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ZOOPLANKTON OF A SUB-TROPICAL FISH POND OF HIGH RAINFALL REGION OF MEGHALAYA (N. E. INDIA) : COMPOSITION AND ECOLOGY

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INTRODUCTION

Limnological studies in India began nearly one century ago but little is so far known about composition and ecology of zooplankton of sub-tropical aquatic environs of this country in general and that of North-Eastern India in particular. The related works from the state of Meghalaya of the later region are limited to those in an impoundment (Alfred and Thapa, 1995) and two reservoirs (Sharma, 1995; Sharma and Lyngskor, 2003), and fish-pond communities remain unexplored. The present study is, therefore, of special importance in view of the stated lacuna. Besides, it is a pioneering endeavor on zooplankton synecology of a lentic biotope of Cherrapunjee – an interesting place that experiences heaviest rainfall and is yet the wettest desert of India. This communication deals with temporal variations in composition and abundance of zooplankton and their constituent groups with reference to species composition, community similarity, diversity, dominance, evenness and correlations between abiotic and biotic factors.

MATERIALS AND METHODS

The observations were undertaken (May, 1993–April, 1995) in a fish-pond located at Cherrapunjee (Lat. 25°17' N; long. 91°47' E, altitude 1300 m ASL), West Khasi Hills district, Meghalaya. The sampled pond (area : 5000 sq. m), mainly fed with rainwater, is stocked with *Cyprinus carpio* and is devoid of any aquatic vegetation while the marginal plants consist of *Eriocaulon* sp., *Rotala rotundifolia*, *Schaenoplectus* sp., and *Polygonum hydropiper*. Water and plankton samples were collected at regular monthly intervals; the former were analyzed for various abiotic parameters following APHA (1992). Qualitative and quantitative plankton samples, obtained by a nylobolt plankton net (No. 25) and preserved in 5% formalin, were analyzed for identification of zooplankton and their abundance. Community similarities (Sorensen's index), diversity (Shannon's index), dominance (Berger-Parker's index), and evenness (E I index) were calculated following Ludwig and Reynolds (1988) and Magurran (1988). The significance of temporal variations of plankton was established by ANOVA. Ecological relationships were based on computation of correlation coefficient (r), multiple regression and step-wise regression between biotic and abiotic parameters.

RESULTS AND DISCUSSION

Temporal variations in abiotic factors (Table 1) indicate subtropical nature of the sampled pond, low transparency, moderate dissolved oxygen (saturation : 40.5–75.1, 58.3 ± 10.4%), low free CO_2 and lack of organic pollution (low chloride). This biotope is characterized by low electrolyte content, soft-waters (Ca > Na > Mg > K) and lower nutrient concentrations; such salient features are attributed to leached nature of soil and weathered condition of rocks caused by heavy rainfall (Sharma, 2001) and general degraded environmental nature of the Cherra plateau.

Table 1. : Temporal variations of Abiotic factors

Factors	Range	Mean ± SD
Rainfall (mm)	8.4–3444.3	1091 ± 1209.4
Water Temperature (°C)	13.9–21.3	18.5 ± 2.3
Transparency (m)	0.3–1.0	0.68 ± 0.20
pH	6.9–8.3	7.6 ± 0.5
Specific Conductivity (μS/cm)	30.5–112.0	63.3 ± 24.7
Dissolved Oxygen (mg/l)	4.4–8.8	6.6 ± 1.4
Free CO2 (mg/l)	2.0–10.4	7.0 ± 2.0
Alkalinity (mg/l)	12.5–43.5	26.7 ± 9.2
Hardness (mg/l)	20.8–50.8	32.0 ± 10.7
Calcium (mg/l)	3.7–12.7	7.6 ± 2.5
Magnesium (mg/l)	3.7–9.3	5.9 ± 1.6
Sodium (mg/l)	2.0–11.0	5.9 ± 2.5
Potassium (mg/l)	1.5–9.0	3.6 ± 1.7
Chloride (mg/l)	3.8–8.3	6.5 ± 1.2
Sulphate (mg/l)	0.35–2.35	1.3 ± 0.7
Phosphate (mg/l)	0.05–0.33	0.16 ± 0.07
Nitrate (mg/l)	0.04–0.14	0.09 ± 0.02
Silicate (mg/l)	0.18–1.25	0.58 ± 0.28

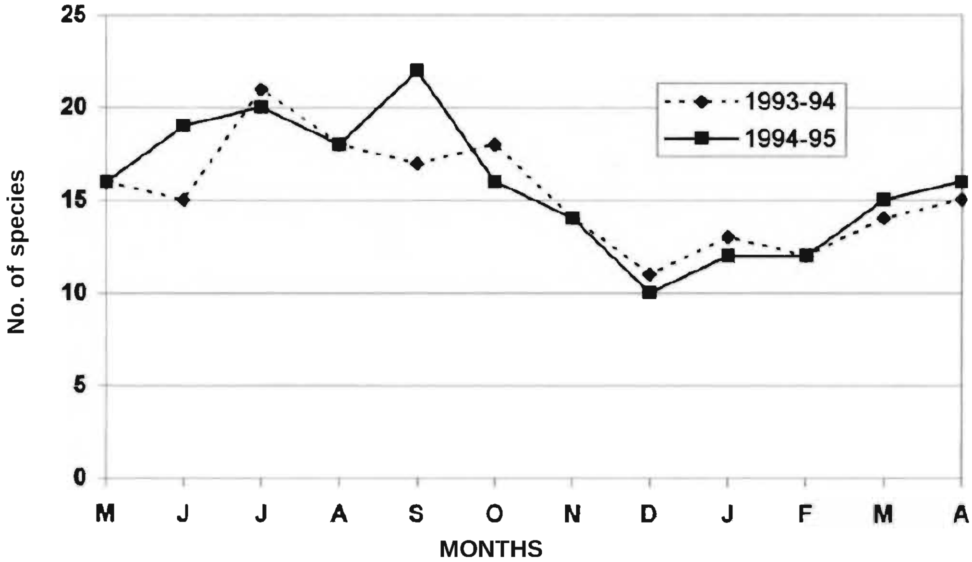

Fig. 1. : Zooplankton richness.

The zooplankton communities (Table 2) of the Cherra pond are less speciose (28 species); these are represented by Rotifera > Cladocera > Rhizopoda > Copepoda > Ostracoda and exhibit dominance of the first two groups. Their lower monthly richness (15 ± 3 species) registers significant differences between months ($F_{11.23}$ = 8.631, p < 0.001) but records insignificant variations between two annual cycles ($F_{1.23}$ = 0.702); the latter aspect is also affirmed by nearly identical annual ranges (Table 2). Zooplankton follow broadly multimodal richness patterns (Fig. 1) in two annual cycles of the study period respectively, exhibit peak values during July, 93 and September, 94 and minima during December. In general, higher richness is noticed during monsoon and lowest during winter. Overall qualitative diversity concurs with the report of Sharma and Lyngskor (2003) but is higher than records from other subtropical biotopes of India (Negi and Pant, 1982; Patil and Gouder, 1985; Alfred and Thapa, 1995; Sharma, 1995). The present results record notable temporal variations in species composition of zooplankton. This conclusion is supported by 43.2–97.1% community similarity (*vide* Sorensen's index) which, in turn, follows almost identical annual ranges (43.2–97.1 and 47.4–93.7%) and shows >70% similarity in 77.9% instances included in the similarity matrix.

The sampled pond is characterised (Table 2) by lower zooplankton abundance (78–165; 107 ± 24 n/1) with insignificant variations between two annual cycles ($F_{1.23}$ = 1.549) and between months ($F_{11.23}$ = 1.998) as well as broadly identical annual and mean values. The zooplankton comprise an important component (40.2 ± 6.9%) of net plankton and significantly influence (r = 0.664) their temporal periodicity. The recorded densities are, however, lower than the reports of Bhattacharya and Saha (1986, 1990), Alfred and Thapa (1995) from N. E. India but are relatively higher than

Table 2. : Temporal variations of Zooplankton

	1st annual cycle	**2nd annual cycle**	**Study period**
Net Plankton (n/1)	174–372 (282±73)	174–331 (260±48)	174–372 (271±61)
Qualitative : 28 species; Rotifera > Cladocera > Rhizopoda > Copepoda > Ostracoda = Nematoda			
Species richness	11–21	10–22	10–22 (15±3)
% Similarity	43.2–97.1	47.4–93.7	43.2–97.1
Quantative : Copepoda > Rotifera > Cladocera > Rhizopoda > Ostracoda = Nematoda			
Abundance (n/1)	79–165 (113±25)	78–154 (103±22)	78–165 (107±24)
Percentage	29.3–46.7 (40.6±5.4)	25.3–55.0 (39.8±8.4)	25.3–55.0 (40.2±6.9)
Copepoda (n/1)	24–67 (46±13)	33–76 (46±13)	24–76 (46±13)
Percentage	28.6–65.5 (41.9±11.7)	37.6–62.8 (44.4±7.1)	28.6–65.5 (43.2±9.4)
Rotifera (n/1)	13–69 (37±15)	15–68 (32±14)	13–69 (34±14)
Percentage	12.0–45.6 (32.5±10.9)	14.8–44.2 (30.3±18.4)	12.0–45.6 (31.4±9.7)
Cladocera (n/l)	11–46 (26±13)	13–29 (21±6)	11–46 (23±10)
Percentage	11.7–35.4 (22.4±8.9)	13.6–32.2 (21.3±9.5)	11.7–35.4 (21.9±9.2)
Rhizopoda (n/l)	1–10 (3±3)	1–5 (2±2)	1–10 (2±3)
Percentage	0–9.3 (2.4±2.9)	0–5.0 (2.3±1.8)	0–9.3 (2.4±2.2)
Ostracoda (n/l)	2–4 (1±1)	1–6 (1±2)	1–6 (1±1)
Percentage	0–3.7 (0.6±1.1)	0–5.9 (0.8±1.7)	0–5.9 (0.7±1.4)
Nematoda	2–3 (1±1)	1–3 (1±1)	1–3 (1±1)
Percentage	0–2.5 (0.3±0.8)	0–3.0 (0.9±1.3)	0–3.0 (0.6±1.0)
Species Diversity	1.60–2.39 (1.99±0.2)	1.60–2.31 (2.0±0.3)	1.60–2.39 (2.0±0.3)
Evenness	0.65–0.8 (0.74±0.1)	0.55–0.84 (0.73±0.1)	0.55–0.88 (0.74±0.1)
Dominance	0.11–0.29 (0.18±0.1)	0.11–0.28 (0.17±0.1)	0.11–0.29 (0.18±0.1)

the results of Sharma (1995) and Sharma and Lyngskor (2003). The present study registers broadly tri-modal annual patterns of temporal variations and relatively higher zooplankton densities (Fig. 2) during early monsoon and winter season, with peak during October 1993. In addition, they show insignificant direct relationship with phytoplankton (r = 0.345), thereby, indicating lack of any grazing impact; this feature, in general, may also be due to lower abundance of the former during the study period.

Of the abiotic factors monitored during this limnological survey, zooplankton interestingly register significant inverse relationship only with free CO_2 (r = –0.601). On the other hand, multiple correlation (R^2 = 0.791) depicts significant cumulative (nearly 79%) influence of eighteen parameters on their quantitative abundance. The step-wise regression (R^2 = 0.608) with twelve abiotic factors (rainfall, water temperature, conductivity, alkalinity, hardness. Calcium, Magnesium, Chloride, Sulphate, phosphate, nitrate and silicates) restricts their influence to > 60%. Subsequent reduction in number of abiotic attributes, however, significantly lowers their overall ecological impact while five basic factors namely rainfall, water temperature, conductivity, alkalinity and hardness) depict only about 30% influence.

Copepoda, represented by *Mesocyclops* sp. and *Heliodiaptomus* sp., are mainly comprised of the cyclopoids and their nauplii while the calanoids register poor abundance in the examined samples. The copepods constitute a dominant quantitative component of zooplankton (43.2 ± 9.4%) and, hence, correspond with the reports of Alfred and Thapa (1995), Das *et al.*, (1996), Sharma and Hussain (2001) and Sharma and Lyngskor (2003). Their abundance ranges (Table 2) between 24–76 (46 ± 13) n/1, registers insignificant variations between two annual cycles ($F_{1.23}$ = 0.024) and between months ($F_{11.23}$ = 2.156) and follows irregular pattern of monthly variations (Fig. 3) with peak abundance in November 1994 and minima in February. On the other hand *Mesocyclops* sp. (18–59; 32 ± 13 n/1) significantly influences temporal variations of this group; it depicts (Table 3) trimodal but different annual patterns and shows peak abundance during autumn (November) in each annual cycle. Occurrence of nauplii throughout the present study period indicates an active reproductive phase as also reported by Das *et al.*, (1996), Sharma and Hussain (2001) and Sharma and Lyngskor (2003). The nauplii register density between 2–34 (11 ± 7 n/1) and exhibit indefinite periodicity of abundance. The Copepoda exert a distinct influence on net

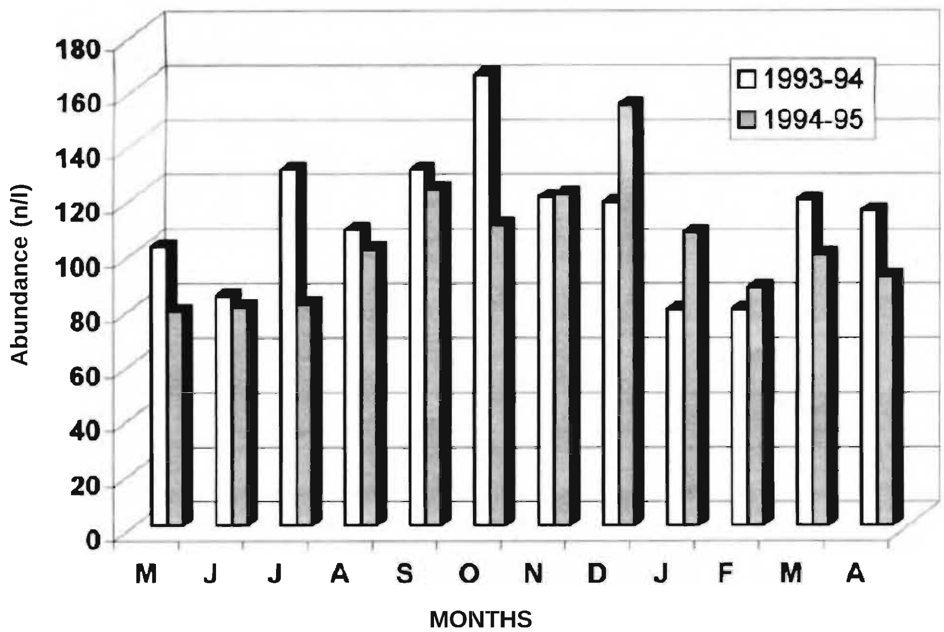

Fig. 2. : Zooplankton abundance.

Table 3. : Monthly variations in Zooplankton abundance (n/l).

	1993								1994												1995			
	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
ROTIFERA																								
Brachionus angularis	–	–	–	–	–	–	18	30	17	6	13	7	–	–	–	–	–	3	16	46	11	4	10	6
B. quadridentatus	–	–	–	–	–	–	–	–	1	8	2	1	–	–	–	–	–	–	–	–	1	2	–	–
Keratella cochlearis	22	5	–	–	10	54	14	17	10	12	21	8	8	1	4	–	14	18	2	21	15	16	15	15
K. tropica	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1	–	2	–	–	–	–	–	–	–
Euchlanis dilatata	–	–	1	2	–	1	–	–	–	–	–	–	–	1	3	2	–	–	1	–	–	–	–	–
Colurella obtusa	–	–	1	–	–	–	–	–	–	–	–	–	2	–	–	–	1	2	–	–	–	–	1	–
Lepadella patella	–	–	–	2	–	–	1	1	–	–	–	–	–	–	1	2	1	1	1	–	–	–	–	–
Lecane bulla	5	7	4	4	14	–	–	–	1	4	7	5	4	7	4	–	6	–	1	–	2	2	4	5
L. curvicornis	–	–	8	1	7	–	–	–	2	–	–	–	–	3	–	–	–	–	–	–	2	–	1	–
L. lunaris	–	–	4	–	2	3	–	1	1	–	–	–	1	–	1	5	1	1	1	–	–	–	–	–
Trichocerca cylindrica	–	–	5	–	–	2	–	–	–	–	–	–	1	1	2	–	1	–	–	–	–	–	–	–
T. similis	–	2	1	–	1	1	1	–	–	–	–	–	–	–	–	1	2	1	2	–	–	–	–	–
Pleosoma lenticulare	4	–	3	2	–	3	–	–	–	5	2	3	2	–	–	1	6	1	1	–	4	–	2	–
Pompholyx sulcata	–	–	–	–	1	–	–	–	1	1	–	–	–	–	–	1	1	2	–	1	–	–	–	–
Philodina sp.	3	2	3	2	4	5	4	1	–	–	6	4	9	4	8	3	4	–	1	–	2	1	5	9
CLADOCERA																								
Ceriodaphnia reticulata	–	–	2	9	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
Macrothrix rosea	–	–	–	1	–	1	–	–	–	–	–	–	–	–	4	–	1	2	–	–	–	–	–	–
Alonella excisa	2	1	1	8	9	1	–	–	–	2	2	5	2	2	–	4	2	–	–	–	3	4	1	3
Bosmina longiristris	10	4	2	7	4	32	6	12	14	6	15	16	10	3	2	4	15	14	15	17	13	9	5	7

Table 3. : (Cont'd)

	1993								1994												1995			
	M	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**
CLADOCERA																								
Chydorus sphaericus	2	3	15	11	33	9	8	4	3	11	14	19	1	12	11	14	11	12	4	4	12	15	11	5
Pleuroxus similis	–	3	–	–	–	–	–	–	–	–	–	–	–	1	2	–	–	–	–	–	–	–	–	–
COPEDODA																								
Mesocyclops sp.	40	43	29	25	23	32	52	44	24	18	27	36	25	20	21	48	28	29	59	52	37	20	33	26
Heliodiaptomus sp.	3	1	4	2	5	–	3	4	2	–	–	–	3	3	2	–	–	4	1	–	–	2	3	3
Nauplii	9	11	34	18	12	17	10	4	2	6	7	10	8	15	10	4	19	17	16	12	5	11	4	9
RHIZOPODA																								
Difflugia oblonga	–	1	3	–	–	–	1	–	–	–	–	–	–	–	2	–	1	–	–	–	–	–	–	1
Centropyxis aculeata	–	–	4	5	–	1	–	–	–	–	–	–	–	2	1	3	–	2	–	–	–	–	–	–
Arcella vulgaris	2	1	2	5	2	3	1	–	1	–	–	1	2	2	1	1	4	1	–	–	–	1	1	1
OSTRACODA																								
Cypris sp.	–	–	2	4	2	–	–	–	–	–	–	–	–	1	–	6	2	–	–	–	–	–	–	–
NEMATODA																								
Nematoda	–	–	2	–	–	–	–	–	–	–	3	–	–	2	–	2	1	–	–	1	–	–	3	1
ZOOPLANKTON	**102**	**84**	**130**	**103**	**130**	**165**	**120**	**118**	**79**	**79**	**119**	**115**	**78**	**80**	**81**	**101**	**123**	**110**	**121**	**154**	**107**	**87**	**99**	**91**

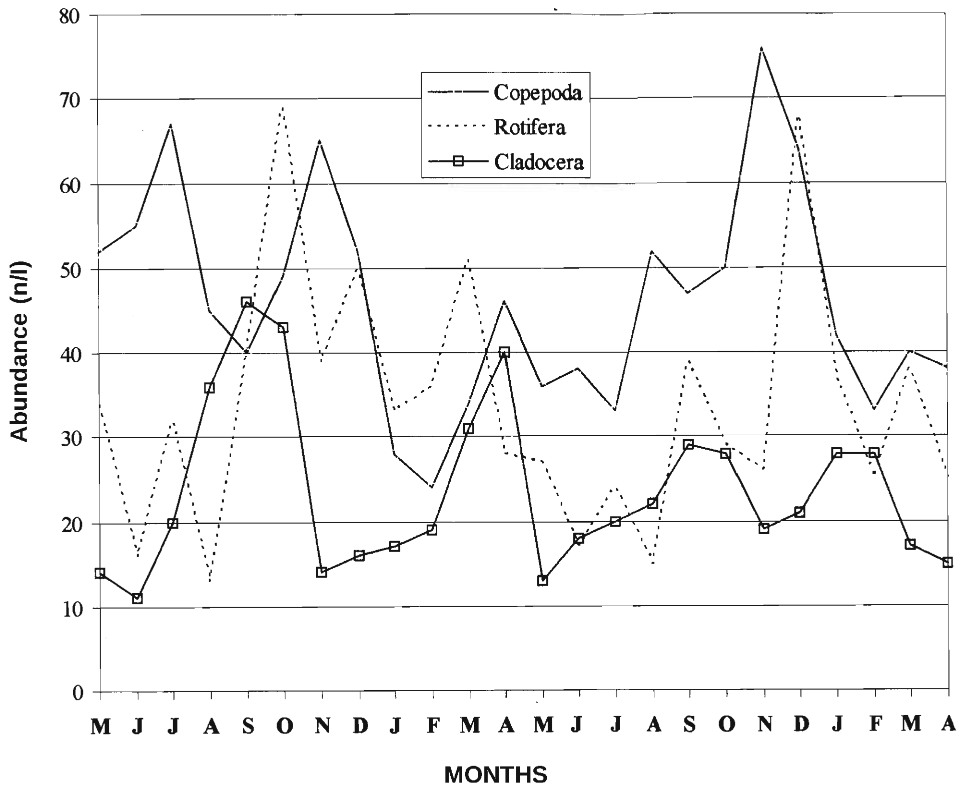

Fig. 3. : Abundance of zooplankton groups.

plankton (r = 0.419) and zooplankton (r = 0.709) periodicity while this group shows an insignificant direct and inverse relations with Rotifera and Cladocera, respectively. The last aspect indicates lack of resource sharing or competition with the stated two biotic components because of their relatively lower population densities. Among the recorded abiotic factors, high copepod production concurs with the periods of low free CO_2 content (r = –0.517) while this group records an inverse correlation with specific conductivity (r = –0.405).

Rotifera (Table 2 & 3) show qualitative dominance (15 species) and thus correspond with the results of Zutshi *et al.*, (1980). Their richness is relatively higher than other subtropical water bodies of Meghalaya (Alfred and Thapa, 1995; Sharma, 1995; Das *et al.*, 1996). The present study does not depict any definite trend but in general higher number of species are recorded during monsoon and low during winter. The rotifers depict lower abundance (34 ± 14 n/1) with nearly identical annual ranges and mean abundance. They constitute a sub-dominant quantitative component (31.4 ± 9.7%) of zooplankton. The rotifers register significant density differences between months ($F_{11.23}$ = 3.448, $p < 0.02$) and insignificant temporal variations between two annual cycles ($F_{1.23}$ = 2.193). This group, however, does not depict any distinct monthly trend of abundance which is in contrast to trimodal pattern reported earlier by Sharma (1995). The peak rotifer densities are observed in October 1993 and December 1994 while lowest abundance is noticed during August 1993. Of the documented species, only two species namely *Keratella cochlearis* (13 ± 11 n/1) and *Brachionus angularis* (8 ± 11 n/1) notably influence the rotifer production while *Lecane bulla*, *Pleosoma lenticulare* and *Philodina* sp. are other important taxa. All the stated species, however, exhibit indefinite patterns of occurrence and abundance (Table 3). *K. cochlearis* contributes primarily to the rotifer peak during October, 93. *B. angularis* > *K. cochlearis* result in the rotifer winter maxima (December) in the second annual cycle; the former brachionid is noted in the second half of each year of the study period and shows peak abundance during December (winter) in each year.

The rotifers contribute significantly to temporal variations of zooplankton (r = 0.709) but show insignificant influence on net plankton periodicity. They record direct correlation with Dinophyta (r = 0.554) and an inverse relationship with Euglenophyta (r = –0.412) in the sampled pond. Their insignificant positive relationship with Cladocera indicates lack of competition and is apparently the result of lower densities of these two biotic communities. Among the recorded abiotic factors, the Rotifera exhibit significant direct correlations with dissolved oxygen (r = 0.614), magnesium (r = 0.433), sulphate (r = 0.574) and nitrate (r = 0.429) and inverse relationships with rainfall (r = –0.555) and free CO_2 (r = –0.621).

The Cladocera (6 species), another sub-dominant component (23 ± 19 n/1), depict insignificant variations between two annual cycles ($F_{1.23}$ = 1.348) and between months ($F_{11.23}$ = 1.604). These micro-crustaceans comprise about 11.7–35.4 (21.9 ± 9.2)% of zooplankton and influence their abundance (r = 0.528) as well that of net plankton (r = 0.520). The recorded cladoceran density is relatively higher than the reports by Sharma (1995), Das *et al.*, (1996) and Sharma and Lyngskor (2003). This group does not depict any regular pattern of monthly variations but higher density is recorded in October 1993 and minima is noticed in June 1993. This aspect is in contrast to higher density during summer and lower during winter reported earlier from Meghalaya (Sharma and Lyngskor, 2003). The present study does not indicate any significant correlation between the cladocerans and abiotic factors. Among the documented species, only *Bosmina longirostris* (2–32; 10 ± 7 n/1) and *Chydorus sphaericus* (2–33; 10 ± 7 n/1) indicate quantitative importance. These two cladocerans exhibits indefinite periodicity and record their peak densities in October and September respectively during the first annual cycle. In addition, *Alonella excisa* (1–9 n/1) shows limited qualitative importance.

The Rhizopoda, represented by *Arcella vulgaris*, *Centropyxis aculeata* and *Difflugia oblonga* indicate very low abundance (2 ± 3 n/1) but show positive correlations with rainfall (r_1 = 0.535) and water temperature (r_1 = 0.627). *Cypris* sp., the sole representative of the Ostracoda as well as nematodes exhibit extremely low densities and occasional occurrences.

The zooplankton record lower diversity (1.60–2.39; 2.0 ± 0.3) which, in turn, is apparently influenced by the copepod abundance and that of fewer species of Rotifera and Cladocera. The recorded diversity range is marginally higher than earlier results from Meghalaya (Sharma, 1995; Sharma and Lyngskor, 2003). Highest species diversity is recorded during July 1993 while lower values are recorded during November 1993, August 1994 and December 1994. The present study indicates higher zooplankton evenness (0.74 ± 0.10) which can be attributed to lesser temporal variations in abundance of individual taxa and equitable densities of majority of species. The evenness varies between 0.55 (August 1994) – 0.88 (February 1994) and follows an indefinite pattern. In addition, this study depicts low dominance with mean annual values of 0.18 ± 0.1.

In general, the present study highlights aspects of lower species richness, lower abundance and lack of definite periodicity of occurrence and abundance of zooplankton communities. In fact, only three of the documented 28 zooplankton taxa occur throughout the study period while only 4–5 species exert quantitative importance. These aspects may be due to habitat instability caused due to heavy precipitation in the study area which in turn experiences heaviest rainfall of the country. Sharma (2001) earlier indicated significant inverse influence of rainfall on majority of abiotic factors (thirteen) in the sampled pond. Such an influence cannot be ruled out on plankton communities as well. The rainfall presently depicts an inverse correlation only with Rotifera but its resultant indirect effect on other groups cannot be overlooked. This point is further asserted by little influence of other abiotic factors on zooplankton and their constituent groups. Further investigations are desired to analyse in detail interesting direct or indirect influence of heavy rainfall on water bodies of this region and their aquatic communities.

SUMMARY

The zooplankton (28 species : Rotifera > Cladocera > Rhizopoda > Copepoda > Ostracoda) indicate lower monthly richness (15 ± 3 species) with significant variations between months and insignificant between two annual cycles. They depict 43.2–97.1% community similarity (*vide* Sorensen's index) and follow almost identical annual ranges (43.2–97.1 and 47.4–93.7%). The zooplankton are characterized by lower abundance (78–165; 107 ± 24 n/1) and insignificant temporal variations between two annual cycles and between months. They contribute an important component (40.2 ± 6.9%) of net plankton and exhibit broadly trimodal annual patterns of temporal variations. Copepoda (46 ± 13 n/1), dominant quantitative component of zooplankton (43.2 ± 9.4%), register insignificant variations between two annual cycles and between months and follow irregular pattern of monthly variations. Rotifera (34 ± 14 n/1), constitute a sub-dominant quantitative component (31.4 ± 9.7%) of zooplankton and register significant density differences between months and insignificant between two annual cycles. The Cladocera (23 ± 19 n/1), another sub-dominant component depict insignificant variations between two annual cycles and between months and

comprise 21.9 ± 9.2% of zooplankton. The Rhizopoda, Ostracoda and Nematoda are quantitatively insignificant. The zooplankton communities are characterised by moderate species diversity (2.0 ± 0.3), higher evenness (0.74 ± 0.10) and low dominance (0.18 ± 0.1). Multiple regression of zooplankton with eighteen abiotic parameters indicates higher cumulative impact and individual factors register limited influence on zooplankton and their constituent groups.

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