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Md. Saiful Islam
Department of Zoology,
University of Chittagong,
Chittagong, Bangladesh

MA Azadi
International Islamic University
Chittagong, Chittagong,
Bangladesh

Munira Nasiruddin
Department of Zoology,
University of Chittagong,
Chittagong, Bangladesh

M Safiqul Islam
Department of Zoology,
University of Chittagong,
Chittagong, Bangladesh

Corresponding Author:
Md. Saiful Islam
Department of Zoology,
University of Chittagong,
Chittagong, Bangladesh

Zooplankton abundance, diversity and its relationship with physicochemical parameters of three ponds in Chittagong University campus, Bangladesh

Md. Saiful Islam, MA Azadi, Munira Nasiruddin and M Safiqul Islam

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Abstract
Abundance and diversity of zooplankton with relation to physicochemical parameters in three ponds at Chittagong University campus was conducted for two years period from January 2017 to December 2018. A total of 72 samples were collected from the three ponds, whereby 33 zooplankton species belonging to five classes were identified. Among the 5 classes, Rotifera was the most dominant and abundant group which contributed 54.17%-72.73% of the total zooplankton population. The overall contribution of Rotifera was 72.73%, 54.17% and 61.90% in ponds 1, 2 and 3 respectively and among Rotifera, Brachionus was the most dominant and abundant genus. Copepoda (8.33- 14.29%) and Cladocera (9.09-25.0%) were moderately abundant and Nematoda (4.17-4.76%) and Protozoa (4.55-8.33%) were the least abundant groups in all the three ponds. Significant direct or inverse relationships of zooplankton were observed with some physicochemical parameters. Zooplankton in Pond 1 showed positive significant relationship with air temperature ($r = 0.61$, $P<0.05$), water temperature ($r = 0.57$, $P<0.1$), BOD ($r = 0.69$, $P<0.05$) and freeCO_2 ($r = 0.66$, $P<0.05$). In Pond 2, Zooplankton showed positive significant relationship with air temperature ($r = 0.55$, $P<0.1$), water temperature ($r = 0.67$, $P<0.05$) and transparency ($r = 0.52$, $P<0.1$) and Zooplankton in Pond 3 showed inverse relationship with alkalinity ($r = -0.52$, $P<0.1$).

Keywords: Zooplankton diversity, physicochemical parameters, ponds, correlation

1. Introduction
Plankton occupies an important and outstanding position in the biotic world for their indispensable role in the aquatic ecosystem. Though they are very small or microscopic their absence might lead the entire life processes in the aquatic medium specially the animal life to a halt. Phytoplankton play a vital role in synthesizing light energy into food while the zooplankton are consumers of phytoplankton and these zooplankton are subsequently being eaten by other animals in their trophic interrelationships. As a result of this energy transfer from one living being to another living being which play a vital role for the survival and welfare of the entire aquatic lives. Zooplankton plays an indispensable role in the aquatic ecosystem. Zooplanktons are the primary consumers in the trophic level which directly or indirectly comprises major protein source of all fishes. So, the study of zooplankton is of great importance as some of them are linked to the production and distribution of fishes. According to Fraser [1] the favored food of fish larvae is the early *Nauplius* stages of copepods. Some adult pelagic fishes are also plankton feeders. Aquaculture depends almost completely on qualities of water. Fisheries and other aquatic organisms perform all kinds of their life processes in water. So, it is apparent that the water quality plays an indispensable role for a sustainable life in water [2].
Chittagong University (CU) is situated in the hilly area of Hathazari Upazilla and covering an area of 1754 acres. The campus is located 25 km North of Chattogram city, where some manmade lentic and natural lotic water bodies i.e. lake, marshy lands, hilly stream and ponds are present. The three ponds selected for study in Chittagong University campus were constructed for fulfilling the various necessities of campus residents i.e. various household purposes including fish culture.

In Bangladesh and India some research works were done on the zooplankton diversity and their abundance in pond water by different authors (Roy *et al.* [3], Kumar *et al.* [4], Islam and Chowdhury [5], Manoharan *et al.* [6], Rahaman *et al.* [7]. and Dhanasekaran *et al.*) [8]. So far, no study was done on the abundance and diversity of zooplankton in relation to water quality of three selected ponds at Chittagong University campus. Thus the present study was undertaken to assess the abundance and diversity of zooplankton communities of three ponds in Chittagong University campus in relation to their water qualities.

2. Materials and Methods

2.1 Study area

Location and information of three ponds at Chittagong University campus (Fig. 1)

Pond-1 is known as Shova colony pond (Latitude 22° 483778′ and Longitude 91° 79082′) (Fig. 1) is about 25 years old manmade pond located in North-West side of the CU Campus and near to north side of CU central playground, about 1.7 km northerly from CU Zero Point (Fig. 1). The pond was rectangular in shape, covered 838 m^2 area with an average depth 3.1 m. This was excavated for general use and is now extensively used by CU employees residing around the pond for their household purposes and also for dumping their wastes mainly during rainy season.

Pond-2 is known as Gol pukur (Latitude 22° 466205′ and Longitude 91° 792128′) (Fig. 1) is a round shaped perennial pond with an area of 1288 m^2, constructed during 1970 mainly for swimming, water polo and other recreational purposes and also for bathing during water scarcity in the teacher's quarters. Later on fish culture was introduced. Now, some road side people were found to use this pond for bathing and farmers use it for washing their vegetables before taking to different markets. The pond was not used for any household washing purposes except sometimes for swimming and water polo by the CU students.

Pond-3 is known as Biological Science Faculty pond (Latitude 22° 466197′and Longitude 91° 781166′) (Fig. 1) is a rectangular perennial pond covered an area of 2632 m^2 with an average depth 4.2 m, which was excavated during 2006 for using in the construction work of Biological Science faculty as well as for various uses of the construction workers. After the construction work of CU-BSF, the pond was sometimes used for swimming and bathing by the students and some local inhabitants and local farmers for washing their locally produced vegetables and to some extent for fish culture.

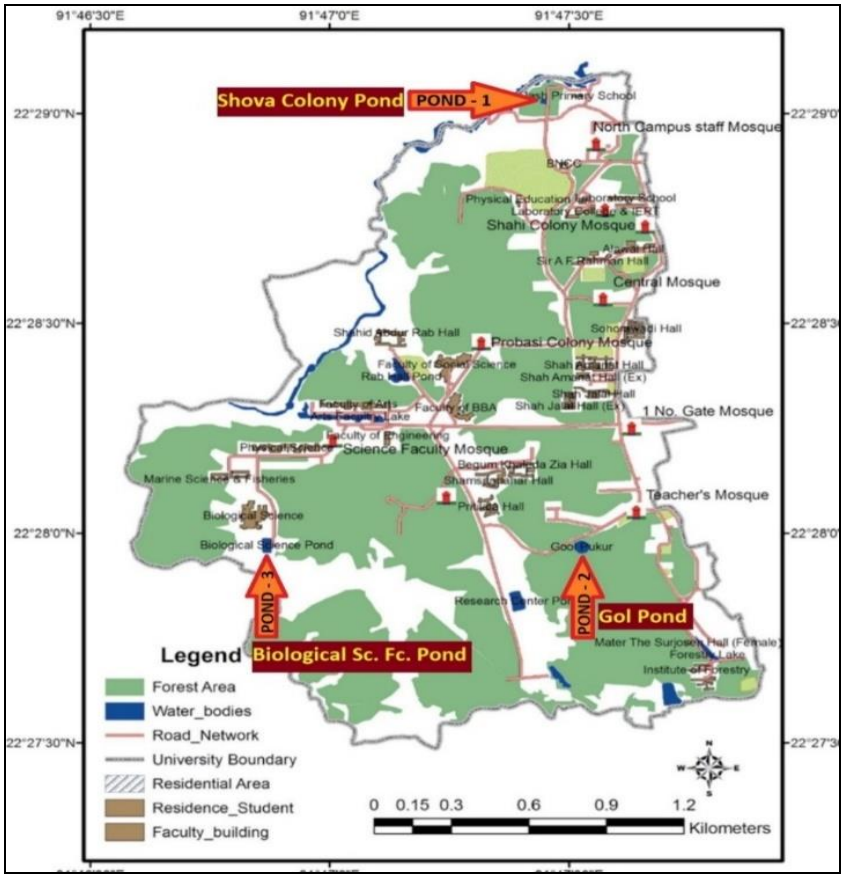

Fig 1: Map showing location of three experimental ponds (Pond 1: Shova colony pond, Pond 2: Gol Pukur and Pond 3: Biological Science Faculty pond) in the Chittagong University campus.

2.2 Sample collection and sampling procedure

Monthly water samples and plankton from subsurface layers of three experimental ponds (Pond-1, Pond-2, and Pond-3) were collected by brown color 500 ml reagent bottles and plastic pot between 9.00 - 11.30 am for two years period during January 2017 to December 2018. Some of the parameters [air and water temperature, transparency, pH, conductivity and total dissolved solid (TDS)] of the collected samples were tested in the field and some [dissolved oxygen (DO), biological oxygen demand (BOD), free carbon dioxide (fCO_2), calcium (Ca^{++}), total hardness (TH) and total alkalinity (TA)] were taken in the departmental laboratory for further analysis following the standard methods of APHA [9]. The plankton samples were collected from each pond by

dragging the plankton net made of bolting silk of 55 mesh size (Hydrobios, Germany) for 1 m distance thrice. The collected concentrated plankton samples were preserved by adding 5% commercial formaldehyde for identification with the help of keys given by APHA [9], Ward and Whipple [10], Needham and Needham [11] and Bhouyain and Asmat [12]. The SD (standard deviation) and 'correlation coefficient (r)' were done following MS Excel version 2013.

3. Results and Discussion

During the study period, 33 species under 19 genera of zooplankton belonging to five major groups, Cladocera, Copepoda, Rotifera, Protozoa and Nematoda were recorded. A total of 22 species under 12 genera, 24 species under 16 genera and 21 species under 13 genera belonging to five groups of zooplankton in the ponds 1, 2 and 3 respectively were recorded during the study period from January 2017 to December 2018 (Tables 2-4 & PLATES 1 and 2).

Zooplankton species composition in Pond 1 comprised of 9.09% Cladocera, 9.09% Copepoda, 72.73% Rotifera, 4.55% Protozoa and 4.55% Nematoda (Fig. 2); in Pond 2 were 25% Cladocera, 8.33% Copepoda, 54.17% Rotifera, 8.33% Protozoa and 4.17% Nematoda (Fig. 3) and in Pond 3, 14.29% Cladocera, 14.29% Copepoda, 61.90% Rotifera, 4.76% Protozoa and 4.76% Nematoda were found (Fig. 4). Rotifera was the most dominant group in all the three ponds throughout the study period. Among the three ponds, percentage composition of Rotifera was more in Pond 1 (72.73%) and Pond 3 (61.90%). The dominance of Rotifera in ponds 1 and 3 indicated that the ponds were eutrophic in nature. Present observation is similar with the findings of Kumar *et al.* [4] for two high altitude Himalayan Ponds, Badirnath, Uttarkhand and Dhanasekaran *et al.* [8] for a perennial lake at Dharmapuri, Tamil Nadu, India. In various temperate water bodies predominance of Rotifera had also been reported by some researchers in different water bodies [4, 13, 14].

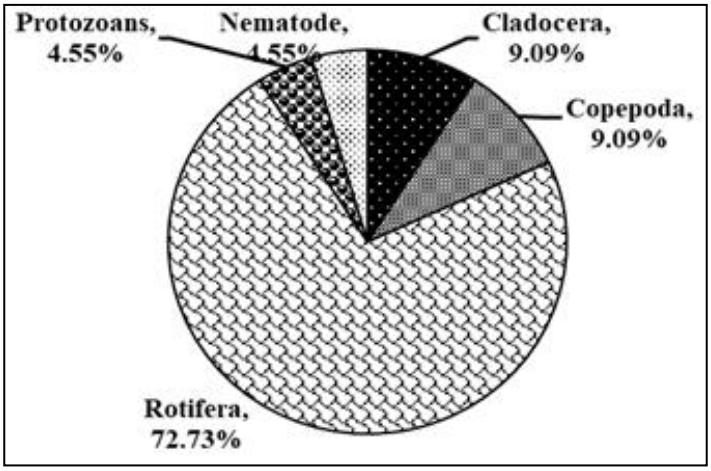

Fig 2: Distribution zooplankton in pond 1

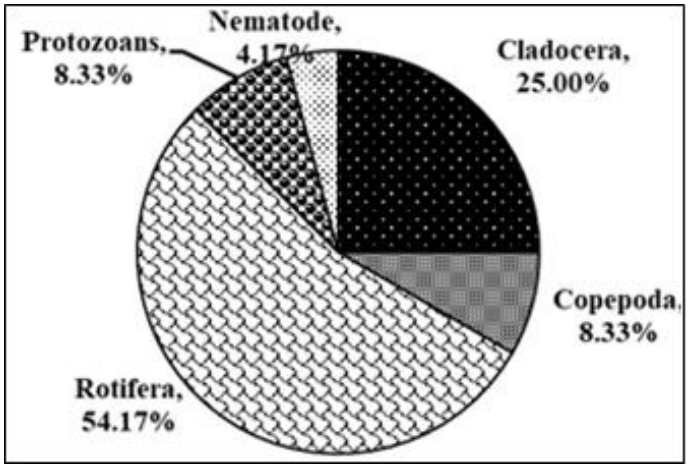

Fig 3: Distribution zooplankton in pond 2

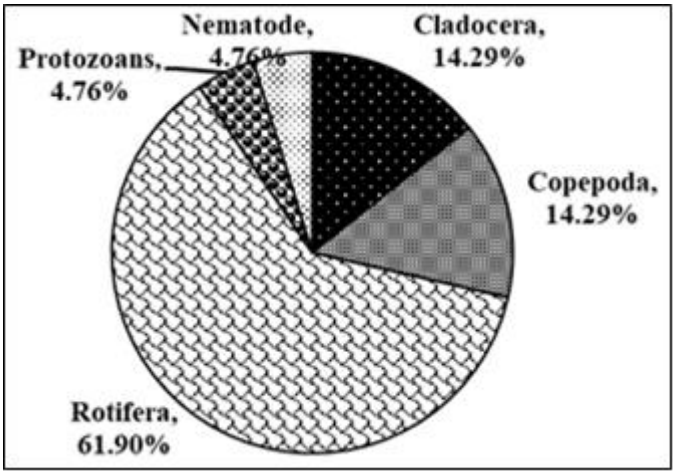

Fig 4: Distribution zooplankton in pond 3

The mean±SD values of physicochemical parameters of the three experimental ponds are given in Table 1. During 24 months study period air temperature varied from 20.1-32^{0}C (28.17±3.61^{0}C), 21-32^{0}C (28.75±3.0^{0}C) and 21-33^{0}C (28.67±3.14^{0}C) in ponds 1, 2 and 3 respectively. Water temperature varied between 18-31^{0}C (26.94±3.89^{0}C), 20-32^{0}C (27.94±3.64^{0}C) and 20-33^{0}C (28.08±3.34^{0}C) in ponds 1, 2 and 3 respectively. Water transparency varied from 14-72 cm (46.69±13.79cm), 20.5-85 cm (64.98±14.65cm) and 16-75 cm (39.96±12.01) in the ponds 1, 2 and 3 respectively. Electrical conductivity varied from 180-423 µS/cm (278.90±69.40 µS/cm), 22-85 µS/cm (43.83±14.51 µS/cm) and 44-154 µS/cm (108.80±34.11 µS/cm) in ponds 1, 2 and 3 respectively. Total dissolved solids (TDS) varied from 10-230 mg/l (131.00±49.19mg/l), 0-20 mg/l (9.58±5.5mg/l) and 10-70 mg/l (43.80±17.4) in ponds 1, 2 and 3 respectively. The pH varied from 6.7-7.8 (7.25±0.29), 6.1-8.4 (7.48±0.55) and 6.4-7.9 (7.23±0.32) in ponds 1, 2 and 3 respectively. The dissolved oxygen (DO) varied from 0.9-8.2 mg/l (4.06±1.99mg/l), 4.4-16.5 mg/l (9.39±3.2mg/l) and 4.4-14.1 mg/l (7.73±2.76mg/l) in the ponds 1, 2 and 3 respectively. Biological oxygen demand (BOD) varied from 4.2-12.3 mg/l (6.73±2mg/l) in Pond 1, 0.8-3 mg/l (1.98±0.65mg/l) in Pond 2 and 2.6-9.8 mg/l (4.69±1.94mg/l) in Pond 3. The free-CO_2 varied from 8.99-26.97 mg/l (15.02±5.53mg/l), 2-16.98 mg/l (9.66±4.73mg/l) and 4.99-19.98 mg/l (10.20±4.12mg/l) in ponds 1, 2 and 3 respectively. Calcium (Ca^{++}) varied from 9.46-32.68 mg/l (17.85±4.77mg/l), 1.72-18.92 mg/l (7.17±3.47) and 5.16-30.96 mg/l (11.57±6.81) in the ponds 1, 2 and 3 respectively. Total hardness (TH) ranged from 31-110 mg/l (55.63±15.97mg/l), 4-69 mg/l (22.04±17.41mg/l) and 15-56 mg/l (39.04±11.65mg/l) in ponds 1, 2 and 3 respectively. The values of total alkalinity (TA) ranged from 42-98 mg/l (63.92±16.64mg/l), 40-82 mg/l (53.83±11.43mg/l) and 42-92 mg/l (58.13±13.41mg/l) in ponds 1, 2 and 3 respectively.

Table 1: Mean±SD values of physicochemical parameters of ponds 1, 2 and 3 during the study period.

Parameters	Pond 1	Pond 2	Pond 3
Air temperature (^{0}C)	28.17±3.61	28.75±3.0	28.67±3.14
Water temperature (^{0}C)	26.94±3.89	27.94±3.64	28.08±3.34
Secchi depth (cm)	46.69±13.79	64.98±14.65	39.96±12.01
Conductivity (µS/cm)	278.90±69.40	43.83±14.51	108.80±34.11
TDS (ppt)	131.00±49.19	9.58±5.5	43.80±17.4
pH	7.25±0.29	7.48±0.55	7.23±0.32
DO (mg/l)	4.06±1.99	9.39±3.2	7.73±2.76
BOD (mg/l)	6.73±2	1.98±0.65	4.69±1.94
free CO_2 (mg/l)	15.02±5.53	9.66±4.73	10.20±4.12
Calcium (mg/l)	17.85±4.77	7.17±3.47	11.57±6.81
TH (mg/l)	55.63±15.97	22.04±17.41	39.04±11.65
Alkalinity (mg/l)	63.92±16.64	53.83±11.43	58.13±13.41

Diversity of zooplankton in ponds 1, 2 and 3 during the study period are shown in Tables 2, 3 and 4 respectively and in Plates- 1 and 2. Among the five major groups of zooplankton in ponds 1, 2 and 3, Cladocera, Copepoda and Rotifera were more abundant. In Pond 1, the abundant species of cladocerans were *Diaphanosoma brachyurum* and *Moina brachiata, c*opepods were *Cyclops varicans rubellus* and Nauplius and rotifers were *Brachionus angularis*, *B. diversicornis*, *B. quadridentatus*, *B. caudatus*, *B. falcatus*, *B. urceolaris*, *B. calyciflorus*, *B. nilsoni*, *Keratella tropica*, *K. cochlearis*, *Filinia opolinesis*, *F. camascela*, *Trichocerca capucina*, *Testudinella patina*, *Platyias patulus*, and *P. quadridentatus.* In Pond 2 the abundant species of cladocerans were *Daphnia lumholtzi*, *Ceriodaphnia cornuta*, *Diaphanosoma brachyurum*, *Moina brachiata*, *Alona guttata* and *Bosmina longirostris*, *c*opepods were *Cyclops varicans rubellus* and Nauplius and rotifers were *Brachionus angularis*, *B. diversicornis*, *B. forficula*, *B. caudatus*, *B. falcatus*, *B. urceolaris*, *B. donneri*, *Keratella tropica*, *K. cochlearis*, *Trichocerca capucina*, *T. cylindrica*, *Lecane curvicornis*, and *Filinia opolinesis.* In Pond 3 the abundant species of cladocerans were *Daphnia lumholtzi*, *Diaphanosoma brachyurum* and *Moina brachiata*, copepods were *Cyclops varicans rubellus*, *Mesocyclops leukarti* and Nauplius and rotifers were *Brachionus angularis*, *B. diversicornis*, *B. forficula*, *B. caudatus*, *B. falcatus*, *B. donneri*, *Keratella tropica*, *K. cochlearis*, *Trichocerca capucina*, *T. cylindrica*, *Filinia terminalis*, *F. opolinesis*, and *Testudinella patina*. Rotifera was the most dominant group in all the three ponds throughout the study period and among the Rotifera, most abundant species were recorded under the genus *Brachionus*. Similar results were also observed by researches in different water bodies in Bangladesh and India [4, 6, 7, 8].

Correlation: For the two years study period, amongst the mean values of the parameters, the correlation coefficient of Zooplankton with physicochemical parameters of three ponds were calculated and is shown in Table 5. The mean values of Zooplankton in Pond 1 showed positive significant relationship with air temperature (r = 0.61, $P<0.05$) and water temperature (r = 0.57, $P<0.1$), BOD (r = 0.69, $P<0.05$) and freeCO_2 (r = 0.66, $P<0.05$). The mean values of zooplankton in Pond 2 showed positive significant relationship with air temperature (r = 0.55, $P<0.1$), water temperature (r=0.67, $P<0.05$) and transparency (r = 0.52, $P<0.1$). The mean values of zooplankton in Pond 3 showed inverse relationship with alkalinity (r = -0.52, $P<0.1$). Roy *et al.* [3] reported a direct relationship of zooplankton with free carbon dioxide in a brood pond of Bangladesh. A positive significant relationship was found between zooplankton and air temperature (r = 0.61, $P<0.05$) and zooplankton and water temperature (r = 0.67, $P<0.05$) in ponds 1 and 2 respectively. The abundance of plankton showed a direct relationship with temperature [15].

Table 2: List of groups, genus and species of Zooplankton collected from Pond 1 during January 2017 to December 2018.

Groups	Genus	Species	Photographs
Cladocera	*Diaphanosoma*	*Diaphanosoma brachyurum*	Plate I (c)
	Moina	*Moina brachiata*	Plate I (d)
Copepoda	*Cyclops*	*Cyclops varicans rubellus*	Plate I (g)
	Nauplius	Nauplius	Plate I (i)
Rotifera	*Brachionus*	*Brachionus angularis*	Plate I (j)
		Brachionus diversicornis	Plate I (k)
		Brachionus quadridentatus	Plate I (l)
		Brachionus caudatus	Plate I (n)
		Brachionus falcatus	Plate I (o)
		Brachionus urceolaris	Plate I (p)
		Brachionus calyciflorus	Plate II (q)
		Brachionus nilsoni	Plate II (r)
	Keratella	*Keratella tropica*	Plate II (t)
		Keratella cochlearis	Plate II (u)
	Filinia	*Filinia opolinesis*	Plate II (w)
		Filinia camascela	Plate II (x)
	Trichocerca	*Trichocerca capucina*	Plate II (y)
	Testudinella	*Testudinella patina*	Plate II (ac)
	Platyias	*Platyias patulus*	Plate II (aa)
		Platyias quadridentatus	Plate II (ab)
Protozoa	*Euglena*	*Euglena gracilis*	Plate II (ae)
Nematoda	Nematode worm	Nematode worm	Plate II (ag)

Table 3: List of groups, genus and species of Zooplankton collected from Pond 2 during January 2017 to December 2018.

Groups	Genus	Species	Photographs
Cladocera	*Daphnia*	*Daphnia lumholtzi*	Plate I (a)
	Ceriodaphnia	*Ceriodaphnia cornuta*	Plate I (b)
	Diaphanosoma	*Diaphanosoma brachyurum*	Plate I (c)
	Moina	*Moina brachiata*	Plate I (d)
	Alona	*Alona guttata*	Plate I (e)
	Bosmina	*Bosmina longirostris*	Plate I (f)
Copepoda	*Cyclops*	*Cyclops varicans rubellus*	Plate I (g)
	Nauplius	Nauplius	Plate I (i)
Rotifera	*Brachionus*	*Brachionus angularis*	Plate I (j)
		Brachionus diversicornis	Plate I (k)
		Brachionus forficula	Plate I (m)
		Brachionus caudatus	Plate I (n)
		Brachionus falcatus	Plate I (o)
		Brachionus urceolaris	Plate I (p)

		Brachionus donneri	Plate II (s)
	Keratella	*Keratella tropica*	Plate II (t)
		Keratella cochlearis	Plate II (u)
	Trichocerca	*Trichocerca capucina*	Plate II (y)
		Trichocerca cylindrica	Plate II (z)
	Lecane	*Lecane curvicornis*	Plate II (ad)
	Filinia	*Filinia opolinesis*	Plate II (w)
Protozoa	*Euglena*	*Euglena gracilis*	Plate II (ae)
	Ceratium	*Ceratium hirundinella*	Plate II (af)
Nematoda	Nematode worm	Nematode worm	Plate II (ag)

Table 4: List of groups, genus and species of Zooplankton collected from Pond 3 during January 2017 to December 2018.

Groups	Genus	Species	Photographs
Cladocera	*Daphnia*	*Daphnia lumholtzi*	Plate I (a)
	Diaphanosoma	*Diaphanosoma brachyurum*	Plate I (c)
	Moina	*Moina brachiata*	Plate I (d)
Copepoda	*Cyclops*	*Cyclops varicans rubellus*	Plate I (g)
	Mesocyclops	*Mesocyclops leukarti*	Plate I (h)
	Nauplius	Nauplius	Plate I (i)
Rotifera	*Brachionus*	*Brachionus angularis*	Plate I (j)
		Brachionus diversicornis	Plate I (k)
		Brachionus forficula	Plate I (m)
		Brachionus caudatus	Plate I (n)
		Brachionus falcatus	Plate I (o)
		Brachionus donneri	Plate II (s)
	Keratella	*Keratella tropica*	Plate II (t)
		Keratella cochlearis	Plate II (u)
	Trichocerca	*Trichocerca capucina*	Plate II (y)
		Trichocerca cylindrica	Plate II (z)
	Filinia	*Filinia terminalis*	Plate II (v)
		Filinia opolinesis	Plate II (w)
	Testudinella	*Testudinella patina*	Plate II (ac)
Protozoa	*Ceratium*	*Ceratium hirundinella*	Plate II (af)
Nematoda	Nematode worm	Nematode worm	Plate II (ag)

Table 5: Correlation amongst the mean values of Zooplankton with different physicochemical parameters of ponds 1, 2 and 3.

Factors	Pond 1	Pond 2	Pond 3
Zooplankton with air temperature (^{0}C)	0.61 **	0.55 *	0.05
Zooplankton with water temperature (^{0}C)	0.57 *	0.67 **	0.20
Zooplankton with transparency (cm)	-0.29	0.52 *	0.10
Zooplankton with conductivity (µS/cm)	-0.05	0.08	-0.06
Zooplankton with pH	0.07	0.26	-0.04
Zooplankton with DO (mg/l)	0.01	-0.14	-0.09
Zooplankton with BOD (mg/l)	0.69 **	0.21	-0.17
Zooplankton with fCO_2 (mg/l)	0.66 **	0.43	-0.39
Zooplankton with Ca^{++} (mg/l)	0.10	-0.27	-0.34
Zooplankton with TDS (mg/l)	-0.34	-0.17	-0.09
Zooplankton with total hardness (mg/l)	-0.13	-0.33	-0.01
Zooplankton with alkalinity (mg/l)	0.28	-0.40	-0.52 *

Significant level: ** = $P<0.05$, * = $P<0.1$

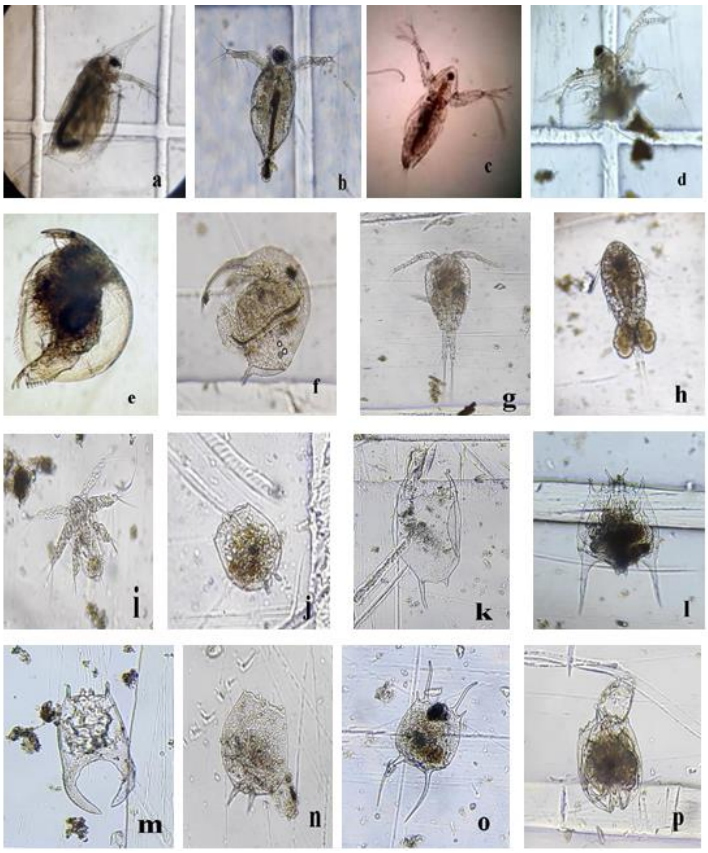

Plate 1: Photographs of collected zooplankton: (a) *Daphnia lumholtzi*, (b) *Ceriodaphnia cornuta*, (c) *Diaphanosoma brachyurum*, (d) *Moina brachiata*, (e) *Alona guttata*, (f) *Bosmina longirostris*, (g) *Cyclops varicans rubellus*, (h) *Mesocyclops leukarti*, (i) Nauplius, (j) *Brachionus angularis*, (k) *Brachionus diversicornis*, (l) *Brachionus quadridentatus*, (m) B*rachionus forficula*, (n) *Brachionus caudatus*, (o) *Brachionus falcatus* and (p) *Brachionus urceolaris.*

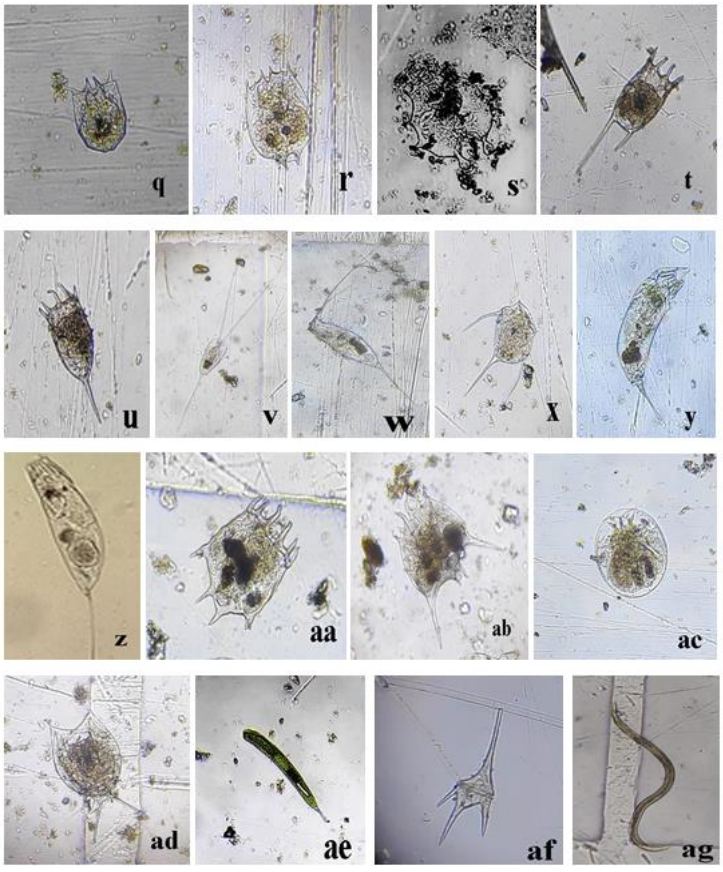

Plate 2: Photographs of collected Zooplankton: (q) *Brachionus calyciflorus*, (r) *Brachionus nilsoni* (s) B*rachionus donneri*, (t) *Keratella tropica*, (u) *Keratella cochlearis*, (v) *Filinia terminalis*, (w) *Filinia opolinesis*, (x) *Filinia camascela*, (y) *Trichocerca capucina*, (z) *Trichocerca cylindrica*, (aa) *Platyias patulus*, (ab) *Platyias quadridentatus*, (ac) *Testudinella patina*, (ad) *Lecane curvicornis*, (ae) *Euglena gracilis*, (af) *Ceratium hirundinella* and (ag) Nematode worm.

Conclusion

The studied three ponds in Chittagong University campus supported moderate levels of zooplankton which was constituted largely by Rotifera and among Rotifera greater number of species under the genus *Brachionus* was observed in all the three ponds. Rotifera was more in ponds 1 and 3 which indicated the more eutrophic nature of these ponds than Pond 2. It was also seen that, relatively highwater temperature was favorable and suitable for the growth of zooplankton.

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