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Structure and diversity of cladoceran communities in two lakes with varying nutrient compositions in the Jhelum River Basin, Kashmir

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Abstract
Comparative studies on cladocera were carried in 2 lakes with varying nutrient compositions in the basins of the Jhelum River, Kashmir: Lake Manasbal and Lake Anchar. Samples were taken monthly at 5 stations in each lake from March 2012 to February 2014 and a total of 22 and 15 taxa of cladocera were recorded in Lake Manasbal and Lake Anchar, respectively. Shannon-Wiener, Margalef and evenness indices indicated that cladocera were more diverse in Lake Manasbal than in Lake Anchar. Overall average density of cladocera was higher in Lake Anchar as compared to Lake Manasbal: 267 vs 134 individuals/litre respectively. The present investigation revealed that the distribution and abundance of plankton species depend upon the physico-chemical parameter of the environment.

Keywords: Cladocera, Community structure, Diversity indices, trophic status, Lakes, Kashmir.

1. Introduction

The fresh water lakes of the Kashmir Himalayas have been playing a great role in the socio-cultural and economic status of the valley since ancient times. Besides being a source of attraction for tourists from all over the world, the valley lakes are a great source of natural products like fish, fodder and a variety of economically aquatic plants. However, the ecology of these lakes has changed considerably in the last few decades due to unplanned urbanization, illegal encroachments, deforestation, soil erosion, reckless use of pesticides for horticulture and agriculture and other human activities, which has resulted in decreased water quality. Consequently, these factors are expected to have an adverse effect on aquatic biota of these lakes. In this scenario, limnologists as well as aquatic biologists in this part of world are concerned about the ecological impact of deteriorating environmental conditions on aquatic fauna.

To deal with these threats and associated problems (e.g chemical contamination, loss of diversity) it is necessary to implement adequate restoration measures. However, the first step towards ecological rehabilitation is to assess the status of these lakes, by analysing the structure of its biological communities. Among freshwater communities, of particular importance is the zooplankton which consists of different taxonomic groups, among which cladocera are of crucial importance. Cladocerans (Crustacea: Branchiopoda) commonly known as water fleas are an important component of most freshwater lakes. In addition to providing an important food source for planktivorous fish and invertebrates, they are important grazers on algae and detritus (Balayla and Moss, 2004) [2] and can play a crucial role in the recycling of nutrients in aquatic ecosystems (Hudson *et al*., 1999 [20]; Urabe *et al*., 2002) [58]. Because of their intermediate trophic position, they often help in the transfer of energy through aquatic food webs, as well as in regulating the transfer of contaminants and pollutants to higher trophic levels (Hall *et al*., 1997) [15]. To obtain a better understanding of the functional significance of cladocera, a basic knowledge of community structure, population dynamics and trophic dominance is required.

Cladoceran species composition can differ markedly between lakes, even when situated close together, particularly when physically isolated, or when the trophic degree is very different, or when in different stages of ecological succession. The relationship between the composition and abundance of cladocera and the trophic state of lakes has been studied elsewhere in the world (De Bie *et al*, 2008 [8]; Neves *et al* 2003; Pinel-Allou and Mimouni 2012 [41]; Sweetman,

2010) [55] but similar investigations are scarce in Kashmir valley lakes. The purpose of the present study is to compare community structure, population dynamics of cladocera in two different types of lakes in Kashmir, India and to discuss the effects of environmental influences on cladoceran communities. The data can be used to assist in the management of lake fishery resources and inform environmental protection policies for aquatic ecosystems.

2. Materials and Methods

2.1 Study Area

The valley of Kashmir is situated in the middle of the Himalayas between the northwest and southeast (33°01′–35°00′N latitude and 73°48′-75°30′ E longitude) at an altitude ≥1500 m above sea level. The study was carried out in 2 valley lakes, viz., Manasbal Lake (34°15′ N, 74°40′E) and Anchar Lake (34°01′ N, 74°02′ E).

Manasbal lake, the deepest freshwater valley lake of Kashmir, is located at the mean geographical coordinates of 74° 39′ 07” E longitude and 34° 14′ 38” N to 34° 15′ 26” N latitude at an altitude of 1584 m amsl, at a distance of about 32 km to the north-north west of Srinagar, the summer capital of Jammu and Kashmir state. It is a semi drainage rural lake, having an area of about 2.83 sq. km, oblong in outline and extends in northeast- southwest direction with the maximum length and breadth of 3.5 km and 1.5 km, respectively. It is the deepest of all valley lakes with a depth of 12.5m.

The lake inflow is chiefly derived from underground springs, in addition to which a small irrigation stream (Laar Kuhl) on the eastern side also drains water into the lake during spring-autumn. The Laar kuhl stream takes off water from the Sindh Nallah (a tributary of river Jhelum) and irrigates the agricultural fields throughout its course in the neighbourhood of the lake, thus bringing in allochthonous material into the lake including major and minor nutrients, polythene, bottles and other material. The lake is connected to the river Jhelum by a permanent channel which leaves the lake on its western side and runs in southwest direction to join the river at a place about 0.7 km below the village Sumbal. It is semi drainage, warm monomictic lake, which receives stratification from March till November, followed by mixing in early December (Yousuf, 1979 [67]; Zutshi and Khan, 1978) [68].

Anchar Lake, a shallow basin lake with fluviatile origin is situated at an altitude of 1,583 m above m.s.l, within the geographical coordinates of 34º 20´ to 34º 26´N latitude and 74º 28´ to 74º 85´E longitude, at a distance of 12 km to the North-west of Srinagar city. The lake is mono-basined with surface area of 6.6 km^2 of which about 1.69 km2 at present represent open water and the remaining portion has been transformed into a marshland due to increased human perturbations of the ecosystem. The lake receives water from the Sind stream on the northern side and a channel from Khushalsar Lake on its southern side. The excess water of the lake flows through Shalabugh wetland into the Jhelum river.

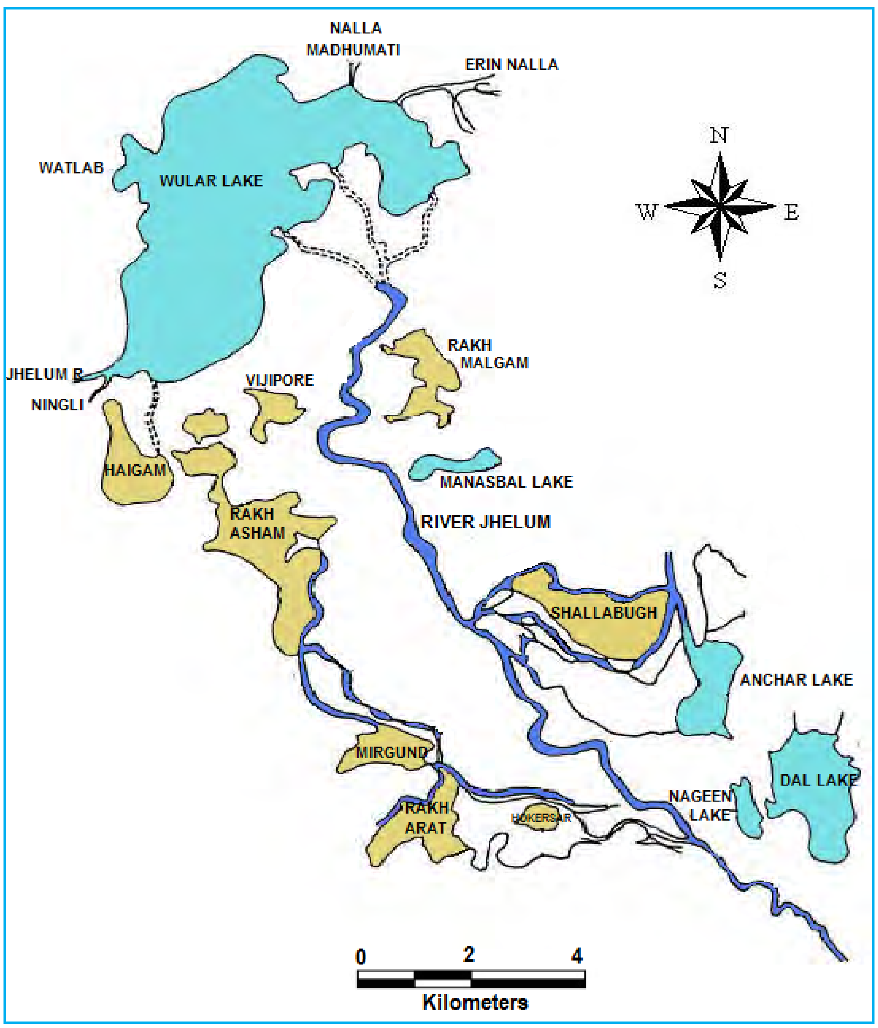

Fig 1: Map showing location of two lakes (Manasbal and Anchar) in Jhelum river basin, Kashmir

2.2 Methods for Chemical and Physical Analyses
Water samples from 10 sites of two lakes were collected at 0.5m (a depth representative of the mixed water columns) on the basis of monthly intervals between March 2012 and Febuary 2014. The samples were kept in 2 L polyethylene plastic bottles which had been previously cleaned with metal free soap, rinsed repeatedly with distilled water, soaked in 10% nitric acid for 24 h, and finally rinsed with ultrapure water. All water samples were maintained at 4 °C first during transportation to the laboratory, and then later for processing and analysis. As shown in Table 1, the measurements of water quality parameters are summarized on the basis of standard methods established for surface water monitoring in India [APHA, 1998] [1]. The temperature and pH of each water sample were measured in situ by field instruments including a digital mercury thermometer and digital pH respectively. All water samples were analyzed for different physico-chemical parameters within 48 h of collection. Total hardness was measured by EDTA complexometry titration. Total alkalinity was determined by acid titration using methyl-orange as endpoint, and chloride by silver nitrate ($AgNO_3$) titration using potassium chromate (K_2CrO_4) solution as an indicator. NH4-N was measured with Phenate method (APHA, 1998) [1]. NO_3-N and NO_2-N were analyzed by Salicyalate method and N-(1-naphthyl)-ethylenediamine colorimetry, respectively. T. Phosphorus were analyzed by absorption spectrophotometry after decomposition with sulphuric acid-nitric acid digestion (Stannous chloride method).

2.3 Biological analysis
Samples for Cladoceran zooplankton were collected with the help of a plankton net by filtering 10 litre sub-surface water from five study sites from each lake and fixed in 4% formalin. All cladocerans were counted and identified to species or taxa groups using appropriate keys (Edmondson, 1959; Pennak, 1978) [39]. Counts of cladoceran species were expressed as number of individuals per liter accounting for subsampling fractionation during microscopic analysis and the total volume of water filtered during field sampling. For quantitative cladoceran study, a sedge-wick rafter cell was used which is 50 mm long, 20mm wide and 1mm deep. The samples were transferred to the cell with a dropper. The air bubbles were avoided while transferring the sample to the cell. The number of each species was calculated by the following formula (Welch, 1948) [62].

N= <u>a×c</u> /l
N= Number of cladocera per litre.   l
a= the average number of cladocera in all counts in a counting cell of 1 ml capacity.
c= the volume of original concentrate in ml (20 ml).
l= volume of original water filtered (10 litres).
All the organisms were represented numerically as organisms per liter.
Three indices were used to obtain the estimation of species diversity, species richness and species evenness using Microsoft Excel 2007.

1. Species diversity was determined following Shannon-Wiener's Index (Shannon and Weaver, 1963, Ludwig and Reynolds, 1988) [27] using the formula: H′= (Σ pi ln pi) Where, Pi = n/N n= No. of individual species, N = total density of all organisms.
2. Species richness' or Margalef's diversity index (d) was calculated by the formula: d = S-1 / log N as proposed by (Margalef,1958)
3. Evenness was calculated using the formula: e = H′/ ln S (Pielou, 1966) [40] Where, H′ = Shannon-weiner index; S = species richness.

3. Results and Discussion
3.1 Physicochemical parameter
Fluctuations in the average value of the various physicochemical parameters at two selected lakes during study period are shown in Table 1.

Table 1: Mean of Physico-chemical Parameters in the surface waters of Manasbal and Anchar Lakes, Mar 2012-Feb 2014

S. No	P. C parameter	Manasbal	Anchar
1	AT (^{0}C)	19.00±9.36	19.98±9.74
2	WT(^{0}C)	15.75±8.68	16.50±8.98
3	Depth (m)	3.75±4.27	1.19±0.33
4	Trans (m)	1.68±1.79	0.55±0.16
5	DO (mg/L)	8.12±1.46	4.05±1.68
6	F.CO_2 (mg/L)	10.03±5.18	16.10±8.75
7	pH	8.07±0.48	8.22±0.32
8	T. Alk (mg/L)	170.55±42.46	264.39±67.24
9	EC (µS/cm)	249.72±53.60	407.72±61.14
10	Cl_2 (mg/L)	24.34±4.33	28.76±8.15
11	T. Hard (mg/L)	160.33±33.15	200.23±35.00
12	NH_4-N (µg/l)	48.28±17.22	398.23±105.79
13	NO_2-N (µg/l)	16.70±6.77	27.35±11.95
14	NO_3-N (µg/l)	261.00±56.20	350.78±70.85
15	T. Phos (µg/l)	225.18±82.26	382.05±82.95

Water temperature is one of the most important limnological parameter that plays a prominent role in regulating nearly all other physico-chemical characteristics of the water as well as biological productivity (Wetzel, 1983) [63]. Temperature showed average value of 16.50±8.98 ^{0}C in Anchar Lake and 15.75±8.68 ^{0}C in Manasbal Lake. Water temperature influences the chemical and biological activity besides growth of aquatic organisms (Pawar, 2010) [38].
Depth of an aquatic body plays an important role in concentrating ions in water mass, besides being an important determinant for the growth and development of various life forms of vegetation (Kaul and Handoo, 1980) [24]. Persistence and level of water column is determined by hydrological factors like the amount of water brought in and sent out, precipitation, melting of snow. During the present study higher average values of depth were recorded in Manasbal lake (3.75±4.27 m) and lowest in Anchar lake (1.19±0.33 m). The lowest mean depth is an indication of an evolutionary process coinciding with higher trophic status of the lake as also opined by Hayes (1957) [18] and Pandit (2002) [34].
Transparency is one of the important physical properties of water indicative of degree to which sunlight can pass through water. Higher average values of Trans were recorded in Manasbal Lake (1.68±1.79 m) as compared to Anchar Lake (0.55±0.16 m) (Table 1). Relatively lower transparency values in Anchar lake seem to be related to large quantities of swamp material brought from the catchment.
Dissolved oxygen is of paramount importance because it is critical to the survival of most forms of aquatic life besides being the most reliable criterion in assessing the trophic status and the magnitude of eutrophication (Edmondson, 1966) [11]. Dissolved Oxygen level in lakes vary according to the lake trophic levels, and depletion of dissolved in water probably is the most frequent result of water pollution (Srivastava *et al*., 2009) [52]. Higher average values of dissolved oxygen were found at Manasbal Lake (8.12±1.46 mg/l) and lower at Anchar

Lake (4.05±1.68 mg/l) as given (Table 1) indicating Anchar Lake with higher levels of contamination. Low values of Dissolved oxygen implies higher trophic status (Naz and Turkmen, 2005 [31]; Sheela *et al*., 2011) [49].

The average values of $F.CO_2$ during the present investigation were 16.10±8.75 at Anchar and 10.03±5.18 at Manasbal. The higher values of $F.CO_2$ in Anchar lake may be attributed to the presence of high amount of organic matter which on microbial decomposition release large amount of $F.CO_2$ as a by-product of their metabolic activity. The high value of the free carbon dioxide content is an indication of high degree of pollution, a fact also supported by Todda (1970) [56] and Coole (1979) [6] which related high value of free carbon dioxide content to high degree of pollution. The present results also support the statement of Mohapatra (1987) [30] that dissolved oxygen and $F.CO_2$ concentrations usually behave reciprocally.

pH is one of the very significant chemical characters of all waters explaining certain significant biotic and abiotic ecological characteristic of an ecosystem in general (Chandrasekhar *et al*., 2003) [5]. pH varying among the lakes had a range of 8.22±0.32 in Anchar Lake and 8.07±0.48 in Manasbal Lake (Table 1). pH recorded being in alkaline range indicates that the lakes were well buffered throughout the study period. pH range between 6.0 and 8.5 indicates productive nature of water body (Garg *et al*., 2010) [13].

Total alkalinity is a measure of buffering capacity of water and is important for aquatic life in a freshwater system (Kaushik and Saxena, 1994). Total Alkalinity exhibited variation between the two lakes with higher values in Anchar Lake (264.39±67.24 mg/l) and lower in Manasbal Lake (170.55±42.46 mg/l) (Table 1). The alkalinity of the present lakes appears to be greatly influenced by the inflow from catchment and also by the decomposition of autochthonous organic matter (Sugunan, 2000) [53]. Das *et al*., (2009) [7] have concluded that high alkalinity indicates pollution.

Conductance is a measure of the ability of water to conduct an electric current and has been used for assessing the trophic status of water bodies (Shastree *et al*., 1991) [47]. Electrical Conductivity indicates the quantity of dissolved salts in water (Gupta *et al*., 2008) [14] besides the nutrient loading of the lakes. The average Electrical Conductivity was 407.72±61.14 mS/cm in Anchar Lake and 249.72±53.60 mS/cm in Manasbal Lake (Table 1). The relatively higher average values of Electrical Conductivity recorded during the present study in Anchar Lake is attributed to the high degree of anthropogenic activities such as waste disposal, sewage inflow and agricultural runoff (Pandit, 2002) [34].

A high concentration of chloride is always regarded as an indicator of eutrophication (Hynes 1963) [22] and is usually taken as an index of pollution (Hasalam 1991 [17]; Verma *et al*., 2012) [59]. Higher l average value of chlorides (28.76±8.15mg/l) were recorded in Anchar Lake and lower in Manasbal Lake (24.34±4.43 mg/l). The relatively higher values of chlorides observed at Anchar were due to the addition of city sewage and domestic waste (Dwivedi and Odi 2003 [10]; Sanap *et al*., 2006) [43].

The total hardness in all the three habitats was very high indicating hard water nature which seems to be related to the source of Ca^{++} and Mg^{++} owing to its origin to the lacustrine deposits in the valley (Wadia, 1961) [61]. The mean values of total hardness were found highest for Anchar lake (200.23±35.00 mg/l) and lowest for Manasbal lake (160.33±33.15 mg/l). Higher hardness in Anchar lake may be due to presence of large quantities of sewage, detergents and more anthropogenic activities.

Ammonical-nitrogen has been reported to be the preferred nitrogen for phytoplankton uptake (Wetzel, 2001) and is also a product of many organic degradation processes and thus could be expected to show large variations in concentration. NH4-N exhibited variations between the lakes with higher average values in Anchar Lake (398.23±105.79 µg/l) and lower in Manasbal Lake (48.28±17.22 µg/l) (Table 1). Organically polluted waters with high levels of NH4-N show increased biological productivity due to readily available nutrients (Sheela *et al*., 2010) [49].

Nitrite-nitrogen concentrations in unmodified waters are generally low in the range of 0-10 µg/l (Wetzel, 2001) while concentration above 10 µg/l are regarded to be indicative of sewage contamination. Bhat and Yousuf (2004) [4] found nitrite-nitrate in some water bodies of kashmir in the range of 1-12 µg/l while in the present investigation, the NO_2-N concentration varied between lakes and had a range of 27.35±11.95 µg/l in Anchar and 16.70 ± 6.77 µg/l in Manasbal (Table 1). The higher concentration of nitrite in Anchar lake may be attributed to the greater sewage contamination and use of fertilizers in the catchment area.

The range of NO_3-N was 350.78±70.85 µg/l and 261.00±56.20 µg/l in Anchar Lake and Manasbal Lake, respectively (Table1) indicating Anchar Lake as having the highest concentration of NO_3-N. Average concentration of Total Phosphorus was higher in Anchar Lake (382.05±82.95 µg/l) as compared to Manasbal Lake (225.18±82.26 µg/l) (Table. 1). The presence of high amounts of nitrogen and phosphorous indicate a eutrophic nature, leading to subsequent algal blooms. Comparatively, high nitrate and phosphorus values in Anchar lake indicated higher biological productivity. According to Sylvester (1961) [54], domestic sewage is mainly responsible for the greater concentration of nitrates and Phosphates in freshwaters, accounting for the accelerated eutrophication (Vyas *et al*., 2006) [60] and the augmented concentration of Total Phosphorus and NO_3-N in lakes resulted in enhanced phytoplankton productivity (Pandit and Yousuf, 2002) [34].

3.2 Cladoceran species composition

The cladoceran community was represented by 22 species in Manasbal lake and 15 species in Anchar lake as shown in Table 2. The rich faunal diversity in Manasbal lake may be attributed to low trophic status and the lower number of species in Anchar lake can be attributed to its more eutrophic status than the former, as more a waterbody is eutrophic, the lower is cladoceran species diversity in it (Trivedi, 1981 [57]; Hanson and Butler, 1994) [16]. In the present study, cladocera recorded highest species diversity during late spring/early summer which may be attributed to favourable temperature and increase of phytoplankton population (food supply) during the period (Wright 1954 [65]; Singh 2000 [50]; Hulyal and Kaliwal, 2008 [21]; Shah and Pandit, 2013) [45]. Qadri and Yousuf (1980) [42] found the temperature to be the primary factor affecting the occurrence and distribution of cladocerans. The low diversity of cladocera during winter may be attributed to non-availability of food together with low temperature that modulates the duration of egg development (Saunders *et al*., 1999) [44].

3.3 Diversity Indices

Diversity index is commonly used as a biocriteria for the interpretation of the environmental status, as well as to measure the average degree of uncertainty within the community. Balloch *et al*., (1976) [3]; Ismael and Dorgham (2003) [23] found Shannon diversity to be a suitable indicator for water quality assessment. According to Mason, (1988) a diversity index of <1 indicates highly polluted conditions while as index of 1-3 indicates moderately polluted conditions and an index of >3 reveals unpolluted conditions of any water body. The data on Shannon weiner diversity index in the present study showed higher values for Manasbal (2.244) while lowest for Anchar (2.127) (Table 3). The lower values of diversity index at Anchar clearly reflect its higher trophic status & more stressed and polluted conditions (Bass and Harrel, 1981) than Manasbal. Latha and Thanga (2010) [26] reported lower diversity at polluted sites while as highest species diversity was reported in the unpolluted sites. Richness index was maximum in Manasbal lake (2.177) and minimum in the Anchar lake (1.552) (Table 3). Larger richness index value denotes more healthy body of water (Somasheker and Ramaswamy, 1984) [51]. Similar trend as of richness index was also recorded in evenness index with highest value at Manasbal (0.950) and lowest at Anchar (0.947). The results of evenness index suggest that, Manasbal lake was with higher equal representation of species and Anchar lake with lower representation or highest unequal representation. Comparing the data on the Diversity indices of the two lakes, it has been observed that maximum values of Shannon-Weiner index (2.244), Margalef index (2.177) and evenness index (0.950) were observed in Manasbal lake, whereas the lowest values of Shannon-Weiner index (2.127), Margalef index (1.552) and evenness index (0.947) were recorded in Anchar lake. The higher index values in Manasbal lake indicated the healthy status of lake and the lowest values in Anchar lake showed the unhealthy and pollution status of lake. Furthermore, diversity, richness and evenness indices are in accordance with the results of the chemical water properties.

3.4 Cladoceran density

The highest average population density of cladocera was recorded in Anchar lake and lowest in Manasbal lake, being 267 ind/L and 134 ind/L respectively. The comparatively higher population density values in Anchar than Manasbal may be attributed to high nutrient content of the former than the latter (Wright, 1965 [66]; Patalas, 1972 [37]; Shah and Pandit, 2013) [45]. Low cladoceran abundance in Manasbal lake could probably be related to reduced nutrient content and reduced food availability. The maximum population of cladocerans in summer season in both the lakes may be attributed to favorable temperature and availability of food in the form of bacteria, nanoplankton and suspended detritus. Further, the dominance of cladoceran in this period has been attributed to multiple environmental factors including water temperature enhancing rapid hatching of eggs, high nutrient conditions and food availability as maintained by Pandit (1980, 1998) [35, 36] for Kashmir waters and Dejen *et al*., (2004) [9] for Lake Tana, Ethopia.

Table 2: List of cladoceran species recorded from two selected lakes during Mar. 2012 to Feb. 2014

Name of Taxa	Manasbal	Anchar
Acropeus harpae	+	+
Alona affinis	+	+
A. costata	+	+
A. guttata	+	-
A. rectangula	+	-
Alonella dentifera	+	-
Camptocercus rectirostris	+	+
Chydorus sphaericus	+	+
C. ovalis	+	+
Graptolebris testudinaria	+	-
Pleuroxus denticulatus	+	+
Ceriodaphnia quadrangula	+	+
Ceriodaphnia rectirostris	+	-
Ceriodaphnia reticulata	+	-
Daphnia laevis	+	+
D. magna	+	+
D. pulex	+	+
D.rosea	-	+
Bosmina coregoni	+	+
B. longirostris	+	+
Macrothrix rosea	+	-
Diaphanosoma brachyurum	+	+
Sida crystallina	+	-

Table: 3: Average value of Cladoceran community indices in the two lakes

Lake	Shannon-Weiner index	Margalefs index	Evenness index
Manasbal	2.244	2.177	0.950
Anchar	2.127	1.552	0.947

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