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Research Article

Diversity and Abundance of Cladoceran Zooplankton in Wular Lake, Kashmir Himalaya

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Abstract: The present study was carried out on Wular lake, the largest freshwater lake of India to obtain a baseline data on the dynamics of species composition and density of cladoceran zooplankton for the period of one year from September 2010 to August 2011 at five different study sites. Investigations revealed about 23 species of Cladocera belonging to six families were reported during the entire study. Among the six families, Chydoridae was numerically dominant, being represented by nine species, followed by Daphnidae with seven species, Bosminidae, Moinidae and Sididae with two species each and Macrothricidae with only one species. Shannon index was noticed highest for site III reflecting the stable environmental conditions of this biotope.

Keywords: Chydoridae, Cladocera, Daphnidae, Himalaya, Kashmir, Wular

INTRODUCTION

Zooplankton holds a central position in the food chain of most of the lakes, reservoirs and ponds and are highly sensitive to environmental variations which as a result bring changes in their abundance, species diversity or community composition, because most species have short generation time (Pandit, 1980; Sharma *et al*., 2008; Shah and Pandit, 2013). Cladocerans generally contribute largely to zooplankton biomass and act as a key element in the freshwater food webs (Hessen *et al*., 2003). They control the algal growth by efficient grazing, therefore, are considered as indicators of water quality (Pinto-Coelho *et al*., 2005; Rajashekhar *et al*., 2009; Joshi, 2011) and are important diet for zooplanktivorous fish (Christoffersen *et al*., 1993; Balayla and Moss, 2004). They also play a crucial role in the recycling of nutrients in aquatic ecosystems (Urabe *et al*., 2002). 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). Thus, cladocerans are an important link in the transmission of the energy from the primary producers to the top consumers. Water fleas are important components of the fauna of fresh waters; they are particularly significant in the food web of stagnant waters (Forro *et al*., 2008). In view of the fact that no published report on zooplankton community is available on Wular lake a Ramsar site, in Kashmir Himalaya. The present study is, therefore, aimed to collate a baseline data on the cladoceran community of Wular lake in terms of spatial and temporal variations in species composition and abundance by using various diversity indices.

Study area: Wular lake the largest freshwater lake of India, is situated at an altitude of 1580 m (a. m. s. l) and lies between 34°16´-34°20´N and 74°33´-74°44´E geographical co-ordinates The lake extends from Bandipora to Sopore and is at a distance of 34 km from Srinagar city of Kashmir valley (Fig. 1). The lake has been declared as the wetland of national importance (1986) under wetland programme of Ministry of Environment and Forests (MOEF), Govt. of India and was designated as Ramsar Site (a Wetland of International Importance under Ramsar convention, 1990). The lake with its associated wetlands is an important habitat for migratory water birds within Central Asian Flyway and supports rich biodiversity. It is a major fishery resource in the valley supporting a large population living along its fringes. In ancient times surface area of the was 202 km^2, (Stein, 1961) but due to heavy anthropogenic stresses like agriculture, industrialization and urbanization, the lake has shrunk today and its surface area is reduced to about 24 km^2 indicating ecologically stressed condition of the lake.

Study sites: Five sampling sites were chosen to collect the zooplankton in Wular lake (Table 1, Fig. 1).

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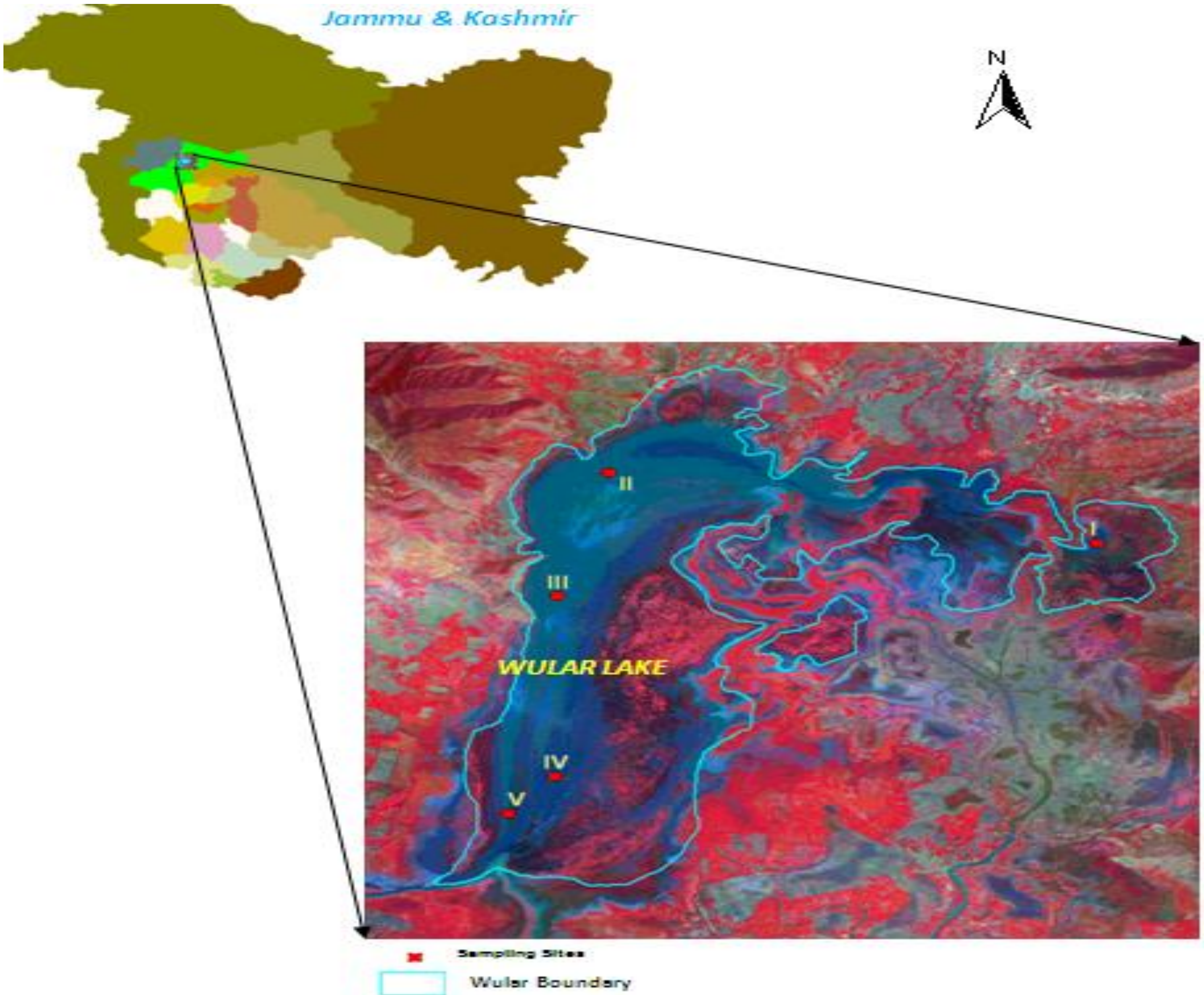

Fig. 1: Location of Wular lake with sampling sites

Table 1: Location of five study sites in Wular lake

Sites	Latitude (N)	Longitude (E)	Features
I	34°21´ 51”	74°39´ 42”	Human interference
II	34°24´ 15”	74°32´ 35”	Good macrophytic growth
III	34°21´ 29”	74°31´ 48”	Profuse growth of macrophytes
IV	34°17´ 43.1”	74°31´ 29.8”	Centre of lake basin
V	34°17´ 15.8”	74°30´ 24.9”	Adjacent to site IV

MATERIALS AND METHODS

Cladoceran samples were collected by filtering 100 L of the subsurface lake water using a hand net made up of nylon cloth with mesh size of 60 µm. The content collected in the plankton tube attached to lower end of the net were transferred to separate polyethylene tubes and after centrifugation a subsample of 30 mL was taken. The cladoceran organisms were preserved in 4% formalin, added with 4-5 drops of glycerine (organism remain flexible) and 5% sucrose (retain eggs in their brood chamber) and results were expressed as organisms/L (org./L). Identification of the specimens was carried out by standard works of Pennak (1978), Edmondson (1992) and Battish (1992). For determining species diversity, various indices were employed (Shannon and Weaver, 1963), Equitability (Pielou, 1966; Margalef, 1957) using Microsoft Excel 2007). The relationship between cladoceran species abundance with different seasons was determined using a similarity percentage program PAST (statistical Version 1.93 for Windows 7).

RESULTS AND DISCUSSION

Species composition: Twenty three species of Cladocera belonging to six families were recorded from the wetland. Among the six families, Chydoridae was numerically dominant, represented by nine species, followed by seven species of Daphnidae, two each of Bosminidae, Moinidae and Sididae and only one species of Macrothricidae were recorded. Whiteside (1974) recognized that the species diversity of chydorids is a function of available habitat and concluded that the distribution of most chydorid species within a region is determined by habitat diversity. Cladocera was represented by a varying number of

Table 2: Seasonal variations in the population density of cladoceran (org./L.) at different sites*

		Seasons			
S. No.	Taxa	Autumn	Winter	Spring	Summer
Site 1					
1	*Alona rectangula*	19.0	13.0	53.3	28.4
2	*Bosmina coregoni*	16.3	24.0	44.0	28.1
3	*B. longirostris*	18.0	17.3	50.3	0.0
4	*Ceriodaphnia quadrangula*	28.0	25.3	46.3	33.2
5	*Chydorus sphaericus*	12.3	54.3	60.0	42.2
6	*Daphnia pulex*	27.7	14.7	72.0	38.1
7	*Sida crystallina*	31.0	13.3	67.3	37.2
	Total	152.3	162.0	393.3	207.3
Site II					
1	*Alona affinis*	82.0	72.0	43.3	65.8
2	*A. costata*	26.3	23.3	53.7	34.4
3	*Alonella dentifera*	30.7	36.7	51.3	39.6
4	*Bosmina longirostris*	36.0	43.3	50.0	N.D
5	*Ceriodaphnia quadrangula*	27.3	N.D	58.7	28.7
6	*Chydorus sphaericus*	27.7	70.3	66.0	54.7
7	*Daphnia pulex*	23.3	23.0	84.3	43.6
8	*D. rosea*	23.3	44.7	47.0	38.3
9	*Macrothrix rosea*	30.0	70.0	31.7	43.9
10	*Moina affinis*	41.0	52.3	29.3	40.9
11	*Sida crystallina*	37.3	14.7	90.0	47.3
	Total	385.0	450.3	605.3	437.1
Site III					
1	*Alona affinis*	99.3	72.0	30.0	67.1
2	*A. costata*	38.3	21.7	63.0	41.0
3	*A. guttata*	30.3	N.D	26.7	19.0
4	*A. rectangula*	17.7	13.0	45.7	25.4
5	*Alonella dentifera*	36.3	38.0	70.0	48.1
6	*A. exigua*	49.3	34.0	50.3	44.6
7	*Bosmina coregoni*	32.0	10.3	47.7	30.0
8	*B. longirostris*	21.0	43.0	35.0	N.D
9	*Camptocercus rectirostris*	33.0	N.D	28.3	20.4
10	*Ceriodaphnia quadrangula*	30.0	N.D	48.3	26.1
11	*Chydorus sphaericus*	35.7	68.7	32.7	45.7
12	*C. ovalis*	33.0	38.3	54.3	41.9
13	*Daphnia laevis*	17.0	39.3	53.3	36.6
14	*D. magna*	22.7	43.7	29.3	31.9
15	*D. pulex*	31.7	41.3	20.0	31.0
16	*D. retrocurva*	30.3	45.0	37.3	37.6
17	*D. rosea*	20.7	29.0	47.3	32.3
18	*Diaphanosoma brachyurum*	34.0	13.7	53.7	33.8
19	*Macrothrix rosea*	40.7	73.0	25.7	46.4
20	*Moina brachiata*	29.7	44.0	29.3	34.3
21	*Moinodaphnia* sp.	19.0	4.0	44.7	22.6
22	*Sida crystallina*	20.0	16.0	93.3	43.1
	Total	721.7	688.0	966.0	758.9
Site IV					
1	*Alona affinis*	41.0	57.7	25.0	41.2
2	*A. guttata*	24.3	N.D	28.3	26.3
3	*A. rectangula*	24.0	20.7	49.0	31.2
4	*Alonella dentifera*	20.3	32.3	47.7	33.4
5	*A. exigua*	33.3	31.3	69.0	44.6
6	*Bosmina coregoni*	32.7	20.3	59.3	37.4
7	*B. longirostris*	19.3	37.0	30.0	N.D
8	*Camptocercus rectirostris*	31.3	N.D	42.0	36.7
9	*Ceriodaphnia quadrangula*	32.3	N.D	53.3	42.8
10	*Chydorus sphaericus*	27.7	91.0	58.0	58.9
11	*Daphnia laevis*	40.0	46.7	37.0	41.2
12	*D. pulex*	21.7	44.3	22.7	29.6
13	*D. rosea*	31.0	48.7	45.0	41.6
14	*Macrothrix rosea*	43.7	73.0	30.0	48.9
15	*Sida crystallina*	33.7	9.3	65.7	36.2
	Total	456.3	512.3	662.0	550.1
Site V					
1	*Alona affinis*	18.6	53.3	41.0	37.6
2	*A. guttata*	19.3	N.D	42.3	20.5
3	*A. rectangula*	26.0	11.0	54.6	30.5
4	*Alonella dentifera*	36.0	25.3	47.3	36.2
5	*A. exigua*	26.6	36.0	64.6	42.4
6	*Bosmina coregoni*	30.0	15.6	56.0	33.8
7	*B. longirostris*	23.6	52.3	20.0	N.D
8	*Camptocercus rectirostris*	31.0	N.D	43.3	37.1
9	*Ceriodaphnia quadrangula*	48.3	N.D	63.3	55.8
10	*Chydorus sphaericus*	31.0	59.6	31.0	40.5
11	*Daphnia laevis*	47.3	56.6	20.6	41.5
12	*D. pulex*	15.0	60.6	18.3	31.3
13	*Diaphanosoma brachyurum*	27.6	N.D	42.6	35.1
14	*Macrothrix rosea*	27.6	53.3	22.3	34.4
15	*Moinodaphnia* sp.	26.6	10.0	129.3	55.3
16	*Sida crystallina*	34.0	18.5	57.6	36.7
	Total	469	452.5	754.67	569.44

*: Average results based on three analyses; N.D: Not detected

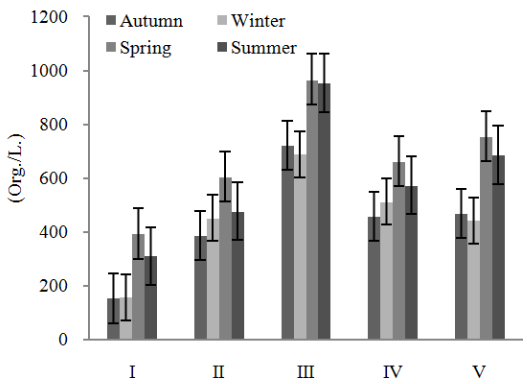

Fig. 2: Seasonal variations in the mean density (org./L) of cladocerans at five study sites

species at different selected sites, recording 22, 16, 15, 11 and 07 species at sites III, V, IV, II and I respectively. In general, Cladocera showed maximum growth and development in terms of population density in spring (May) and summer (August). However, it exhibited invariably low prevalence in the remaining seasons.

The most dominant cladocerans reported in the lake were *Chydorus sphaericus*, *Alona affinis*, *Macrothrix rosea* and *Moinodaphnia* sp., *Chydorus sphaericus* is a species of cosmopolitan distribution and a wide range tolerance to a multiplicity of environmental factors such as pH (3.2-10.6) or temperature (Flößner, 1972; Deneke, 2000). Further, the Cladoceran species which showed restricted distribution were *Chydorus ovalis*, *Daphnia magna* and *D. retrocurva* at site III, *Moina affinis* at site II, *Moina brachiata* and *Moinodaphnia* sp., at site III.

Among the species *Alona affinis* and *Ceriodaphnia reticulate* showed wider distribution and are considered lacustrine zooplankton (Baloch *et al*., 1998) which usually dominates food rich environments (Baloch and Suzuki, 2009). *Alona guttata*, *Diaphanosoma brachyurum* and *Chydorus sphaericus* showed their peak populations in warmer periods while *Daphnia laevis* maintained peak populations in late winter. Some cladoceran genera like *Alona*, *Chydorus*, *Macrothrix* and *Moina* are generally considered as littoral species. Their common occurrence in shallow water bodies is therefore, in consonance with their general behavior.

Seasonal variation in density: Seasonal variation on the basis of density of Cladocera revealed a unimodal growth curve with one dominant peak being registered in spring at all sites (Table 2). At site I Cladoceran population varied between the minimum of 152.3 ind./L in the autumn season and the maximum of 393.3 org./L in the spring season (Fig. 2). At site II, peak population of 605.3 org./L being registered in the spring season. *Moina affinis* was the species restricted only to this biotope. At site III, water fleas showed their highest abundance with maximum number of individuals (966 org./L.) being obtained in spring whileas, the lowest ebb was noticed in winter season registering 688 org./L. The site exhibited great species richness and was characterized by the presence of species like *Alona affinis*, *A. costata*, *A. guttata*, *A. rectangula*, *Alonella dentifera*, *A. exigua*, *Bosmina coregoni*, *B. longirostris*, *Camptocercus rectirostris*, *Ceriodaphnia quadrangula*, *Chydorus sphaericus*, *C. ovalis*, *Daphnia laevis*, *D. magna*, *D. pulex*, *D. retrocurva*, *D. rosea*, *Diaphanosoma brachyurum*, *Macrothrix rosea*, *Moina brachiata*, *Moinodaphnia* sp. and *Sida crystalline*. At site IV Cladocera population remained low during the autumn season and continued to remain so in winter respectively contributing 456 and 512 org./L. However, with the advent of warmer environmental conditions during spring an abrupt increase

At site V Cladocera density registered its numerical surge in warm water periods, registering its peak population of 754.67 org./L in spring which remained fairly so (569.4 org./L) during the summer season also, thus exhibiting a long growth periods. Cladocerans are constantly exposed to a great variety of environmental factors, whose fluctuations constrain the size, reproduction and survival of populations. The data on seasonal variation in Cladocera populations suggests that the most favorable period for growth is from May to August, which may be attributed to the increase of phytoplankton population during the period. 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) for Kashmir waters and Dejen *et al*. (2004) for Lake Tana. Water temperature constrains the life history traits of zooplanktonic organisms by changing metabolic rate and activity level, with direct effects on growth and reproduction (Burns, 1969; Goss and Bunting, 1983; Orcutt and Porter, 1984). Furthermore, Mergeay *et al*. (2006) related high population density to water temperature and other environmental conditions that are prerequisites for the hatching of resting cladoceran eggs in natural water. However, Wright (1965) and Patalas (1972) found increase in zooplankton densities with the increase in the nutrient content of the water body. It is also believed that the mechanism for reaching extreme population sizes for cladocerans is associated with rapid parthenogenetic reproduction.

Pennak (1957) further opined that crustacean plankton in a freshwater habitat at a particular moment is generally composed of one dominant species; one or two sub dominant species and the remaining species make up only a small fraction of the whole population. The present data does not support this view point as the shallow nature of the wetland, supporting luxuriant

Table 3: Shannon-Weiner index values (H') of cladocerans in Wular lake from Sep. 2010 to Aug. 2011

Sites	Autumn (H')	Winter (H')	Spring (H')	Summer (H')
I	(1.74)	(1.77)	(1.93)	(1.71)
II	(2.31)	(2.19)	(2.34)	(2.12)
III	(2.99)	(2.78)	(3.02)	(2.84)
IV	(0.57)	(2.34)	(2.65)	(2.48)
V	(2.72)	(2.28)	(2.64)	(2.59)

Table 4: Species richness and evenness at different sites based on Margalef's index (d) and equitability index (J)

Sites	Margalef's index (D)	Equitability index (J)
I	0.74	2.80
II	1.15	3.45
III	2.28	4.45
IV	1.59	3.90
V	1.69	4.00

growth of macrophytes, provides varied micro-habitats for different animal associations including Cladocera. The data revealed that different species appear at different times of the year and their abundance varies greatly from one another. All these variations may be related to their tolerance range of various physical and chemical characteristics of water. Among the Cladocera, *Bosmina longirostris* was the only species absent in summer while the species like *Ceriodaphnia quadrangula*, *Alona guttata* and *Camptocercus rectirostris* were totally absent in winter (Yousuf and Qadri, 1985).

During the entire study, the low population size of cladocerans was registered in colder months. The main reason for this is not immediately known but we believe that direct and indirect effects of fish have contributed to the decline in cladoceran population (Pandit, 1980; Sommer *et al*., 1986; Mwebaza-Ndawula, 1994; Ovie and Ovie, 2002). In addition to the large impact of size selective predation, zooplanktivorous fish also influence the morphology, life history traits and behaviour of zooplanktonic prey species through the release of infochemicals (Stibor, 1992; Gliwicz, 1994; Reede, 1995; Boersma *et al*., 1998). Hebert and Hann (1986) suggested that differences in the life cycle of the species could explain differences in the dispersion patterns. On the other hand, Soto (1989) demonstrated that the reproductive characteristics of micro-crustaceans are of great importance in determining their persistence or extinction in certain environments. Solomon *et al*. (2009) recognized various anthropogenic stressors effecting the abundance and diversity of the Cladocera population. Species like *Bosmina longirostris* being thermophobic, was completely absent in summer season at all the sites while as species like *Alona guttata*, *Camptocercus rectirostris*, *Ceriodaphnia quadrangula* and *Diaphanosoma brachyurum* were not encountered throughout winter, an observation also made by Hakkari (1977) on Finland lakes, Yousuf and Qadri (1981, 1983), Yousuf *et al*. (1984) and Balkhi and Yousuf (1996) on Kashmir lakes.

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. The species diversity tends to be low in stressed and polluted ecosystem (Bass and Harrel, 1981). The highest

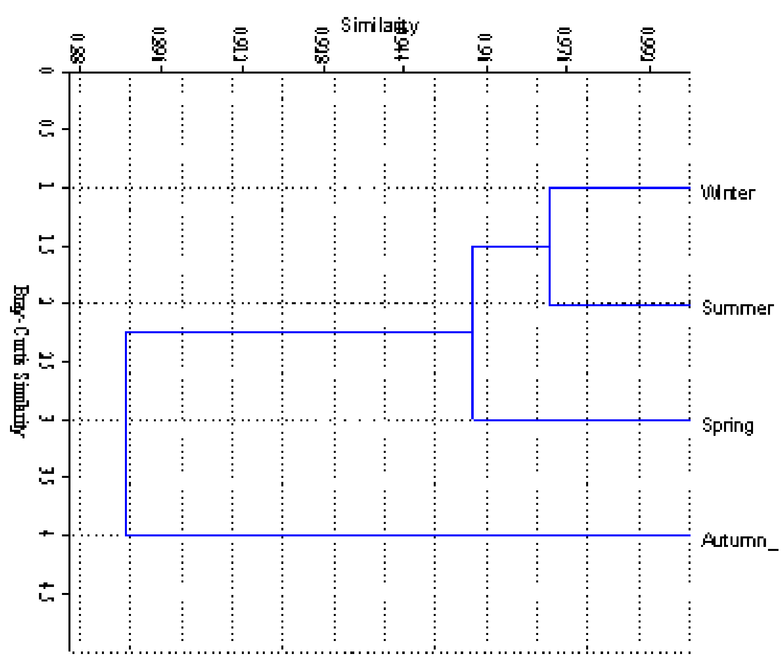

Fig. 3: Bray-curtis cluster analysis based on Shannon Weiner index (H)

diversity values of cladoceran community was found for the sites situated among submerged vegetation which create a favorable anti-predation refuge against a number of predators, both invertebrate and vertebrates (Kuczyńska-Kippen and Nagengast, 2006). This ecological type of macrophytes also often serve as a nutritional source for their inhabiting organisms (Jones *et al*., 2000). Site III registered the highest (H) value (3.02) in spring followed by (2.99) in autumn. Shannon's index was almost equal in spring at sites IV and V registering respectively 2.65 and 2.64 (Table 3). However, the lowest index (0.57) was maintained by site IV in autumn. The absence of a well-developed macrophyte community at site I besides its gross pollution due to human settlement which results in depletion of oxygen may have impact on cladoceran richness and abundance. Species richness was computed using Margalef's index (D). This measure relies only on cladoceran abundance and the number of taxa. Species richness of Cladocera revealed clear spatial variations (Table 4). The maximum value of 2.28 was recorded for site III indicating higher faunal diversity and the least diversity was recorded for site I (0.74). Site II, IV and V showed values intermediate between the two extremes. As for as evenness index is concerned comparatively high values were found atsites III and V, indicating that these two sites have much even distribution as compared to remaining sites (Table 4). In general, however, these index values indicate that this lake has a well balanced cladoceran community that enjoys an even representation of several species indicating the dynamic nature of this aquatic ecosystem. Bray-Curtis cluster analysis based on seasonal Shannon Weiner index (H) values falling between (0.97-0.096%) showed great similarity between winter and summer lies Contrary to this, autumn showed maximum dissimilarity during the entire study period (Fig. 3). Spring and summer, however, showed moderate similarity.

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REFERENCES

Balayla, D.J. and B. Moss, 2004. Relative importance of grazing on algae by plant-associated and open-water microcrustacea (Cladocera). Archiv. fur Hydrobiol., 161: 199-224.

Balkhi, M.H. and A.R. Yousuf, 1996. Distributional pattern of cladoceran plankton in the freshwaters of Kashmir. Oriental. Sci., 1: 75- 81.

Baloch, W.A. and H. Suzuki, 2009. Summer zooplankton composition, vertical distribution and biomass in Lake Ikeda, Southern Kyushu, Japan. Sindh Univ. Res. Jour**.**, 41: 35-40.

Baloch, W.A., H. Maeda and T. Saisho, 1998. Seasonal abundance and vertical distribution of zooplankton in Lake Ikeda, southern Japan. Microb. Environ., 13: 1-8.

Bass, D. and R.C. Harrel, 1981. Water quality of south-east texas stream. Hydrobiologia, 76: 69-79.

Battish, S.K., 1992. Freshwater Zooplankton of India. Oxford and IBH Publishing Co., New Delhi.

Boersma, M., P. Spaak and L. De Meester, 1998. Predator mediated plasticity in morphology, life history and behavior of *Daphnia*: The uncoupling of responses. Amer. Nat., 152: 237-248.

Burns, C.W., 1969. Relation between filtering rate, temperature and body size in four species of *Daphnia*. Limnol. Oceanogr., 14: 693-700.

Christoffersen, K., B. Riemann, A. Klysner and M. Sondergaard, 1993. Potential role of fish predation and naturalpopulations of zooplankton in structuring a plankton community in eutrophic lake water. Limnol. Oceanogr., 38: 561-573.

Dejen, E., J. Vijverberg, L. Nagelkerke and F. Sibbing, 2004. Temporal and spatial distribution of microcrustacean zooplankton in relation to turbidity and other environmental factors in large tropical lake (Lake Tana, Ethiopia). Hydrobiologia, 513: 39-49.

Deneke, R., 2000. Review of rotifers and crustaceans in highly acidic environments of pH values ≤ 3. Hydrobiologia, 433: 167-172.

Edmondson, W.T., 1992. Ward and Whiple Freshwater Biology. 2nd Edn., Intern. Books and Periodicals Supply Service, New Delhi.

Flößner, D., 1972. Krebstiere, crustacea. Kiemen und Blattfüßer, Branchiopoda, Fischläuse, Branchiura. VEB Gustav Fisher Verlag Jena, pp: 478.

Forro, L., N.M. Korovchinsky, A.A. Kotov and A. Petrusek, 2008. Global diversity of cladocerans (Cladocera; Crustacea) in freshwater. Hydrobiologia, 595: 177-184.

Gliwicz, Z.M., 1994. Relative significance of direct and indirect effects of predation by planktivorous fish on zooplankton. Hydrobiologia, 272: 201-210.

Goss, B.L. and D.L. Bunting, 1983. *Daphnia* development and reproduction: Responses to temperature. J. Therm. Biol., 8: 375-380.

Hakkari, L., 1977. On the productivity and ecology of zooplankton and its role as food for fish in some lakes in Central Finland. Biol. Res. Rep. Uni. Jyudskyla, 4: 3-87.

Hall, B.D., R.A. Bodaly, R.J.P. Fudge, J.W.M. Rudd and D.M. Rosenberg, 1997. Food as the dominant pathway of methylmercury uptake by fish. Water Air Soil Poll., 100: 13-24.

Hebert, P.D.N. and B. Hann, 1986. Patterns in the composition of Arctic Tundra pond microcru stacean communities. Can. J. Fish. Aquat. Sci., 43: 1416-1425.

Hessen, D.O., B.A. Faafeng and P. Brettum, 2003. Autotroph: Herbivore biomass ratios; carbon deficits judged from plankton data. Hydrobiologia, 491: 167-175.

Jones, J.I., B. Moss, J.W. Eaton and J.O. Young, 2000. Do submerged aquatic plants influence periphyton community composition for the benefit of invertebrate mutualists? Freshwat. Biol., 43: 591-604.

Joshi, P.S., 2011. Studies on zooplanktons of Rajura lake of Buldhana district, Maharashtra India. Sci. Res. Reporter, 1(3): 132-137.

Kuczyńska-Kippen, N.M. and B. Nagengast, 2006. The influence of the spatial structure of hydromacrophytes and differentiating habitat on the structure of rotifer and cladoceran communities. Hydrobiologia, 559: 203-212.

Margalef, R., 1957. Information theory in ecology. Gen. Syst., 3: 36-71.

Mergeay, J., S. Declerck, D. Verschuren and L. Meester, 2006. *Daphnia* community analysis in shallow Kenyan lakes and ponds using dormant eggs in surface sediments. Freshwat. Biol., 51: 399-411.

Mwebaza-Ndawula, L., 1994. Changes in relative abundance of zooplankton in two northern lakes of Victoria, East Africa. Hydrobiologia, 272: 259-264.

Orcutt, J.D. and K.G. Porter, 1984. The synergistic effects of temperature and food concentration on life-history parameters of *Daphnia*. Oecologia, 63: 300-306.

Ovie, S.I. and S.O. Ovie, 2002. Fish-larval rearing: The effect of pure/mixed zooplankton and artificial diet on the growth and survival of *Clarias anguillaris* (Linnaeus, 1758) larvae. Afr. J. Aquat. Sci., 17: 69-73.

Pandit, A.K., 1980. Biotic factor and food chain structure in some typical wetlands of Kashmir. Ph.D. Thesis, University of Kashmir, Srinagar-190006, J&K, India.

Pandit, A.K.,1998. Plankton Dynamics in Freshwater Wetlands of Kashmir. In: Mishra, K.D. (Ed.), Ecology of Polluted Waters and Toxicology. Technoscience Publications, Jaipur, India, pp: 22-68.

Patalas, K., 1972. Crustacean plankton and the eutrophication of St. Lawrence Great Lakes. J. Fish. Res. Bd. Can., 29: 1451-1462.

Pennak, R.W., 1957. Species composition of limnetic zooplankton communities. Limnol. Oceanogr., 2: 222-232.

Pennak, R.W., 1978. Freshwater Invertebrates of United States of America. Wiley Interscience Pub., NY.

Pielou, E.C., 1966. The measurement of diversity of different types of biological collections. J. Theor. Biol., 13: 131-144.

Pinto-Coelho, R., B. Pinel-Alloul, G. Méthot and K.E. Havens, 2005. Crustacean zooplankton in lakes and reservoirs of temperate and tropical regions: Variation with trophic status. Can. J. Fish. Aquat. Sci., 62: 348-361.

Rajashekhar, M., K. Vijaykumar and Z. Parveen, 2009. Zooplankton diversity of three freshwater lakes with relation to trophic status, Gulbarga district, North-East Karnataka, South India. Int. J. Syst. Biol., 1(2): 32-37.

Reede, T., 1995. Life-history shifts in response to different levels of fish Kairomones in *Daphnia*. J. Plankton Res., 17: 1661-1667.

Shah, J.A. and A.K. Pandit, 2013. Relation between physico–chemical limnology and crustacean community in Wular lake of Kashmir Himalaya, Pak. J. Biol. Sci. 16 (19): 976-983.

Shannon, C.E. and W. Weaver, 1963. The Mathematical Theory of Communication. Univ. Illinois Press, Urbana.

Sharma, V., M.S. Sharma, H. Malara, R. Sharma and S.B. Brijraj, 2008. Trophic status and zooplankton diversity of Lake Jaisamand in relation to its physico-chemical characteristics. In: Sengupta, M. and R. Dalwani (Eds.), Proceding of Taal the 12th WorldLake Conference, Jaipur, India, pp: 490-495.

Solomon, S.G., G.A. Ataguba and A.S. Baiyewunmi, 2009. Study of dry season zooplankton of Lower River Benue at Makurdi, Nigeria. J. Anim. Plant Sci., 1(3): 42-50.

Sommer, U., M. Gliwicz, W. Lampert and A. Duncan, 1986. The PEG-model of seasonal succession of planktonic events in fresh waters. Arch. Hydrobiol., 106: 433-471.

Soto, D., 1989. The relevance of zooplankton reproductive characteristics to experimental manipulations in outdoor enclosures. Hydrobiologia, 182: 35-47.

Stein, M.A., 1961. Khlhana's Rajatarangini. A Chronicle of the Kings of Kashmir. M/S A Constable & Co. Ltd., London.

Stibor, 1992. Predator-induced life-history shifts in a freshwater cladoceran. Oecologia, 192: 162-165.

Urabe, J., M. Kyle, W. Makino, T. Yoshida, T. Andersen and J.J. Elser, 2002. Reduced light increases herbivore production due to stoichiometric effects of light: nutrient balance. Ecology, 83: 619-627.

Whiteside, M.C., 1974. Chydorid (Cladocera) ecology: Seasonal patterns and abundance of populations in Elk Lake, Minnesota. Ecology, 55: 538-550.

Wright, J.C., 1965. The population dynamics and production of *Daphnia* in Canyon Ferry Reservoir, Montana. Limnol. Oceanogr., 12: 492-502.

Yousuf, A.R. and M.Y. Qadri, 1981. Ecology of *Diaphanosoma brachyurum* Lieven (Cladocera: Crustacea) in Lake Manabal, Kashmir. J. Indian Inst. Sci., 63: 35-45.

Yousuf, A.R. and M.Y. Qadri, 1983. Seasonal distribution of families: Sididae, Daphnidae, Bosminidae, Macro- thricidae and Leptodoridae (cladocera: crustacea) in the Lake Manasbal, Kashmir. J. Inland Fish. Soc. India, 15: 13-20.

Yousuf, A.R., M.H. Balkhi and M.Y. Qadri, 1984. Summer and winter Cladocera in Anchar lake. Geobios (New Rep.), 3: 167-169.

Yousuf, A.R. and M.Y. Qadri, 1985. Seasonal fluctuations of zooplankton in Lake Manasbal. Indian J. Ecol., 12: 354-359.