Institute of Oceanography, Dona Paula, Goa. 2004;6:403–404 .
5. Ochang SN, Ayotunde EO, Okey IB. Some aspects of the physico-chemical and biological properties of Cross River, an inland water body in South- Eastern Nigeria. *Global J Agricultural Sciences.* 2005;4:139–148.
6. Sharma BK. Biodiversity of freshwater Rotifera in India a status report. *Proc Zool Soc Calcutta.* 1996;49:7385.
7. Sharma BK. Faunal Diversity in India: Rotifera. *Faunal Diversity of India*. 1998.
8. Sharma BK. Synecology of Rotifers in a tropical floodplain lake of Upper Assam (N. E. India). *Indian J. Anim. Sciences.* 2000;70:880–885.
9. Sharma BK. Rotifer communities of floodplain lakes of the Brahmaputra basin of lower Assam (N. E. India): Biodiversity, distribution and ecology. *Hydrobiologia.* 2005;533:209–221.
10. Sharma BK. Diversity of Rotifers (Rotifera: Eurotatoria) of Loktak lake, North- Eastern India. *Trop Ecol.* 2009;50(2):277–285.
11. Sharma BK. Rotifer communities of Deepor beel, Assam, India: Richness, abundance and ecology. *Journal of Threatened Taxa.* 2010;2(8):1077–1086.
12. Sharma BK. Rotifers (Rotifera: Eurotatoria) from wetlands of Majuli - the largest river island, the Brahmaputra river basin of upper Assam, Northeast India. *Check List.* 2014.
13. Sharma BK, Sharma S. Freshwater Rotifers (Rotifera: Eurotatoria). In: *State Fauna Series: Fauna of Meghalaya.* Zool Surv. India, Calcutta. 1999;4(9):11–161.
14. Sharma BK, Sharma S. Freshwater Rotifers (Rotifera: Eurotatoria). In: *State Fauna Series: Fauna of Tripura.* 2000;7(4):163–224.
15. Sharma BK, Sharma S. Biodiversity of Rotifera in some tropical floodplain lakes of the Brahmaputra river basin, Assam (N. E. India). *Hydrobiologia.* 2001;446/447:305–313.
16. Sharma BK, Sharma S. Biodiversity of freshwater Rotifers (Rotifera: Eurotatoria) from North -Eastern India. *Mitt Mus Nat kd Berl Zool Reihe.* 2005;81:81–88.
17. Sharma BK, Sharma S. Rotifera diversity of a floodplain lake of the Brahmaputra river basin of lower Assam Northeast India. *Opusc. Zool. Budapest.* 2012a;43(1):67–77.
18. Sharma BK, Sharma S. Freshwater Cladocerans (Crustacea: Branchiopoda: Cladocera). In: *Fauna of Meghalaya; State Fauna Series.* Zool Surv. India, Calcutta.1999;4(9):469–550.
19. Sharma BK, Sharma S. New records of two interesting Chydorid Cladocerans (Branchiopoda: Cladocera: Chydoridae) from floodplain lakes of Assam (N. E. India). *Zoos' Print Journal.* 2007;22(8):2799–2801.
20. Sharma BK, Sharma S. Faunal diversity of Cladocera (Crustacea: Branchiopoda) of Deepor Beel, Assam (Northeast India) - A Ramsar site. *J Bombay Nat Hist Soc*. 2008;105(2):196–201.
21. Sharma BK, Sharma S. Taxonomic notes on some interesting Cladocerans (Crustacea: Branchiopoda: Cladocera) from Assam (N. E. India). *Rec zool Surv India.* 2010;110(2):39–47.
22. Sharma BK, Sharma S. Notes on some rare and interesting Cladocera (Crustacea: Branchiopoda: Anomopoda: Chydoridae) from Deepor Beel, Assam, India. *Journal of Threatened Taxa.* 2012b;4(1):2304–2309.
23. Das SM, Daftari S, Singh H, et al. Studies on organic production in high altitude lakes of India. Part-I: The general ecology and zooplankton of Kashmir lakes. *Kashmir Science*. 1969;6(1&2):1–22.
24. Das SM, Chaudhary S, Ahmed N, et al. Studies on organic production in high altitude lakes of India. Part-II: The zooplankton, phytoplankton and pedon of the high altitude of Kashmir lakes, Kousarnag and Aepather with correlation of plankton volume, pH and temperature of Dal Lake. *Kashmir Science*. 1970;7(1&2):119–132.
25. Jyoti MK, Sehgal N. Ecology of Rotifers of Surinsar, a subtropical, freshwater lake in Jammu (J&K), India. *Hydrobiologia.* 1979;65(1):23.
26. Yousuf AR. Copepod plankton of Manasbal lake, Kashmir. *J Indian Inst Sci.*1988;68:307–313.
27. Balkhi MH, Yousuf AR. Community structure of crustacean plankton in relation to trophic conditions. *Int J Ecol Env Sci*. 1992;18:155–168.
28. Sharma RC. Potamological studies on lotic environment of the upland River Bhagirathi of Garhwal Himalaya. *Environment and Ecology*. 1984;2:239–242.
29. Sharma RC. Response of biomass and production of zooplankton community in upper Ganges to Tehri Dam construction in Garhwal Himalaya. *Journal of Ecology and Sustainable Development.* 2006;1:51–63.
30. Wetzel RG, Likens GE. *Limnological Analysis*, 2nd ed. Springer-Verlags, New York. Inc: 1991:1–391.
31. APHA. *Standard Methods for the Examination of Water and Waste water*. NewYork, American Public Health Association. 1998.
32. Battish SK. *Freshwater Zooplankton*. Oxford and IBH Publ. Co. Pvt. Ltd., New Delhi. 1994.
33. Pennak RW. *Freshwater Invertebrates of United States of America.* 1978;1–803.
34. Tonapi GT. *Freshwater Animals of India: An Ecological Approach*. 1980;1-341.
35. Ward HF, GC Whipple. *Freshwater Biology.* New York; John Wiley and Sons. 1992:1–1248.
36. Korovchiasky NM, Sididae Holopedidae. *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World.* The Hague. 1992:1–82.
37. Simrnov NN. The Marothricidae of the world. *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World*. 1992.
38. Segers H. Rotifera: Lecanidae. In: *Guides to Identification of the Microinvertebrates of the Continental Waters of the World*. 1995.
39. Segers H. Annotated checklist of the Rotifers (Phylum Rotifera), with notes on nomenclature, taxonomy and distribution. *Zootaxa.* 2007;1564:1–104.
40. Fernando CH. *A Guide to Tropical Freshwater Zooplankton. Identification, Ecology and Impact on Fisheries*. Backhuys Publishers, Leiden, The Netherlands. 2002:1–291.
41. Orlova Bienkowskaja MY. Cladocera: Anomopoda. Daphniidae: genus S*imocephalus*. In: *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World.* 2001:1–130.
42. Korinek V. Cladocera. In: *A Guide to Tropical Freshwater Zooplankton. Identification, Ecology and Impact on Fisheries*. 2002:1–291.

Citation: Sharma RC. Habitat ecology and diversity of freshwater zooplankton of Uttarakhand Himalaya, India. *Biodiversity Int J.* 2020;4(5):188–196.
DOI: 10.15406/bij.2020.04.00184

43. Jersabek CD, Leitner MF. *The Rotifer World Catalog*. 2013.

44. Sharma RC. Rhithronology of Bhagirathi, Garhwal Himalaya (India). In: Bhatt SD, editor. *Ecology of Himalayan Waters.* Gynodaya Publ. Nainital. 1992:125-135.

45. Sladecek V. Rotifers as indicators of water quality. *Hydrobiologia*. 1983;100:169–201.

46. Arnold WR, Diamond RL, Smith DS. Acute and chronic toxicity of copper to the euryhaline rotifer, *Brachionusplicatilis*("L" strain). *Arch Environ Con Tox.* 2011;60:250–260.

47. Lubzens E. Raising rotifers for use in aquaculture. *Hydrobiologia.* 1987;147:245–255.

48. Ogata Y, Kurokura H. Use of the freshwater rotifer *Brachionus angularis* as the first food for larvae of the Siamese fighting fish *Betta splendens*. *Fisheries Sci*. 2011;78:109–112.

49. Baird W. Description of two new species of *Entomostracous* crustacean from India. *Proc Zool Soc London.* 1860;28;231–234.

50. Bhatt SD, Bisht Y, Ngi U. Ecology of the limnofauna in the river Kosi of the Kumaun Himalaya (Uttar Pradesh). Proc. *Indian Natn Sci Acad.* 1984;50(4):395–405.

51. Johal MS. *Ecology of Hillstreams of Himachal Pradesh and Garhwal Region with Special Reference to Fish Communities*. F.T.R. submitted to U.S Fish and Wildlife Services, Arligton. 2002:1-63.

52. Pathani SS, Upadhyay KK. An inventory of zooplankton, zoobenthos, and fish fauna in the river Ramganga (west) of Uttranchal, India. *ENVIS Bulletin: Himalayan Ecology*. 2006;14(2):33–42.

53. Bahuguna M. *Impact of Tehri Dam Construction on Aquatic Ecosystem of Bhagirathi of Garhwal Himalaya.* D Phil Thesis, submitted to H.N.B. Garhwal University. 2008:1–102.

54. Ayyoade AA, Agrawal NK,ChandolaAS. Changes in physico-chemical features and planktons of two regulated high altitude rivers of Garhwal Himalaya, India. *European Journal of Scientific Research*. 2009;27(1):77–92.

55. Arambam R. *Monitoring and Conservation of Aquatic Biodiversity of Tons River in Yamuna Valley*. DPhil Thesis, submitted to H.N.B. Garhwal University. 2010:1–129.

56. Negi RK, Negi T. Diversity of zooplankton in the Hinval Freshwater stream at Shivpuri (Garhwal region), Uttrakhand. *J Env Biol Sci.* 2010;24(2):167–169.

57. Joshi P, Tripathi P. A case study of some biotic factors of Nanak Sagar Reservoir, Nanak Matha, Uttarakhand, India. *J Env Biosci.* 2010;24(1):121–125.

58. Kanwal BPS, Pathani SS. Plankton diversity in some tributries of River Suyal of Kumaun Himalaya, Uttrakkhand. *International Journal of Innovations in Biosciences*. 2012;2(3):146–153.

59. Kumar P, Wanganeo A, Sonaullah F, et al. Limnological study on two high altitude Himalayan ponds, Badrinath, Uttarakhand. *Int Journal of Ecosystem*. 2012;2(5):101–111.

60. Negi RK, Mamgain S. Zooplankton diversity of Tons River of Uttrakhand State, India. *International Journal of Zoology and Research.* 2013;3(2):1–8.

61. Kotlia BS, Kramer M, Joshi LM, et al. Recent freshwater Ostracoda and Bivalariafron Indo-Nepal border (Tethys Himalaya): Ecological implications. *Himalayan Geology.*2014;35(1):56–65.

62. Sharma RC. Biodiversity of upper Ganga: Status, stress and management. In: Sinha RK, Ahmad B, editors. *River for life, IUCN*. 2014:25–44.

63. Sharma RC. Water quality of upper Ganga. *Geography and you*. 2015;15(91):537–544.

64. Malik DS, Panwar S. Zooplankton Diversity, Species Richness and their Distribution Pattern in Bhimtal Lake of Kumaun Region, (Uttarakhand). *Hydrology: Current Research.* 2016;7:219.

65. Kumar S, Trakroo MD, Goswami K, et al. Observations of Zooplanton Community of Nanak Sagar Reservoir, Uttarakhand, India. *Int J Curr Microbiol App Sci.* 2018;7(10):339–349.

66. Singh D, Goswami G, Diversity of seasonal variations of plankton communities after major flood in the River Mandakini of Garhwal Himalaya. *Nature Environment & Pollution Technology.* 2019;18(4):1177–1184.

67. Crayton WM, Sommerfeld MR. Composition and abundance of phytoplankton in tributaries of the lower Colorado river, Grand Caryon Region. *Hydrobiologia.*1979;66:81–93.

68. Shaikhom Inaotombi, Prem Kumar Gupta. Community structure of zooplankton across environmental variables in a high-altitude lake of central Himalaya, India. *Chemistry and Ecology.* 2019;35(10):937–953.

69. Makarrewicz JC, Likens GE. Structure and function of the zooplankton community of Mirror Lake, New Hampshire. *Ecol Monograph.*1979;49:109–127.

70. Cairns JJ. Protozoans (Protozoa). In: Hart CW, Fuller LH, editors. *Pollution Ecology of Freshwater Invertebrates.* Academic press, New York; 1974:1–28.

71. Bisht KL. *Environmental parameters and seasonal succession in planktonic biomass in the River Pindar of Garhwal Himalaya.* In: Singh HR, editor. Advances in Limnology, Narendra Publ. House, Delhi; 1993.

72. Dobriyal AK, Bahuguna AK, Neeraj K, et al. Ecology and seasonal diversity of plankton in a springfed stream Khandagad of Garhwal Himalaya. In: Singh HR, editor. Advances in Limnology, Narendra Publ. House, Delhi; 1993.

73. Wetzel RG. *Limnology, Lakes and River Ecosystems.* USA: Academic Press; 2001:1–1006.

74. Battish SK, Kumari P. Effect of physico-chemical factors on the seasonal abundance of cladocera in typical pond at village of Raqba, Ludhiana. *Ecology.* 1986;13(1):146–151.

75. Kaushik S, Agarka MS, Saxena DN. Distribution of phytoplankton in riverine waters on Chambal area, Madhya Pradesh. *Bionature.* 1992;12:1–7.

76. Vass KF, Sachlan M. Limnological studies on diurnal fluctuation in shallow ponds in Indonesia. *Verh Int Ver Theor Angew. Limnol.*1953;12:309–319.

77. Singh DN. Diurnal vertical migration of plankton in Mc Pherson lake, Allahabad. *Proc Nat Acad Sci India.*1990;60(B):141–147.

78. Chandrasekhar SVA, Kodarkar MS. Diurnal variations of zooplankton in Sazoornagar lake, Hyderabad. *Indian J Environ Health.*1997;39(2):155–159.

79. Jindal R, Thakur RK. Diurnal variations of plankton diversity and physico-chemical characteristics of Rewalsar wetland, Himachal Pradesh, India. *Recent Research in Science and Technology.* 2013;5(3):4–9.

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DOI: 10.15406/bij.2020.04.00184