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Correspondence of zooplankton assemblage and water quality in wetlands of Cachar, Assam, India: Implications for environmental management

Sulata Kar[1], Papia Das[1], Uma Das[1], Maibam Bimola[2], Devashish Kar[1], Gautam Aditya[3]*

[1] Department of Life Science and Bioinformatics, Assam University, Silchar 788011, India, e-mail: kar_sulata@rediffmail.com, moonpapiadas@gmail.com, u_das10@rediffmail.com, devashishkar@yahoo.com
[2] Department of Zoology, Chanambam Ibomcha College, Bishnupur 795126, Manipur, India, e-mail: maibam_bimola@yahoo.co.in
[3] Department of Zoology, University of Calcutta, 35 Ballygunge Circular Road, Kolkata 700019, India, e-mail: gautamaditya2001@gmail.com (*corresponding author)

Abstract: The zooplankton assemblage of selected wetlands of Assam, India was assessed to deduce the structural variation in the context of water quality parameters. A two year study between 2012 and 2014 comprising of 530 samples from the five wetlands revealed the presence of 46 taxa, 26 Rotifera, 15 Cladocera, 4 Copepoda and 1 Ostracoda, in varying density. The rotifers dominated in terms of abundance (48 ind. cm^{-3}) followed by the cladocerans (28 ind. cm^{-3}) and the copepods (19 ind. cm^{-3}) and showed significant ($p < 0.05$) correlations with turbidity, alkalinity, hardness and phosphate contents of the water samples. The diversity and the richness of the zooplankton showed an increasing trend with the water temperature. Among the different taxa, *Brachionus* sp. was most abundant followed by *Mesocyclops* sp. while *Beauchampiella* sp. was represented in the least numbers. Application of the cluster analysis allowed the segregation of the different zooplankton based on the similarities of abundance in the samples. The water quality parameters like temperature, alkalinity, turbidity, magnesium and calcium were observed to be significant contributors in shaping the zooplankton community composition of the wetlands, revealed through the correlations and canonical correspondence analysis. As an extension, the information can be used in monitoring the quality of the freshwater habitats of the concerned and similar geographical regions, using the zooplankton as the major constituents. The variations in the abundance of cladoceran, copepod and rotifer zooplanktons can be used to understand the mechanisms that sustain the food webs of the aquatic community of the freshwater bodies.

Key words: wetlands, zooplankton, environment relationship, canonical correspondence analysis

Introduction

Zooplankton assemblages of freshwater ecosystems like lakes and ponds vary in space and time. Among the spatial features, habitat heterogeneity, area and depth of habitats, relative abundance of predators and presence of macrophytes, alone or in combination act as determinants for the zooplankton abundance pattern in lakes and ponds (Anton-Pardo and Armengol 2010; Anton-Pardo et al. 2013, 2016). Although the influence of the individual biotic and abiotic factors varies both on spatial and temporal scales, the water quality parameters are considered suitable surrogates in collating the effects on zooplankton assemblages. Species specific correspondence for one or more water quality parameters enables identification of the responses and allows a judgement to be made of the indicator potential of the zooplankton species (Guo et al. 2009; Havens and Beaver 2011; Swadling et al. 2000). The influence of the water quality parameters is a key aspect in shaping macrophyte assemblages (Zealand and Jeffereies 2009), macroinvertebrates (Roy and Nandi 2010) and zooplankton (Akbulut 2005; Atlayde and Bozelli 1998; Gislason et al. 2009) and also provides a means to understanding the prospective food web structure. The correspondence of the water quality parameters and zooplankton abundance is used for portrayal of the species composition of zooplankton in freshwater ecosystems following different levels of ordination techniques (Pepin et al. 2015). Ordination of the species against the environmental factors enables prediction of the species specific relation to one or more environmental variables (ter Braak and Verdonschot 1995; ter Braak and Smilauer 2002), and requires repeated monitoring of the concerned habitats (Pinto-Coelho et al. 2005; Wang et al. 2007). As an extension, the community structure and the prospective coexistence of multiple species can be deduced with corresponding affinity for one or more factors. These propositions are supported by different empirical studies that employed the zooplankton orientation against the environmental parameters (Benitez-Diaz Miron et al. 2014; Sharma et al. 2017).

In the Indian context, and particularly for the lakes and ponds of the Northeast India, several studies have been carried out in the recent past on the pattern of zooplankton assemblages. The zooplankton assemblages of canals (Smitha et al. 2013), dam (Shinde et al. 2012), lakes (Savitha and Yamakanamardi 2012), and ponds (Rajagopal et al. 2010), indicate a considerable level of diversity of rotifers, cladocerans and copepods on spatio temporal scales. In Northeast India, similar variations in the composition of zooplankton are observed for the *beels*, *pats* and *anuas* (Sharma 1998, 2005, 2007, 2009; 2011, 2014; Sharma and Sharma 2005, 2008, 2012), which are wetlands providing diverse ecosystem services for human well-being. In many such studies the relevance of the water quality parameters as a surrogate of environmental factors are considered (Sharma et al. 2017), and used for ordination of the zooplankton assemblages. Such observations provide significant information on the influence of the environmental features on zooplankton assemblages, which facilitates management of the water bodies with higher precision, both for commercial aquaculture and biomonitoring. Extending the effort to decipher the environmental quality as a determinant of the pattern of zooplankton assemblages, the present study elaborates the relationship of the environmental variables and the zooplankton assemblages of selected water bodies of Assam, India as model habitats. The water bodies selected for the study qualify as shallow lakes with seasonal cycles of changes in the water volume and the quality, which would predictably affect the zooplankton assemblages. The data on the water quality and the zooplankton species were obtained through continued monitoring over a period of two years and subsequently used for ordination to decipher the relationships among the multiple environmental variables and the zooplankton. The species composition and the functional roles of the major groups of zooplankton like Cladocera, Copepoda and Rotifera vary considerably with reference to habitat quality (Akbulut 2005; Atlayde and Bozelli 1998; Gislason et al. 2009; Anton-Pardo and Armengol 2010; Anton-Pardo et al. 2013, 2016). Ordination of zooplankton using both the generic level as well as major groups would help understand the relationships on both broad and finer scales of taxonomic resolution. While higher richness of the species may limit the ordination of the species on the finer scale, the group wise ordination may supplement the required information on a broader scale.

Information on zooplankton assemblages is useful for the sustenance and the management of the freshwater ecosystems. Since zooplankton is a crucial link between the producers and the higher order consumers like fish and crustaceans, monitoring of zooplankton assemblages would provide a clear picture of environmental quality and the conditions for ecosystem health and community organization on the whole. The results of the study will therefore be useful in understanding the composition of zooplankton assemblage in water bodies and a comparison with similar wetland habitats of the concerned region, useful for aquaculture (Sharma et al. 2016) or the preservation of wildlife (Sharma et al. 2017).

Materials and Methods

Study sites

The study was carried out on five freshwater wetlands viz., Madhura *anua* (24°50'27.6"N, 92°49'51.1"E), Salchapra *anua* (24°49'28.8"N, 92°39'43.9"E), Malini *beel* (24°49'33.1"N, 92°46'24.8"E), Sat *beel* (24°50'03.8"N, 92°49'21.4"E) and Narsingtola pond (24°49'36.6"N, 92°47'58"E) located in the Cachar district of Assam, India (Fig. 1), for two consecutive years between June 2012 and September 2014. The term *anua* means an ox-

Fig. 1. Geographical position of the study area

bow lake, while a *beel* is a billabong or a lake-like wetland, as an extension of the Barak river of Assam, India. The distance of Madhura *anua* (MA), Salchapra *anua* (SA), Sat *beel* (SB) and Malini *beel* (MB) respectively is 12 km, 25 km, 8 km and 6 km from the central location.

Zooplankton collection

Plankton samples were collected using a 125 µm mesh size conical plankton net with a diameter of 30 cm. The mesh size was estimated by following the count of the number of holes found in a linear inch of the plankton sampling net. A portion of the net was placed under the binocular and the number of the holes per inch was counted followed by a calculation of the mesh size in terms of microns, which was 125 µm (Nash 1997). The size of the mesh enabled collections of the mesozooplankton and macrozooplankton from the water bodies. Monthly sampling of the sites for collection of zooplankton was carried out for two years from June 2012 to September 2014 following the standard methods by Edmondson (1959), Michael and Sharma (1988) and APHA (2005). The plankton net was used for hauling from the surface and water column at varying depths between 20 and 60 cm. For a particular collection, the plankton net was hauled from the bank for a distance of between 5 to 10 m from the bank. In the course of pulling the net through the water column, an even force was applied to provide a smooth flow of water through the net. A repeat of at least three hauls from three separate points of the investigated water body was undertaken for a particular sample. The collected zooplankton were filtered and the samples were transferred into a sample tube (Tarsons® 100ml) and fixed in Lugol's solution for further study. Quantification of the zooplankton in the samples was estimated using the Sedgwick-Rafter counting chamber under the required magnification (×10 initially, followed by ×40). Identification of zooplankton was done following the standard literature by Edmondson (1959), Battish (1992) and Sharma and Sharma (2008).

Analysis of water quality parameters

During the collection of zooplankton analysis of some physico-chemical parameters of water from the same wetlands were conducted. Parameters such as water temperature, pH, dissolved oxygen, free CO_2 were measured on the spot using a thermometer, a portable calibrated pH meter and DO and FCO_2 following standard methods of APHA (2005). For total alkalinity, turbidity, specific conductivity, hardness, phosphate, nitrate, potassium, calcium and magnesium of water, the collected water samples were brought to the laboratory and were estimated following standard methods of APHA (2005).

Statistical Analysis

A total of 530 samples from five freshwater wetlands were considered for this study. Data on the relative abundance of the species and the groups (Cladocera, Copepoda and Rotifera) were taken separately for each of the samples. A separate ratio of the Crustacea and Rotifera and the Copepoda and Rotifera was deduced from the relative abundance for each of the samples, to compare the group specific contributions to the zooplankton community (Ejsmont-Karabin and Karabin 2013). Data on the abundance of zooplankton and physico-chemical parameters were subjected to bivariate and multivariate analysis (Manly 1994; Legendre and Legendre 1998; Zar 1999). The correlation coefficients between the three major groups of zooplankton and the water quality features were deduced followed by a cluster analysis (CA). On the basis of the relative abundance of the zooplankton taxa, the CA were performed to portray the structure of the zooplankton community observed in the wetlands. The species and water quality (environment) data were used for the Canonical Correspondence Analysis (CCA) (ter Braak 1987; ter Braak and Verdonschot 1995; ter Braak and Smilauer 2002) used to comment on the species environment relationship. In the ordination diagram (a biplot), the environmental variables are represented as arrows and the zooplankton as scattered points in the ordination space. The direction of maximum change of an environmental variable in respect to the ordination axes are specified by the points of the arrow, while the length of the arrow indicates the rate of change in the corresponding direction. The length of the arrow of an environmental variable is proportional to the strength of correlations with the ordination axes, and thus with the pattern of community variations shown in the ordination (ter Braak 1987; ter Braak and Verdonschot 1995). The direction of an environmental arrow can be viewed as an axis allowing the projection of the species points in order of the zooplankton group rank in terms of weighted averages in the context of that environmental variable (ter Braak 1987). Two levels of analysis were carried out using CCA, one using the genera as the response variables and in another, the species richness, diversity index and genera as the response variables. Since many of the genera showed similarity in the response against the environmental variables, the levels of the resolution remained low. A supplementary analysis using the major groups of the zooplankton as the response variables was carried out. The experimental design, the objectives and the outline of the work are elaborated in Figure 2. All the statistical analyses (Manly 1994; Legendre and Legendre 1998; Zar 1999) were carried out using *XL* STAT software (Addinsoft 2010), CANOCO 4.5 for Windows (ter Braak 1987), PAST (Hammer et al. 2001).

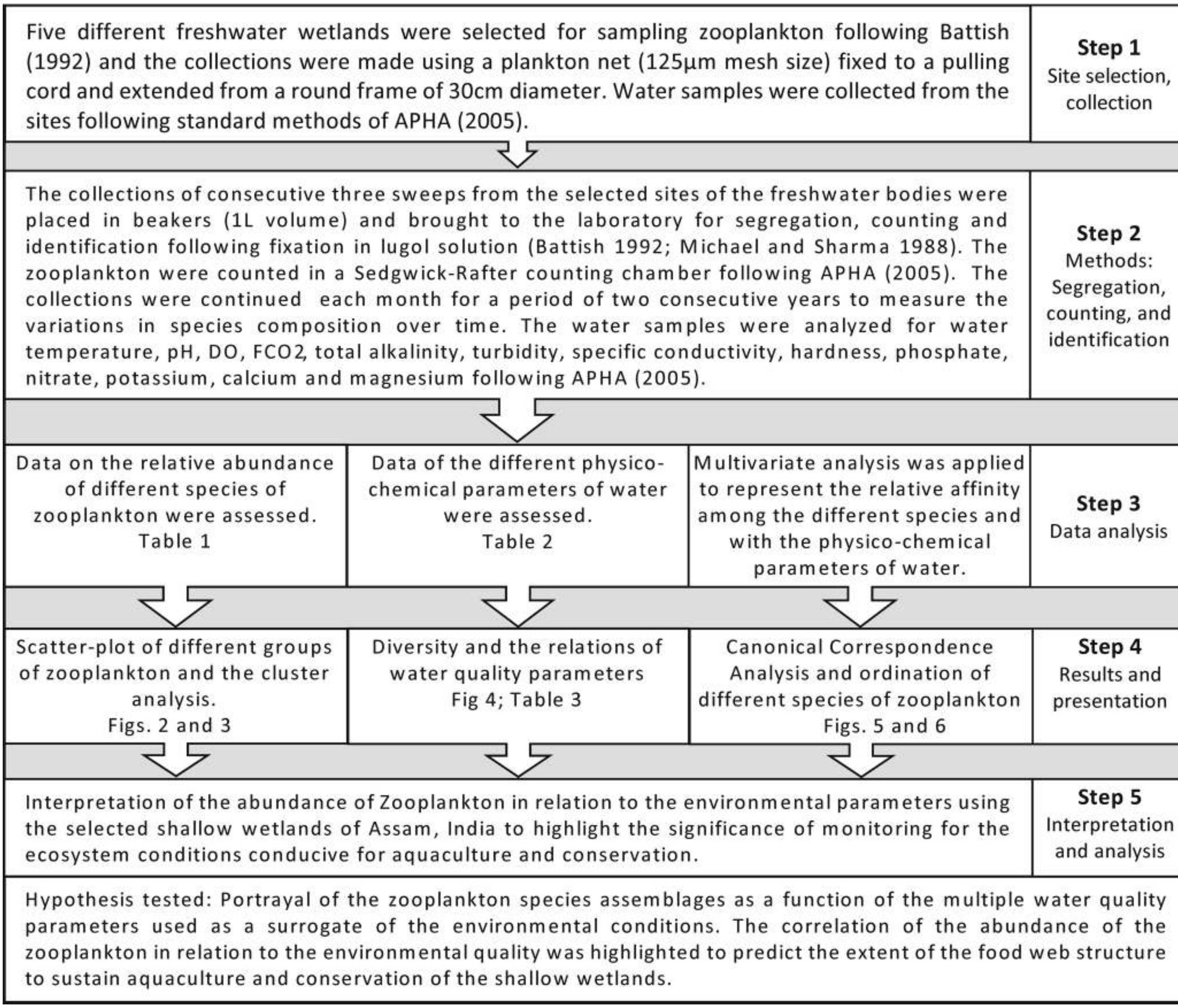

Fig. 2. Outline of work carried out (steps 1 through 5) to assess the abundance of zooplankton in relation to the environmental parameters in selected freshwater shallow water bodies of the Cachar district, Assam, India

Results

In course of sampling the selected wetlands, representatives of 46 different genera of zooplankton were encountered in varying numbers in each sample. Individuals of the genus *Brachionus* dominated in numerical abundance while individuals of the genus *Beauchampiella* was least represented (Table 1). Corresponding variations in the water quality parameters were also observed in the wetlands selected for the study (Table 2). In each sample the mean representation of rotifers was 47.63 followed by cladocerans 27.78 and copepods 19.36 ind. cm^{-3} of water (Fig. 3). The relative abundance of the three groups of zooplankton exhibited strong significant correlations with selected water quality parameters (Table 3), indicating that the relative abundance of the groups was highly influenced by the habitat conditions. The diversity index (Shannon-Weiner diversity index) value remained between 3.06 and 3.24 (mean 3.15 ±0.06) with the species richness between 29 and 46 (mean 42.29 ±3.75), both showing significant correlations with selected water quality parameters. The ratio of abundance of crustacean zooplankton (Copepoda and Cladocera) and rotifer (Rotifera) zooplankton was expressed in two ways: the CRUST/ROT ratio remained between 0.304 and 2.143 (mean 1.032 ±0.298) and the COP/ROT ratio remaining between 0.154 and 1.143 (mean 0.423 ±0.126) in samples with significant correlations with species richness and the diversity index (H'). Using the agglomerative hierarchical clustering method, based on the similarity (Pearson correlation coefficient) of relative

Table 1. Relative abundance (mean ±SE) of the individual zooplankton species observed in all five studied water bodies of Cachar, Assam, India. Data obtained from observations conducted in two consecutive years (2012–2014) with weekly sampling intervals (number of samplings N = 530). Acronyms used for zooplankton species the same as those used in the figures. Explanation: CLA – Cladocera; COP – Copepoda; OST – Ostracoda; ROT – Rotifera

Species	Acronym	Mean±SE	Group	Species	Acronym	Mean±SE	Group
Brachionus forficula	BRA	13.817±0.26	ROT	*Colurella* sp.	COL	0.991±0.09	ROT
Mesocyclops leuckarti	MES	9.830±0.16	COP	*Lepadella* sp.	LEP	0.698±0.05	ROT
Testudinella brevicaudata	TES	9.357±0.26	ROT	*Macrothrix* sp.	MAC	0.694±0.04	CLA
Diaphanosoma excisum	DIA	8.543±0.25	CLA	*Cypris* sp.	CYP	0.599±0.03	OST
Moina micrura	MOI	6.815±0.24	CLA	Scaridium longicaudum	SCAR	0.560±0.04	ROT
Neodiaptomus schamakeri	NEO	4.556±0.17	COP	*Bosminopsis deitersi*	BOSP	0.420±0.04	CLA
Asplanchna brightwelli	ASP	4.017±0.12	ROT	*Horaella brehmi*	HOR	0.408±0.04	ROT
Chydorus sphaericus	CHY	3.433±0.11	CLA	*Scapholeberis kingi*	SCA	0.388±0.04	CLA
Heliodiaptomus contortus	HEL	2.809±0.13	COP	*Simocephalus* sp.	SIM	0.331±0.04	CLA
Ascomorpha ovalis	ASC	2.679±0.09	ROT	*Pompholyx sulcata*	POM	0.319±0.04	ROT
Lecane sp.	LEC	2.611±0.10	ROT	*Rotaria* sp.	ROT	0.216±0.03	ROT
Keratella sp.	KER	2.446±0.08	ROT	*Macrochaetus* sp.	MACR	0.212±0.02	ROT
Trichocerca sp.	TRI	2.336±0.08	ROT	*Mytilina* sp.	MYT	0.176±0.02	ROT
Thermocyclops crassus	THE	2.176±0.12	COP	*Moinodaphnia macleayi*	MOID	0.170±0.02	CLA
Ceriodaphnia cornuta	CER	2.074±0.09	CLA	*Trochosphaera aequitorialis*	TRO	0.168±0.02	ROT
Anuraeopsis fissa	ANU	1.767±0.13	ROT	*Daphnia* sp.	DAP	0.112±0.02	CLA
Bosmina sp.	BOS	1.728±0.07	CLA	*Trichotria tetractis*	TRIT	0.078±0.02	ROT
Filinia sp.	FIL	1.541±0.07	ROT	*Euryalona* sp.	EUR	0.078±0.01	CLA
Alona sp.	ALO	1.217±0.06	CLA	*Platyias* sp.	PLAY	0.023±0.01	ROT
Sida sp.	SID	1.216±0.06	CLA	*Polyarthra vulgaris*	POL	0.021±0.01	ROT
Cephalodella sp.	CEP	1.070±0.07	ROT	*Conochilus unicornis*	CON	0.013±0.01	ROT
Plationus patulus	PLA	1.059±0.07	ROT	*Dicranophoroides* sp.	DIC	0.009±0.004	ROT
Alonella sp.	ALON	1.019±0.08	CLA	*Beauchampiella eudactylota*	BEA	0.002±0.002	ROT

abundance of the zooplankton in the samples, a total of four groups respectively with 15, 29, 1 and 1 numbers of genera could be constituted. With the exception of the genera *Dicranophoroides* sp. and *Rotaria* sp. the rest of the 44 genera could be grouped under the two clusters with maximum proportional representations (Fig. 4). The diversity of the zooplankton and species richness in the samples exhibited considerable variations in the samples and increased with the water temperature (Fig. 5). The ratio of crustacean to rotifer zooplankton showed significant positive correlations with the ln N and species richness (S) indicating that the richness of the cladocerans in the samples positively contributed to the overall diversity of the zooplankton (Table 4).

An ordination of the zooplankton against the background of the water quality parameters was made fol-

Table 2. Water quality parameters (mean ±SE) of the five studied water bodies of Cachar, Assam, India. Data obtained from observations conducted in two consecutive years (2012–2014) with weekly sampling intervals (number of samplings N = 530)

Parameters	Water body				
	Madhura anua	Salchapra anua	Sat beel	Malni beel	Narsingtola pond
Water temperature WaT [°C]	24.86 ±0.15	21.86 ±0.18	21.97 ±0.23	24.19 ±0.19	24.03 ±0.16
pH	6.77 ±0.02	6.75 ±0.02	6.76 ±0.02	6.7 ±0.02	6.76 ±0.02
Dissolved oxygen DO [mg dm^{-3}]	7.26 ±0.05	7.2 ±0.05	6.99 ±0.04	7.12 ±0.05	7.22 ±0.05
Free carbon dioxide FCO$_2$ [mg dm^{-3}]	0.76 ±0.02	0.74 ±0.02	0.76 ±0.02	0.74 ±0.02	0.72 ±0.02
Total Alkalinity TA [mg dm^{-3}]	57.51 ±0.2	57.27 ±0.23	57.57 ±0.19	53.65 ±0.31	57.03 ±0.21
Turbidity TURB [NTU]	89.11 ±0.13	86.37 ±0.33	88.47 ±0.18	84.59 ±0.25	88.84 ±0.17
Specific conductivity SPCON [µS cm^{-1}]	153.49 ±0.66	129.08 ±0.54	157.78 ±0.45	145.61 ±0.9	147.73 ±0.74
Hardness HARD [mg dm^{-3}]	69.2 ±0.09	65.99 ±0.38	69.16 ±0.1	67.8 ±0.31	65.51 ±0.52
Phosphate PHOS [mg dm^{-3}]	0.32 ±0.005	0.30 ±0.004	0.31 ±0.004	0.3 ±0.003	0.32 ±0.01
Nitrate NIT [mg dm^{-3}]	0.39 ±0.003	0.36 ±0.005	0.39 ±0.004	0.39 ±0.004	0.38 ±0.003
Potassium POT [mg dm^{-3}]	6.86 ±0.02	6.86 ± 0.06	6.87 ±0.03	6.95 ±0.04	6.53 ±0.04
Calcium CAL [mg dm^{-3}]	30.14 ±0.38	30.60 ±0.35	30.86 ±0.35	22.25 ±0.43	27.27 ±0.12
Magnesium MAG [mg dm^{-3}]	21.82 ±0.18	21.64 ±0.14	22.98 ±0.16	24.98 ±0.13	24.74 ±0.11

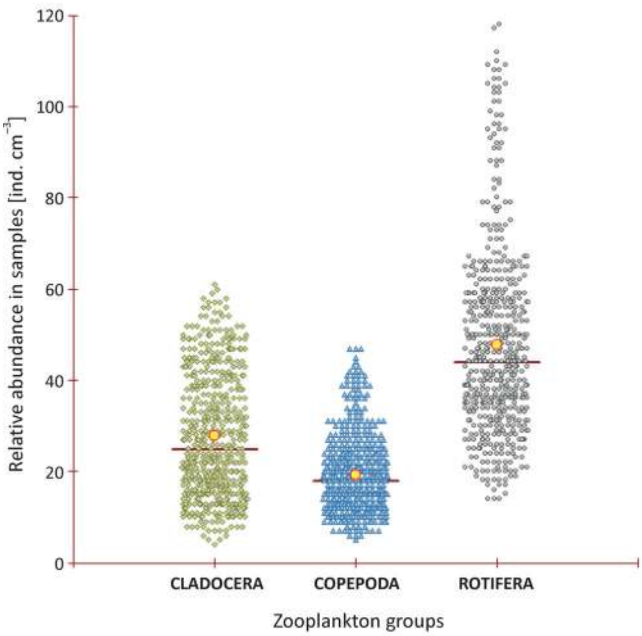

Fig. 3. Scatter plot representing the relative abundance of three major groups of zooplankton observed in the studied water bodies of Cachar, Assam, India. The circles represent the mean, while the horizontal lines the median values

Table 3. Pearson correlation coefficients between abundance of major zooplankton groups (Cladocera, Copepoda, Rotifera), species richness (S) and Shannon-Wiener diversity index (H') and the water quality parameters in five water bodies of Cachar, Assam, India. Values given in bold indicate statistical significance at $p < 0.001$ level (N = 530). Abbreviations of water quality parameters as in Table 2

Variables	Zooplankton abundance			H'	S
	Cladocera	Copepoda	Rotifera		
WaT	**–0.119**	0.009	0.073	**0.466**	**–0.433**
pH	**0.124**	**0.107**	**0.189**	0.008	0.058
DO	0.049	**0.117**	**0.090**	**0.162**	**–0.109**
FCO_2	–0.063	0.004	0.009	0.030	–0.043
TA	0.241	0.289	0.308	–0.235	0.209
TURB	0.315	0.401	0.421	–0.101	0.088
SPCON	–0.001	**0.407**	**0.423**	0.063	**–0.158**
HARD	–0.091	0.167	0.224	0.086	–0.194
PHOS	**0.103**	**0.101**	**0.207**	0.012	0.013
NIT	0.002	0.062	**0.163**	**0.101**	**–0.106**
POT	**–0.225**	**–0.093**	–0.002	0.058	**–0.134**
CAL	0.267	0.246	0.299	–0.428	0.272
MAG	–0.074	**–0.207**	**–0.127**	**0.221**	0.020

lowing the canonical correspondence analysis. Initial results of the detrended correspondence analysis showed that the mean values of the water quality parameters were more than twice the standard deviations and thus CCA application was justified. The four canonical axes explained 92% of the species-environmental relationship, with the total inertia being 0.669 and the sum of all canonical eigenvalue being 0.172. The first two canonical axes represents 68.4% (λ_1 = 47.9% and λ_2 =20.5%) of the weighted averages of the species with respect to the environmental variables. The eigenvalue of the first canonical axis (λ_1 = 0.082) remained 2.34 times the second λ_2 =0.035), with the test of significance for the first canonical axis yielding an F value of 68.989; P = 0.001). The ordination of the zooplankton and the environmental variables is presented in the

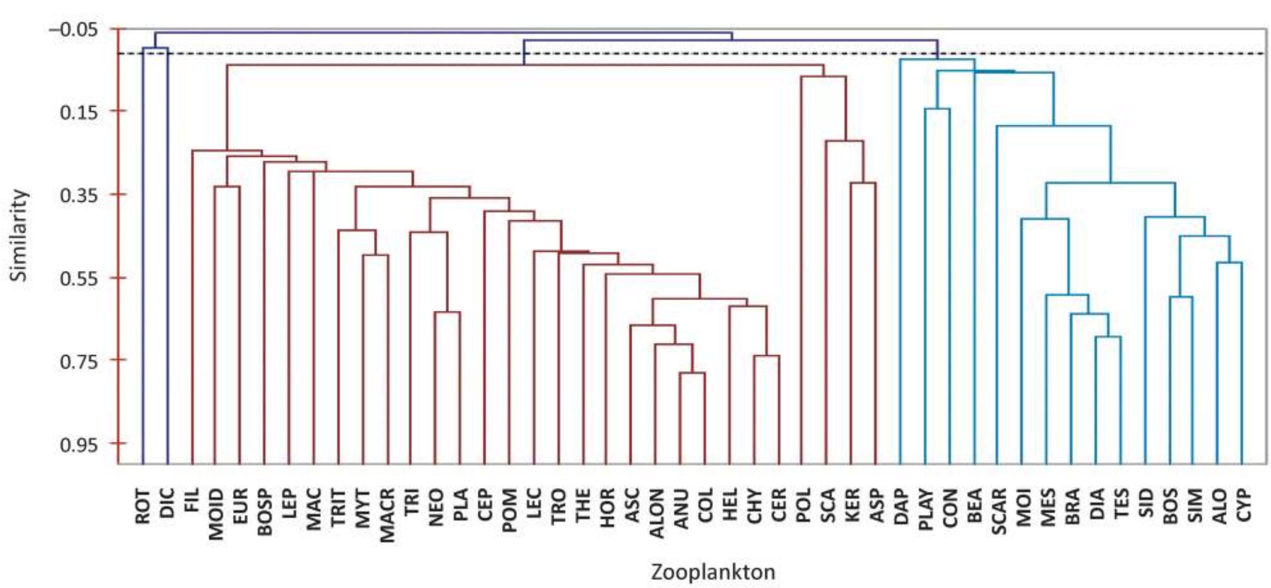

Fig. 4. Results of the cluster analysis based on the relative abundance of the individual zooplankton taxa observed in samples taken from five investigated water bodies (N = 530)

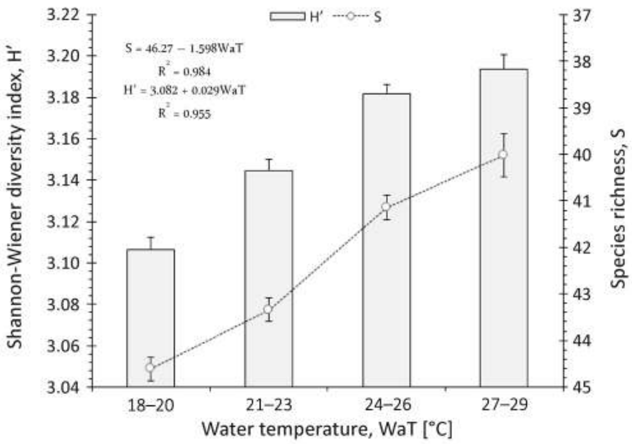

Fig. 5. Dependence of the Shannon-Wiener diversity index (H') and zooplankton species richness (S) from water temperature established for the studied water bodies

biplot (Fig. 6), where the length of the environmental variable turbidity (TUR) and potassium (POT) bear a stronger correlation with the ordination axes than rest of the environmental variables. Similarly, the environmental variables like nitrate, phosphate and pH bear least correlation with the ordination axes. The orienta-

Table 4. Pearson correlation matrix of zooplankton abundance parameters and indices. Values given in bold indicate statistical significance at $p < 0.001$ level. Explanation: N – total abundance, S – species richness, CLA – Cladocera abundance, COP – Copepoda abundance, ROT – Rotifera abundance, CRUST/ROT – Crustacea to Rotifera ratio, COP/ROT – Copepoda to Rotifera ratio

Variables	ln N	S	CLA	COP	ROT	CRUST/ROT
S	0.880					
CLA	0.070	**0.361**				
COP	**–0.258**	–0.038	**0.604**			
ROT	–0.304	–0.107	0.535	0.786		
CRUST/ROT	0.260	0.365	0.488	0.104	–0.327	
COP/ROT	0.036	0.026	–0.004	**0.285**	**–0.304**	**0.656**

tion of the zooplankton against the environmental variables reflects that the water temperature and hardness remained significant determinants for the majority of the zooplankton groups included in the analysis. An additional CCA was conducted for species richness, diversity index, zooplankton abundance and selected water quality parameters. As shown in the biplot (Fig. 7), the rotifer and copepod abundances were linked with the nitrate, phosphate and hardness of the water samples while water temperature and the potassium content of the water were linked with the diversity indices and the species richness of the samples. The two canonical axes explained more than 97% of variations of the spe-

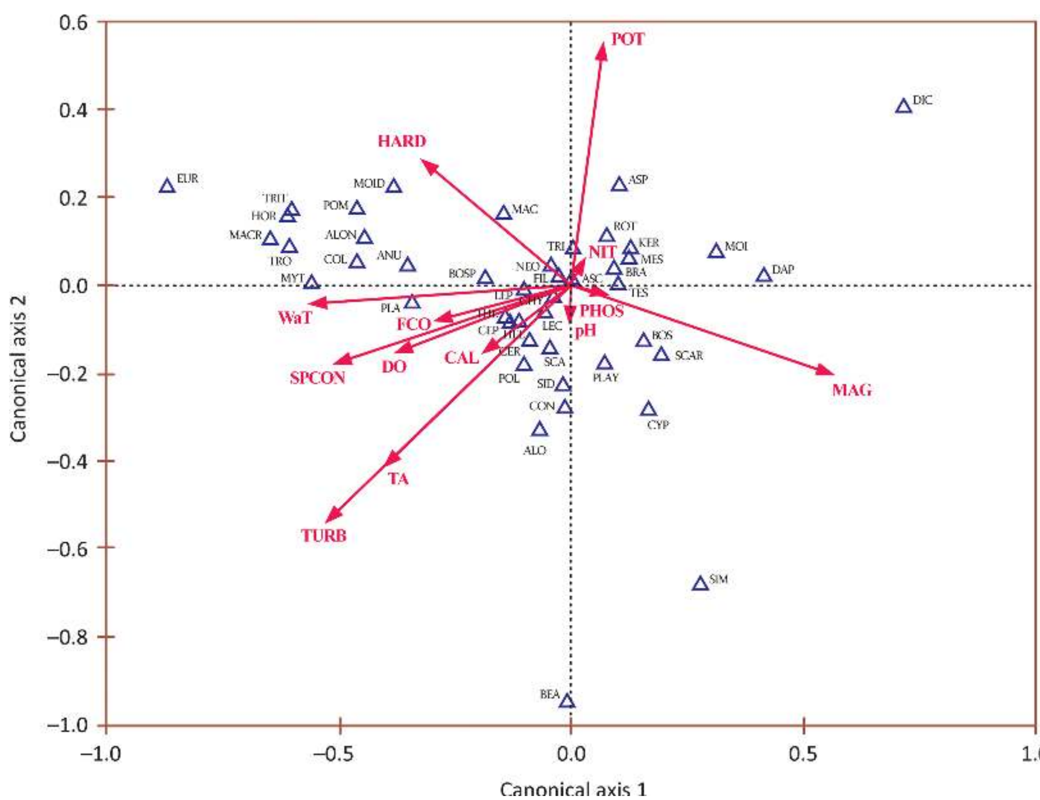

Fig. 6. Canonical correspondence analysis (CCA) biplot of the zooplankton species abundance against environmental variables in five water bodies of Cachar, Assam, India. The arrows represent the extent of the environmental variables while the triangles the zooplankton species. Acronyms used for zooplankton species the same as in Table 1

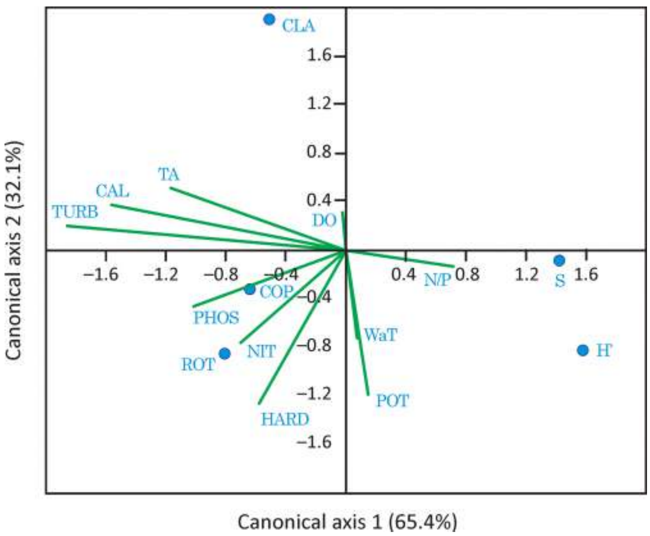

Fig. 7. Canonical correspondence analysis (CCA) biplot of the three zooplankton groups (Rotifera – ROT, Cladocera – CLA, Copepoda – COP), the Shannon-Weiner diversity index (H') and species richness (S) as dependent variables against selected water quality parameters strongly correlated with them

cies environment data with the eigen values being 0.009 and 0.004 respectively. Thus, the structural components of the zooplankton assemblages showed a considerable significant relationship with the water quality.

Discussion

In the present study, 46 different genera of zooplankton were reported of which *Brachionus* was dominant in terms of abundance while *Beauchampiella* were encountered in the least numbers. The ordination of the zooplankton against the environment variables shows a significant relationship with the temperature, alkalinity and hardness of the water. The abundance of the different groups of zooplankton relative to the water quality parameters have been documented in several studies around the world, including eutrophic lakes and ponds within reserve areas (Anton-Pardo et al. 2016). The correspondence of the water quality parameters and the zooplankton assemblages of the reserve areas in Manipur (Sharma and Sharma 2011; Sharma et al. 2017), Assam (Sharma and Sharma 2012; Gupta and Devi 2014) and Mizoram (Sharma and Pachuau 2013) have been carried out on the basis of such propositions. In the present instance the zooplankton composition appeared to be similar and comparable to these earlier findings. In comparison to the zooplankton species from the lake of Keibul Lamjao National Park, Manipur, the observed number of species in the present study was considerably higher (Sharma et al. 2016). In the Indian context, wetlands similar to those of the present instance, bear a comparable diversity of zooplankton. For example, 25 genera of zooplankton was observed in the Harsool-Savangi dam of Maharashtra, India (Shinde et al. 2012), and 51 genera of zooplankton were observed in a canal in Karnataka (Smitha et al. 2013). However, the relative abundance of the zooplankton is considerably low in these and other wetlands in comparison to the present study (Shinde et al. 2012; Ahmad et al. 2012; Smitha et al. 2013). Although rotifers dominated in most of the cases (Shinde et al. 2012; Ahmad et al. 2012; Smitha et al. 2013), the relative abundance was comparatively low compared to the present study. As observed in the present study, rotifers were represented as 48 ind. cm^{-3}, cladocerans were represented as 28 ind. cm^{-3}, and copepods were represented as 19 ind. cm^{-3}. The relative abundance of these three groups remained considerably low as observed in other studies (Shinde et al. 2012; Ahmad et al. 2012; Smitha et al. 2013). In unit samples, the dominance of rotifers was observed followed by cladocerans and copepods, which is possibly a reflection that planktivorous fish are abundant and regulated the numbers (Pinto-Coelho et al. 2005), or the water bodies were in a eutrophic state. Among the rotifers, *Rotaria* and *Dicranophoroides* were substantially abundant in contrast to the rest of the zooplankton shown in the dendrogram (Fig. 4). When compared with the water quality parameters the abundance of the three groups of zooplankton was linked positively with turbidity, alkalinity, hardness, phosphate and the calcium contents, apart from the pH of the water bodies. The water temperature appeared to be a significant factor for the abundance of cladocerans, while the magnesium content and nitrate were significant factors for the rotifers in the samples. Such a pattern was also evident in several studies on the zooplankton abundance and water quality parameters observed in other parts of the world (Stemberger and Miller 1998; de Senerpont Domis et al. 2013; Joniak and Kuczynska-Kippen 2016; Burdis and Hirsch 2017).

As observed in the ordination of zooplankton against the water quality parameters, nitrate and pH appeared to be least important in shaping the plankton community while the water hardness, turbidity, specific conductivity and phosphate contents appeared to influence the community structure of the zooplankton significantly. Apparently, *Bosmina* was influenced by the phosphate content of the water at a higher degree in comparison to the turbidity or hardness of the water. However, zooplankton like *Beauchampiella* and *Simocephalus* did not exhibit a clear affinity towards the environmental quality, possibly reflecting more of a generalist nature. Overall, the ordination of the rotifers and the copepods remained different from the cladocerans (Fig. 7). The zooplankton composition observed in the present instance appeared to be similar to that of the adjoining regions of Meghalaya, Manipur and other parts of Northeast India (Sharma and Sharma 2011; Sharma and Sharma 2012; Sharma and Pachuau 2013; Gupta and Devi 2014; Sharma et al. 2016; Sharma et al. 2017). Perhaps the habitat conditions and the water quality parameters of the wetland in the investigated geographical area may remain different from those observed in Maharashtra and Tamilnadu (Rajagopal et al. 2010; Shinde et al. 2012). In addition to the geographical factors the differences in the zooplankton composition can be attributed to the water quality parameters like phosphate and nitrate contents, turbidity and temperature regime, as evident in studies of tropical lakes around the world (Burdis and Hirsch 2017). Compared to the temperate regions, in the lakes of tropical and subtropical regions, hydroperiod and temperature regime are considered as important drivers of zooplankton composition. Precipitation along with the temperature mediates the shift in zooplankton composition particularly in shallow tropical systems (de Senerpont Domis et al. 2013). Drought induced disturbances also increase the temporal variability in the zooplankton assemblages observed in floodplain wetlands (Simoes et al. 2013).

Among the nutrient factors of freshwater ecosystems, zooplankton assemblages are dependent on the gradient of the N/P ratio for rotifers while cladocerans prefer high P and copepods require high N (Stemberger and Miller 1998), this was also revealed in the present study and has been found to be the case for wetlands of similar geographical regions of India (Sharma et al. 2016; Sharma et al. 2017). In the present study the structure of the zooplankton assemblage is elaborated to highlight availability and variations in accordance with the water quality parameters. Apart from differences in the numerical abundance of the three groups of zooplankton, the richness aspects were found to vary considerably, concurrent with the water quality. The affinity of a particular zooplankton for an environmental factor was portrayed through the CCA, at two levels, comparable to findings from different water bodies in the same area (Gupta and Devi 2014; Sharma et al. 2016; Sharma et al. 2017). Using the results of the present study as a foundation, further monitoring of the concerned wetlands may be continued for assessing the ecosystem health and integrity of the aquatic community.

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