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Research Article

Seasonal Succession of Zooplankton of Three Distinct Aquaculture Ponds in Chattogram, Bangladesh

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ABSTRACT

Zooplankton is crucial dietary sources for omnivorous fishes and an essential component in freshwater food webs. A six-month investigation carried out from February to July 2023, encompassing three separate seasons, to examine the abundance and variety of zooplankton in connection to physico-chemical parameters in three different waterbodies: intensive, semi-intensive and extensive ponds at Chittagong University campus. Two ponds were chosen for each of the waterbodies that were classified. Monthly fluctuations of some physico-chemical parameters were noted. Most of the ponds were found to be alkaline and TDS, EC, and the variations of air and water temperature were also examined. Remarkable correlations observed between zooplankton and several physico-chemical parameters, either directly or indirectly. Zooplankton in Intensive ponds showed positive significant relationship with TDS (r=0.78, P< 0.1), EC (r=0.81, P< 0.05) and pH (r=0.34, P<0.1). Zooplankton demonstrated positive correlation with air temperature (r=0.61, P<0.1), TDS (r=0.38, P< 0.1) and EC (r=0.33, P<0.05) in semi-intensive ponds and all water parameters except TDS (r=-0.05, P<0.1) displayed strong significant link with extensive ponds. A total of 33 zooplankton species belonging to 19 genera with 3 classes were identified. Rotifers were the most prominent and abundant group of zooplankton, making up 76.75% to 86.49% of entire population and the most numerous genus was *Brachionus.* Copepods (5.88%-15.79%) and Cladocerans (2.35%-7.63%) were relatively abundant in three waterbodies. Semi-intensive and Extensive ponds showed maximum number of Rotifer abundance (35680u/l & 34980u/l) in summer season. Regarding copepod, maximum abundance were 1320u/l and 4560u/l in Intensive and Extensive ponds respectively during rainy season. Clodocera displayed sporadic abundance across several waterbodies and seasons, where's Semi-intensive ponds showed maximum abundance in winter season (2680u/l). The current study revealed that extensive ponds had higher zooplankton production density than that of the Intensive and Semi-intensive ponds, with rotifers and copepods being most abundant in summer and rainy seasons, respectively.

Introduction

The aquatic environment supports diverse living organism communities, including phytoplankton, photosynthetic organisms, and zooplankton, heterotrophic organisms (Ikpi et al., 2013). Zooplankton, inhabiting pelagic and littoral zones, serve as natural purifiers in aquatic ecosystems, enhancing the quality of freshwater, coastal and marine water bodies (Ferdous & Muktadir, 2009; Sultana et al., 2023). Rotifers, cladocerans, copepods, and ostracods are major zooplankton groups responsible for water quality, nutrient recycling, eutrophication management, energy recycling, and sewage disposal (Singh et al. 2021; Karmakar et al., 2022). Zooplankton are key components in the aquatic food chain and play a vital role in the planktonic food web, acting as a link between primary producers and even at high trophic levels (Al et al., 2019).

Plankton communities of small and shallow waterbodies in tropical regions are related to seasonal changes with wind speed, rainfall, and water runoff through water mixing and nutrient loading (Geraldes and Boavida, 2004). Seasonal effects on plankton diversity are influenced by the depth of water bodies, water

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parameters (turbidity, light intensity), flushing rate, meteorological conditions, and residence times of small water bodies (Borges et al., 2008; Srifa et al., 2016). According to the principle of competitive exclusion, seasonality leads to a variability in plankton richness and diversity (Figueredo & Giani, 2009) in a constant environment. Throughout different seasons, zooplankton abundance can fluctuate substantially with respect to environmental circumstances. The tropical and subtropical zooplankton community was characterized by high species diversity, complex trophic networks, and minimal biomass changes throughout the year (Piontkovski, 2003). The qualitative and quantitative abundance of zooplankton in water bodies is crucial for successful aquaculture operations, as they vary across locations and ponds, even within similar ecological conditions (Boyd, 1982). Among the various waterbodies, the inclusion of organic and inorganic fertilizers in cultured ponds enhanced the zooplankton population, which is a crucial source of food for both carnivorous and omnivorous fishes (Alam et al., 2016). In order to promote semi-intensive aquaculture in Bangladesh and establish fertilizer-based rural aquaculture methods, it is essential to comprehend the natural food production in ponds, especially zooplankton production (Rahman & Hussain, 2008). Non-culture ponds with minimal native fish populations and no artificial fertilizers show a positive correlation with zooplankton abundance, influenced by pond size, water temperature, pH, free carbon dioxide, depth, and alkalinity (Pal et al. 2023). Thus, the relationship between the plankton community, various waterbodies, and aquaculture production was noticeable. Extensive limnological research in Bangladesh has primarily focused on zooplankton species diversity and seasonal distribution in ponds (Sultana et al., 2023; Karmakar et al. 2022; Hossain et al. 2015; Roy et al. 2010), rivers (Parvez et al., 2019; Sharif & Hoque, 2017; Ahsan et al., 2012) and other water bodies (Ali et al., 2019; Akter et al.2015; Iqbal et al. 2014; Shil et al. 2013; Naz & Najia, 2008). Additionally, some studies have examined the role of various aquatic, environmental and limnological parameters in zooplankton abundance (Sultana et al. 2023; Parvez et al., 2019; Haque et al., 2015& 2018; Bashar et al., 2015). A single research study comparing the abundance of plankton in various waterbodies has been conducted in Bangladesh (Rahman & Hussain, 2008). However, little targeted research has been done on the significance of seasonal fluctuation in the plankton ecosystem on different waterbodies. Therefore, the goal of the current study was to evaluate the diversity and abundance of zooplankton populations in three distinct waterbodies of Chittagong University campus in connection with their pond nature and physico-chemical aspects. This study elucidates the ways in which natural environments and human activity combine to affect these crucial organisms.

Materials and Methods

Description of the study area

Six ponds from Chittagong University campus were selected for current study, categorized into intensive (ponds 1 and 2), semi-intensive (ponds 3 and 4), and extensive (ponds 5 and 6) based on physico-chemical parameters and feeding habitats of fishes to examine plankton species diversity and abundance.

Intensive ponds

Palm bagan pond (pond 1, 22° 27´ 49´´ N 91° 47´ 7´´ E) enclosed with an area of 10304 m^2 and depth of 4.5m and Science Faculty Lake (pond 2, 22° 28´ 10´´ N 91° 46´ 56´´E) with an area of 5784 m^2 and depth of 3m (Figure 1). Both of these rectangular ponds were utilized for commercial fish farming. Farmers used "Quickfume" and "Sumithion" to clean aquatic weeds during stocking management for removing predatory fish. Lime was also applied during pond preparation. TSP and cow dung were added to the culture ponds during the grow-out management.

Semi-intensive ponds

Shova colony pond (pond 3, 22° 29´ 1´´ N 91° 47´ 26´´ E) was a rectangular shaped pond with an area of 790 m^2 and depth of 3.1 m and Majar pond (pond 4, 22° 28´ 18´´N 91° 47´ 49´´ E) was a square shaped pond enclosed with an area of 1790 m^2 and depth of 4m were semi-intensive ponds (Figure 1) where fish fry released into the ponds but artificial food were not given regularly like as culture pond. The local residents used both the ponds for various activities such as washing, bathing, fishing etc.

Extensive ponds

Forestry pond (Spot 5, 22° 27´41´´ N 91° 47´ 53´´E) and Mosjid pond (Spot 6, 22° 28´13´´ N 91° 47´ 1´´ E) were two small square shaped non-culture ponds had an area of 460 m^2 and 490 m^2 and a depth of 4.2 m and 3.1 m. (Figure 1). These ponds were usually used for swimming, bathing, washing clothes and other household purposes. These non-culture ponds provide limited recreational fishing opportunities, where fish raised on natural aquatic food supplies without additional fertilizer or supplementary food.

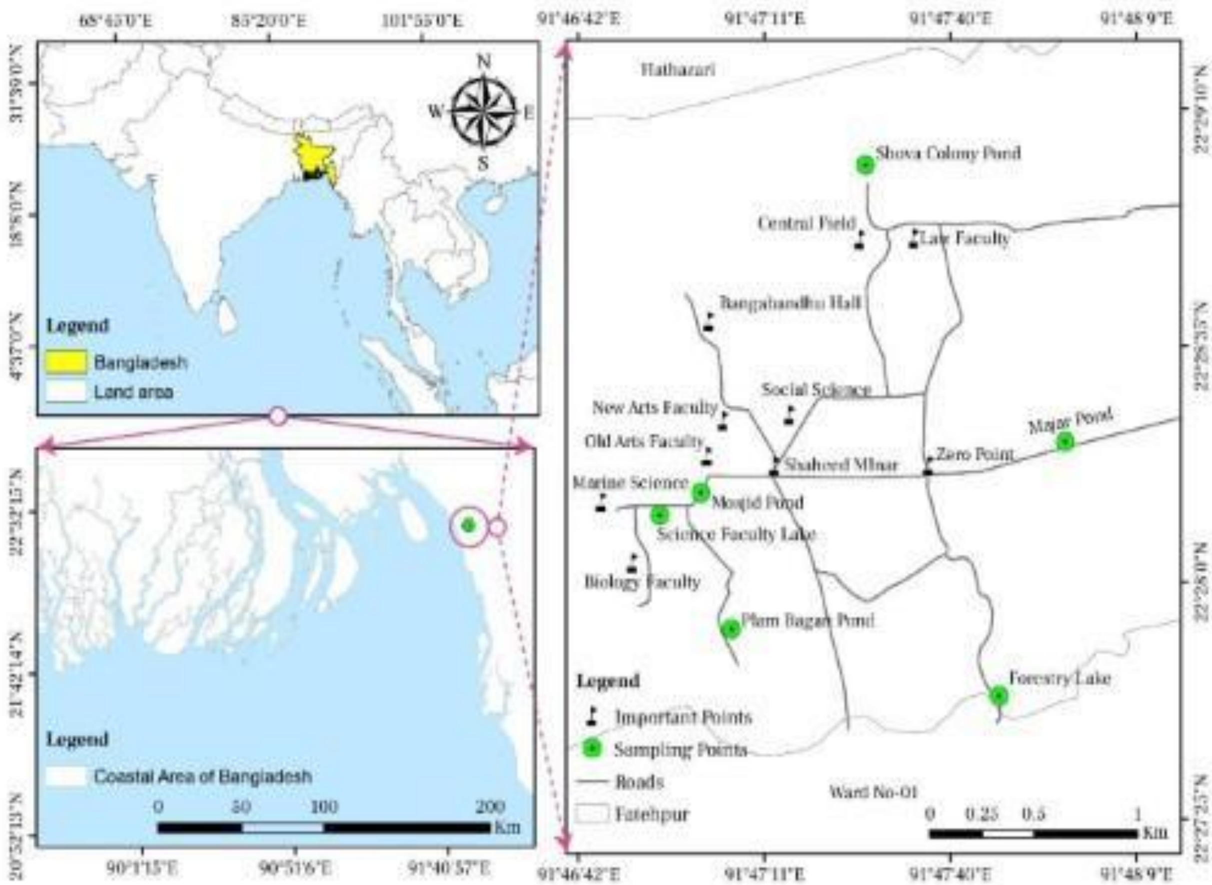

Fig. 1. Map showing the location of six study areas including three different waterbodies.

Analysis of water quality

During the study period, environmental variables (temperature, pH, transparency, total dissolved solids and electric conductivity) were recorded monthly twice in the sampling ponds (morning 6 am and evening 5 pm). A centigrade thermometer was used to measure temperature. Transparency (cm) was measured with a secchi disc of 15.5 cm diameter. pH was measured by a digital pH meter (HANNA-HI96107). TDS meter (Smart TDS-AR8011) and EC meter (DiSt 4 HI98304) were used for measuring total dissolved solids and electric conductivity respectively. The means and correlation coefficient (r) were done following MS Excel version 2013.

Zooplankton sample collection, identification and counting

Plankton samples were collected from February to July 2023; once a month from each spot at two time points – dawn and dusk. Collection of plankton was made by sieving 8 liters of habitat water from approximately 12-17 cm below the surface level passed through a 50 µm mesh net and finally concentrated to 200ml. The population of plankton accumulated in the container were then transferred to another bottle and immediately preserved in 6-7% formalin, labeled and then transferred to the laboratory for further experimentation. Each sample was stirred smoothly just before microscope examination. The quantitative estimation of the zooplankton was performed using a Sedgewick-Rafter chamber. 1 ml from the agitated sample was transferred to a S- R (Sedgewick-Rafter) counting cell with a wide mouth graduated pipettes. Then, we used a light microscope (Euromex microscope, OXION; NIS-EU 1640407) at different magnifications (40x, 100x and 400x) to identify the different species of zooplankton. The zooplankton identification was carried out according to various taxonomic books (Dang et al., 2015; Bhouyian & Asmat, 1992; Needham & Needham, 1962; Edmondson, 1959), articles, and online publications were consulted. The zooplankton densities were calculated as ind./L. The following formula was used to count the zooplankton:

$$No/m^3 = (C \times V') / (V'' \times V''')$$

Where C= Number of organism counted
V'= Volume of the concentrated sample, ml.
V"= Volume counted, ml and
V'''= Volume of the grab sample, m^3.
To obtain organism number per liter, divide by 1000. (Longhurst et al. 1997; Gannon 1971 and McEwen et al. 1954)

Result and Discussion

Physico-chemical features

The seasonal mean values of various physico-chemical water parameters analyzed from extensive, semi-intensive and intensive ponds were displayed in Table 2.

Temperature

Summer and rainy seasons brought the highest water temperatures in the extensive pond (32.3°C and 32.3°C, respectively), while winter had the lowest temperature in the intensive pond (28.98°C). However, Maximum air temperature found in summer at 33.1ºC in Intensive Pond and minimum in winter season 30.1ºC in semi-intensive pond.

Transparency

Transparency was observed to be maximum and minimum in the rainy season 54.5ºC and 38.75ºC respectively in extensive ponds.

pH

Each and every pond's water was alkaline. It was observed that the pH of the extensive pond was 8.4 (highest) in the winter and 7.34 in the summer (lowest).

TDS

The maximum TDS value in a semi-intensive pond is 138 ppt during the rainy season, while the minimum value is 49 ppt in an intensive pond during the same season.

EC

The semi-intensive pond showed the highest EC value (272.66 µS/cm) during the rainy season while the intensive pond had the lowest (99.5 µS/cm).

Table 1. Mean values of physico-chemical parameters of three different ponds during study period

Mean values of physiochemical parameters of pond (Intensive, Semi-intensive and Extensive pond)																		
	Secchi depth (cm)			Air temp. (°C)			Water temp.(°C)			TDS (ppt)			EC (µS/cm)			pH		
	In	S.I	Ex.	In	S.I	Ext	In	S.I	Ex	In	S.I	Ex	In	S.I	Ex	In	S.I	Ex
WIN	39.7	46	47.9	31	30.1	30.4	28.98	30.1	31.3	79	126	77	167.3	264	147.5	7.6	8.2	8.4
SUM	41	48	51.5	33	32.7	32.8	31.35	29.9	32.1	77	137	79	169.5	271.5	151.45	7.34	7.81	8.3
RAI	42.8	38.8	54.5	33	32.2	32.7	32.1	30.1	32.3	49	98	72	99.5	272.7	145	7.56	7.9	8.1

N.B. In= Intensive pond, S.I= Semi intensive pond, Ex= Extensive pond. WIN= Winter, SUM=Summer, RAI=Rainy

The analyzed pond's water transparency, temperature, TDS, and EC were found to fluctuate over the course of the study, while the pH and air temperature remained relatively consistent. Perhaps that the weather has an impact on the temperature changes in the water. But according to Hossain et al. (2015) and Begum et al. (2018), temperature should be between 25 and 30 degrees Celsius to maximize zooplankton production in tropical ponds. For fish culture, 26.06°C to 31.97°C was the ideal temperature range (Boyd et al., 1986). Water transparency varies according to a number of characteristics, including silting, phytoplankton density, suspended organic matter, latitude, season, and incident light intensity and angle (Reid et al., 1976). Furthermore, it should be mentioned that differences in zooplankton densities may not be explained solely by temperature because high pH, conductivity, and nutrients are additional elements that contribute to organic production.

Summer temperatures were the highest recorded with regard to water and air, while winter temperatures were the lowest. From Bangladeshi Pond, similar findings were noted by Mozumder et al. (2014) and Miah et al. (1981).

According to the analysis, the pH value of each pond water indicated that it was alkaline in nature, while Khan & Bari (2019) reported a pH value of 7.20-8.60 from the pond of Noakhali, Bangladesh. Boyd et al. (1986) found that the recorded pH range (7.34-8.4) of all sampling ponds was in conformity with the optimal pH range (6.5-9.0) in fish production ponds. The average pH value of Rajshahi University ponds were 8.1 to 9.4 (Rahman and Hossain, 2008) which was closely related with our study.

Water transparency in lakes is influenced by factors like rainfall, sun position, ray incidence angle, cloudiness, visibility, turbidity, and planktonic growth. In our present study, the maximum and minimum range of transparency was 38.75cm and 54.5cm during the rainy season, which disagreed with the findings of Rahman & Hossain (2008) reported lowest transparency in winter season. Dokulil et al. (2006) highlighted water transparency as a crucial parameter for lake optics and eutrophication evaluation, indicating the degree of lake limpidity and muddiness, influenced by suspended matter.

TDS are crucial for determining water quality regulations as they are directly proportional to pollution levels (Jayakumar et al. 2009). Summertime offered the highest TDS levels, while the monsoon season showed the lowest (Narayan et al. 2007). Present study has revealed seasonal variations in TDS levels, with rainy seasons causing lower levels due to diluted ions and dry seasons increasing concentrations due to water evaporation.

Water velocity, evaporation, and temperature has affected conductivity seasonally. Rain enhances conductivity due to higher ionic levels in purified water, resulting from leachate infiltration from the soil (Sastry et al. 2014). Semi-intensive ponds showed the highest conductivity (272.66 µS/cm) during the rainy season, whereas intensive ponds showed the minimum conductivity (99.5 µS/cm) over the same period. The other two ponds, with the exception of semi-intensive ponds, displayed their highest conductivity throughout the summer. Even still, the greatest conductivity value of the semi-intensive ponds during the wet season was rather near to the summertime value.

Zooplankton diversity and abundance

Copepods, rotifers, and cladocerans were the zooplanktonic creatures that were observed in our present study. Three different types of ponds (intensive, semi-intensive and extensive) had significantly different densities of total zooplankton. A total 33 species of zooplankton under 19 genera were recorded from three types of ponds. Among these species rotifers were dominant with 24 (11 genera) species followed by 05 (05 genera) species of Copepod and 04 (03 genera) species of Cladocera. Total zooplankton species list was given in Table 2. (Plate I and Plate II).

Table 2. List of group, genus and species of zooplankton collected from three distinct ponds (P1 & P2=Intensive, P3&P4=Semi-intensive and P5&P6= Extensive ponds)

Group name	Species name	P-1	P-2	P-3	P-4	P-5	P-6
	Daphnia lumholtzi	×	×	×	√	×	√
	Diaphanosoma brachyurum	√	√	√	√	√	√
Cladocera	*D. leuchtembergianum*	√	×	√	×	√	√
	Moina brachiata	√	√	√	√	√	√
	Neodiaptomus strigilipes	√	√	√	√	√	√
	Cyclops varicans rubellus	√	√	√	√	√	√
	Mesocyclops leuckarti	√	√	√	√	√	√
Copepoda	*Thermocyclops inversus*	√	√	√	√	√	√
	Macrocyclpos distictus	√	√	√	×	√	√
	Brachionus urceolaris	√	×	√	×	√	√
	B. diversicornis	√	√	√	√	√	√
	B. falcatus	√	√	√	×	×	√
	B. calyciflorus	√	√	×	√	×	√
	B.quadridentatus	√	×	×	×	×	×
	B. caudatus	√	√	√	√	×	√
	B. nilsoni	×	√	×	√	×	√
	B. angularis	√	√	√	×	×	×
	B. forficula	√	√	√	√	√	√
	Keratella tropica	√	×	×	×	√	×
	K. cochlearis	√	√	√	√	√	√
	Lecane luna	√	√	×	×	×	×
Rotifera	*Asplanchna priodonta*	√	√	×	×	×	√
	A. herricki	√	√	×	×	√	×
	A. sieboldi	√	√	√	×	√	×
	Fillinia opoliensis	√	√	×	×	√	×
	F. longiseta	×	√	×	×	×	×
	Testudinella patina	√	√	√	×	√	√

Lapadella patella	×	×	×	√	×	√
Rotaria sp	×	×	×	×	×	√
Trichocerca cylindrica	√	√	×	×	×	×
T.similis	√	×	×	×	×	×
Polyarthra vulgaris	√	√	×	×	×	×
Platyias patulus	√	√	×	×	×	×

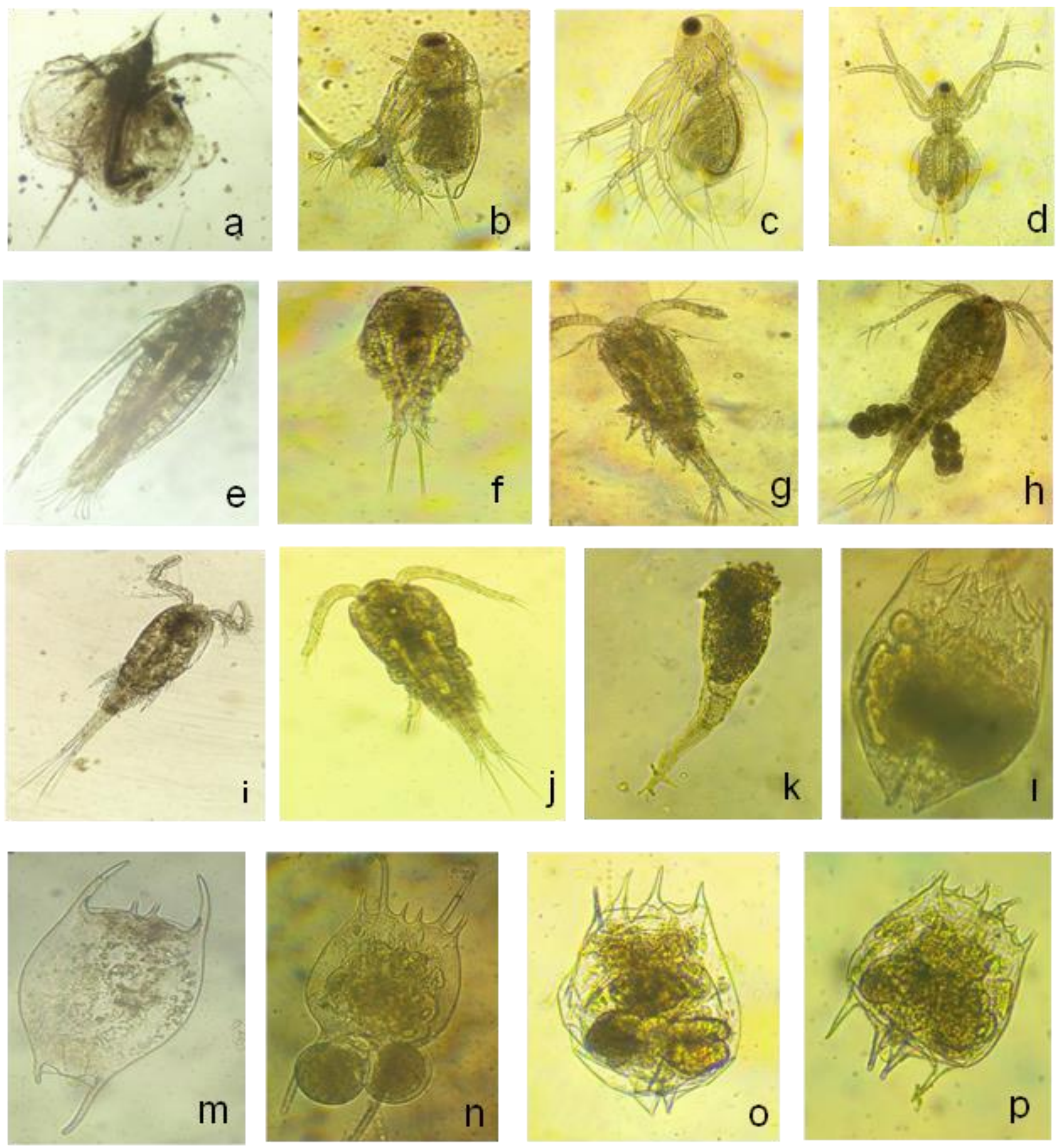

Plate 1. Photographs of collected zooplankton: (a) *Daphnia lumholtzi*, (b) *Diaphanosoma brachyurum,* (c) *Diaphanosoma leuchtembergianum,* d) *Moina brachiata*, (e) *Neodiaptomus Strigilipes*, (f) *Cyclops varicans rubellus,* (g) *Mesocyclops leuckarti* (M), (h) *Mesocyclops leuckarti* (F) (i) *Thermocyclops inversus* (M) (j) *Macrocyclops distinctus,* (k*) Rotaria sp,* (l) *Brachionus urceolaris,* (m) *Brachionus diversicornis*, (n) *Brachionus falcatus*, (0) *Brachionus calyciflorus*, (p) *Brachionus quadridentatus*

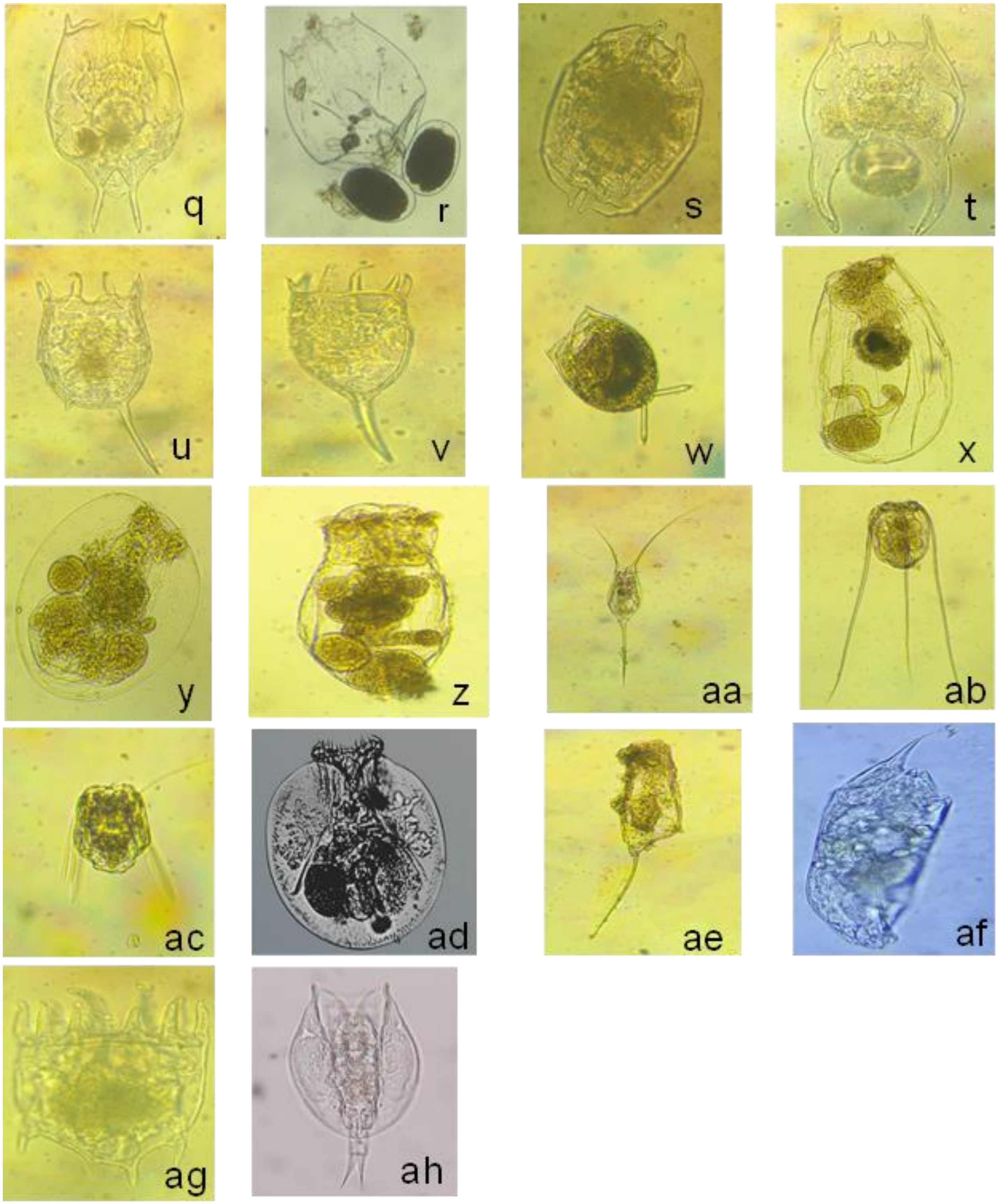

Plate II. Photographs of collected zooplankton: (q) *Brachionus caudatus*, (r) *Brachionus nilsoni*, (s) *Brachionus angularis*, (t) *Brachionus forficula*, (u) *keratella tropica*, (v) *keratella cochlearis*, (w) *Lecane luna*, (x) *Asplanchna priodonta*, (y) *Asplanchna herricki*, (z) *Asplanchna seiboldi*, (aa) *Filinia opoliensis*, (ab) *Filinia longiseta*, (ac) *Polyarthra vulgaris*, (ad) *Testudinella patina,* (ae) *Trichocerca cylindrica*, (af) *Trichocerca similis,* (ag) *Platyias patulus*, (ah) *Lepadella patella*

From the observation, the intensive pond had a minimum of 3020 units/l of zooplankton during the rainy season and a maximum of 9680 units/l during the winter.

In a semi-intensive pond, the lowest amount of zooplankton was 3180 u/l during the rainy season, and the highest amount was 37360 u/l during the summer. There was a minimum of 7660 u/l in the winter and maximum of 37600 u/l in the summer in an extensive pond (Table 3, Table 4 and Table 5). Except extensive ponds, the other two ponds showed minimum number of plankton species in the rainy season. Warmer temperatures in wet season may cause higher stratification, which results in minimal abundance in plankton populations and may reduce vertical mixing and nutrient availability to the euphotic zone (Lim et al.2024). During our study period, extensive ponds showed lower abundance of the plankton community. Winter's harsher light and thermal conditions reduce zooplankton levels, while copepod nauplii multiply as a result of increased sunlight penetration (Jensen, 2019). Semi-intensive and extensive ponds showed highest zooplankton abundance in the summer season whereas intensive ponds showed in the winter season. According to Engeland et al. (2023), the biomass of big zooplankton was lowest in the spring and highest in the summer and early winter. Higher temperatures increase zooplankton reproductive rates, reducing plankton blooms time and promoting water evaporation, enriching nutrient levels in the water which were responsible for increasing the numbers of plankton populations (Richardson, 2008).

Table 3. Seasonal distribution of zooplankton (units/L) in Intensive pond

Seasonal distribution of zooplankton (units/L) in Intensive pond												
Species name	Winter			Summer			Rainy				%of Zoo plankton	% of group
Cladocera	P 1	P 2	total	P 1	P 2	total	P 1	P 2	total	G.total		
Diaphanosoma	80	0	80	40	0	40	0	0	0	120	0.67%	28.58%
Moina	60	0	60	0	100	100	0	140	140	300	1.68%	71.42%
Total	140	0	140	40	100	140	0	140	140	420	2.35%	100.00%
Copepoda												
Neodiaptomus	100	0	100	100	0	100	340	60	400	600	3.36%	25.42%
Cyclops	100	80	180	60	40	100	300	80	380	660	3.69%	27.97%
Mesocyclops	0	140	140	120	40	160	60	20	80	380	2.13%	16.10%
Thermocyclops	0	140	140	20	100	120	80	60	140	400	2.24%	16.95%
Macrocyclops	0	0	0	0	0	0	200	120	320	320	1.79%	13.56%
Total	200	360	560	300	180	480	980	340	1320	2360	13.20%	100.00%
Rotifera												
Brachionus	1740	4820	6560	1280	2460	3740	100	800	900	11200	62.64%	74.17%
Keratella	1420	100	1520	0	220	220	0	20	20	1760	9.84%	11.66%
Lecane	0	40	40	20	40	60	0	0	0	100	0.56%	0.66%
Asplanchna	300	240	540	260	40	300	20	340	360	1200	6.71%	7.95%
Filinia	0	40	40	0	0	0	20	60	80	120	0.67%	0.79%
Polyarthra	160	0	160	60	0	60	60	0	60	280	1.57%	1.85%
Testudinella	0	0	0	100	0	100	20	0	20	120	0.67%	0.79%
Trichocerca	120	0	120	60	0	60	100	0	100	280	1.57%	1.85%
Platyias	0	0	0	0	20	20	20	0	20	40	0.22%	0.26%
Total	3740	5240	8980	1780	2780	4560	340	1220	1560	15100	84.45%	100.00%
Total zooplankton										17880		

Table 4. Seasonal distribution of zooplankton (units/L) in Semi-Intensive pond

Seasonal distribution of zooplankton (units/L) in Semi-Intensive pond												
Species name	Winter			Summer			Rainy				% of zoo plankton	% of group
Cladocera	P 3	P 4	total	P 3	P 4	total	P 3	P 4	total	G.total		
Daphnia	0	2200	2200	0	200	200	0	60	60	2460	5.36%	70%
Diaphanosoma	20	0	20	0	160	160	20	0	20	200	0.44%	6%
Moina	140	320	460	80	220	300	0	80	80	840	1.83%	24%
Total	160	2520	2680	80	580	660	20	140	160	3500	7.63%	100%
Copepoda												
Neodiaptomus	40	180	220	0	560	560	0	100	100	880	1.92%	33%
Cyclops	80	120	200	0	40	40	0	20	20	260	0.57%	10%
Mesocyclops	80	280	360	40	360	400	0	0	0	760	1.66%	28%
Thermocyclops	80	220	300	20	0	20	0	40	40	360	0.78%	13%
Macrocyclops	420	0	420	0	0	0	20	0	20	440	0.96%	16%
Total	700	800	1500	60	960	1020	20	160	180	2700	5.88%	100%

Rotifera											
Brachionus	880	80	960	4720	30500	35220	2540	200	2740	38920	84.83%	98%
Keratella	100	40	140	0	0	0	0	20	20	160	0.35%	0%
Asplanchna	60	0	60	200	0	200	80	0	80	340	0.74%	1%
Testudinella	0	0	0	0	60	60	0	0	0	60	0.13%	0%
Lepadella	0	0	0	0	200	200	0	0	0	200	0.44%	1%
Total	1040	120	1160	4920	30760	35680	2620	220	2840	39680	86.49%	100%
Total zooplankton										45880		

Table 5. Seasonal distribution of zooplankton (units/L) in Extensive pond

Seasonal distribution of zooplankton (units/L) in Extensive pond												
Species name	Winter			Summer			Rainy				%of zoo plankton	% of group
Cladocera	P 5	P 6	sub total	P 5	P 6	sub total	P 5	P 6	sub total	G.total		
Daphnia	0	200	200	0	0	0	0	0	0	200	0.38%	5%
Diaphanosoma	0	0	0	0	200	200	1480	400	1880	2080	3.94%	53%
Moina	300	160	460	0	0	0	920	280	1200	1660	3.14%	42%
Total	300	360	660	0	200	200	2400	680	3080	3940	7.46%	100%
Copepoda												
Neodiaptomus	500	80	580	1020	0	1020	200	60	260	1860	3.52%	22%
Cyclops	0	80	80	0	0	0	180	80	260	340	0.64%	4%
Mesocyclops	0	520	520	0	480	480	1540	1260	2800	3800	7.19%	46%
Thermocyclops	160	340	500	0	440	440	340	480	820	1760	3.33%	21%
Macrocyclops	0	40	40	0	120	120	160	260	420	580	1.10%	7%
Total	660	1060	1720	1020	1040	2060	2420	2140	4560	8340	15.79%	100%
Rotifera												
Rotaria	0	40	40	0	0	0	0	0	0	40	0.08%	0%
Brachionus	660	120	780	360	30500	30860	0	200	200	31840	60.28%	79%
Keratella	2680	80	2760	2920	0	2920	0	20	20	5700	10.79%	14%
Lecane	0	0	0	0	0	0	0	0	0	0	0.00%	0%
Asplanchna	360	0	360	200	0	200	20	0	20	580	1.10%	1%
Filinia	1040	0	1040	740	0	740	0	0	0	1780	3.37%	4%
Testudinella	300	0	300	0	60	60	40	0	40	400	0.76%	1%
Lepadella	0	0	0	0	200	200	0	0	0	200	0.38%	0%
Total	5040	240	5280	4220	30760	34980	60	220	280	40540	76.75%	100%
Total zooplankton										52820		

Rotifera

Rotifera formed the most important group contributing more than two thirds (84.45%, 86.49% and 76.75%) of the zooplankton population of different ponds (Table 3, Table 4 and Table 5). The dominance of the rotifers both in forms and density was observed in the present study in accordance with the findings (Saiful et al.2020; Hossain et al. 2015; Begum et al. 2014). *Brachionus, Keratella, Asplanchna, filinia, Trichocerca, Testudinella, Polyarthra, Platyias, Lecane, Rotaria and Lepadella* were identified genera where's *Brachionous* was most dominant (74.17%, 98% and 79% of total rotifers) in all types of ponds (Fig. 2). *Keratella*, the second dominant genus, exhibits unique characteristics in semi-intensive ponds, with the highest abundance in extensive and intensive ponds (14% and 11.66% of total rotifers), but very few in semi-intensive ponds (1% of total rotifers). Compared to other pond types, *Asplanchna* is the third most prevalent genus in intensive ponds. A minor proportion of other rotifers has been found in all categorized ponds. The highest diversity of rotifer species were observed in intensive ponds (Table 3), while the highest density of rotifers was observed in semi-intensive ponds (Table 4).

In Intensive Pond, highest number of rotifers (8980u/l) was observed in winter and lowest in (1560u/l) in rainy (Table 3). In semi-intensive ponds the highest number

(35680u/l) was observed in summer and lowest number (1160u/l) in winter Table-4. On the other hand, in the extensive pond the highest (34980u/l) was observed in summer and lowest number (280u/l) in the rainy season. Present investigation revealed that the majority of ponds had the highest rotifer density during the summer and the lowest during the wet season. Only semi-intensive ponds showed the lowest density in the winter season. Heavy rainfall negatively impacts zooplankton communities in freshwater ecosystems, increasing water discharge and velocity, leading to minimum rotifer population density (AF-Hasan et al. 2018; Dhembare & Gholap, 2011; and Choi & Kim, 2020). The culture pond exhibits highest density during winter due to cold temperature favorable for rotifers morphotype and food availability affecting population growth.

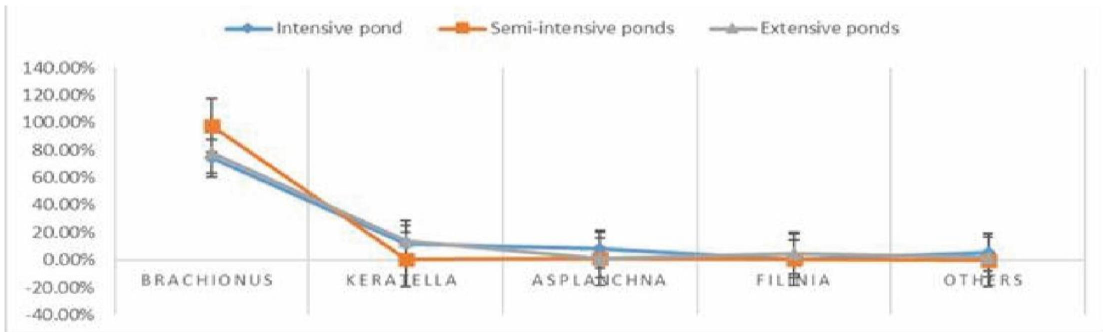

Fig. 2. Relative abundance of rotifers in Intensive, Semi-intensive and Extensive ponds

Copepoda

Copepods were the second dominant group in both intensive and extensive ponds of the total zooplankton population, contributing 13.20% and 15.79%, respectively (Table 3 and Table 5) but a small number of this species were found in the semi-intensive pond (5.88% of total zooplankton). The study revealed that copepods were most abundant during the rainy season in all categorized ponds (1320u/l, 2700u/l and 4560u/l), while minimal values were observed in the summer season in intensive (480u/l) and semi-intensive (1020u/l) ponds and winter in extensive (1720u/l) ponds. (Table 3, 4 and 5). Among the calanoid and cyclopoid copepods, the taxa *Neodiaptomus, Cyclops, Mesocyclops, Thermocyclops, and Macrocyclops* were identified during our study period. Copepod populations increased in number throughout the rainy season under the influence of rainfall, water temperature, dissolved oxygen, and chlorophyll (Panarelli et al. 2001). In accordance with our findings, Bhuiyan et al. (2008) observed the greatest copepod density (768 units/l) in Rajshahi university ponds during the rainy season. Cyclops was most dominant in all categorized ponds (74.58%, 67% and 78%). (Fig. 3).

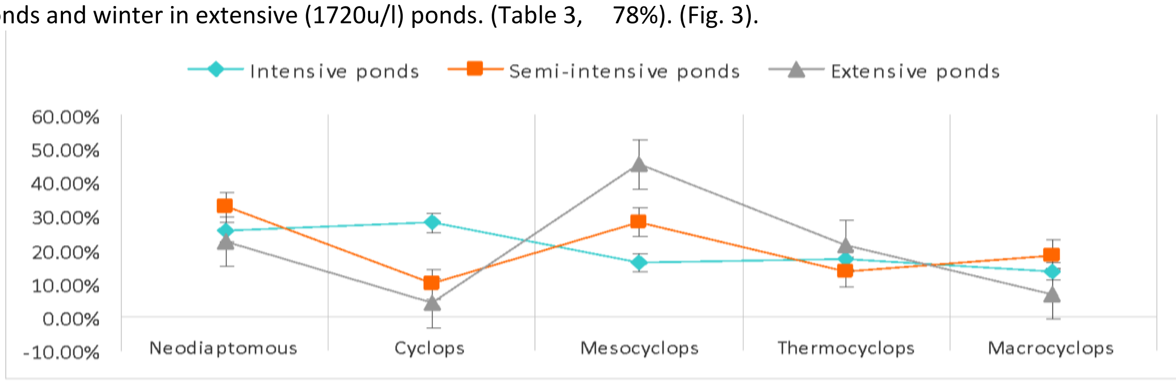

Fig. 3. Relative abundance of Copepods in Intensive, Semi-intensive and Extensive ponds

Cladocera

Cladocerans were the third most prevalent in intensive and extensive ponds, although they were greater in number than copepods in semi-intensive ponds. Of all the studied plankton groups, cladocera exhibited varying abundances throughout different waterbodies and seasons (Table 4). *Daphnia, Diaphanosoma and Moina* were identified genera which were found in all classified ponds. Intensive pond showed similar number of zooplankton density in all seasons (140u/l), but extensive ponds showed lowest density in summer (200u/l) and highest density in rainy (3080u/l).Nevertheless, Semi-intensive pond showed highest plankton density in winter (2680u/l). The leading species in the intensive pond was *Moina* (71.42%), followed by *Daphnia* (70%) in the semi-intensive pond and *Diaphanosoma* (53%) and *Moina* (42%) in the extensive pond (Fig. 4) Seasonal variations in cladoceran density can be attributed to a variety of environmental conditions that support their growth, including temperature, food availability, water body depth and salinity (Green et al., 2005; Thakur & Kocher, 2017). Perhaps the low density of cladocera in culture ponds was caused by the fact that they were the main food supply for fish, copepods, predaceous cladocerans, mysids, and aquatic insects.

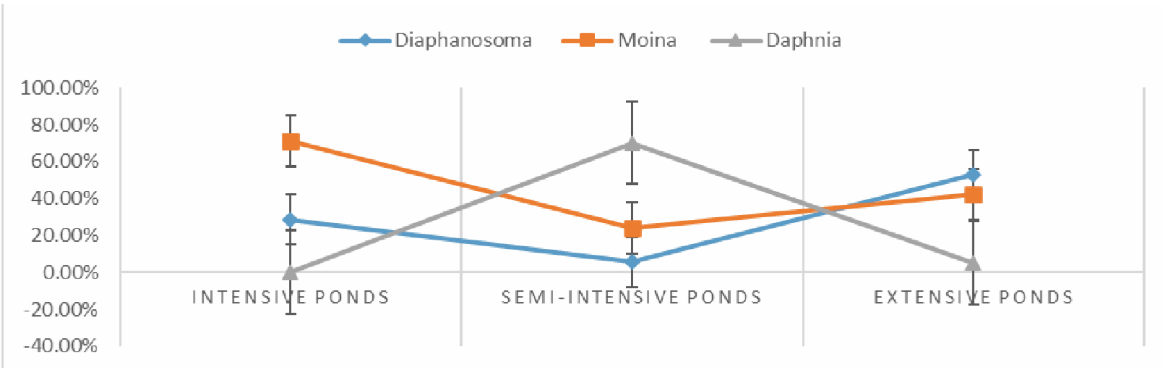

Fig. 4. Relative abundance of Cladocerans in Intensive, Semi-intensive and Extensive ponds

Correlation among physicochemical factors

For the six month study period, Intensive pond zooplankton showed a positive significant relationship with TDS (r=0.78, P<0.05), pH (r=0.34, P<0.05) and EC (r=0.81, P<0.05). In semi- intensive pond, positive correlationship between zooplankton abundance and air temperature (r=0.61, P<0.01), TDS (r=0.38, P<0.05), EC (r=0.33, P<0.05) and transparency (r=0.71, P<0.05) were found. In extensive ponds zooplankton showed positive correlation with almost all parameters except TDS (Table 6). Zooplankton showed negative correlation with transparency, air temperature and water temperature in intensive pond but in semi-intensive pond negative correlation showed with water temperature and pH. Mozumder et al. (2014) and Ali et al. (1980) found that most of the zooplankton had positive correlation coefficient with physic-chemical parameters and plankton abundance. Positive correlation between plankton and physicochemical parameters indicates that the plankton population is positively related to the water's chemical and physical characteristics which supports our present study.

Table 6. Relationship between zooplankton density and physico-chemical parameters

Correlation between zooplankton density and physicochemical parameters			
Correlation coefficient	Intensive pond	Semi-Intensive Pond	Extensive pond
zooplankton Vs Secchi depth	-0.957384492	0.708233471	0.063102178
zooplankton Vs Air temperature	-0.909336096	0.607756971	0.544765994
zooplankton Vs Water temp.	-0.995851807	-0.998406896	0.343660189
zooplankton Vs TDS	0.787483607	0.38201908	-0.046008029
zooplankton Vs EC	0.814798353	0.336736813	0.920248368
zooplankton Vs pH	0.33677027	-0.636023705	0.181559774

Copepods, cladocera, and rotifers were the three main kinds of zooplankton that we identified throughout our investigation. Similar results were obtained by Rahman & Hussain (2008), Hussain and Ahmed (1999), and Islam et al. (2020, 2022). Compared to intensive (17880u/l) and semi-intensive (458880 u/l) ponds, extensive ponds had a relatively higher zooplankton concentration (52820 u/l) during our study period. Plankton density might be higher in extensive ponds because of things including productive water quality, loamy bottom soil, and regional differences in plankton variety. The majority of earlier studies (Pal et al., 2023; Sharma et al. 2022; Rahman & Hussain, 2008; found that the plankton density was relatively higher in cultured ponds, which somewhat contradicted our findings. According to other researchers (Tulsankar et al., 2021), pond size and age also significantly affected the number of plankton; smaller ponds had a larger ratio of bottom area to water volume, which increased the amount of zooplankton, while older ponds showed the highest abundance.

During the present investigations, the extensive ponds we have chosen were significantly smaller than other classified ponds. This is why extensive ponds may contain higher concentrations of zooplankton. Given that decline of planktivorous fish also increases zooplankton concentrations, this could be another factor causing the elevated zooplankton concentrations in non-culture ponds (Belifiore et al.2021).

Conclusion

The studied three different waterbodies including six ponds in CUC supported moderate levels of zooplankton where rotifers were dominant groups in all types of waterbodies throughout the study; intensive ponds showed dominance in the winter, while semi-intensive and extensive ponds displayed greater density in the summer. Rotifera dominance in water bodies indicates eutrophic conditions, with selective predation by planktivorous fish shifting zooplankton communities. Compared to intensive and semi-intensive ponds, copepods and cladocerans were more prevalent in extensive ponds. Copepods exhibited a higher density during the rainy season, whereas cladocerans displayed scattered data across the seasons. The highest plankton abundance was found in extensive ponds because of their small size, greater nutrient levels, and concentrated organic matter, which encourage zooplankton to proliferate quickly and exhibit an advantageous association with physico-chemical parameters.

References

Akter, S., Rahman, M. M., & Akter, M. 2015. Composition and abundance of phytoplankton population in fish ponds of Noakhali District, Bangladesh. *American-Eurasian Journal of Agriculture and Environmental Science*, *15*(11), 2143-2148.

Al, M. A., Akhtar, A., Hassan, M. L., Rahman, M. F., & Warren, A. 2019. An approach to analyzing environmental drivers of phytoplankton community patterns in coastal waters in the northern Bay of Bengal, Bangladesh. *Regional Studies in Marine Science*, *29*, 100642.

Alam, M. A., Hossain, M. R. A., Rubel, A. S. A., Tanu, M. B., & Khan, M. H. (2016). Assessment of physicochemical conditions and plankton populations of the river Padma, Bangladesh. *Asian-Australasian Journal of Bioscience and Biotechnology*, *1*(1), 86-94.

Ali S.F., F.M. Hassan 2019. Ecological study of epiphytic diatoms on two submerged aquatic macrophytes in Tigris River, Iraq. Agriculture Journal.50 (4):1109–19.

Bashar, M. A., Basak, S. S., l Uddin, K. B., Islam, A. S., & Mahmud, Y. 2015. Seasonal variation of zooplankton population with reference to water quality of Kaptai lake; Bangladesh.

Begum, K. 2018. Effects of the endangered freshwater pearl mussel Margaritifera on river ecosystem and water quality.

Belfiore, A. P., Buley, R. P., Fernandez-Figueroa, E. G., Gladfelter, M. F., & Wilson, A. E. 2021. Zooplankton as an alternative method for controlling phytoplankton in catfish pond aquaculture. *Aquaculture Reports*, *21*, 100897.

Bhouyain, A.M and Asmat. G.S.M. 1992. Freshwater zooplankton from Bangladesh. Ghazi Publishers. Dhaka.

Bhuiyan, A. S., Islam, M. T., & Sharmeen, R. 2008. Occurrence and Abundance of some Copepods in a Fish Pond in Rajshahi, Bangladesh in relation to the Physico-Chemical Conditions. *Journal of Bio-Science*, *16*, 115-119.

Borges, P. A. F., Train, S., & Rodrigues, L. C. 2008. Spatial and temporal variation of phytoplankton in two subtropical Brazilian reservoirs. *Hydrobiologia*, *607*, 63-74.

Boyd, C. E. (1982). *Water quality management for pond fish culture* (pp. xii+-318pp).

A. Oceanographic Research Papers, *33*(11-12), 1885-1905.

Choi, J. Y., Kim, J. C., & Kim, S. K. 2020. Changing distributions of zooplankton communities in a coastal lagoon in response to rainfall seasonality. *Journal of Coastal Research*, *102*(SI), 69-74.

Dang, P., Khoi, N., Nga, L., Thanh, D., & Hai, H. 2015. Identification Handbook of Freshwater Zooplankton of the Mekong River and its Tributaries.

Dhembare, A. J., & Gholap, A. B. 2011. Seasonal variation and diversity of rotifer in Dnyaneshwar water, Rahuri, Ahmednagar, Maharashtra.

Dokulil, M. T., Donabaum, K., & Teubner, K. 2007. Modifications in phytoplankton size structure by environmental constraints induced by regime shifts in an urban lake. *Hydrobiologia*, *578*, 59-63.

Edmondson, W.T. 1959. Freshwater Biology. 2nd Edition, John Wiley and Sons Inc., New York.

Edwards, E. S., Burkill, P. H., & Stelfox, C. E. 1999. Zooplankton herbivory in the Arabian Sea during and after the SW monsoon, 1994. *Deep Sea Research Part II: Topical Studies in Oceanography*, *46*(3-4), 843-863.

Ferdous, Z., & Muktadir, A. K. M. 2009. A review: potentiality of zooplankton as bioindicator.

Fernando, C. H. 1994. Zooplankton, fish and fisheries in tropical freshwaters. *Studies on the Ecology of Tropical Zooplankton*, 105-123.

Figueredo, C. C., & Giani, A. 2009. Phytoplankton community in the tropical lake of Lagoa Santa (Brazil): conditions favoring a persistent bloom of Cylindrospermopsis raciborskii. *Limnologica*, *39*(4), 264-272.

Geraldes, A.M. and M.J. Boavida. 2005. Seasonal water level fluctuations: Implications for reservoir limnology and management. . Lakes & Reservoirs: Research and Management 10: 59–693.

Green,A.Z. Fuentes,C., Moreno-Ostos,E., Rodrigues da Silva, S.L 2005. Factors influencing cladoceran abundance and species richness in brackish lakes in Eastern Spain. *Ann. Limnol. – Int.*

Haque, A. K. M. F., Begum, N., & Islam, M. S. 2015. Seasonal variations in phytoplankton and zooplankton population in relation to some environmental factors at the tidal Sangu River in Chittagong of Bangladesh. *Journal of the Sylhet Agricultural University*, *2*(2), 209-219.

Haque, M. A., Nabi, M. R. U., Billah, M. M., Al Asif, A., Rezowan, M., Mondal, M. A. I., & Khan, M. R. 2018. Effect of water parameters on temporal distribution and abundance of zooplankton at Kaptai lake reservoir, Rangamati, Bangladesh. *Asian Journal of Medical and Biological Research*, *4*(4), 389-399.

Hasan, A. F., Al-Mayaly, I. K. A., & Farhan, T. Y. 2018. Planktonic community of algae in Sawa Lake, Southern Iraq.

Hossain, S., Rahman, M. M., Akter, M., & Bhowmik, S. 2015. Species composition and abundance of zooplankton population in freshwater pond of Noakhali district, Bangladesh. *World Journal of Fish and Marine Sciences*, *7*(5), 387-393.

Hussain, & Ahmed. 1999 Influence of hydrographic conditions on the interaction between ichthyoplankton and macrozooplankton at Khor Al-Zubair lagoon, Iraq, Arabian Gulf.

Ikpi, G. U., Offem, B. O., & Okey, I. B. 2013 Plankton distribution and diversity in tropical earthen fish ponds. *Environment and Natural Resources Research*, *3*(3), 45.

Iqbal, M. M., Islam, M. S., & Haider, M. N. 2014. Heterogeneity of zooplankton of the Rezukhal Estuary, Cox's Bazar, Bangladesh with seasonal environmental effects. *International Journal of Fisheries and Aquatic Studies*, *2*(2), 275-282.

Islam, M. S., Azadi, M. A., Nasiruddin, M., & Islam, M. S. 2020. Diversity of phytoplankton and its relationship with physicochemical parameters of three ponds in Chittagong University campus, Bangladesh. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 46-52.

Islam, M. S., Uddin, M., Jaman, A., Bhowmik, S., Rifa, T. J., Mashkova, I., & Khan, N. S. 2022 Freshwater zooplankton in Rain-fed wild ponds: A perspective on species diversity and water quality. *Curr Environ*, *2*, 28-32.

J. Lim. 2005, 41 (2), 73-81.

Jayakumar, A., Naqvi, S. W. A., & Ward, B. B. 2009. Distribution and relative quantification of key genes involved in fixed nitrogen loss from the Arabian Sea oxygen minimum zone. *Indian Ocean biogeochemical processes and ecological variability*, *185*, 187-203.

Karmakar, S. R., Hossain, M. B., Sarker, M. M., Nur, A. A. U., Habib, A., Paray, B. A., ... & Arai, T. 2022 Diversity and community Structure of zooplankton in homestead ponds of a tropical coastal area. *Diversity*, *14*(9), 755.

Khan, N. S., & Bari, J. B. A. 2019. The effects of physico-chemical parameters on plankton distribution in poultry manure and artificial formulated feed-treated fish ponds, Noakhali, Bangladesh. *International Journal of Fisheries and Aquatic Studies*, *7*(5), 1-7.

Lim, Y. K., Hong, S., Lee, C. H., Kim, M., & Baek, S. H. 2024. Influence of Region-Specific Marine Environments on Phytoplankton and Bacterial Communities in the Korean Coastal Waters in winter 2021. *Ocean Science Journal*, *59*(4), 1-16.

Longhurst, A. R. & Seibert, D. L. R. 1967.Skill in the use of Folsom's plankton sample splitter. Limnol. Oceanogr. 12:334.

Mazumder, A., Khare, N., & Govil, P. 2014. The interdependency of the morphological variations of the planktonic foraminiferal species Globigerina bulloides in surface sediments on the environmental parameters of the southwestern Indian Ocean. *International Scholarly Research Notices*, *2014*(1), 621479.

Mcewen, G. F., Johnson, M. W., Folsom T. R. 1954 A statistical analysis of the Folsom sample splitter based upon test observations. Arch. Meteorol. Geophys. Bioklimatol. Ser. A, 6:502.

Miah, M. I., Bhuiyan, I., & Dewan, S. 1981. A comparative study of the rate of growth of major carps in relation to physico-chemical and biological factors.

Narayanan, N., Priya, M., Haridas, A., & Manilal, V. B. 2007. Isolation and culturing of a most common anaerobic ciliate, Metopus sp. *Anaerobe*, *13*(1), 14-20.

Naz, S., & Najia, S. 2008. Study on the zooplankton of Sona Dighi in Rajshahi, Bangladesh. *University Journal of Zoology, Rajshahi University*, *27*, 7-11.

Needham, J.G. and Needham, P.R. 1962 A Guide to the Study of Freshwater Biology. Holden Day, Inc, San Francisco.

Pal, P., Kumar, J., & Dwivedi, A. C. 2023. Comparative study on plankton diversity of ponds (culture and non-culture) ecosystem in Prayagraj, Uttar Pradesh: a note. *Journal of Kalash Science*, *11*(1), 14-24.

Panarelli, E. A., Nogueira, M. G., & Henry, R. 2001. Short-term variability of copepod abundance in Jurumirim Reservoir, São Paulo, Brazil. *Brazilian Journal of Biology*, *61*, 577-598.

Parvez, M. A., Uddin, M. M., Islam, M. K., & Kibria, M. M. 2019. Physicochemical and biological monitoring of water quality of Halda River, Bangladesh. *International Journal of Environmental and Science Education*, *14*(4), 169-181.

Piontkovski, S. A., Landry, M. R., Finenko, Z. Z., Kovalev, A. V., Williams, R., Gallienne, C. P., ... & Nikolsky, V. N. 2003. Plankton communities of the South Atlantic anticyclonic gyre. *Oceanologica Acta*, *26*(3), 255-268.

Rahman, S., & Hussain, M. A. 2008. A study on the abundance of zooplankton of a culture and a non-culture pond of the Rajshahi University campus. *University journal of zoology, Rajshahi University*, *27*, 35-41.

Rahman, S., & Hussain, M. A. 2008. A study on the abundance of zooplankton of a culture and a non-culture pond of the Rajshahi University campus. *University journal of zoology, Rajshahi University*, *27*, 35-41.

Richardson, A. J. 2008 In hot water: zooplankton and climate change. *ICES Journal of Marine Science*, *65*(3), 279-295.

Roy, R. 2010. Short-term variability in halocarbons in relation to phytoplankton pigments in coastal waters of the central eastern Arabian Sea. *Estuarine, Coastal and Shelf Science*, *88*(3), 311-321.

Sharif, A. S. M., Bakar, M. A., & Bhuyan, M. S. 2017. Assessment of water quality of the lower Meghna river estuary using multivariate analyses and RPI. *Intern. J Chem. Pharm. Technol*, *2*, 57-73.

Sharma, K., Gulati, R., Bamel, K., Singh, S., & Devi, P. (2022). Plankton density and diversity in Litopenaeus vannamei culture ponds of Haryana.

Shil, J., Ghosh, A. K., & Rahaman, S. B. 2013. Abundance and diversity of zooplankton in semi intensive prawn (Macrobrachium rosenbergii) farm. *SpringerPlus*, *2*, 1-8.

Singh, S., Usmani, E., Dutta, R., Kumari, V., Praveen, S., Priya, S., & Mohommad, A. 2021. Study on zooplankton diversity and physico chemical parameter of Pampoo pond of madhupur, Jharkhand, India. *International Journal of Advancement in Life Sciences Research*, 34-44.

Srifa, A., Philips, E. J., & Hendrickson, J. 2016 How many seasons are there in a sub-tropical lake? A multivariate statistical approach to determine seasonality and its application to phytoplankton dynamics. *Limnologica*, *60*, 39-50.

Sultana, S., Khan, S., & Hena, S. M. 2023. Seasonal dynamics of zooplankton in a eutrophic fish pond of Bangladesh in relation to environmental factors. *J Aquac Mar Biol*, *12*(2), 129-136.

Thakur, A., & Kocher, D. K. 2017. Diversity and density of cladoceran population in different types of water bodies of Ludhiana, Punjab (India). *Journal of Entomology and Zoology Studies*, *5*(3), 1568-1572.

Tulsankar, S. S., Cole, A. J., Gagnon, M. M., & Fotedar, R. 2021. Temporal variations and pond age effect on plankton communities in semi-intensive freshwater marron (Cherax cainii, Austin and Ryan, 2002) earthen aquaculture ponds in Western Australia. *Saudi Journal of Biological Sciences*, *28*(2), 1392-1400.

Van Engeland, T., Bagøien, E., Wold, A., Cannaby, H. A., Majaneva, S., Vader, A., & Ingvaldsen, R. B. 2023. Diversity and seasonal development of large zooplankton along physical gradients in the Arctic Barents Sea. *Progress in Oceanography*, *216*, 103065.