Bangladesh J. Environ. Sci., Vol. 47, 88-103, 2024 **@ BAED ISSN 1561-9206**

MORPHOMETRIC DIVERSIFICATIONS OF IDENTIFIED ZOOPLANKTON AT THREE DIFFERENT WATER BODIES IN CHITTAGONG UNIVERSITY CAMPUS, BANGLADESH

H. Hoque, S. S. Reema, M. A. Azadi[1] and Munira Nasiruddin*
Department of Zoology, University of Chittagong, Chattogram 4331, Bangladesh
[1]International Islamic University Chittagong, Bangladesh
***Corresponding author's email: muniranasiruddin@yahoo.com

ABSTRACT

The current research focused on the diversity and morphometric variations especially the total body length (TBL) and maximum body width (MW) of zooplankton groups affected by different water bodies (extensive, semi-intensive and intensive) in Chittagong University Campus of Bangladesh. A total of 32 zooplankton species have been identified from the selected waterbodies, where rotifers identified (71.8%) as the dominant group followed by copepods (15.6%) and cladocerans (12.5%). Regarding water bodies, the highest diversity was observed in the intensive water bodies (93.8%), while the lowest in the semi-intensive (71.8%). Among the cladoceran species, the genera *Daphnia* and *Moina* were present in every picked waterbody. Of the copepod species, cyclopoid copepods were the prevalent group. Within the rotifer population, *Brachionus* (39.1%) was the dominant genus followed by *Asplanchna* (13%), *Keratella* (8.7%) and *Filinia* (8.7%). Morphometrically, most of the cladocerans (75%) and rotifers (34.8%) showed higher TBL and maximum width (MW) in extensive water bodies, while copepods (60%) in the semi-intensive water bodies. Only a few *Brachionus* species showed highest TBL in intensive water bodies. Both observational and statistical data indicated that the extensive and semi-intensive water bodies were the favored types for the highest TBL and MW of the main zooplanktonic groups.

Key words: Zooplankton, cladocerans, rotifers, copepods, intensive, extensive, semi-intensive, water bodies.

Introduction

The zooplankton, more specifically the cladocerans, copepods and the rotifers, are advocated as indispensable component of freshwater ecosystem and they provide nutrients like amino acids, proteins, fatty acids, lipids, enzymes and minerals to fish larvae and fingerlings (Elser and Carpenter, 1988). However, the zooplankton living in pelagic and littoral zones of different water bodies are considered as an integral ecological indicator of the water bodies because of their inevitable role in water quality determination or eutrophication and potency as natural water-cleaner by assisting with sewage disposal (Neetu*et al*., 2020). The fish fries, mostly the carp and shrimps, prefer to selectively feed on *Daphnia* sp. and *Moina* sp. because of their large body size and higher nutrient value, but in absence of this zooplankton the fries prefer *Brachionus calyciflorus* (Domínguez-Domínguez *et al*., 2002). This selectivity differs between water bodies and literally has impact on healthiness of the water bodies as well as fish nutrition, since high predation pressure, exerted by the planktivorous fishes, has been noted to result into small-sized zooplankton with fewer nutrients (Agasild and Nõges, 2005). To justify the fact, in the present study, special focus has been paid on the zooplankton species diversity in six spots of three different pond types (intensive, semi-intensive and extensive) of Chittagong University Campus (CUC) to make a comparative account on morphological difference of zooplankton in respect to the condition of the water bodies.

Materials and Methods

Study area: Prior to the present study, a preliminary survey was conducted to select six ponds of three water body types from CUC and adjacent areas (Fig. 1). Based on the water body types the ponds were subdivided into three types- intensive (ponds 1& 2), semi-intensive (ponds 3 & 4) and extensive (ponds 5 & 6) with the aim to compare the species composition of zooplankton among the ponds.

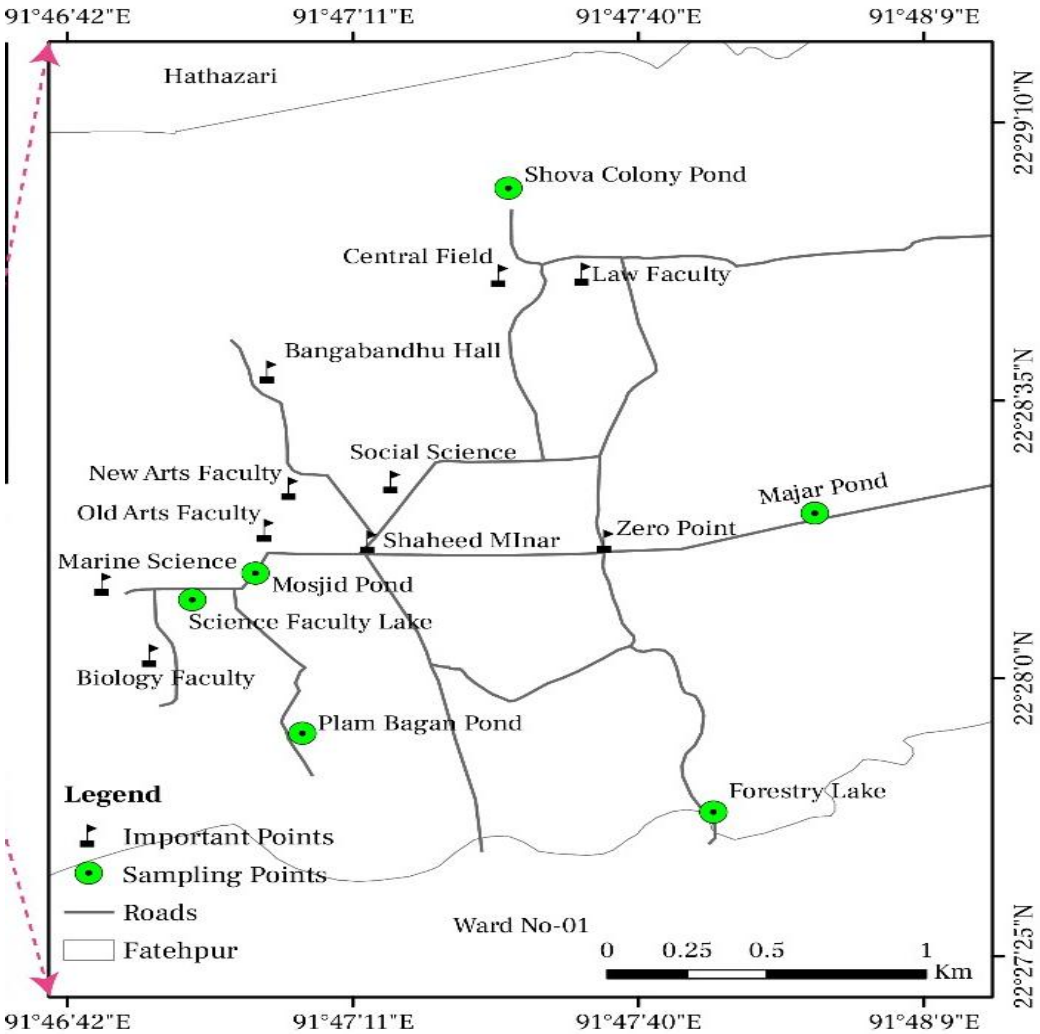

Fig. 1. Map showing the selected six ponds in Chittagong University Campus (CUC)

Sampling: Collection and further studies of zooplankton were conducted following the methods mentioned by Islam *et al*. (2022) with some modifications. In brief, water samples from the ponds were collected fortnightly at dawn and dusk between February 2023 and July 2023. Vertical diurnal movement of zooplankton was the reason for sampling at two time point (Murby, 2006). Samples were collected from littoral and pelagic zones of the ponds. Plankton net of 50 µm mesh size tied with a collecting tube of 120 mL was used for sampling from the spots. In each case, the plankton samples were collected from the water depth between 0 and 12-17 cm. The plankton nets were thrown and propelled through the water keeping a constant depth between 0 and 12-17 cm. However, multiplicative sampling was done until the total volume of the collected water sample reached up to 8 liters to confirm maximum species richness. Finally, the pooled 8 liters of water was sieved, washed and concentrated into 200 mL stock with the aid of plankton net and distilled water. Finally, buffered formaldehyde solution was added with the stock to a final concentration of 6-7% and transferred into a screw-capped polystyrene bottle, labeled appropriately with the spot, date, time, total volume and preserved until further study.

Microscopic study: From each stock, about 5-10 mL samples were studied under light microscope (trinocular microscope, OXION; NIS-EU 1640407) at different magnifications (40x, 100x and 400x) and microdissection was conducted for some species, especially at the urosome of the copepods, to understand cryptic characters. Microphotographs of each zooplankton and their different body parts were taken with the aid of a microscopic camera (Euromex, CIMEX 10PRO). For identification of zooplankton, Błędzki and Rybak (2016), Dang *et al*. (2015), Segers (2008), Witty (2004) and various online resources were used.

Morphometric measurements: The micrometry of the identified zooplankton species was recorded with ocular scale and stage micrometer. For each species, from each sampling of specific pond type, morphometry of at least six samples (three each from dawn and dusk), were studied to calculate the morphological variations. Mean, standard deviation and statistical tests (t-test) of the recorded morphometric data was calculated using Excel and SPSS Statistics 24.0 (IBM SPSS Statistics).

Results and Discussion

In the present study, attempts were made to make a comparative morphometric study of the major zooplankton groups collected from three different types of water bodies in CUC areas of Bangladesh.

A total of 32 different zooplankton species belonging to the three major zooplanktonic groups have been identified from the collected plankton samples of the selected six ponds of three different water bodies type (Table 1). Of them the rotifers (23) outnumbered the copepods (5) and cladocerans (4) (Table 1). While working on the extensive and semi-intensive ponds from the same locality, Islam *et al*. (2022) reported 33 zooplankton species dominated by the rotifers (54.17%-72.73%). Almost in all freshwater habitat types, irrespective to seasons, the rotifers were recorded to be the main contributors to the zooplankton diversity and density (Umi *et al*., 2024; Islam *et al*., 2022), which has also been observed in the present study by reporting 71.8% rotifers of the total identified zooplankton species. The smaller body size, growth pattern, short life cycle, opportunistic nature of rotifers and the presence or absence of macrophytes attributed to their higher density in the zooplankton assembles (Umi *et al*., 2024). Among the different pond types, the zooplanktonic diversity was the highest in intensive ponds (30) followed by extensive (26) and semi-intensive ponds (23) (Table 1). Numerous nauplius larvae were also found throughout the study period from every ponds. The growth acceleration of zooplankton by the microorganisms and phytoplankton promoted by the supplemented nutrients and the efficiency of the zooplankton especially the rotifers and cladocerans to reproduce parthenogenetically in response to the altered water condition of intensive ponds could be the reason behind this diversity pattern (Paray and Al-Sadoon, 2016). About 62.5% (20 out of 32 species) of the total diversity was similar in all water body types (Table 1). In freshwater habitats, the cladoceran considered as keystone species and can be dispersed in either pelagic or littoral zones (Jones and Jordan, 2013). In the present study, all the four identified cladocerans species (Fig. 2) were reported from both zones of all the pond types. While studying the cladocerans of ponds, similar trend of having an average of 4.5 and 5 pelagic cladocerans species had been recorded by Cottenie *et al*. (2001).

Among the reported cladoceran species of the ponds, for being their larger body size, *Moina* and *Daphnia* were reported to be the most preferred prey for fish larvae from nutrient perspective (Domínguez-Domínguez *et al*., 2002). Relevantly, both the genera have been reported from the present studied ponds and morphometrically the *Daphnia lumholtzi* was found to be the biggest in size followed by *Diaphanosoma* spp. and *Moina brachiata* (Fig. 3), which were very much close with the morphometric data of Peterson *et al*. (2006) and Dang *et al*. (2015). Also, statistically *D. lumholtzi* showed the highest TBL ($t= -4.84$, $p < 0.001$) and MW ($t= - 3.556$, $0.001< p <0.05$) for semi-intensive water bodies compared to intensive water bodies (Tables 2-4). However, all the cladoceran species showed the lowest TBL and MW in intensive ponds (Table 2). The eutrophication of the intensive water bodies because of the inflow of agrochemicals, food additives and nutrient through the fish feed and also the fish excreta could be the guiding factors to alter the optimum condition required for the growth of the cladocerans (Dulić *et al*., 2014; Arthaud *et al*., 2012). Other than above-mentioned factors, the high predation pressure in intensive system compared to other two systems could attribute a stronger controlling effect on the zooplankton community and their growth (Daewel and Schrum, 2013). However, during the study *D. leuchtembergianum* was not found in the semi-intensive ponds (Table 1). The study noted that five identified copepods species of the present study, four belonged to cyclopoids while one to calanoid (Fig. 4) and the diversity was same in all waterbody types (Table 1). This pattern supports the dominancy of cyclopoids in freshwater habitat. Other than the *Cyclops varicans rubellus* and *Macrocyclops distinctus*, remaining species showed the highest TBL in case of semi-intensive water bodies, whereas both *C. varicans rubellus* and *M. distinctus* in extensive water bodies (Table 2). Of the identified copepods, the only calanoid copepods *Neodiaptomus strigilipes* showed the highest TBL and MW in case of semi-intensive water bodies and statistically significant difference was observed between semi-intensive and extensive water bodies (TBL: $t= 1.81$, $p<0.05$; MW: $t= 2.265$, $p<0.05$) (Fig.5; Tables 2-4).

Table 1. Identified zooplankton species from three distinct water bodies

Species	Intensive pond (IP)				Semi-intensive pond (SIP)				Extensive pond (EP)			
	Pond-1		Pond-2		Pond-3		Pond-4		Pond-5		Pond-6	
	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk	Dawn	Dusk
Species under Cladocera group												
Daphnia lumholtzi	×	×	×	√	√	√	×	√	×	√	√	√
Diaphanosoma brachyurum	√	×	×	×	√	√	×	×	×	√	√	√
D.leuchtembergianum	√	√	×	√	×	×	×	×	√	×	√	×
Moina brachiata	√	×	√	√	√	√	√	√	√	√	×	√
Species under Copepoda group												
Neodiaptomus strigilipes	√	×	√	×	√	√	×	×	√	√	√	×
Cyclops varicans rubellus	√	√	√	√	√	√	×	×	×	√	√	×
Mesocyclops leuckarti	√	√	√	√	√	√	√	√	√	√	√	√
Thermocyclops inversus	√	√	√	×	√	×	×	√	×	×	√	√
Macrocyclops distinctus	√	×	√	√	×	√	×	√	×	√	√	√
Species under Rotife group												
Brachionus urceolaris	×	√	×	×	×	×	√	√	×	×	√	√
B. diversicornis	√	√	√	√	√	√	×	√	×	√	×	√
B. falcatus	×	√	√	√	×	×	√	√	√	√	×	×
B.calyciflorus	×	√	√	√	×	×	×	√	×	×	√	√
B. caudatus	√	√	√	√	√	√	×	√	×	×	×	×
B. nilsoni	×	×	√	√	√	√	√	√	×	×	√	√
B.angularis	×	√	√	√	×	×	×	√	×	×	√	√
B.forficula	√	√	√	√	√	√	×	√	√	√	√	×
B.quadridentatus	√	√	√	√	√	√	×	√	√	×	√	×
Keratella tropica	×	√	×	√	×	×	×	×	√	√	×	×
K.cochlearis	×	√	√	√	√	√	×	×	√	√	√	×
Lecane luna	×	×	√	√	√	√	×	√	×	×	√	×
Asplanchna herricki	√	√	×	√	×	×	×	×	√	×	√	√
A. priodonta	×	×	√	√	×	×	×	×	√	×	×	×
A. seiboldi	√	√	×	×	×	×	√	√	×	×	×	√
Filinia opolinesis	×	√	√	√	×	×	×	×	√	√	√	×
F. longiseta	×	×	√	√	×	×	×	×	×	×	×	×
Polyarthra vulgaris	×	√	×	√	×	×	×	×	×	×	×	×
Testudinella petina	√	√	×	×	×	×	×	√	√	×	√	×
Lepadella patella	×	×	×	×	√	√	×	√	×	×	×	×
Rotaria neptunia	×	×	×	×	×	×	√	×	√	×	√	×
Platyias patulus	√	√	√	√	×	×	×	×	×	×	×	×
Trichocera cylindrica	√	√	√	√	×	×	×	×	×	×	×	×
Nauplius larvae	√	√	×	×	√	√	√	√	√	×	√	√

Table 2. Comparative morphometry [TBL=Total body length (mean±SD), MW= Maximum width (mean± SD) in mm] of the identified zooplankton species from different pond types

Species name	Intensive pond (IP)	Semi-intensive pond (SIP)	Extensive pond (EP)
	TBL, MW	TBL, MW	TBL, MW
Cladocerans			
Daphnia lumholtzi	1.62±0.26, 0.71±0.27	2.16±0.18, 1.08±0.13	1.82±0.18, 1.04±0.06
Diaphanosoma brachyurum	1.05±0.03, 0.22±0.01	1.09±0.04, 0.26±0.01	1.24±0.05, 0.35±0.08
D.leuchtembergianum	1.15±0.02, 0.32±0.03	Not found	1.32±0.04, 0.42±0.04
Moina brachiata	0.80±0.13, 0.34±0.08	1.14±0.21,0.33±0.07	1.34±0.16, 0.47±0.06
Copepods			
Neodiaptomus strigilipes	1.24±0.30, 0.27±0.08	1.36±0.08, 0.33±0.04	1.20±0.25, 0.27±0.07
Cyclops varicans rubellus	0.53±0.08, 0.15±0.04	0.61±0.09, 0.13±0.01	0.63±0.15, 0.16±0.04
Mesocyclops leuckarti(M)	0.83±0.10, 0.17±0.03	0.99±0.13, 0.18±0.02	0.92±0.10, 0.20±0.04
M. leuckarti (F)	0.94±0.13, 0.24±0.04	1.08±0.15, 0.26±0.05	0.99±0.11, 0.26±0.03
Thermocyclops inversus	0.88±0.04, 0.18±0.02	0.96±0.03, 0.18±0.02	0.95±0.03, 0.21±0.02
Macrocyclops distinctus	0.81±0.19, 0.23±0.03	0.83±0.11, 0.23±0.01	0.92±0.19, 0.24±0.06
Rotifers			
Brachionus urceolaris	0.21±0.03, 0.15±0.01	0.26±0.02, 0.18±0.01	0.28±0.02, 0.19±0.01
B. diversicornis	0.33±0.06, 0.12±0.03	0.30±0.03, 0.13±0.02	0.34±0.01, 0.13±0.01
B. falcatus	0.28±0.03, 0.11±0.03	0.25±0.04, 0.11±0.01	0.33±0.06, 0.12±0.02
B.calyciflorus	0.22±0.04, 0.16±0.04	0.22±0.04, 0.14±0.03	0.32±0.01, 0.17±0.03
B. caudatus	0.16±0.02, 0.10±0.03	0.18±0.04, 0.11±0.01,	Not found
B. nilsoni	0.21±0.04, 0.14±0.04	0.22±0.04, 0.16±0.02	0.19±0.03, 0.14±0.03
B.angularis	0.12±0.02, 0.09±0.01	0.12±0.01, 0.09±0.01	0.12±0.01, 0.09±0.01
B.forficula	0.15±0.02, 0.09±0.02	0.24±0.02, 0.11±0.01	0.18±0.03, 0.10±0.02
B.quadridentatus	0.20±0.02, 0.15±0.01	0.23±0.03, 0.16±0.01,	0.24±0.01, 0.16±0.01
Keratella tropica	0.20±0.01, 0.06±0.01	Not found	0.23±0.01, 0.06±0.01
K.cochlearis	0.17±0.02, 0.06±0.01	0.19±0.03, 0.06±0.01	0.20±0.04, 0.05±0.02
Lecane luna	0.16±0.02, 0.11±0.01	0.20±0.03, 0.11±0.03	0.15±0.02, 0.11±0.01
Asplanchna herricki	0.25±0.06, 0.21±0.07	Not found	0.37±0.05, 0.27±0.04
A. priodonta	0.31±0.03, 0.19±0.02	Not found	0.37±0.07, 0.22±0.05
A. seiboldi	0.34±0.03, 0.19±0.03	0.31±0.03, 0.17±0.01	0.27±0.01, 0.12±0.01
Filinia opoliensis	0.64±0.10, 0.06±0.01	Not found	0.78±0.01, 0.07±0.01
F. longiseta	0.59±0.04, 0.08±0.02	Not found	Not found
Polyarthra vulgaris	0.11±0.01, 0.08±0.01	Not found	Not found
Testudinella petina	0.18±0.04, 0.12±0.02	0.19±0.02, 0.14±0.01	0.25±0.06, 0.16±0.02
Lepadella patella	Not found	0.11±0.01, 0.07±0.01	Not found
Trichocerca cylindrica	0.38±0.03,0.06±0.01	Not found	Not found
Platyias patulus	0.17±0.01, 0.11±0.01	Not found	Not found
Rotaria neptunia	Not found	0.27±0.03, 0.07±0.01	0.39±0.05, 0.08±0.01

This finding correlates with the findings of Suárez-Morales *et al*. (2003) and Suárez-Morales *et al*. (2005) of getting larger diaptomid calanoid from freshwater of Costa Rica. Because of their unique swimming patterns, the copepods always face predation pressure that leads to altered life strategy and body size abnormality which might be the reason of lower TBL in intensive and extensive water bodies (Lu and Xie, 2001). Moreover, co-existence (Maly and Maly, 2004), population density (Islam *et al*. 2006), environmental and geographical factors (Borutzky, 1972), algal diet composition (Gusmão and McKinnon, 2009) and climatic variability (Seebens *et al*., 2007) could also attribute to have lower body size of copepods in extensive water bodies. The female *Mesocyclops leuckarti* showed slightly bigger TBL than male in each water body types (Table 2; Fig. 5).

Table 3. Results of statistical analysis (t-test) for TBL (Total body length) of identified species from three pond types

Species name	Variable 1	Variable 2	t-value	One tail p value	Two-tail p value
Daphnia lumholtzi	IP	SIP	-4.84***	0.0000764	0.000152
	IP	EP	-1.96**	0.033049	0.0661
	SIP	EP	3.675**	0.001125	0.00225
Diaphanosoma brachyurum	IP	SIP	-2.84**	0.0066	0.013
	IP	EP	-8.80***	0.0000007	0.0000014
	SIP	EP	-6.40***	0.0000083	0.000017
D. leuchtembergianum	IP	EP	-8.21**	0.000088	0.000175
Moina brachiata	IP	SIP	-3.43**	0.00251	0.00502
	IP	EP	-6.69***	0.000011	0.000022
	SIP	EP	-1.93**	0.04	0.08
Neodiaptomus strigilipes	IP	SIP	-1.36	0.103	0.206
	IP	EP	0.029	0.488	0.977
	SIP	EP	1.81**	0.0477	0.095
Cyclops varicans rubellus	IP	SIP	-1.699	0.06	0.12
	IP	EP	-1.64	0.633	0.127
	SIP	EP	-0.251	0.403	0.803
Mesocyclops leuckarti	IP	SIP	-2.744**	0.0075	0.0151
	IP	EP	-1.616	0.062	0.126
	SIP	EP	1.28	0.110	0.220
Thermocyclops inversus	IP	SIP	-3.13**	0.008	0.016
	IP	EP	-2.061**	0.039	0.078
	SIP	EP	0.416	0.347	0.695
Macrocyclops distinctus	IP	SIP	-0.11	0.458	0.917
	IP	EP	-0.863	0.205	0.410
	SIP	EP	-0.965	0.181	0.363
Brachionus urceolaris	IP	SIP	-2.655**	0.0145	0.029
	IP	EP	-4.318**	0.0025	0.004995
	SIP	EP	-1.571	0.077	0.154
B. diversicornis	IP	SIP	2.131**	0.022	0.044
	IP	EP	-0.711	0.243	0.486
	SIP	EP	-3.921**	0.00077	0.001536
B. falcatus	IP	SIP	0.702	0.248	0.496
	IP	EP	-1.302	0.117	0.234
	SIP	EP	-1.554	0.074	0.148
B. calyciflorus	IP	SIP	0.423	0.341	0.683
	IP	EP	-5.481***	0.000462	0.000925
	SIP	EP	-5.805**	0.000573	0.00114
B. quadridentatus	IP	SIP	-1.304	0.114	0.229
	IP	EP	-3.522**	0.0194	0.0389
	SIP	EP	-1.064	0.1680	0.336
B. caudatus	IP	SIP	-1.702	0.0554	0.1108
B. nilsoni	IP	SIP	-1.356	0.112	0.224
	IP	EP	-0.08156	0.4691	0.938
	SIP	EP	1.662	0.064	0.127
B. angularis	IP	SIP	-0.406	0.356	0.712
	IP	EP	-0.226	0.416	0.832
	SIP	EP	0.302	0.387	0.773
B. forficula	IP	SIP	-10.760 ***	0.000000038	0.000000076
	IP	EP	-10.760***	0.000000038	0.000000076
	SIP	EP	5.187***	0.000113	0.000227
Assplanchna priodonta	IP	EP	-1.744	0.06	0.119

Species name	Variable 1	Variable 2	t-value	One tail p value	Two-tail p value
A. herricki	IP	EP	-3.991**	0.0009	0.0018
A. seiboldi	IP	SIP	1.558	0.082	0.1632
	IP	EP	5.122**	0.000682	0.0013
	SIP	EP	1.802	0.0657	0.131
Keratella tropica	IP	EP	-9.428***	0.000015	0.0000315
K. cochlearis	IP	SIP	-0.709	0.253	0.505
	IP	EP	-1.599	0.092	0.185
	SIP	EP	-0.9005	0.201	0.403
Filinia opoliensis	IP	EP	-3.642**	0.0027	0.0054
Lecane luna	IP	SIP	-2.312	0.0518	0.104
	IP	EP	0.544	0.308	0.615
	SIP	EP	3.641**	0.0074	0.015
Testudinella patina	IP	SIP	-0.616	0.279	0.557
	IP	EP	-1.848	0.0535	0.107
	SIP	EP	-1.602	0.085	0.1698
Rotaria neptunia	SIP	EP	-3.904**	0.006	0.011

** Significant at 0.05 level, *** Significant at 0.001 level

Table 4. Results of statistical analysis (t-test) for MW (Maximum width) of identified species from three pond types

Species name	Variable 1	Variable 2	t-value	One-tail p value	Two-tail p value
Daphnia lumholtzi	IP	SIP	-3.556**	0.0014	0.00288
	IP	EP	-3.56**	0.002	0.004
	SIP	EP	0.563	0.292	0.585
Diaphanosoma brachyurum	IP	SIP	-4.236***	0.0003	0.0006
	IP	EP	-6.38***	0.0001	0.00021
	SIP	EP	-3.535**	0.002	0.0047
D. leuchtembergianum	IP	EP	-4.278**	0.002	0.0037
Moina brachiata	IP	SIP	0.084	0.4675	0.9351
	IP	EP	-3.0307**	0.008	0.016
	SIP	EP	-4.062***	0.0005	0.001
Neodiaptomus strigilipes	IP	SIP	-1.754	0.052	0.105
	IP	EP	0.022	0.491	0.983
	SIP	EP	2.265**	0.019	0.0378
Cyclops varicans rubellus	IP	SIP	1.1	0.152	0.303
	IP	EP	-0.79	0.221	0.441
	SIP	EP	-2.506**	0.017	0.033
Mesocyclops leuckarti (M)	IP	SIP	-2.22**	0.022	0.043
	IP	EP	-2.33**	0.018	0.035
	SIP	EP	-0.915	0.19	0.38
Mesocyclops leuckarti (F)	IP	SIP	-1.232	0.126	0.252
	IP	EP	-1.452	0.1	0.197
	SIP	EP	-0.0337	0.487	0.974
Thermocyclops inversus	IP	SIP	-0.599	0.282	0.564
	IP	EP	-2.132**	0.04	0.077
	SIP	EP	-1.775	0.068	0.136
Macrocyclops distinctus	IP	SIP	0.138	0.448	0.896
	IP	EP	-0.282	0.392	0.785
	SIP	EP	-0.420	0.344	0.689
Brachionus urceolaris	IP	SIP	-4.824***	0.00066	0.0013
	IP	EP	-7.561***	0.000065	0.00013
	SIP	EP	-2.91**	0.0078	0.0156

Species name	Variable 1	Variable 2	t-value	One-tail p value	Two-tail p value
B. diversicornis	IP	SIP	-0.194	0.424	0.848
	IP	EP	-2.387**	0.0132	0.0264
	SIP	EP	-2.083**	0.03	0.06
B. falcatus	IP	SIP	-0.222	0.413	0.826
	IP	EP	-0.736	0.239	0.478
	SIP	EP	-0.563	0.293	0.586
B. calyciflorus	IP	SIP	0.552	0.298	0.596
	IP	EP	-1.08	0.165	0.330
	SIP	EP	-1.41	0.104	0.208
B. quadridentatus	IP	SIP	-1.557	0.082	0.163
	IP	EP	-1.572	0.096	0.191
	SIP	EP	0.305	0.384	0.768
B. caudatus	IP	SIP	-0.603	0.283	0.566
B. nilsoni	IP	SIP	-0.993	0.197	0.394
	IP	EP	-0.743	0.25	0.50
	SIP	EP	0.652	0.264	0.53
B. angularis	IP	SIP	0.279	0.396	0.791
	IP	EP	0.279	0.396	0.791
	SIP	EP	0.00004	0.5	1.0
B. forficula	IP	SIP	-1.432	0.086	0.171
	IP	EP	-0.649	0.262	0.525
	SIP	EP	0.68	0.254	0.508
Assplanchna priodonta	IP	EP	-0.718	0.25	0.50
A. herricki	IP	EP	-2.99**	0.0062	0.012
A. seiboldi	IP	SIP	1.877	0.06	0.12
	IP	EP	7.444***	0.000345	0.00069
	SIP	EP	15.286***	0.00000062	0.0000012
Keratella tropica	IP	EP	0.255	0.403	0.806
K. cochlearis	IP	SIP	0.38	0.36	0.71
	IP	EP	1.611	0.08	0.168
	SIP	EP	1.307	0.124	0.248
Filinia opoliensis	IP	EP	-0.939	0.183	0.366
Lecane luna	IP	SIP	-0.435	0.341	0.682
	IP	EP	0.143	0.446	0.892
	SIP	EP	0.488	0.321	0.643
Testudinella patina	IP	SIP	-3.873	0.0031	0.0061
	IP	EP	-4.191	0.0029	0.0057
	SIP	EP	-1.986	0.0518	0.104
Rotaria neptunia	SIP	EP	-1.285	0.123	0.246

** Significant at 0.05 level, *** Significant at 0.001 level

In the present study, out of 23 identified rotifers, 22 species belonged to Monogononta while only one species (*Rotaria neptunia*) was from Bdelloidea (Table 1, Fig. 6). However, the rotifer diversity between the selected habitat types was not same, showing the highest (91.3%) in the intensive ponds followed by extensive ponds (73.9%) and semi-intensive ponds (65.2%) (Table 1). Kuczyńska-Kippen (2005) mentioned that the occurrence and even the size of the rotifers differed between habitat types. The *Brachionus* was the dominant (39.1%) genus among the identified rotifers followed by *Asplanchna* genus (13%) (Table 1). The efficiency of *Brachionus* species to withstand in eutrophic water bodies and reduced predation pressure because of co-existence with cladocerans could have impact in rotifers diversity in fresh water bodies types (Toruan *et al*., 2022). It has been observed that planktivorous fishes mostly prefer cladocerans over the rotifers because of their larger forms that inversely helping the rotifers to have higher diversity and population size (Liu *et al*., 2023).

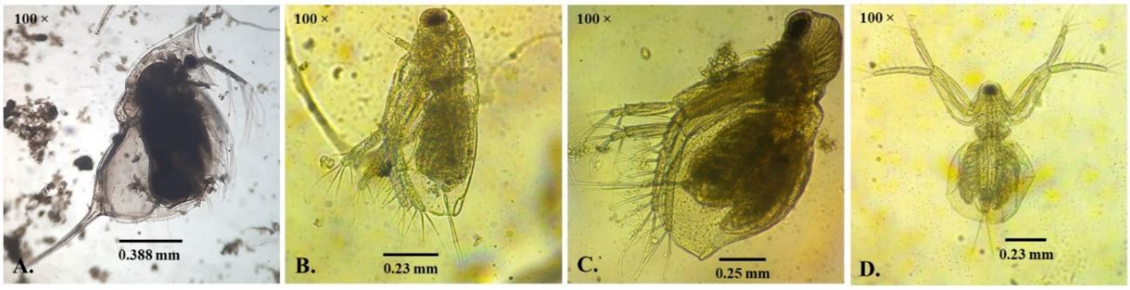

Fig. 2. Identified cladoceran species. **A.** *Daphnia lumholtzi*; **B.** *Diaphanosoma brachyurum*; **C.** *D. leuchtembergianum*; **D.** *Moina brachiata*

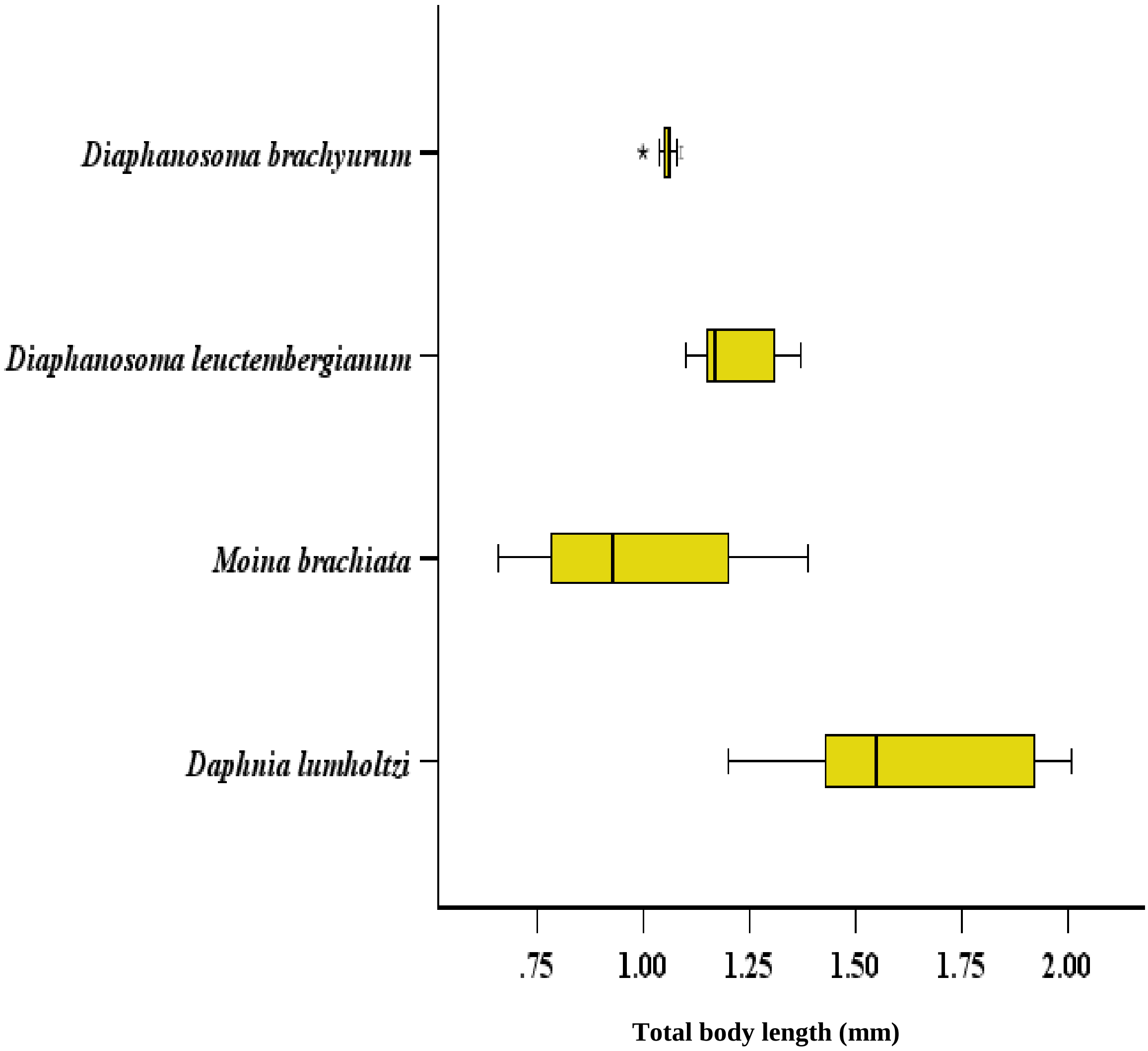

Fig. 3. Total body length (TBL, in mm) of the identified cladoceran species

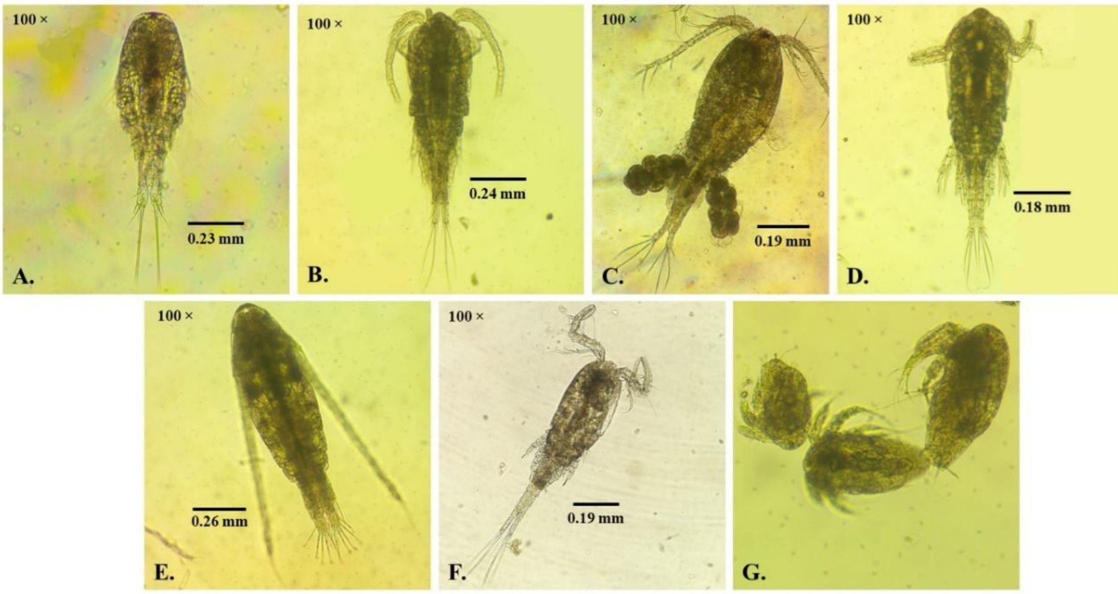

Fig. 4. Identified copepods. **A.** *Cyclops varicansrubellus*; **B.** *Mesocyclops distinctus*; **C.** *Mesocyclops leuckarti* (Female); **D.** *M. leuckarti* (Male); **E.** *Neodiaptomus strigilipes*; **F.** *Thermocyclops inversus*; **G.** Nauplius larvae

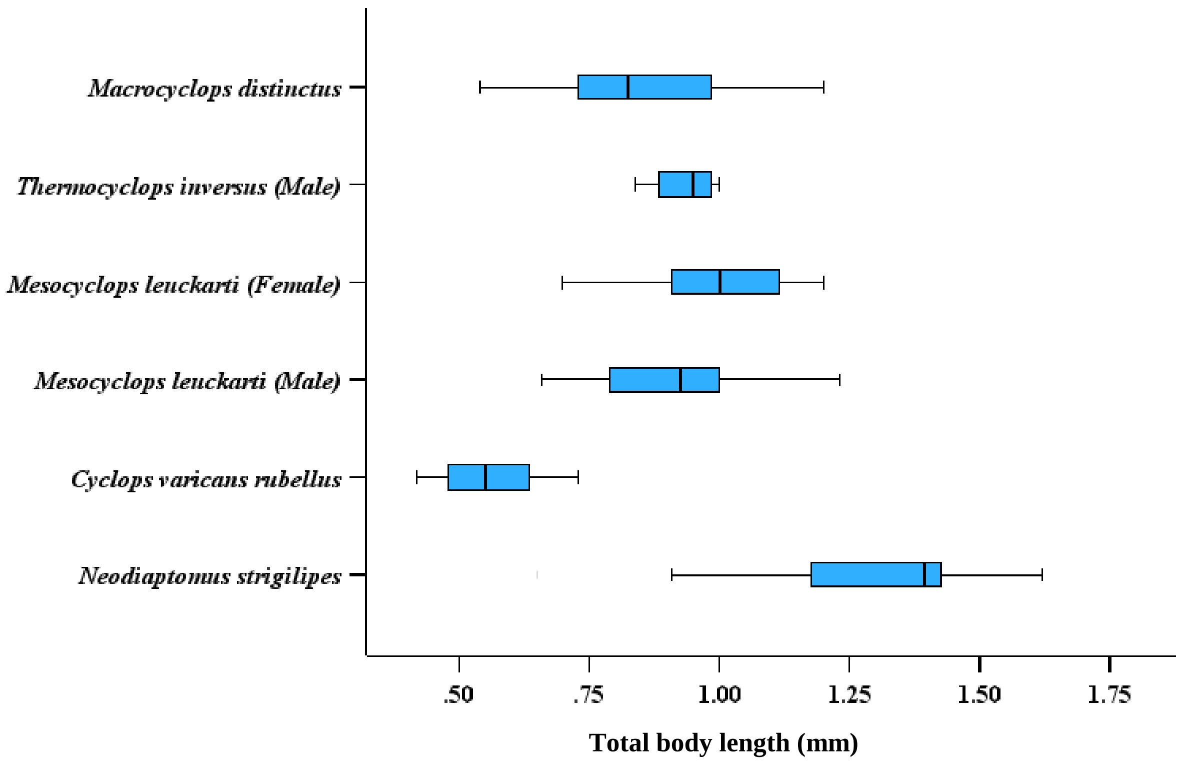

Fig. 5. Total body length (TBL, in mm) of the identified copepod species

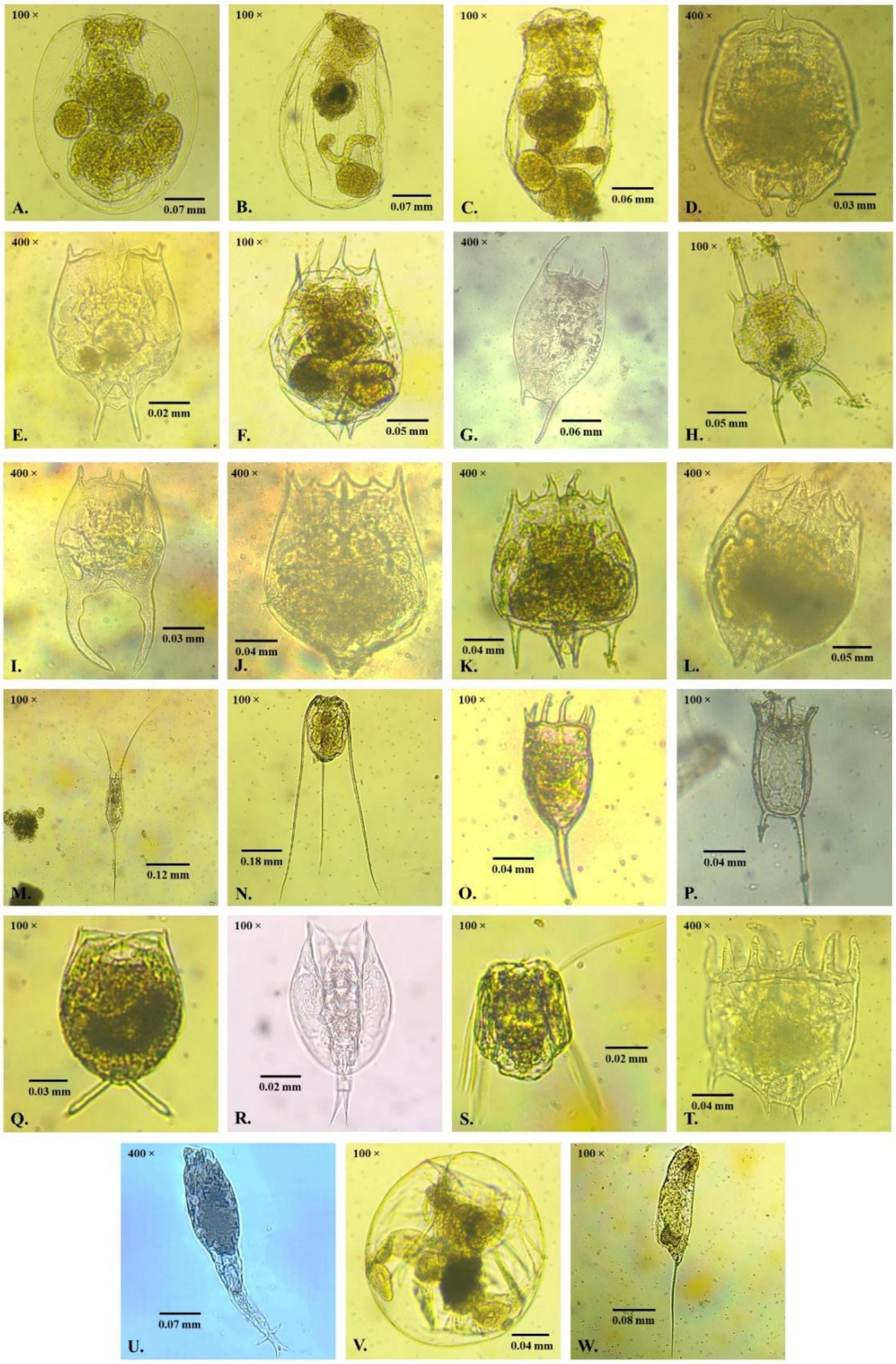

Fig. 6. Identified rotifers. **A.** *Asplanchna herricki*;**B.** *A. priodonta*;**C.** *A. seiboldi*;**D.** *Brachionus angularis*; **E.** *B. caudatus*;**F.** *B. calyciflorus*;**G.** *B. diversicornis*;**H.** *B. falcatus*;**I.** *B. forficula*;**J.** *B. nilsoni*;**K.** *B. quadridentatus*;**L.** *B. urceolaris*;**M.** *Filinia opoliensis*;**N.** *F. longiseta*;**O.** *Keratella cochlearis*;**P.** *K. tropica*;**Q.** *Leca neluna*;**R.** *Lepadella patella*;**S.** *Polyarthra vulgaris*;**T.** *Platyias patulus*;**U.** *Rotaria neptunia*;**V.** *Testudinella patina*;**W.** *Trichocerca cylindrica*

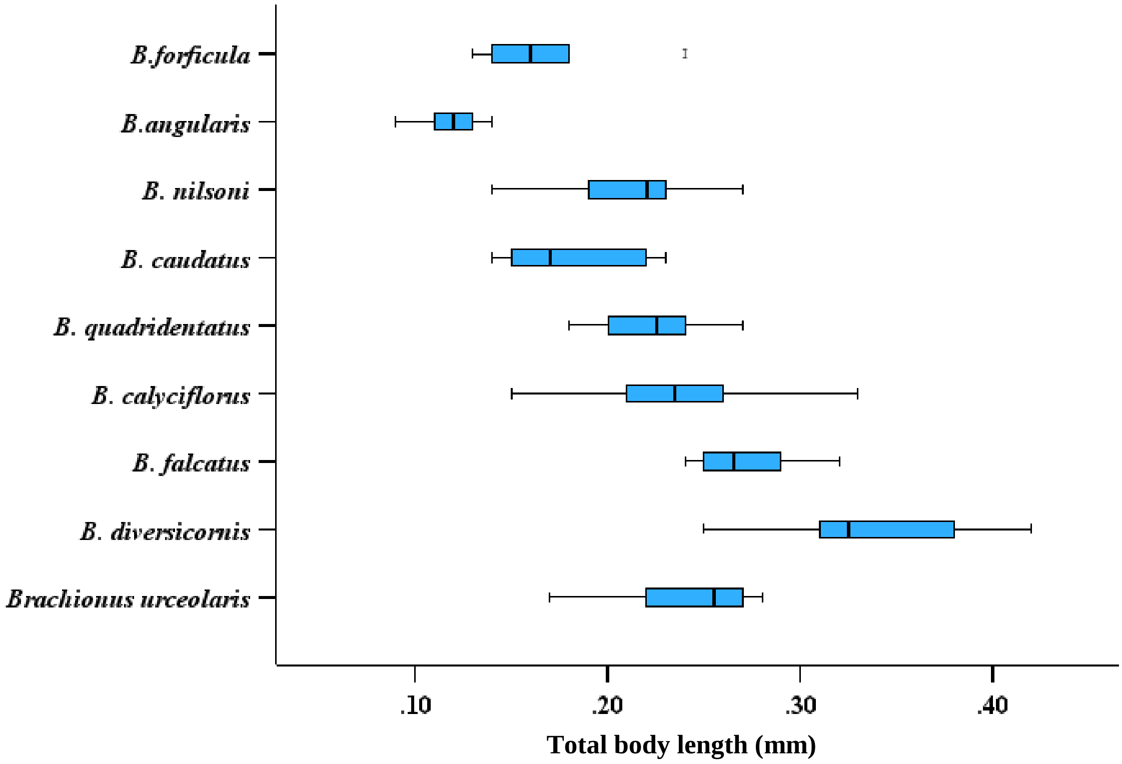

Fig. 7. Total body length (TBL, in mm) of the identified *Brachionus* species

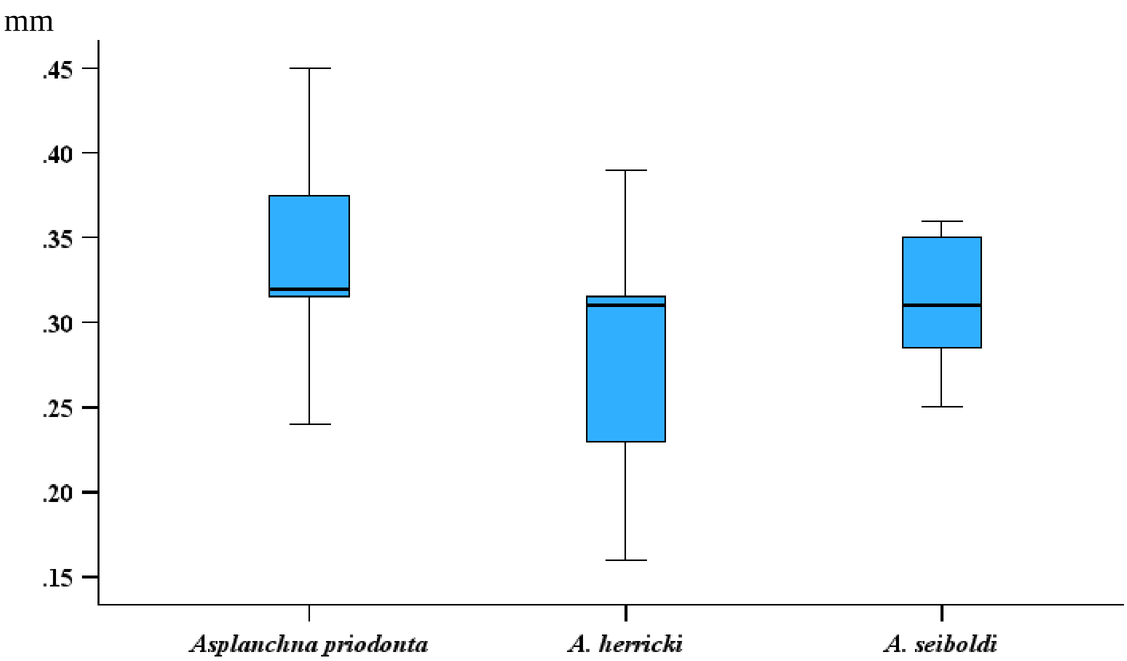

Fig. 8. Total body length (TBL, in mm) of the identified *Asplanchna* species

In addition, quantitatively and qualitatively the rotifers diversity increases from oligotrophy to mesotrophy and finally to eutrophy (Neetu*et al*., 2020). Among the *Brachionus* species, *B. calyciflorus* always drew special consideration of the researchers because of their importance as food for fish larvae in intensive water bodies (Groeneweg and Schlüter, 1981). In the present study, *B. calyciflorus* showed the highest TBL in extensive water bodies which further was also proved from statistical analysis ($t= -5.48$, $p<0.001$) (Tables 2-4). Perhaps high predation pressure could be the guiding factor of having smaller TBL in intensive and semi-intensive water bodies. Except *B. caudatus*, *B. nilsoni* and *B. forficula*, all the other identified *Brachionus* species had the highest TBL in extensive water bodies, whereas *B. angularis* didn't show any difference between different water bodies (Table 2; Fig. 7). It has already been reported that *B. angularis* can show morphological plasticity which allows them to have varying morphology (Marcé *et al*., 2004). However, biological parameters like intra- and inter-specific competition as well as physical-chemical factors like macrophyte substrate type and trophic state and catchment area conditions might be responsible for the lower TBL in intensive fish pond (Angeler and Goedkoop, 2010). Three *Asplanchna* species have been recorded in the present study, of which *A. herricki* and *A. priodonta* were present only in extensive and intensive water bodies and the maximum TBL was found for extensive water bodies. In contrast, *A. seiboldi* was present in all water bodies' type and TBL was the highest in intensive water bodies (Table 2; Fig. 8). Availability of food has been proposed as the guiding factor for the morphological variation among the studied *Asplanchna* species (Cheng *et al*., 2011). On the other hand, the *Keratella* species were the most prevalent and widespread rotifer of freshwater (Segers, 2001), in the present study represented by two species, both of which showed the highest TBL in extensive water bodies, though *K. tropica* was not present in semi-intensive water bodies (Table 2).

Among the identified two shallow-water *Filinia* species, *F. longiseta* was present only in intensive water bodies, while *F. opolinesis* in both extensive and intensive water bodies. Studies showed that the morphological variation and the composition of *F. longiseta* relies on wind mixing, surface food, physico-chemical and biological parameters of the water (Ejsmont-Karabin, 2012). However, the only Bdelloid rotifer was not present in intensive water bodies, because the species of this genus was reported to be more sensitive to the eutrophication and polluted water (Patnaik, 2011). *Polyarthra vulgaris*, *Platyias patulus* and *Trichocerca cylindrica* were found as inhabitant of intensive water bodies only.

Conclusion

Diversity and morphological comparison between different water bodies showed that the diversity of the reported zooplankton species tended to be the highest in intensive water bodies, while the highest TBL was found in extensive water bodies. Constant nutrient supply favored the zooplankton to increase their diversity and population, but simultaneously deteriorated the water quality, mostly because of eutrophication and imbalanced organic and inorganic supply, that might result into smaller TBL for most of the zooplankton groups. Also, the predation pressure in the intensive settings may have concurrent effect of having smaller TBL.

Conflict of Interest

The authors declare that they have no conflicts of interest.

Acknowledgement

The authors thank Mr. Nazmul Hasan Shuvo and Md. Iqbal Hossain for their consistent support during the sample collection and procurement of the plankton samples from the selected ponds.

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