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DIVERSITY OF CLADOCERA (CRUSTACEA : BRANCHIOPODA) IN FLOODPLAIN LAKES OF MANIPUR, NORTHEASTERN INDIA

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INTRODUCTION

Cladocera, a group of the branchiopod crustaceans, serve as important fish-food organisms, comprise an integral component of metazooplankton and contribute significantly to secondary productivity in lentic freshwater biotopes. These entomostracous Crustacea have been studied from distant parts of this country since about one and half century but the Indian literature shows paucity of works on their ecosystem diversity in aquatic environments in general and in the floodplain lakes of India in particular (Sharma and Sharma, 2008). Referring to the later, important contribution is limited to the recent study by Sharma and Sharma (*loc cit.*) in the floodplain lakes (beels) of the Brahmaputra river basin, Assam, N.E. India.

The present study on the cladoceran diversity of fifteen floodplain lakes (pats) of Manipur, therefore, merits special mention for its biodiversity and ecological importance. The observations are made on faunal diversity, nature and composition, distribution of important species and community similarities of Cladocera in the different pats. In addition, the study deals with seasonal variations in richness and abundance, and their species diversity, dominance and evenness in the sampled lakes. Individual and cumulative influences of the abiotic factors on richness and abundance are analyzed and comments are made on ecology of Cladocera.

MATERIALS AND METHODS

The observations were undertaken (during November 2002-October 2003) in fifteen floodplain lakes (pats) of the Iral, Imphal and Thoubal river basins (Longitude : 93° 45´-94° 00´ E, Latitude : 24° 25´-24° 45´ N) and located in Bishnupur, Imphal and Thoubal districts of Manipur.

Sr. No.	Name of Lake (Pat)	District
1.	Loktak Pat	Bishnupur/Imphal
2.	Waithou Pat	Thoubal
3.	Utra Pat	Bishnupur
4.	Sana Pat	Bishnupur
5.	Lakoi Pat	Bishnupur
6.	Takmu Pat	Bishnupur
7.	Ikop Pat	Thoubal
8.	Kharung Pat	Thoubal
9.	Khoidum Pat	Thoubal
10.	Pumlen Pat	Thoubal
11.	Lousi Pat	Thoubal
12.	Karam Pat	Thoubal
13.	Ngagua Pat	Thoubal
14.	Tankha Pat	Imphal
15.	Lamphel Pat	Imphal

The common aquatic plants noticed at the sampled sites of these pats include *Eichhornia crassipes*, *Hydrilla verticellata*, *Euryale ferox*, *Vallisnaria spiralis*, *Utricularia flexuosa*, *Trapa natans*, *Lemna trisula*, *Pistia striates*, *Salvinia* sp. *Nymphaea* spp., *Nymphoides* spp., *Nelumbo mucifera*, *Potamageton* spp. and *Azolla pinnata.* It is not possible to categorize different pats because of heterogeneous occurrence of different aquatic macrophytes but all the stated species occur in Loktak Pat.

Water samples were collected seasonally from different pats during study period and were analyzed for water temperature, specific conductivity, pH, dissolved oxygen, alkalinity and hardness. Besides, qualitative and quantitative plankton samples were collected seasonally, from 4-5 sites each based on habitat variations, from various pats with nylobolt plankton net (Mesh size : 50 µm); the former were obtained by towing and the later by filtering 25 litres of water each. All the plankton samples were preserved in 5% formalin. Qualitative samples were screened; individual species were isolated and were identified following the works of Smirnov (1971, 1976, 1992, 1996), Michael and Sharma (1988), Sharma and Sharma (1999) and Orlova-Bienkowskaja (2001). Quantitative plankton samples were analyzed for enumeration of the cladoceran densities (n/1).

Percentage similarities between cladoceran communities were calculated *vide* Sorensen's index and were analyzed by hierarchical cluster analysis (SPSS version 10). Species diversity (Shannon's index), dominance (Berger-Parker's index) and evenness (Pileou's index) were calculated following Ludwing and Reynolds (1988) and Magurran (1988). The significance of temporal variations of richness and densities were ascertained by ANOVA. Ecological relationships were analyzed with simple correleation coefficients (r) and multiple regression (R^2).

RESULTS AND DISCUSSION

Abiotic parameters

The sampled lakes (pats) depict subtropical nature (water temperature : 20.7 ± 4.1 – 22.8 ± 4.7°C) and are characterized by slightly acidic-circumneutral (pH : 5.70-6.92, mean pH : 6.02-6.44) and, relatively well oxygenated (mean D.O. : 5.4 ± 2.6-7.2 ± 1.6 mg/1) waters (Table-1). Specific conductivity (36.0-200 µS/cm) indicates very low ionic concentrations of all the parts and, hence, warrants their inclusion under 'Class I' category of 'trophic classification' of Talling and Talling (1965). Alkalinity (21.2 ± 4.9 – 32.4 ± 4.2 mg/I) and hardness (18.3 ± 3.3 – 38.3 ± 7.8 mg/I) affirm 'soft-water character' (*vide* Moyle 1946) of the different pats (Table-1).

Cladocera composition and distribution

Cladocera, second important qualitative component of zooplankton of all the pats of Manipur, reveal in all 56 species and comprise a significant fraction (50.9%) of the Indian Cladocera. The qualitative diversity assumes importance in light of a conservative estimate (Sharma and Michael, 1987; Sharma, 1991) of occurrence of up to 60-65 species of these branchiopod Crustaceans from tropical and subtropical parts of India. Amongst 42 genera and 10 families of freshwater cladocerans so far known from India (BKS, unpublished), 30 genera and 7 families are represented in our collections. Number of the examined species and higher taxa reflect rich and diverse taxocoenosis of Cladocera. The recorded families represent two phylogenetic stems of this group (Dumont and Negrea, 2002) namely the Ctenopoda and the Anomopoda; the former includes only the family Sididae while six families of the latter (Daphniidae-Bosminidae-Moinidae-Macrothricidae-Ilyocryptidae-Chydoridae) are noticed in our collections.

Overall Cladocera richness observed in the pats of Manipur tallies with their report from the floodplain lakes (beels) of the Brahmaputra river basin of Assam (Sharma and Sharma, 2008). On the other hand, the richness is notably higher than the reports of 36 species from 20 floodplain wetlands of Southeastern West Bengal (Khan, 2003), 11 species from two floodplain lakes (Khan, 1987) of Kashmir, 9 species from 65 wetlands of 24-Parganas district (Nandi *et al.*, 1993) of West Bengal, 12 species (Sanjer and Sharma 1995) from floodplains of Bihar and 14 species from 37 floodplain lakes (Sarma, 2000) of Assam. Total richness is even higher than 41 species reported in state faunas of Meghalaya (Sharma and Sharma, 1999) and Tripura (Venkataraman and Das, 2000) from Northeastern India.

Table-1 : Abiotic factors of Floodplain Lakes (Pats) of Manipur

Abiotic Factors	Water temp. (°C)	Specific conductivity (µS/cm)	pH	Dissolved oxygen (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)
Loktak Pat	14.2-28.5	66.0-132.0	5.70-6.92	4.2-9.0	10.0-41.2	24.0-54.0
	21.8 ± 4.2	**93.3 ± 17.1**	**6.31 ± 0.32**	**5.7 ± 1.1**	**19.1 ± 7.1**	**38.3 ± 7.8**
Waithou Pat	14.5-29.2	52.0-120.5	5.59-6.60	2.4-12.0	10.0-36.2	20.1-56.0
	21.6 ± 4.8	**92.3 ± 16.8**	**6.21 ± 0.28**	**5.3 ± 2.8**	**19.7 ± 5.6**	**33.6 ± 7.8**
Utra Pat	16.2-27.9	48.0-120.5	5.40-6.68	4.0-10.0	10.0-44.0	19.5 ± 9.4
	22.2 ± 3.5	**77.2 ± 21.6**	**6.23 ± 0.32**	**6.0 ± 1.4**	**19.5 ± 9.4**	**33.0 ± 7.4**
Sana Pat	13.1-28.5	69.3-107.0	6.12-6.78	4.8-7.9	25.1-38.5	19.2-32.5
	21.2 ± 5.2	**80.2 ± 8.3**	**6.37 ± 0.14**	**5.4 ± 2.6**	**29.2 ± 4.1**	**25.9 ± 3.7**
Lakoi Pat	14.5-29.0	41.8-82.0	6.15-6.81	5.2-9.0	12.0-36.0	10.0-34.2
	22.1 ± 4.9	**61.4 ± 5.9**	**6.37 ± 0.12**	**6.6 ± 2.2**	**24.2 ± 4.9**	**20.4 ± 4.6**
Takmu Pat	15.1-28.2	79.5-128.0	5.89-6.86	4.2-10.0	16.0-39.4	15.4-48.0
	22.6 ± 3.1	**100.5 ± 8.6**	**6.02 ± 0.34**	**5.8 ± 2.1**	**21.4 ± 5.3**	**24.9 ± 5.1**
Ikop Pat	13.9-21.6	124.1-200.0	6.18-6.77	4.0-9.2	22.3-50.0	18.0-48.4
	21.3 ± 5.5	**168.7 ± 13.9**	**6.39 ± 0.12**	**6.9 ± 1.8**	**30.4 ± 5.9**	**24.9 ± 5.8**
Kharung Pat	14.0-28.5	36.0-68.0	5.91-6.89	6.0-9.0	26.2-48.0	22.0-44.2
	21.0 ± 4.0	**46.0 ± 5.1**	**6.30 ± 0.29**	**7.2 ± 1.6**	**32.4 ± 4.2**	**30.0 ± 4.7**
Khoidum Pat	12.4-27.6	72.4-100.0	5.92-6.62	4.4-8.4	21.4-32.6	14.0-29.4
	22.8 ± 4.7	**87.9 ± 7.2**	**6.22 ± 0.13**	**5.8 ± 2.1**	**25.8 ± 3.9**	**18.3 ± 3.3**
Lousi Pat	14.5-27.9	94.2-149.0	6.12-6.89	5.2-10.4	12.0-35.4	14.0-36.0
	21.7 ± 4.1	**121.2 ± 9.0**	**6.44 ± 0.14**	**6.5 ± 2.6**	**24.1 ± 4.3**	**23.9 ± 3.7**
Karam Pat	12.9-28.0	78.1-108.0	5.72-6.48	4.2-8.8	18.4-29.4	16.2-28.0
	20.7 ± 4.1	**80.8 ± 6.7**	**6.16 ± 0.10**	**6.4 ± 1.2**	**23.1 ± 2.1**	**21.2 ± 3.2**
Ngagua Pat	14.0-29.2	105.4-183.0	6.12-6.78	5.6-7.8	20.1-38.8	16.2-29.6
	22.2 ± 3.6	**134.2 ± 16.7**	**6.43 ± 0.11**	**6.4 ± 1.3**	**32.2 ± 3.9**	**20.7 ± 3.9**
Tankha Pat	14.0-29.0	87.0-125.0	6.01-6.77	6.2-9.6	25.2-48.0	16.8-39.1
	22.0 ± 4.0	**105.1 ± 6.6**	**6.37 ± 0.13**	**6.8 ± 2.4**	**30.3 ± 4.0**	**26.0 ± 4.4**
Lamphel Pat	13.5-28.7	153.0-200.0	6.12-6.86	5.4-9.8	18.4-38.0	16.8-36.2
	21.4 ± 3.5	**177.4 ± 9.3**	**6.38 ± 0.12**	**6.0 ± 2.5**	**27.8 ± 4.2**	**26.2 ± 4.2**
Pumlen Pat	13.5-30.0	98.4-127.0	5.82-6.78	6.2-9.0	12.5-37.4	10.2-30.2
	21.5 ± 4.2	**107.8 ± 5.3**	**6.26 ± 0.16**	**7.0 ± 1.8**	**21.6 ± 4.3**	**20.6 ± 3.7**

Fifty-one species recorded from Loktak Pat is highest richness of Cladocera known till date from any floodplain lake or individual freshwater ecosystem of India and, hence, reflects greater micro-habitat diversity as well as environmental heterogeneity of this Ramsar site. The present report differs prominently than only 12 species (including certain un-determined and doubtful species) listed earlier by Shyamananda Singh (1991) from this wetland. Interestingly, the cladoceran diversity of Loktak Pat even exceeds the highest Indian record of 45 species (Sharma and Sharma, 2008) from Deepor beel-another Ramsar site and one of the important beel of N.E. India.

Chydoridae, the largest family of Cladocera, is highly speciose (31 species, 55.3%) and also reflects rich higher diversity (16 genera). This family, in turn, includes

members of two sub-families namely Aloninae (13 species) and Chydorinae (18). The greater richness of the chydorids confirms with the composition of the Indian Cladocera (Sharma, 1991) in general and with the floodplain lakes of Assam (Sharma and Sharma, 2008) in particular. The sub-dominant families, Daphniidae (9 species) > Macrothricidae (6 species) > Sididae (5 species), together comprise an important component (35.7%). Among 30 genera, only *Alona* (10 species) > *Simocephalus* (6 species) are more speciose. Interestingly, lack of any species of *Daphnia* (the globally highly speciose genus of Cladocera) in the pats of Manipur is noteworthy. This interesting feature assumes special importance in light of earlier remarks (Sharma, 1991) on very limited distribution of this member of the Daphniidae in aquatic ecosystems of Northeastern India.

Amongst biogeographically interesting species (Sharma and Sharma, 2008) documented presently, *Disperalona caudata* is an Australasian species (Sharma and Sharma, 2007); *Simocephalus acutirostratus* is known with certainty only from Australia and South-East Asia; *Sida crystallina* and *Picripleuroxus laevis* are Palaearctic species; *Diaphanosoma senegal* and *Kurzia latissima* are the Palaeotropical elements, and *Chydorus reticulatus* is known only from the Indian subcontinent (India, Sri Lanka), Malaysia and tropical Australia. Besides, *Alonella clathratula, Alona davidi, A. globulosa, A. guttata, Camptocercus uncinatus, Ceriodaphnia laticaudata, Chydorus faviformis, C. reticulatus, C. ventricosus, Dadaya macrops, Guernella, raphaelis, Kurzia longirostris, Macrothrix odiosa, Moinodaphnia maclyeai, Pseudochydorus globosus, Simocephalus heilongjiangensis, S. mixtus, S. serrulatus* and *Streblocerus serricaudatus* are examples of regional distributional interest with a majority of these species characterized by disjunct populations in freshwater ecosystems of India.

The Cladocera are invariably considered as a group showing cosmopolitan distribution while recent bio-geographical considerations comment on careful analysis of cosmopolitan nature of various species and of geographical vicariants (Dumont and Negrea, 2002). The present study indicates dominance of cosmopolitan species (42.8%) while cosmotropical and circumtropical species, together, form an important component (35.7%). These features impart a general 'tropical character' to the studied fauna and concur with the composition of other tropical Cladoceran faunas (Fernando, 1980; Fernando and Kanduru, 1984; Dussart *et al.*, 1984; Sharma, 1991). The cladoceran communities are characterized by dominance of the littoral-periphytonic taxa particularly of the Chydoridae, Macrothricidae, Ilyocryptidae and littoral species of *Pseudosida, Sida and Simocephalus*. On the other hand, fewer planktonic species include *Bosmina longirostris, Bosminopsis deitersi, Ceriodaphania cornuta, Diaphanosoma sarsi, D. excisum, Moina micrura* and *Moinodaphnia macleayi* and even these exhibit restricted occurrence in different pats. Further, only 12 species (21.4%) occur in all the lakes and may be categorized as common while a majority of the rest (25 species, 46.4%) are rare and occur in fewer pats.

Cladocera richness and community similarities

The present study indicates notable variations in Cladoceran richness (Table-2) in the different pats (21-51, 27 ± 7 species); the recorded range is higher than the results in the beels (21-39 species) of Assam (Sharma and Sharma, 2008). Distinctly higher richness noticed in Loktak Pat reflects micro-habitat diversity resulting from diverse nature of aquatic macrophytes in this pat and, hence, affirms greater environmental heterogeneity of the Ramsar site than the remaining pats. This statement is also affirmed by a relatively narrow range (21-31 species) of richness in the other sampled pats. Family Chydoridae (31 species) distinctly dominates cladoceran richness in all individual pats (9-29, 17 ± 9 species); peak chydorid richness is observed in Loktak Pat and the number of species in rest of the Pats varies between 9-18 (12 ± 2 species).

The cladoceran communities of the sampled pats depict 52.3-84.7% similarities (*vide* Sorenson's index); peak similarity is noticed between Waithou Pat and Utra Pat and lowest value is recorded between Loktak Pat and Ngagua Pat (Table-3). Only few instances in the matrix indicates similarity > 60% or < 80.0% and it ranges between 60-70% and 70-80% in 47.6% and 43.8% instances respectively. Relatively higher similarities result from common occurrence of several cosmopolitan

Table-2 : Cladocera of Floodplain lakes (Pats) of Manipur

Floodplain lakes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Phylum ARTHROPODA																
Superclass CRUSTACEA																
Class BRANCHIOPODA																
Superorder CLADOCERA (*s. str.*)																
Order CTENOPODA																
Family SIDIDAE																
Diaphanosoma excisum Sars, 1885	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
D. sarsi Richard, 1895	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
D. senegal Gauthier, 1951	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Pseudosida bidentata Herrick, 1884	+	+	+	–	–	–	–	+	–	–	–	–	–	+	+	
Sida crystallina (O.F. Müller, 1776)	+	+	–	+	+	+	–	–	+	+	–	–	+	–	–	
Order ANOMOPODA																
Family DAPHNIIDAE																
Ceriodaphnia cornuta Sars, 1885	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
C. laticaudata P.E. Müller, 1867	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	R
Scapholeberis kingi Sars, 1901	+	+	+	–	–	+	+	–	+	+	+	+	–	–	–	
Simocephalus acutirostratus (King, 1853)	+	+	+	+	+	–	–	–	–	–	–	–	+	+	–	
S. heilongjiangensis Shi & Shi, 1994	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
S. exspinosus (De Geer, 1778)	–	–	–	–	+	+	–	–	+	+	–	+	–	–	+	
S. serrulatus (Koch, 1841)	+	–	–	+	–	–	+	+	+	–	+	–	–	–	+	
S. mixtus Sars, 1903	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
S. vetuloides Sars, 1898	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	R
Family BOSMINIDAE																
Bosmina longirostris (O.F. Müller, 1776)	+	+	+	+	+	+	+	+	+	–	+	+	+	+	–	
Bosminopsis deitersi Richard, 1895	+	–	–	+	–	+	+	+	–	+	+	+	–	–	+	
Family MOINIDAE																
Moina micrura Kurz, 1874	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
Moinodaphnia macleayi (King, 1853)	–	+	–	+	–	–	–	–	+	–	+	–	+	–	–	R
Family MACROTHRICIDAE																
Guernella raphaelis Richard, 1892	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	R
Macrothrix laticornis (Fischer, 1857)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
M. odiosa (Gurney, 1907)	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	R
M. spinosa King, 1853	+	–	–	+	–	–	–	–	+	–	–	–	+	+	–	R
M. triserialis (Brady, 1886)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
Streblocerus serricaudatus (Fischer, 1849)	–	–	–	+	–	–	–	–	–	–	+	+	–	–	+	R
Family ILYOCRYPTIDAE																
Ilyocryptus spinifer Herrick, 1882	+	–	–	+	+	–	–	–	+	+	–	–	–	+	–	R
Family CHYDORIDAE																
Subfamily CHYDORINAE																
Alonella clathratula Sars, 1886	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	R

Table-2 : *Cont'd.*

Floodplain lakes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
A. excisa (Fischer, 1854)	+	+	+	+	–	+	–	–	+	+	+	+	–	+	+	
Chydorus faviformis Birge, 1893	+	+	+	–	–	–	–	–	–	–	–	+	+	–	–	R
Family CHYDORIDAE																
Subfamily CHYDORINAE																
Chydorus reticulatus Daday, 1898	–	–	–	+	+	–	+	–	–	–	–	–	+	–	+	
C. sphaericus (O.F. Müller, 1776)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
C. ventricosus Daday, 1898	+	+	+	–	–	–	–	–	–	+	–	–	–	–	–	R
Dadaya macrops (Daday, 1898)	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	R
Disperalona caudata Smirnov, 1996	+	–	–	+	–	–	–	–	–	–	–	–	–	–	+	R
Dunhevedia crassa King, 1853	+	–	+	+	+	+	–	–	+	+	+	+	–	+	–	
Ephemeroporus barroist (Richard, 1894)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
Picripleuroxus laevis Sars, 1861	+	–	–	–	–	–	–	–	–	+	–	–	–	–	–	R
P. similis Vavra, 1700	+	+	+	–	+	–	–	+	–	+	+	–	–	–	–	R
Pseudochydorus globosus (Baird, 1843)	+	+	–	–	–	–	–	–	–	–	–	–	–	+	–	R
Subfamily ALONINAE																
Acroperus harpae (Baird, 1834)	+	+	+	+	+	–	+	+	–	+	+	+	+	+	+	
Alona affinis (Leydig, 1860)	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	
A. costata Sars, 1862	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
A. davidi Richard, 1895	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
A. globulosa (Daday, 1898)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
A. guttata Sars, 1862	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	R
A. intermedia (Sars, 1862)	+	–	–	–	–	–	+	–	+	+	+	–	–	–	+	
A. monacantha Sars, 1901	+	+	–	–	–	–	–	–	–	+	–	–	–	–	–	R
A. quadrangularis (O.F. Müller, 1776)	+	+	+	+	+	+	+	–	–	–	–	+	–	+	+	
A. rectangula Sars, 1862	+	+	+	–	+	–	–	–	+	–	–	–	+	–	+	
A. verrucosa (Sars, 1901)	+	–	–	+	+	–	–	+	–	–	–	–	–	–	–	R
Euryalona orientalis (Daday, 1898)	+	–	+	–	–	+	+	–	+	–	–	–	–	–	–	R
Camptocercus uncinatus Smirnov, 1973	+	+	+	–	–	+	+	–	–	–	–	+	–	–	+	R
Karualona karua (King, 1853)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	C
Kurzia latissima (Kurz, 1875)	–	+	–	–	–	–	–	–	–	–	+	–	–	–	–	R
K. longirostris (Daday, 1898)	+	–	+	–	–	–	–	–	–	+	–	–	–	–	+	R
Leydigia acanthocercoides (Fischer, 1854)	+	+	–	–	+	–	–	–	+	–	–	–	–	–	–	R
Oxyurella singalensis (Daday, 1898)	+	–	–	–	–	–	+	–	–	–	+	–	–	+	–	R
Total No. of Cladocera Species	51	31	28	27	24	22	23	22	26	26	25	21	22	23	26	

1-Loktak Pat, 2-Waithou Pat, 3-Utra Pat, 4-Sana Pat, 5-Lakoi Pat, 6-Takmu Pat, 7-Ikop Pat, 8-Kharung Pat, 9-Khoidum Pat, 10-Lousi Pat, 11-Karam Pat, 12-Ngagua Pat, 13-Tankha Pat, 14-Lamphel Pat, 15-Pumlen Pat

+ present, – absent, C–Common, R–Rare

Table-3 : Percentage similarities between Cladocera communities (Sorensen's index)

Floodplain lakes	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Loktak Pat	–	70.7	70.9	64.1	61.3	54.5	59.4	60.3	63.3	64.9	52.6	52.3	57.5	59.4	57.1
Waithou Pat		–	84.7	65.5	72.7	64.1	62.9	60.4	66.7	66.7	73.1	69.2	67.9	70.4	63.1
Utra Pat			–	69.1	73.1	76.0	62.7	60.0	66.7	70.4	70.6	73.4	68.0	70.6	66.7
Sana Pat				–	82.3	73.4	68.0	73.4	67.9	67.9	73.1	70.8	77.5	76.0	75.5
Lakoi Pat					–	73.9	68.1	65.2	72.0	72.0	65.3	75.6	73.9	72.3	68.0
Takmu Pat						–	75.6	63.6	75.0	70.8	68.1	79.1	72.3	71.1	70.8
Ikop Pat							–	71.1	69.5	65.3	62.5	74.4	75.5	60.9	65.3
Kharung Pat								–	62.5	62.5	72.3	69.8	68.2	71.1	70.8
Khoidum Pat									–	73.1	74.5	70.8	62.5	61.2	69.2
Lousi Pat										–	74.5	72.3	62.5	61.2	69.2
Karam Pat											–	78.3	63.8	66.7	66.7
Ngagua Pat												–	69.8	68.2	72.3
Tankha Pat													–	71.1	62.5
Lamphel Pat														–	65.3
Pumlen Pat															–

1-Loktak Pat, 2-Waithou Pat, 3-Utra Pat, 4-Sana Pat, 5-Lakoi Pat, 6-Takmu Pat, 7-Ikop Pat, 8-Kharung Pat, 9-Khoidum Pat, 10-Lousi Pat, 11-Karam Pat, 12-Ngagua Pat, 13-Tankha Pat, 14-Lamphel Pat, 15-Pumlen Pat

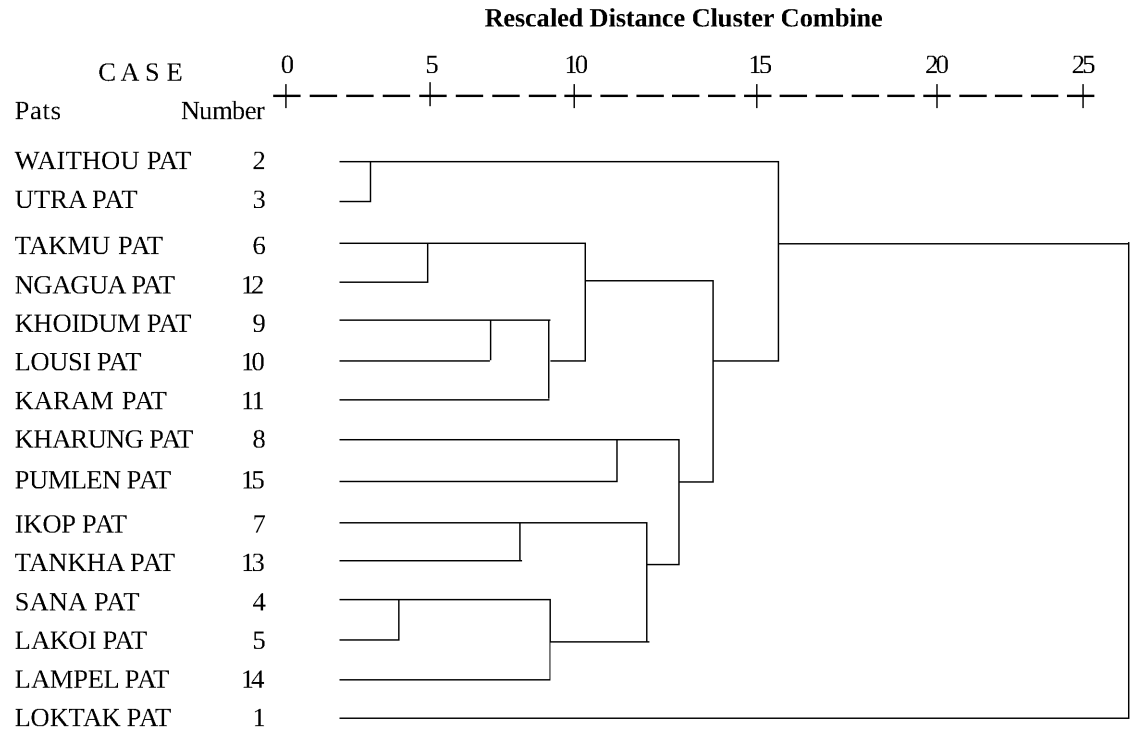

Fig. 1 : Dendrogram showing Hierarchical cluster analysis of Cladocera communities of different lakes (pats) of Manipur

and cosmotropical species in various pats while differences may be ascribed to rare species and their limited occurrence. The cluster analysis (Fig. 1) affirms closer affinity between cladoceran faunas of Waithou Pat and Utra Pat followed by those in Takmu Pat and Ngagua Pat and again between Sana Pat and Lakoi Pat. On the other hand, the cladoceran communities of Loktak Pat differ notably in their composition from rest of the sampled pats; this feature may be ascribed to distinctly higher richness in this Ramsar site together with occurrence of seven rare species observed only this lake as well as presence of eight other rare species with limited distribution in other pats.

Richness depicts significant temporal variations in different seasons ($F_{3.59}$ = 47.733, P < 0.005) and in different pats ($F_{14.59}$ = 22.305, P < 0.005). It shows notable differences (12-42 species) in different seasons in individual pats (Table-4) with peaks during winter and autumn in 13 and 2 pats respectively while lowest richness is noted during monsoon in all the pats. The present results differ from indistinct seasonal maxima reported in the floodplain lakes of Assam (Sharma and Sharma, 2008) while correspond with the latter in monsoon minima. Further, seasonal richness shows maximum extent of variations in Loktak Pat (32 ± 7 species) and shows minima (15 ± 2 species) in Kharung Pat and Ngagua Pat. Peak mean richness in all the pats is noticed during winter (22 ± 6 species) and monsoon communities record (15 ± 2 species) lowest mean richness. Richness is inversely correlated with dissolved oxygen (r = – 0.575) and alkalinity (r = – 0.636) and is positively correlated with hardness (r = 0.683). Multiple regression indicates moderate cumulative influence of six abiotic factors on richness (R^2 = 0.661) while step-wise regression highlights significance of alkalinity, hardness and dissolved oxygen.

Cladocera abundance, diversity, dominance and evenness

Abundance of Cladocera ranges between 30-108 n/1 in different pats (Table-5) and it registers significant temporal variations between seasons ($F_{3.59}$ = 29.943, P < 0.005) as well as between the pats ($F_{14.59}$ = 2.169, P < 0.02). Ngagua Pat records lowest quantitative variations (42 ± 7 n/1) while peak value is noticed in Loktak Pat (72 ± 18 n/1). In general, the densities in different pats are relatively lower than their

Table-5 : Variations in Density, Species diversity, Dominance and Evenness of Cladocera

Lakes	Density (n/1)	Mean density (n/1)	Percentage	Species diversity	Dominance	Evenness
Loktak Pat	42-108	72 ± 18	27.1 ± 5.0	2.822 ± 0.250	0.060 ± 0.018	0.975 ± 0.038
Waithou Pat	32-99	59 ± 26	26.6 ± 4.2	2.673 ± 0.146	0.041 ± 0.011	0.986 ± 0.020
Utra Pat	37-83	59 ± 12	29.1 ± 3.2	2.649 ± 0.190	0.075 ± 0.018	0.943 ± 0.028
Sana Pat	40-76	55 ± 14	26.2 ± 3.1	2.706 ± 0.101	0.102 ± 0.012	0.908 ± 0.011
Lakoi Pat	47-79	57 ± 14	27.3 ± 3.1	2.802 ± 0.097	0.075 ± 0.021	0.933 ± 0.014
Takmu Pat	34-62	47 ± 10	27.6 ± 3.8	2.634 ± 0.112	0.089 ± 0.019	0.908 ± 0.017
Ikop Pat	32-68	48 ± 11	29.4 ± 3.6	2.716 ± 0.101	0.092 ± 0.027	0.909 ± 0.018
Kharung Pat	40-60	48 ± 8	31.7 ± 1.9	2.687 ± 0.106	0.112 ± 0.012	0.880 ± 0.033
Khoidum Pat	38-64	46 ± 10	30.5 ± 2.1	2.643 ± 0.097	0.098 ± 0.017	0.910 ± 0.022
Lousi Pat	30-62	46 ± 12	24.5 ± 3.4	2.534 ± 0.089	0.092 ± 0.021	0.906 ± 0.024
Karam Pat	40-70	51 ± 12	31.6 ± 2.1	2.708 ± 0.103	0.090 ± 0.034	0.903 ± 0.025
Ngagua Pat	31-52	42 ± 7	28.8 ± 3.5	2.660 ± 0.090	0.104 ± 0.020	0.889 ± 0.020
Tankha Pat	30-60	43 ± 12	25.3 ± 3.0	2.568 ± 0.110	0.097 ± 0.029	0.910 ± 0.019
Lamphel Pat	30-61	44 ± 11	25.6 ± 3.4	2.665 ± 0.104	0.091 ± 0.018	0.911 ± 0.020
Pumlen Pat	40-85	60 ± 18	31.2 ± 2.5	2.502 ± 0.089	0.088 ± 0.022	0.921 ± 0.012

counterparts from Assam state (Sharma and Sharma, 2008). Further, Cladocera comprise the second important quantitative component (24.5 ± 3.4 – 31.7 ± 1.9%) of zooplankton in all the sampled pats (Table-5) and concur with the results in the beels of Assam State (Sharma and Sharma, *loc cit.*). The sampled pats indicate no clear pattern of seasonal quantitative variations; peak abundance is recorded in 11, 3 and 1 pats during winter, autumn and summer respectively while minima are noticed in 13 and 2 pats during monsoon and summer respectively. Maximum mean abundance of all the pats is noticed during winter (68 ± 18 n/1), followed by 57 ± 21 n/1 and 44 ± 9 n/1 during autumn and summer respectively while lowest density (37 ± 4 n/1) is observed during monsoon season. Cladocera abundance is inversely correlated with alkalinity (r = – 0.707) and is positively correlated with hardness (r = 0.581). Multiple regression indicates moderate cumulative influence of six abiotic factors on abundance (R^2 = 0.765) while step-wise regression highlights significance of alkalinity, hardness, dissolved oxygen and specific conductivity.

The present results indicate moderately high species diversity of Cladocera with peak in Loktak Pat (2.822 ± 0.250) and minimum value in Pumlen Pat (2.502 ± 0.089). In general the recorded ranges correspond with their counterparts from Assam (Sharma and Sharma 2008). The diversity registers significant temporal differences between seasons ($F_{3, 59}$ = 21.128, P < 0.005 and between pats ($F_{14, 59}$ = 5.017, p < 0.005). The notable feature of high species diversity with relatively lower densities of a large number of species observed in this study may be ascribed to fine niche portioning amongst cladoceran species in combination with high micro- and macro-scale habitat heterogeneity, especially in the littoral environments as hypothesized by Segers (2008). Further, the present results exhibit lower Cladocera dominance (0.041 ± 0.011 – 0.104 ± 0.020) signifying quantitative influence of fewer species; ANOVA registers its insignificant variations between seasons as well as the different pats. The stated feature is re-affirmed by higher cladoceran evenness in various pats (0.880 ± 0.033 – 0.986 ± 0.020) indicating an equitable abundance of different species. ANOVA indicates significant variations of evenness in the different pats ($F_{14, 59}$ = 3.835, P < 0.005) while it shows insignificant seasonal variations. Evenness is inversely correlated with dominance (r = – 0.904) while it is positively correlated with density (r = 0.498). The salient features of lower dominance and higher evenness concur with earlier remarks of Sharma and Sharma (2008).

SUMMARY

Plankton samples collected from fifteen floodplain lakes (pats) of Manipur indicate 56 species of Cladocera belonging to 30 genera and 7 families and exhibit rich and speciose composition. The cladoceran fauna shows dominance of the Chydoridae, cosmopolitan > cosmotropical species and general tropical character. Cladocera comprise the second important qualitative and quantitative group of zooplankton, following Rotifera, in all the pats. Richness ranges between 21-51 species and records 52.3-84.7% community similarities (*vide* Sorenson index). Cladocera form between 24.5 ± 3.4 – 31.7 ± 1.9% of zooplankton abundance, follow indistinct quantitative seasonal patterns but show maxima and minima in majority of pats during winter and monsoon respectively. The cladoceran communities are characterized by moderately high species diversity, high evenness and low dominance in all the pats. ANOVA depicts significant variations of richness and density between pats as well as seasons. Both richness and density are inversely correlated with alkalinity and positively with hardness while richness is also inversely correlated with dissolved oxygen. Multiple regression registers moderate cumulative influence of six abiotic factors on richness and abundance.

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REFERENCES

Dumont, H.J. and Negrea, S.V. 2002. Introduction to the class Branchiopoda. In : *Guides to the identification of the microinvertebrates of the continental waters of the world.* Vol. **19**. Backhuys Publishers, Leiden, the Netherlands, 398 pp.

Dussart, B.H., Fernando, C.H., Matsumura-Tundisi, J. and Shiel, R.J. 1984. A review of systematics, distribution and ecology of tropical freshwater zooplankton. *Hydrobiologia*, **113** : 77-91.

Fernando, C.H. 1980. The freshwater zooplankton of Sri Lanka, with a discussion of tropical freshwater zooplankton composition. *Int. Rev. ges. Hydrobiol.*, **65** : 411-426.

Fernando, C.H. and Kanduru, A. 1984. Some remarks on the latitudinal distribution of Cladocera on the Indian subcontinent. *Hydrobiologia*, **113** : 69-76.

Khan, M.A. 1987. Observations on zooplankton composition, abundance and periodicity in two flood plain lakes of the Kashmir Himalayan valley. *Acta Hydrochem. Hydrobiol.*, **15** : 167-174.

Khan, R.A. 2003. Faunal diversity of zooplankton in freshwater wetlands of Southeastern West Bengal. *Rec. zool. Surv. India, Occ. Paper No.* **204** : 1-107.

Korovchinsky, N.M. 1992. Sididae and Holopedidae. In : *Guides to the identification of the microinvertebrates of the continental waters of the world.* Vol. **3**. SPB Academic Publishers. The Hauge. 82 pp.

Ludwing, J.A. and Reynolds, J.F. 1988. *Statistical ecology : a primer on methods and computing.* John Wiley & Sons, New York, 337 pp.

Magurran, A.E. 1988. *Ecological diversity and its measurement.* Croom Helm Limited, London, 179 pp.

Michael, R.G. and Sharma, B.K. 1988. *Indian Cladocera* (*Crustacea : Branchiopoda : Cladocera*). Fauna of India and adjacent countries Series. Published by Zoological Survey of India, Calcutta, 262 pp.

Nandi, N.C., Das, S.R., Bhuiyan, S. and Dasgupta, J.M. 1993. Wetland faunal resources of West Bengal. I. North and South 24-Parganas district. *Rec. zool. Surv. India, Occ. Paper No.* **150** : 1-50.

Orlova-Bienkowskaja, M.Y. 2001. Cladocera : Anomopoda. Daphniidae : genus *Simocephalus.* In : *Guides to the identification of the microinvertebrates of the continental waters of the world.* Vol. **17**. Backhuys Publishers, Leiden, the Netherlands, 130 pp.

Sarma, P.K. 2000. *Systematics, distribution and ecology of zooplankton of some floodplain wetlands of Assam, India.* Ph. D thesis, Gauhati University, Assam.

Sanjer, L.R. and Sharma, U.P. 1995. Community structure of plankton in Kawar lake wetland, Begusarai, Bihar : II Zooplankton. *J. Freshwater Biol.*, **7** : 165-167.

Sharma, B.K. 1991. Cladocera. In : *Animal Resources of India : Protozoa to Mammalia : State of the Art.* Zoological Survey of India, Calcutta : 205-223.

Sharma, B.K. and Michael, R.G. 1987. Review of taxonomic studies on freshwater Cladocera from India with remarks on biogeography. *Hydrobiologia*, **145** : 29-33.

Sharma, B.K. and Sharma, S. 1999. Freshwater Cladocerans (Crustacea : Branchiopoda : Cladocera). In : *Fauna of Meghalaya; State Fauna Series* 4(**9**) : 469-550. Published by Zoological Survey of India, Calcutta.

Sharma, B.K. and Sharma, S. 2007. New records of two interesting Chydorid cladocerans (Branchiopoda : Cladocera : Chydoridae) from floodplain lakes of Assam, India. *Zoo's Print Journal*, 22(8) : 2799-2801.

Sharma, B.K. and Sharma, S. 2008. Faunal diversity of Cladocera (Crustacea : Branchiopoda) of Deepor beel, Assam (Northeast India)–A Ramsar site. *J. Bombay Nat. Hist. Soc.*, **105**(2) : 196-201.

Sharma, S. and Sharma, B.K. 2008. Zooplankton diversity in floodplain lakes of Assam, *Rec. zool. Surv. India, Occ. Paper No.* **290** : 1-307.

Segers, H. 2008. Global diversity of rotifers (Rotifera) in freshwater. *Hydrobiologia*, **595** : 49-59.

Shyamananda Singh, R.K. 1991. *Study of nutrient enrichment in Loktak Lake with reference to biological indices.* Ph.D. Thesis, Manipur University, Manipur.

Smirnov, N.N. 1971. *The World Chydorid Fauna* (in Russian). USSR Acad. Sci. Zool. Inst. Nova ser. **101**, Leningrad, 539 pp.

Smirnov, N.N. 1976. *The World Macrothricidae* (in Russian). USSR Acad. Sci. Zool. Inst. Nova ser. **104**, Leningrad, 122 pp.

Smirnov, N.N. 1992. The Macrothricidae of the world. In : *Guides to the identification of the microinvertebrates of the continental waters of the World.* Vol. **1**. SPB Academic Publishers, the Hague, 143 pp.

Smirnov, N.N. 1996. Cladocera : The Chydorinae and Sayciinae (Chydoridae) of the world. In : *Guides to the identification of the microinvertebrates of the continental waters of the World.* Vol. **11**. SPB Academic Publishers, The Hague, 197 pp.

Talling, J.F. and Talling, I.B. 1965. The chemical composition of African lake waters. *Int. Rev. ges. Hydrobiol.*, **50** : 421-463.

Venkataraman, K. and Das, S.R. 2000. Cladocera. In : *State Fauna Series : Fauna of Tripura* **7**(4) : 277-316. Published by Zoological Survey of India, Calcutta.