

Distribution and Diversity of Zooplankton with the Environmental Factors in some Lentic Water bodies from Bihar, INDIA

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ABSTRACT

Freshwater ecosystems harbour zooplankton that fills as a significant part of the food chain of water bodies. Tragically, these ecosystems and diversity therein are compromised by a lot environmental pressure and pollution. An investigation was led from January 2018 to December 2019 to examine variation in zooplankton with the physicochemical profiles of Katira pond and Surya Mandir pond, Arrah keeping standard methods. Observations showed that during summer season water temperature, total alkalinity, hardness and chloride were observed more during summer season followed by the rainy , post-rainy and rainy season but a reverse pattern was observed for pH, dissolved oxygen, nitrate and sulfate. The water temperature demonstrated a positive relationship with total alkalinity, hardness and chloride whereas a negative correlation with pH, dissolved oxygen, nitrate and sulfate. 43 genera of zooplankton together with 15 rotifers, 10 protozoa, 9 cladocerans, 6 copepods and 3 ostracods were related to a numerical density from 1 to 538unit/L. The density of zooplankton was more distinguished throughout the colder time followed by summer, pre-rainy and rainy seasons. Zooplankton density showed a positive relationship with pH, dissolved oxygen, nitrate and sulfate however a negative relationship with water temperature, chloride, total alkalinity and hardness. Statistical analysis inferred critical contrasts in the spatial variation over physicochemical parameters (excluding nitrate), zooplankton groupings and biodiversity indices (excluding Simpson index). The observed estimates of the Shannon-Weiner index, Margalef Richness Index, Pielou's Evenness Index and Simpson index showed moderate to high diversity of zooplankton and moderately polluted conditions of these ponds.

Keywords: Zooplankton, Physicochemical parameters, Biodiversity indices, Lentic water bodies

Journal of Economic Literature (JEL) Classification: Q25, Q53

Mathematics Subject Classification: 62P12

1. INTRODUCTION

Zooplankton offers a few advantages as markers of natural water quality in both lentic and lotic water bodies (Tiwari and Nair, 2002; Xiong et. al., 2020). The distribution of zooplankton shows wide spatio-temporal variations due to the distinctive hydrographical variables on individual species (Gluchowska et. al., 2017; Pandit et. al., 2020; Matafonov and Itigilova, 2020).

The amendment of plant protein into animal protein utilizes zooplankton (Terbiyik and Polat, 2015). All freshwater environments together with debased modern and metropolitan wastewater are inhabited by zooplankton. Rotifers, protozoans, cladocerans, copepods and ostracods are engulfed by freshwater zooplankton (Karuthapandi et. al., 2016). About 70% of the all out zooplankton is often comprised of copepods (Cook et. al., 2007). Changes in zooplankton bounty, species variety and community composition can show the amendment or unsettling influence of the climate, such as, supplement cycling (Kehayias et. al., 2014).

Seasonal fluctuations of the water bodies influence the physicochemical parameters of water like temperature, pH, dissolved oxygen etc. (Isakov and Chukaeva, 2016; Sukanya and Joseph, 2020). The distribution, abundance and species diversity of zooplankton is concerned by these parameters (Zhang et al, 2015). To work out the fishery resource of a water body, the species diversity and abundance of the zooplankton appears vital (Jose et. al., 2015).

In many regards, limnological investigations of huge artificial or common lake biological systems in Republic of India is considerably more progressed (Ganesan and Khan, 2008; Bhanja et. al., 2014; Adhikari et. al., 2017) than that of more modest ponds (Das et. al., 2015; Banerjee et al, 2019;). Very little thought has been paid to the ponds in city regions that convert waste into abundance by coping with wastewaters through characteristic physicochemical and biological associations. Yet, information is insufficient in quantitative components of zooplankton with physicochemical boundaries and biodiversity concentrates in Arrah. Henceforth, an endeavor has been created to examine certain aspects of the zooplankton of two lentic water bodies of Arrah. The investigation will give the fundamental information of the complete setting and the current state of these water bodies.

2. MATERIALS AND METHODS

2.1. Study Area

Arrah is a municipal corporation in Bhojpur district, Bihar, India. It is situate at a longitude of 83° 45' to 84° 45'. East and the latitude are between 25°10' to 25°40' north and settled at a height of 193 meters above sea level. This city has 2 perennial ponds namely Katira pond and Surya Mandir pond. These ponds are sewage fed into which the surface runoff water and sewage from the surrounding catchments area enter to degrade water quality. Katira pond is 250m long, 220m width and 9m deep with weed laden bank. Katira pond is closed to HD Jain College, Arrah and Veer Kunwar Singh University, Araah contaminated by sewage and municipal wastewater from the abutting households. Therefore, this pond is chosen as a model aquatic ecosystem for students. Surya Mandir pond is 300m long, 300m width and 10m deep with cemented mound (Figure 1) is located near *Ramna Maidan*. In Surya Mandir pond,

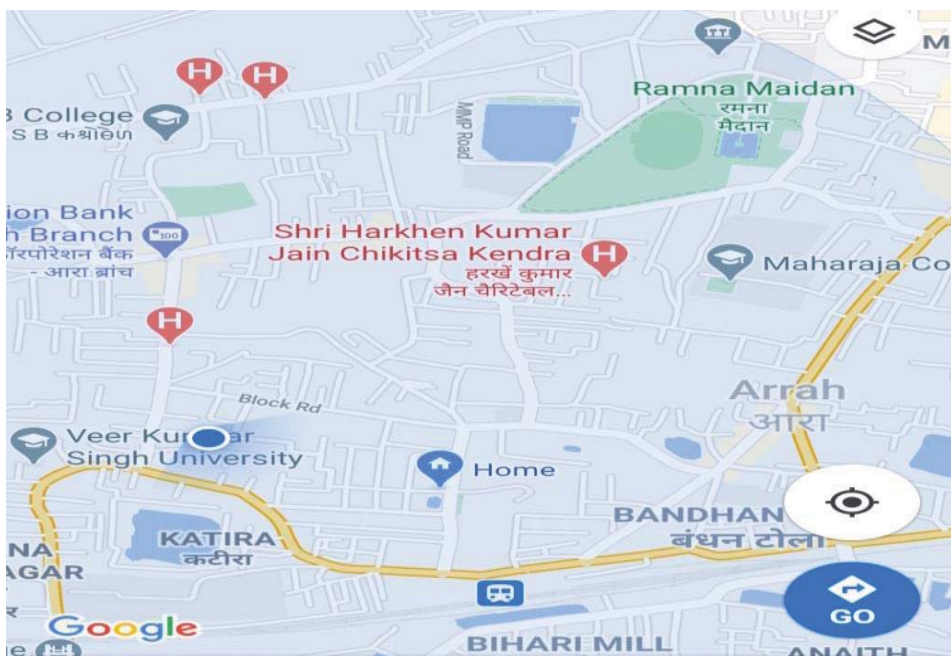


Figure 1. Map of the Arrah and Sampling sites

thousands of devotees come back to celebrate *Chhatha Puja* (*Surya Shasthi Vrata*) twice a year from many areas of the district. *Chhatha Puja* is one of the most awaited holy days in North and Eastern India. During this *Varta*, devotees offer prayers to both the setting as well as the rising Sun.

2.2. Sampling season and Sampling techniques

Water samples were collected monthly basis for a period of January 2018 to December 2019 from three spots fixed at Katira pond and Surya Mandir Pond, Seasonal variations were observed from summer (March, April and May), rainy (June, July, August and September) post-rainy (October and November) and winter (December, January and February) seasons respectively. Water temperature and pH were monitored *in situ* employing a portable refractometer (model 30PX). Dissolved oxygen, total alkalinity, hardness, chloride, nitrate and sulfate were determined following standard methods (APHA, 2012) in the Department of Zoology, VKS University, Arrah.

2.3. Collection, identification and analysis of zooplankton

Samples were collected for qualitative zooplankton analysis by towing in horizontal zig-zag motion at a depth of 0.50 to 1.00 m for 5 to 10 min with a standardized velocity using bolting silk net. The mouth area of the silk net was 0.0855 m² and the mesh size 0.02 mm. For the quantitative analyses, 100L of water was filtered through plankton net of mesh size 55µm. Plankton biomass was transferred to the bottles (50mL) pre-filled with 5% formalin. A stereoscopic microscope and Olympus FX 100 microscope were used for observing plankton and various standard keys were followed for identification (Needham and Needham, 1962). For cell count, a Sedgwick rafter was used. Using the following formula, plankton density present in 1 liter of water sample was calculated (Santhanam et al, 1989):

$$N = n \times \frac{v}{V}$$

Where N = total plankton count per liter of water filtered;

n = average plankton count per 1 ml of plankton sample;

v = concentrated plankton volume (mL) and

V = filtered volume of total water (liter).

2.4. Statistical analysis

The correlation coefficient between physicochemical characteristics and zooplankton were calculated using Microsoft Excel, 2007. Univariate approaches to measure various diversity indices like the Shannon–Wiener index, Simpson's dominance index, Pielou's evenness index, and Margalef's richness index were calculated using Graph Pad Prism 5 software to show zooplankton community structure.

3. OBSERVATIONS AND RESULTS

3.1. Physicochemical parameters

The average water temperature, pH, dissolved oxygen, hardness, chloride and nitrate were determined more in Katira pond compared to Surya Mandir pond. The trend of decrease of water temperature, total alkalinity, hardness and chloride from summer, rainy, post-rainy and winter season was contrary to that of pH, dissolved oxygen, nitrate and sulfate (Figure 2). Values of correlation coefficient and 't' showed significant ($p < 0.05$) differences in the spatial variation of above physicochemical parameters (except nitrate) of Katira pond and Surya Mandir pond (Table 10).

The observations unconcealed that the water temperature of Katira pond and Surya Mandir pond ranged between 15.63 ± 9.78 to 29.58 ± 2.50 °C. Among four different seasons, winter showed the minimum water temperature whereas it had been at peak throughout the summer season during the study period (Figure 2; Tables 1 and 2). The water temperature was found more in summer and less in winter in this study is due to shallowness. Following the trend of water temperature total alkalinity, hardness and chloride of pond water varied between 214.4 ± 29.8 to 308.7 ± 32.2 mg/L, 293.7 ± 7.08 to 326.3 ± 8.91 mg/L and 192.34 ± 5.23 and 228.65 ± 6.65 mg/L respectively. All three parameters were found to be higher in the summer season whereas lower in the winter season (Figure 2; Tables 1 and 2).

Table 1: Physicochemical parameters of water of Katira Pond, Arrah during 2018-2019.

	WT (°C)	pH	DO (mg/L)	TA (mg/L)	TH (mg/L)	Cl ⁻ (mg/L)	NO ₃ ⁻ (mg/L)	SO ₄ ²⁻ (mg/L)
Summer Season	29.58±2.50	7.31±0.05	6.68±0.91	262.3±20.9	326.3±8.91	228.65±6.65	25.3±3.1	180.2±1.42
Monsoon Season	26.37±4.45	7.35±0.58	7.28±0.80	249.6±49.6	323.5±12.6	224.25±6.10	26.7±2.4	184.5±6.02
Post-Monsoon Season	22.10±3.25	7.45±0.21	8.90±0.42	243.6±13.7	311.1±7.88	216.40±6.18	26.9±3.9	202.7±6.40
Winter Season	15.80±3.65	7.54±0.15	9.80±0.20	235.5±25.7	306.2±4.88	212.73±6.13	35.7±2.4	206.7±4.04
Average	24.08±6.28	7.41±0.08	7.98±1.47	248.7±24.8	316.5±1.8	220.63±5.04	28.65±5.0	194.8±7.5

Table 2: Physicochemical parameters of water of Surya Mandir Pond, Arrah during 2018-2019.

	WT (°C)	pH	DO (mg/L)	TA (mg/L)	TH (mg/L)	Cl ⁻ (mg/L)	NO ₃ ⁻ (mg/L)	SO ₄ ²⁻ (mg/L)
Summer Season	29.28±1.60	7.10±0.32	6.47±1.29	308.7±32.2	316.2±10.6	224.40±11.1	24.6±1.7	180.9±1.03
Monsoon Season	26.57±5.41	7.27±0.31	6.70±0.38	264.2±29.5	309.3±13.3	200.64±5.51	25.7±2.1	188.9±8.19
Post-Monsoon Season	22.20±3.39	7.30±0.56	8.65±0.50	246.8±21.6	298.6±7.02	192.67±2.08	28.5±6.4	204.2±5.52
Winter Season	15.63±9.78	7.48±0.37	10.2±0.20	214.4±29.8	293.7±7.08	192.34±5.23	30.0±5.8	208.2±5.69
Average	24.01±6.28	7.29±0.13	8.03±1.73	255.6±45.4	305.3±12.8	202.78±6.75	27.2±5.0	195.6±7.3

On the other hand, pH was found to be alkaline between 7.10 ± 0.32 to 7.54 ± 0.15 throughout the study period and also the lowest was determined throughout summer whereas the highest was in

winter. Similarly, dissolved oxygen, nitrate and sulfate ranged from 6.47 ± 1.29 to 10.2 ± 0.20 mg/L , 24.6 ± 1.70 to 35.7 ± 2.40 mg/L and 180.2 ± 1.42 to 208.20 ± 5.69 mg/L , respectively. All these three parameters showed its' peak in winter season whereas declined in summer season (Figure 2; Tables 1 and 2).

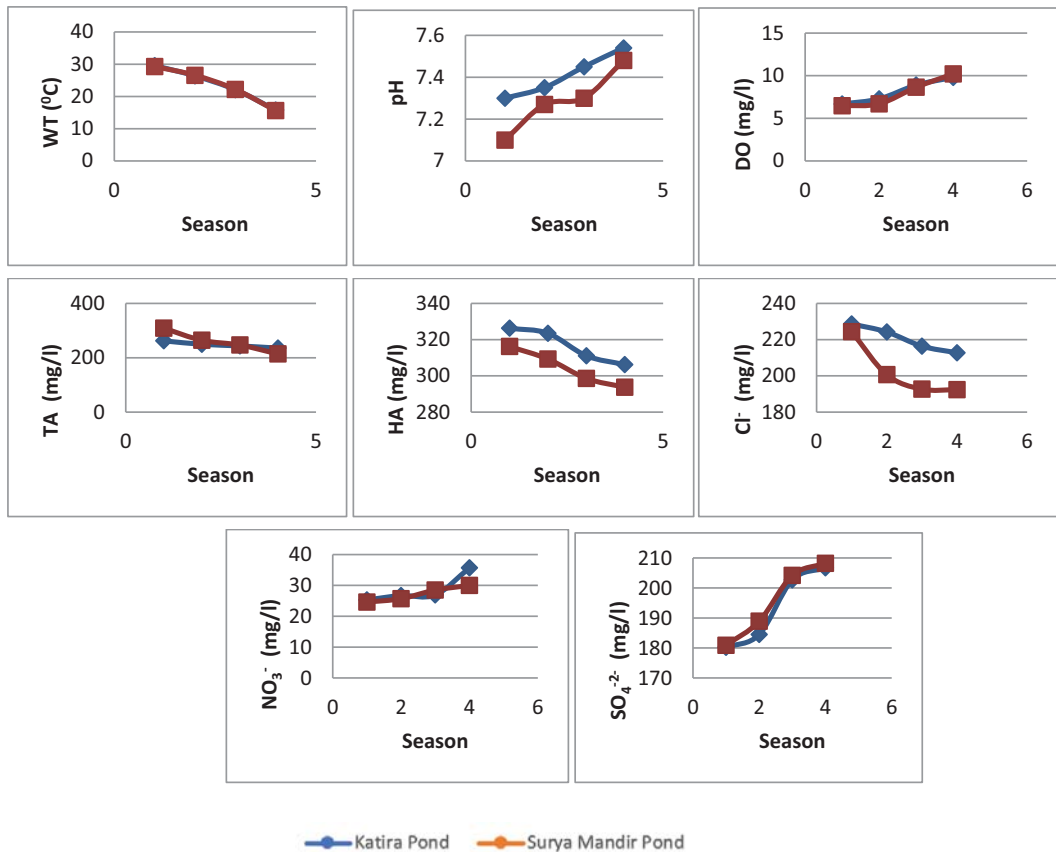


Figure 2. Temporal variation in physicochemical parameters of Katira Pond and Surya Mandir Pond, Arrah.

3.2. Relationship between Physicochemical Parameters

The distinction of water temperature, pH and dissolved oxygen in both the ponds was significant ($p < 0.05$) and vital during this analysis. In addition, the water temperature was positive significant ($p < 0.05$) relationship to total alkalinity, hardness and chloride but negative significant ($p < 0.05$) to pH, dissolved oxygen, nitrate and sulfate. The pH of water showed a significant ($p < 0.05$) positive relationship to dissolved oxygen, nitrate and sulfate. At each location, the dissolved oxygen displayed a significant ($p < 0.05$) relationship of total alkalinity, hardness, chloride, nitrate and sulfate. The hardness of water also showed significant ($p < 0.05$) relationships with chloride and total alkalinity (Tables 3 and 4).

Table 3: Correlation-coefficient of physicochemical parameters of water of Katira Pond, Arrah during 2018-2019.

	WT (°C)	pH	DO (mg/L)	TA (mg/L)	TH (mg/L)	Cl ⁻ (mg/L)	NO ₃ ⁻ (mg/L)	SO ₄ ⁻² (mg/L)
WT (°C))	1.0	-0.994***	-0.980***	0.961**	0.965**	0.972***	-0.916*	-0.943**
pH		1.0	0.994***	-0.949**	-0.987**	-0.985***	0.881*	0.971***
DO (mg/L)			1.0	-0.951**	-0.997***	-0.996***	0.826*	0.990***
TA (mg/L)				1.0	0.929**	0.968**	-0.816 *	-0.922**
TH (mg/L)					1.0	0.991***	-0.796 ^{NS}	-0.996***
Chloride (mg/L)						1.0	-0.795 ^{NS}	-0.989***
Nitrate (mg/L)							1.0	0.743 ^{NS}
Sulfate (mg/L)								1.0

Table 4. Correlation-coefficient of physicochemical parameters of water of Surya Mandir Pond, Arrah during 2018-2019.

	WT (°C)	pH	DO (mg/L)	TA (mg/L)	TH (mg/L)	Cl ⁻ (mg/L)	NO ₃ ⁻ (mg/L)	SO ₄ ⁻² (mg/L)
WT (°C))	1.0	-0.960**	-0.985***	0.954**	0.961**	0.792 ^{NS}	-0.976***	-0.942**
pH		1.0	0.902*	-0.989***	-0.931**	-0.873 *	0.921**	0.902*
DO (mg/L)			1.0	-0.910*	-0.962**	-0.751 ^{NS}	0.985**	0.952**
TA (mg/L)				1.0	0.966**	0.928**	-0.948**	-0.947**
TH (mg/L)					1.0	0.900*	-0.994***	-0.997***
Chloride (mg/L)						1.0	-0.848 *	-0.899*
Nitrate (mg/L)							1.0	0.990***
Sulfate (mg/L)								1.0

(NS= Not Significant, *=Significant, **=Moderately Significant and ***=Highly Significant)

3.3. Composition of Zooplankton

43 genera of zooplankton representing 15 Rotifers followed by 10 of Protozoa, 9 of Cladocerans, 6 of Copepods and solely 3 of Ostracods were identified from Katira pond and Surya Mandir pond (Table 5). The density of zooplankton fluctuated from 1 (0.26%) to 538 (44.98%) unit/l at Katira pond but from 3 (1.16%) to 456 (51.18%) unit/L at the Surya Mandir pond. The average density of various groups of zooplankton (except ostracods) was observed more in Katira pond in comparison to the Surya Mandir pond. The density of zooplankton was at peak during winter followed by summer, post-rainy and rainy seasons. The ostracods showed maximum seasonal variation (Figure 3; Table 6). Values of 'r' and 't' showed significant ($p < 0.05$) differences in the spatial variation of zooplankton groups of Katira pond and Surya Mandir pond (Table 10).

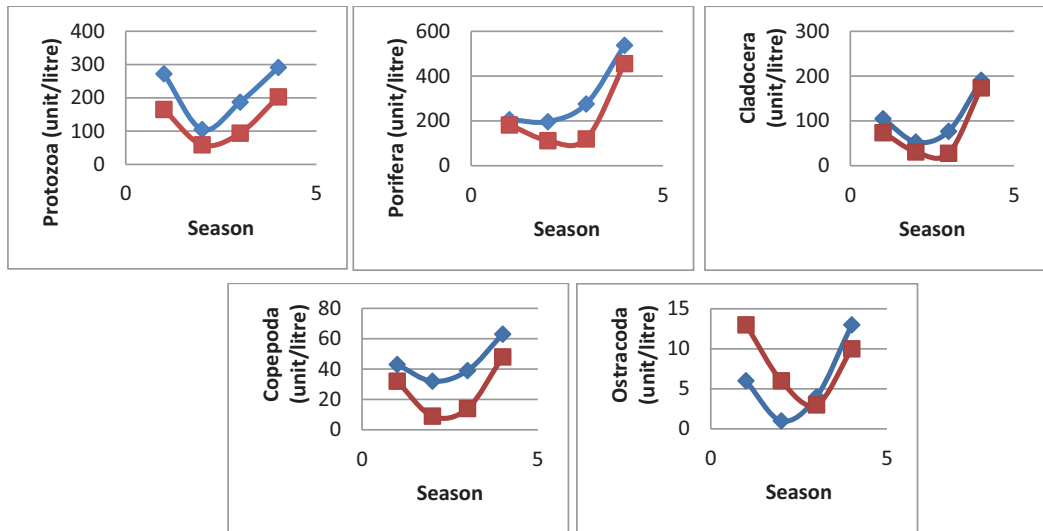


Figure 3. Temporal variation in Zooplankton of Katira Pond and Surya Mandir Pond, Arrah.

Among 43 genera, 14 genera (*Arcella*, *Diffugia*, *Vorticella*, *Brachionus*, *Keratella*, *Lecane*, *Testudinella*, *Bosmina*, *Chydorus*, *Daphnia*, *Diaphanosoma*, *Mesocyclops*, *Thermocyclops* and *Stenocypris*) were found all the four seasons of the study period (Table 5).

Table 5: Representatives of zooplankton composition of Katira Pond and Surya Mandir pond, Arrah during 2018-2019.

Sl. No.	Group	No. of genera	Representatives
1.	Rotifera	15 (34.88%)	<i>Anuraeopsis</i> , <i>Asplanchna</i> , <i>Brachionus</i> , <i>Cephalodella</i> , <i>Filinia</i> , <i>Keratella</i> , <i>Lecane</i> , <i>Lepadella</i> , <i>Monostyla</i> , <i>Mytilina</i> , <i>Notholca</i> , <i>Platys</i> , <i>Polyarthra</i> , <i>Testudinella</i> and <i>Trichocera</i>
2.	Protozoa	10 (23.26%)	<i>Arcella</i> , <i>Balantidium</i> , <i>Ceratium</i> , <i>Centropxyxis</i> , <i>Diffugia</i> , <i>Euglena</i> , <i>Euglypha</i> , <i>Paramecium</i> and <i>Vorticella</i>
3.	Cladocera	9(20.93%)	<i>Alona</i> , <i>Alonella</i> , <i>Bosmina</i> , <i>Chydorus</i> , <i>Daphnia</i> , <i>Daphniosoma</i> , <i>Leydigia</i> , <i>Monia</i> and <i>Pleuroxus</i>
4.	Copepoda	6(13.95%)	<i>Cyclops</i> , <i>Heliodiaptomous</i> , <i>Mesocyclops</i> , <i>Nauplius</i> , <i>Thermocyclops</i> and <i>Tropocyclops</i>
5.	Ostracoda	3(6.98%)	<i>Cypris</i> , <i>Stenocypris</i> and <i>Lothonura</i>

Table 6: Seasonal variation of zooplankton density (unit/Litre) during 2018-2019.

	Katira Pond, Ara					Surya Mandir Pond, Ara				
	Summer	Monsoon	Post-Monsoon	Winter	Total	Summer	Monsoon	Post-Monsoon	Winter	Total
Protozoa	272 (43.04%)	105 (27.06%)	187 (32.08%)	391 (32.96%)	955 (34.12%)	165 (35.41%)	59 (27.19%)	94 (36.29%)	203 (22.78%)	521 (28.42%)
Rotifera	206 (32.59%)	197 (50.77%)	276 (47.34%)	538 (44.98%)	1217 (43.48%)	182 (39.06%)	112 (51.61%)	120 (46.33%)	456 (51.18%)	870 (47.46%)
Cladocera	105 (16.61%)	53 (13.66%)	77 (13.21%)	191 (15.97%)	426 (15.22%)	74 (15.88%)	31 (14.28%)	28 (10.81%)	174 (19.53%)	307 (16.75%)
Copepoda	43 (6.80%)	32 (8.25%)	39 (6.82%)	63 (5.27%)	177 (6.32%)	32 (6.87%)	9 (4.15%)	14 (5.41%)	48 (5.39%)	103 (5.62%)
Ostracoda	6 (0.95%)	1 (0.26%)	4 (0.69%)	13 (1.03%)	24 (0.86%)	13 (2.79%)	6 (2.76%)	3 (1.16%)	10 (1.12%)	32 (1.75%)
	632 (22.58%)	388 (13.86%)	583 (20.83%)	1196 (42.73%)	2799	466 (25.42%)	217 (11.84%)	259 (14.13%)	891 (48.61%)	1833

3.4. Relationship between Physicochemical Parameters and zooplankton

The Correlation-coefficient values of physicochemical parameters of water and zooplankton of Katira pond were found higher compared to the Surya Mandir pond, Arrah. Zooplankton plankton was positively correlated with pH, dissolved oxygen, nitrate and sulfate but negatively correlated with water temperature, chloride, total alkalinity and hardness (Tables 7 and 8). In addition, Rotifers of Katira pond showed a significant positive co-relational statistics with pH, dissolved oxygen, nitrate and sulfate but a significant negative correlation with water temperature, total alkalinity, total hardness and chloride was determined.

Table 7: Correlation-coefficient of physicochemical parameters of water and zooplankton of Katira Pond, Arrah during 2018-2019.

	WT (°C)	pH	DO (mg/L)	TA (mg/L)	TH (mg/L)	Cl ⁻ (mg/L)	NO ₃ ⁻ (mg/L)	SO ₄ ⁻² (mg/L)
Protozoa	-0.586 ^{NS}	0.591 ^{NS}	0.531 ^{NS}	-0.341 ^{NS}	-0.536 ^{NS}	-0.451 ^{NS}	0.753 ^{NS}	0.476 ^{NS}
Rotifera	-0.933 ^{**}	0.918 [*]	0.874 [*]	-0.808 [*]	-0.857 [*]	-0.835 [*]	0.981 ^{***}	0.810 [*]
Cladocera	-0.717 ^{NS}	0.745 ^{NS}	0.639 ^{NS}	-0.507 ^{NS}	-0.631 ^{NS}	-0.571 ^{NS}	0.881 [*]	0.568 ^{NS}
Copepoda	-0.756 ^{NS}	0.748 ^{NS}	0.688 ^{NS}	-0.552 ^{NS}	-0.682 ^{NS}	-0.623 ^{NS}	0.893 [*]	0.623 ^{NS}
Ostracoda	-0.718 ^{NS}	0.714 ^{NS}	0.655 ^{NS}	-0.502 ^{NS}	-0.652 ^{NS}	-0.586 ^{NS}	0.861 [*]	0.593 ^{NS}

Table 8: Correlation-coefficient of physicochemical parameters of water and zooplankton of Surya Mandir Pond, Arrah during 2018 -2019.

	WT (°C)	pH	DO (mg/L)	TA (mg/L)	TH (mg/L)	Cl ⁻ (mg/L)	NO ₃ ⁻ (mg/L)	SO ₄ ⁻² (mg/L)
Protozoa	-0.464 ^{NS}	0.270 ^{NS}	0.508 ^{NS}	-0.187 ^{NS}	-0.253 ^{NS}	0.172 ^{NS}	0.345 ^{NS}	0.227 ^{NS}
Rotifera	-0.787 ^{NS}	0.703 ^{NS}	0.763 ^{NS}	-0.616 ^{NS}	-0.590 ^{NS}	-0.279 ^{NS}	0.655 ^{NS}	0.544 ^{NS}
Cladocera	-0.705 ^{NS}	0.610 ^{NS}	0.683 ^{NS}	-0.512 ^{NS}	-0.487 ^{NS}	-0.157 ^{NS}	0.560 ^{NS}	0.440 ^{NS}
Copepoda	-0.550 ^{NS}	0.391 ^{NS}	0.569 ^{NS}	-0.298 ^{NS}	-0.327 ^{NS}	0.071 ^{NS}	0.420 ^{NS}	0.291 ^{NS}
Ostracoda	0.172 ^{NS}	-0.282 ^{NS}	-0.168 ^{NS}	0.405 ^{NS}	0.423 ^{NS}	0.713 ^{NS}	-0.332 ^{NS}	-0.460 ^{NS}

(NS= Not Significant, *=Significant, **=Moderately Significant and ***=Highly Significant).

3.5. Biodiversity indices of Zooplankton

The mean values of Shannon-Weiner (1949) index ($H' = 1.789$ and 1.812), Pielou (1975) evenness index ($J' = 0.871$ and 0.882), Simpson (1949) index ($1-D' = 0.218$ and 0.312) and Margalef's (1958) index ($d' = 3.465$ and 2.844) of zooplankton composition was more in Surya Mandir pond than Katira pond. On the other hand, the average values of Simpson diversity index ($D' = 0.782$ and 0.688) and Simpson reciprocal index ($\frac{1}{D'} = 4.587$ and 3.207) was more at Katira pond than Surya Mandir pond (Table 9). Values of 'r' and 't' showed significant ($p < 0.05$) differences in spatial variation of biodiversity indices (except Simpson index) of Katira pond and Surya Mandir pond, Arrah (Table 10).

Table 9: Biodiversity indices of Zooplankton in Katira Pond and Surya Mandir Pond, Arrah during 2018-2019.

Phylum/Group	Shannon-Weinner Index		Pielou's Evenness Index		Simpson Diversity Index		Simpson Dominance Index		Simpson Reciprocal Index		Margalef species Richness Index	
	Katira pond	Sutya Mandir pond	Katira pond	Sutya Mandir pond	Katira pond	Sutya Mandir pond	Katira pond	Sutya Mandir pond	Katira pond	Sutya Mandir pond	Katira pond	Sutya Mandir pond
Protozoa	2.164	2.093	0.940	0.909	0.874	0.857	0.126	0.143	7.937	6.993	3.908	3.163
Rotifera	2.385	2.450	0.881	0.905	0.892	0.879	0.108	0.121	9.259	8.264	5.170	3.873
Cladocera	2.011	2.044	0.915	0.930	0.858	0.861	0.142	0.139	7.042	7.194	3.641	3.000
Copepoda	1.570	1.668	0.876	0.931	0.768	0.316	0.232	0.684	4.310	1.462	2.790	2.450
Ostracoda	0.815	0.806	0.742	0.734	0.517	0.525	0.483	0.475	2.072	2.107	1.818	1.732
Average	1.789	1.812	0.871	0.882	0.782	0.688	0.218	0.312	4.587	3.205	3.465	2.844

Table 10: Correlation coefficient (=r) and t-value of physico-chemical parameters, zooplankton groups and biodiversity indices at Katira Pond and Surya Mandir Pond, Arrah during 2018-2019,

Physico-chemical parameters		WT (°C)	pH	DO (mg/L)	TA (mg/L)	TH (mg/L)	Cl ⁻ (mg/L)	NO ₃ ⁻ (mg/L)	SO ₄ ⁻² (mg/L)
Katira Pond v/s	r	0.9992	0.9386	0.9849	0.9955	0.9853	0.8881	0.8208	0.9924
Surya Mandir Pond, Arrah	t	49.96***	4.693*	9.849**	18.11***	10.05**	3.29*	2.49 ^{NS}	14.18***
Zooplankton groups		Protozoa	Rotifera	Cladocera	Copepoda	Ostracoda			
Katira Pond v/s	r	0.9983	0.9848	0.9827	0.9702	0.9076			
Surya Mandir Pond, Arrah	t	30.25***	9.848**	9.184**	6.93**	5.67*			
Biodiversity Indices		Shannon-Weinner Index	Pielou's Evenness Index	Simpson Diversity Index	Simpson Dominance Index	Simpson Reciprocal Index	Margalef genera/species Richness Index		
Katira Pond v/s	r	0.9945	0.9207	0.6186	0.6187	0.9292	0.9977		
Surya Mandir Pond, Arrah	t	19.125***	4.722**	1.578 ^{NS}	1.577 ^{NS}	5.162**	24.94***		

4. DISCUSSION AND CONCLUSIONS

The water temperature, pH, dissolved oxygen, total alkalinity, hardness, chloride, nitrate and sulfate of Katira pond and Surya Mandir pond, Arrah showed significant spatial and temporal variation among the four seasons during the study period. Another major factor for this variation of water parameters could also be the continual discharge of household residuals/sewage effluents (Mamun et. al., 2020). The lowest water temperature is because of heavy breeze and rainfall might be attributed to high radiation (Santhanam and Perumal, 2003). The effect of water temperature on pH, dissolved oxygen and distribution of plankton also are well known (Bhavan et. al., 2015). The observation on pH is in close conformity with the findings of Ghosh (2018) from a pond of West Bengal, India. Aquatic organisms are plagued by pH because most of their metabolic activities are pH-dependent (Balakrishna et. al., 2013). Higher values of dissolved oxygen might well be because of increased photosynthetic activity while lower because of its utilization in the decomposition of organic matter and respiration by aquatic organisms. The findings of Mahobe and Mishra (2013) of two ponds of Chhattisgarh, India have confirmed these results on dissolved oxygen. They clarified that decomposition of organic matters began at a low level of dissolved oxygen. As these ponds obtained

wastewater from neighboring households, it resulted in comparatively high nitrate values. The higher total alkalinity values of these ponds showed that the ambient water had a high buffering capacity. Total alkalinity has been found to be associated to the fluctuations in the photosynthesis of phytoplankton. Ghosh (2018) also recorded the highest total alkalinity during summer in a pond in West Bengal, India and therefore the lowest during winter as observed in our work. Arya et. al., (2011) recorded similar findings on chloride in Laxmi pond, Uttar Pradesh, India as observed in this work. Mishra et. al., (2014) observed the pond water quality in Varanasi and located that the hardness values ranged from 146 to 268 mg/L .

In Assam, India, a positive correlation of water temperature with pH and chloride but negative correlation with hardness, total alkalinity, dissolved oxygen, nitrate and sulfate satisfied the experimental outcome in pond water (Sen et. al., 2011). The pH value of pond water was found to be directly related with total alkalinity, dissolved oxygen and chloride but inversely related with hardness, nitrate and sulfate (Sen et. al., 2011). Chandrashekhar et. al., (2004) observed a negative correlation between hardness and total alkalinity in the Coastal Aquatic Systems round the Industrial Zone of Tuticorin, Tamilnadu. Similarly, Meenakshi et. al., (2002) found a strong positive correlation of hardness with chloride, sulfate and nitrate and an inverse correlation with total alkalinity and dissolved oxygen in the water quality of Western Yamuna, Delhi. Therefore, correlation coefficient analysis is used as a very important technique to interpret the link among the physicochemical variables of the surface water.

To determine water quality of ecosystems worldwide, zooplankton distribution and physicochemical parameters of the water have been previously used (Bhavan et. al., 2015; Adhikari et. al., 2017; Mamun et. al., 2020). During this study, zooplankton abundance peak was documented during the winter season. Earlier, Kumar et. al., (2011) described 19 rotifers, 6 protozoa, 9 cladocerans, 9 copepods and only 3 Ostracods out of 46 genera of zooplankton at Shershab Suri pond, Bihar, India. Shaikh et. al., (2017) identified 25 genera of zooplankton of Copepoda with 17, Protozoa and larva forms consisted of 5 genera and Ostracoda with 3 genera at River Kali of the west coast of India. Among 38 species, Mamun et. al., (2020) reported 17 species during a study in the coastal water of the Northern bay of Bengal, Bangladesh.

During this work, the density of zooplankton fluctuated from 1 (0.26%) to 538 (44.98%) unit/l at these water bodies. Similarly, Nair et. al., (1998) reported that the numerical density of 12 taxa of zooplankton at Vasishti estuary was 108 to 233 unit/l. Almost similar results have also been reported by earlier workers (Bhavan et. al., 2015).

The rotifers contribute to the dominant population and the order of various groups was Rotifers > protozoa > Cladocera > Copepoda > Ostracoda. According to Segers (2008), rotifers are known to be distributed ubiquitously in freshwater ecosystems including sewage ponds. The dominance of rotifers is the indicator of eutrophication and indicates that measures must be taken to minimize aquatic pollution (Manickam et. al., 2015). The abundance and distribution of rotifers have been affected by predation by cladocerans, copepods, etc. The present findings were identical to previous observations by Bhavan et al., (2015) in a perennial lake at Coimbatore, India. From a range of acidic to alkaline

water, the occurrence of *Asplanchna* and *Brachionus* recorded in this work has been documented by Sharma (1992) and also Manickam et. al., (2015).

Zooplankton showed a variation in temporal distribution among the four seasons. The findings indicated that the winter season is that the most subtle period for the growth of zooplankton. Kumar et. al., (2011) also stated that winter season is favorable for the growth of zooplankton because of the rise of the phytoplankton population. The minimum density of zooplankton during rain may well be because of low light intensity, cloudy sky besides high rainfall. Frequent flashing of pond water and gloomy sky during the rain is a major reason for less plankton diversity (Manickam et. al., 2015). Conversely, Sadasivan et. al., (2019) reported a better numerical density of zooplankton during summer and lowest during winter months in Patalganga estuary, Maharashtra, India. Basawarajeshwari et. al., (2015) noted that the highest count of rotifer within the freshwater reservoir from Karnataka, India during the north-east season followed by winter and summer season. Mahor (2011) recorded that ostracods and protozoan were of maximum within the freshwater reservoir in Madhya Pradesh during summer and minimum in rainy months. Higher densities of cladocerans and copepods were observed in Jagat Sagar Pond, Chattapur, India during the winter season and lower in rain by Khare (2005).

The correlation coefficient shows the relationship between density of zooplankton and therefore the major physicochemical variables. It suggests that physicochemical parameters of water are affected by various seasons and it lead to significant differences within the density, diversity, uniformity and richness of zooplankton. The numerical density of zooplankton of ponds and lakes showed an increasing trend during the winter because of favorable temperature, dissolved oxygen etc as explained by Manickam et. al., (2015). Adhikari et. al., (2017) recorded that rotifers were positively correlated with total hardness in a very municipal wastewater-contaminated urban pond of Kolkata, India. Cladocerans, copepods and ostracods of Katira pond also showed significant positive correlations with nitrate. Conversely, a direct relationship between water temperature and zooplankton was observed by Varadharajan and Soundrapandian (2013). During the present study, the utmost zooplankton diversity was recorded within the winter season when pH, dissolved oxygen nitrate and sulfate were higher. This observation indicates that these parameters will form the distribution pattern of zooplankton within the freshwater ecosystem. This result confirms the previous work of Mohanty et. al., (2010).

Community-based features such as diversity indices are commonly used for the assessment of water quality. In general, higher Values of indices indicate better environmental conditions (Abdullah Al et. al., 2018). Wilhm and Dorris (1996) proposed that value of H' <1.0 indicates heavy pollution, from 1.0 to 3.0 moderate pollution and >3.0 non-polluted water. Therefore, present observation ($\bar{x}$ of $H' = 1.806$, range = 0.806 to 2.450) showed heavy to moderately polluted water of these ponds and perhaps a habitat of good diversity. This implies that a community with H' of a maximum value of exp (2.4) of this work has an equivalent diversity as a community with a maximum of 11 equally-common genera. According to Lenat et al. (1980) value of $d' < 1$ indicates heavy pollution, from 1 to 3 moderately polluted conditions and >3 no pollution. Therefore, present observation ($\bar{x}$ of $d' = 3.199$,

range=1.732 to 5.170) showed moderately to non-polluted water of these ponds. The value of d' is passionate about sampling and highlighted genera/species richness of 2 to 5 genera in these ponds. Tiwari and Nair (2002) reported H' from 0.44 to 3.4 and d' from 0.35 to 2.09 at Mumbai harbour. The high values of H' and d' were also calculated by Gholap (2014) at Sadatpur reservoir, Maharashtra, India. The value of J' from 0.734 to 0.940 observed during this work showed similarities with the earlier reports of Gholap (2014). The observation indicated moderate to maximum equitability and a awfully even abundance of genera and permits considerable refinement in diversity studies. The value of D' ranges from 0 to 1. 0 represents numerous genera/species and infinite diversity and 1 for no diversity. Therefore, present observation (D' =0.316 to 0.892) showed numerous genera/species and infinite diversity with mature communities in these ponds. The value of $1-D'$ of $\bar{x}$ =0.88, range=0.108 to 0.684 observed in this work indicates least to moderate diversity. The value of $\frac{1}{D'}$ begins from 1 for only one genus/species. Its value increases with diversity and is influenced by the equitability of percent of each genus present and richness. For a given generic richness, D' decreases because the percent of the genus become more equitable. If there are five genera/species in a sample, then its maximum value will be 5. The value of 1.462 to 9.259 shows conformity with the number of genera (3 to 15) observed in this study. Srichandan et. al., (2013) reported that mean values of H' more than 2 and D' more than 0.9 indicates the healthy diversity of the ecosystem. Some present work indicates some unhealthy diversity of zooplankton in these water bodies.

Based on this study, it may be concluded that the composition and diversity of zooplankton because of the physicochemical parameters of Katira pond and Surya Mandir Pond are in an exceedingly suitable range. Zooplankton including rotifer, protozoa, cladocerans, copepods and ostracods were reported during the study period. Their count was highest during the winter and lowest during the rain. The work infers that temperature has a vital role for the distribution of zooplankton in a freshwater habitat. The values of biodiversity indices indicated a moderate to high diversity of zooplankton, productive and moderately polluted conditions of these ponds. The results depict that more monitoring of the physicochemical parameters of these ponds is critical.

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AUTHOR CONTRIBUTION STATEMENT

First and fourth authors hypothesized and performed experimental works to collect data for this work. Second and third authors analyzed these data and provided the necessary inputs for the design of the manuscript. The methods and findings were discussed by all the authors and contributed to the final manuscript.

CONFLICT OF INTERESTS

The authors have declared that there are no conflicting personal, academic, financial, commercial or political competing interests exist.

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