

## Zooplankton Diversity in Relation to Physico-Chemical Parameters in Subtropical Pond of Jammu, Jammu and Kashmir, India

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The study aim to investigate the zooplankton diversity in relation to physico-chemical parameters of surface water in Barnai pond of Jammu district. Water parameters were analysed by following various standard methods , where as zooplankton were collected through the plankton net of standard bolting silk cloth no. 25 (mesh size 0.003-0.004 im) and the total number of zooplankton was counted by using Drop count method. Statistical analysis of data involves Pearson's Correlation analysis and various diversity indices viz; Shannon-Wiener diversity index ( $H'$ ), Simpson's Index (D), Margalef's Index ( $d'$ ) and Pielou's Evenness (J). A total of 38 zooplankton taxa along with *Nauplius larvae* were observed belonging to 5 major taxonomic groups: Protozoa (6 species), Rotifera (21species), Cladocera (6 species), Copepoda (3 species) and Ostracoda (2species). Physico-chemical parameters of Barnai pond revealed well marked fluctuations with maxima and minima values of each parameter during specific seasons and zooplankton analysis revealed seasonal variations with an increase during summer and a fall during winter and monsoon seasons.

**Keywords:** Physico-chemical parameters, Seasonal variation, Zooplankton, Correlation, Diversity indices.

Functioning of any aquatic system depends to a great extent on the physico-chemical characteristics of its water (Sharmila and Rajeswari, 2015). The quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem (Pandit and Solanki, 2004 and Thirupathaiiah *et al.*, 2012) and it also helps in determining the health of the water body (Shinde *et al.*, 2011). Important physical and chemical parameters influencing the aquatic environment are temperature, rainfall, dissolved oxygen and free carbon dioxide. These parameters are the limiting factors for the survival

of aquatic organisms (flora and fauna) as they provide a way to understand the changes in the abundance and distribution of flora and fauna along with time. Among fauna zooplanktons are key component of food web and their qualitative and quantitative studies play an important role in the water quality assessment. They are an important component of secondary production in aquatic system and act as primary consumers and constitute an important link between primary producers (phytoplankton) and higher consumers like carnivore fish in aquatic food chain (Pradhan,2014). They are known not only to form an integral part of the lentic community

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but also contribute significantly to the biological productivity of the lentic ecosystem (Wetzel, 2001). They are closely linked with their surrounding environment throughout their life cycles, thereby demonstrating abrupt changes in their populations whenever any disturbance occurs. As a result, any change in their abundance, species diversity, or community composition can provide important indications of environmental change or disturbance. Therefore, they are regarded as a potential bio-indicator species for water pollution (Jakhar, 2013). The Zooplankton community fluctuates according to physico-chemical parameter of the environment, and their density in any water is governed by various water quality parameters such as light penetration, temperature, nutrient enrichment, herbivores and heterotrophic microorganisms (Reynolds, 1987). So, the estimation of plankton analysis also helps in explaining the cause of colour, turbidity, presence of odour, taste and visible particles in water (Pradhan, 2014).

The study of zooplankton has been an interesting subject for a long time. In the last two decades much attention has been paid in tropical countries toward the study of biology, ecology and toxicology of zooplankton because of their importance in various emerging concepts in environmental management like environmental Impact assessment (EIA), bio indication of pollution and biological monitoring. Hence zooplankton association, their abundance, seasonal variation, richness and diversity can be used for the assessment of water pollution. The goal of the present paper is to investigate the zooplankton diversity and their seasonal variations in relation to selected water quality parameters to analyse the status of the studied water body.

## MATERIAL AND METHODS

### Study area

Jammu and Kashmir state, the jewelled crown of India with extravagant beauty of Himalayas is located in the extremely northernmost part of Indian sub continent, covering a total geographical area of 2, 22,236 sq. Km. The state shares international border with China and Afghanistan in the north, Tibet in the east and Pakistan in the west, while the states of Punjab and Himachal Pradesh form its southern border.

Major parts of J&K state represent high and rugged mountainous terrain. Moreover, the state is divided into three regions, Jammu, Kashmir, and Ladakh. Jammu is the largest city in Jammu division and the winter capital of state of Jammu and Kashmir.

### Physiography of Jammu

Jammu, like the rest of north-western India, features a humid subtropical climate with a temperature ranging from extreme summer highs reaching 46°C (115°F), to the extreme winter lows reaching 7°C (45°F). The climatic conditions of Jammu experiences four well defined seasons viz; winter, spring, summer and autumn.

Average yearly precipitation is about 42 inches (1,100mm) with the bulk of the rainfall in the months from June to September, although the winters can also be rather wet. Day length varies from 11 hours December to 14 hours in mid-June. Jammu, the southern part of Jammu and Kashmir, lies at the foot hills of Shivalik range at 31°14'29' N latitude and 77°2' 12' E longitude at an elevation of 327m (1,073ft) above mean sea level.

### Barnai pond

Barnai Pond is a stagnant and perennial water body located at 32°45' 50" N latitude and 74°48' 12" E longitude about 10 km away from the Jammu city. The pond is irregularly circular having thick, marshy and sluggish bottom ranging in depth from 14.8 cm during lower water phase to 45 cm during monsoon. It is surrounded by human settlement on one side and temple on other side. Rain water, surface runoff and waste water from the nearby locality are the main sources of water to the pond. During the investigative period, three stations were selected in the pond as

Station I-It was situated near the temple and received anthropogenic as well as domestic waste. This site exhibited luxuriant growth of macrophytes

Station II-This station received domestic waste from the vicinity along with the cattle waste and showed considerable growth of aquatic macrophytes .

Station III- Located exactly opposite to the station I in the shady area. It received huge amount of waste water from the nearby human locality.

### Water: Sampling and Analysis

For the analysis of physico-chemical parameters, monthly collection of water samples

was done for the period of two years (July, 2013-June, 2015) from the selected study sites of water body. Estimation of selected physico-chemical parameters *viz*: temperature, depth, transparency and chemical parameters such as pH, dissolved oxygen, free carbon dioxide, carbonates, bicarbonates, chloride, calcium and magnesium was done on the spot while for rest of the chemical parameters such as nitrates, phosphates and sulphates, water samples were collected in the glass bottles and brought to the laboratory for further analysis.

Methodolgy adopted for analysis of water quality parameters as under:

#### Physical Parameters

1. Air Temperature: It was recorded with the help of a mercury bulb thermometer while avoiding its direct exposure to the sunlight (Welch, 1952).
2. Water Temperature: It was recorded with the help of mercury centigrade thermometer graduated upto 110°C. This was done by dipping the thermometer vertically into the water (Welch, 1952).
3. Transparency: The transparency of the water was determined by Secchi disc of 20cm in diameter (painted black and white on the upper surface) and determined by the formula:

$$T = X + Y/2 \text{ (Welch, 1952)}$$

Where,

T= transparency in cm.

X= depth at which disc becomes invisible.

Y = depth at which disc reappeared while pulling the rope upward.

4. Depth: A graduated meter rode was used for recording the depth (Adoni, 1985)

#### Chemical Parameters

1. pH: pH of the water sample was determined with the help of a portable field pH meter by lowering its bulb directly into the water.
2. Dissolved Oxygen (DO): It was determined by

sodium azide modification of winkler's method (APHA, 1985).

3. Free carbon Dioxide (FCO<sub>2</sub>): Titrimetric method was adopted for the estimation of the free carbon dioxide (APHA, 1985)

4. Carbonate and Bicarbonate: These were estimated following APHA, 1985.

5. Chloride: Argentometric method was used for the estimation of chloride in which Potassium chromate was used as an indicator (APHA, 1985).

6. Calcium and Magnesium: The estimation of calcium and Magnesium was done by the EDTA-Titrimetric method as suggested in APHA (1985).

7. Nitrate: Nitrate was determined by Phenol disulphonic acid method using spectrophotometer (APHA, 1985; Adoni, 1985 and Chopra and Kanwar, 1991).

8. Phosphate: It was determined by Stannous Chloride method using spectrophotometer (APHA, 1985 and Adoni, 1985).

9. Sulphate: Turbiditometric method using spectrophotometer was used to estimate sulphate content of the water samples (APHA, 1985 and Adoni, 1985).

#### Collection of Zooplankton

Planktonic invertebrates or zooplankton were collected by filtering 50 litres of water sample through the plankton net of standard bolting silk cloth no. 25 (mesh size 0.003-0.004 microns). Finally the volume of zooplankton samples was adjusted to 20 ml and preserved by adding 5% formalin. The preserved zooplankton samples were then brought to the laboratory and analysed both qualitatively and quantitatively. The identification was done using the keys by Ward and Whipple (1959), Pennak (1978) and Adoni (1985). Total number of zooplankton was counted by using Drop count method (Adoni, 1985) and calculated using formula:



Station-I



Station-II



Station-III

$$\text{Organisms /litre} = A \times 1/L \times n/v$$

where,

A = no. of organisms per drop.

L = vol. of original sample (l).

n = total vol. of concentrated sample (ml).

v = volume of one drop (ml).

#### Statistical Analysis of Data

Various diversity indices viz; Shannon-Wiener diversity index ( $H'$ ), Simpson's Index(D), Margalef's Index ( $d'$ ), Pielou's Evenness (J) were applied to the resultant data in order to analyse the structural community of zooplankton at different study sites of pond. Pearson's Correlation analysis between abiotic and biotic parameters was also done by using Statistical Package for the Social Sciences software (SPSS Software) (Version -17).

### RESULTS AND DISCUSSION

During the present investigation, a total of 38 Zooplankton taxa along with *Nauplius larvae* were observed from Barnai pond belonging to 5 major taxonomic groups: Protozoa (6 species), Rotifera (21 species), Cladocera (6 species), Copepoda (3 species) and Ostracoda (2 species) (Table 1).

Group Protozoa was taxonomically represented by 4 families viz., Centropxyidae (2 species- *Centropxyxis aculeata* and *C.ecornis*), Difflogiidae (single species- *Difflogia oblonga*), Arcellidae (2 species- *Arcella dentata* and *Arcella megastoma*) and Paramecidae (single species- *Paramecium caudatum*) (Table 1).

Rotifera was taxonomically represented by 6 families viz; Brachionidae (15 species- *Brachionus calyciflorus*, *B.quadridentata*, *B.bidentata*, *B.fulcatus*, *B.plicatilis*, *B.forficula*, *B.angularis*, *Platyias patulus*, *Platyias quadricornis*, *Keratella tropica*, *K.cochlernalis*, *Lepadella sp.*, *Mytilina sp.*, *Cephalodella sp.* and *Colurella sp.*), Lecanidae (2 species- *Lecane luna* and *Monostyla sp.*), Trichoceridae (single species- *Trichocera sulcata*), Asplanchnidae (single species- *Asplanchna sp.*), Testudinellidae (single species- *Filinia longiseta*), Philodinidae (single species- *Philodina sp.*) (Table 1).

Cladocera was represented by 3 families viz; Daphnidae (single species- *Ceriodaphnia sp.*), Sididae (single species- *Diaphanosoma brachyurum*) and Chydoridae (4 species - *Chydorus*

**Table 1.** Diversity of Zooplankton in Barnai Pond (July-2013 to June-2015)

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Protozoa
Family-Centropxyidae
Centropxyxis aculeate
C.ecornis
Family-Difflogiidae
Difflogia oblonga
Family-Arcellidae
Arcella dentata
Arcella megastoma
Family-Paramecidae
Paramecium caudatum
6 species
Rotifera
Family-Brachionidae
Brachionus calyciflorus
B. quadridentata
B.bidentata
B. fulcatus
B.plicatilis
B.forficula
B.angularis
Platyias patulus
Platyias quadricornis
Keratella tropica
K.cochlernalis
Lepadella sp
Mytilina sp
Cephalodella sp
Colurella sp
Family-Lecanidae
Lecane luna
Monostyla sp.
Family-Trichoceridae
Trichocera sulcata
Family-Asplanchnidae
Asplanchna sp.
Family-Testudinellidae
Filinia longiseta
Family-Philodinidae
Philodina sp.
21 species
Cladocera
Family-Daphnidae
Ceriodaphnia sp.
Family-Sididae
Diaphanosoma brachyurum
Family-Chydoridae
Chydorus sphaericus
Alona monocantha
Alonella sp.
Scapholeberis sp.
6 species
Copepoda
Family-Cyclopidae
Cyclops sp.
Mesocyclops leukartii
Tropocyclops sp.
3 species
Nauplius larvae
Ostracoda
Oncocypris pustulosa
Stenocypris sp.
2 species

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*sphaericus*, *Alona monacantha*, *Alonella sp.* and *Scapholeberis sp.*). The fourth most important group *i.e.* Copepoda was represented by a single family Cyclopidae (3 species- *Cyclops sp.*, *Mesocyclops leukartii* and *Tropocyclops sp.*) along with *Nauplius larvae*. The fifth group *i.e.* Ostracoda was represented by only two species *Oncocypris pustulosa* and *Stenocypris sp.* (Table 1).

#### Population dynamics of zooplankton

Overall percent contribution of different groups of total zooplankton population inhabiting

the Barnai pond during the study period of 2 years revealed the dominance of Rotifera (63.54%) followed by Copepoda (19.43%), Cladocera (13.86%), Protozoa (3.02%) and Ostracoda (0.24%)(Fig. 2). Figures 3-5 reveal the order of dominance of different taxonomic groups at all stations depicted the dominance of rotifera over other zooplankton groups and the main species which contributed maximally to the Rotifera population was *Philodina sp.* and its abundance may be due to its high growth rate with attainment

**Table 2.** Mean standard deviations in water quality parameters of Pond depicting minima and maxima in different seasons during the study period (2013-2015)

Water quality parameters	(2013-2014)		(2014-2015)	
	Minimum	Maximum	Minimum	Maximum
Air Temp.(°C)	15.3+0.61(Jan)	39.7+0.17(June)	13.1+0.76(Jan)	40.2+0.76(June)
Water Temp. (°C)	15+0.25(Jan)	29.3+0.32(June)	10+0.76(Jan)	29.8+0.76(June)
Water depth(cm)	16.8+1.79(June)	38 +7.02(Aug.)	16+3(June)	43+4.35(Sept.)
Transparency(cm)	11.5+1(Aug.)	27.3+3.36(Dec.)	12+2.64(Aug.)	27.6+2.51(Dec.)
p H	5.7+0.05(June)	7.3+0.1(Jan)	5.6+0.05(June)	7.2+0.1(Jan)
Dissolved Oxygen(mg/l)	0.5+0.35(June)	4.2+0.5(Jan.)	0.7 + 0.2(June)	4.9 + 0.80(Jan)
Free Carbondioxide	25+ 2(Jan.)	57 + 3.06(June)	27+ 1.53(Jan)	54 + 3.21(June)
Bicarbonates(mg/l)	122.1+2.88(June)	468.3+10.92(Jan.)	115.5+ 5.00(June)	477.3+16.47(Jan)
Chloride(mg/l)	11+2.08(Jan)	37+ 2(June)	10+2.08(Dec.)	37+3.60(June)
Calcium(mg/l)	27.47 + 2.57(June)	65.91+ 1.69(Jan.)	28.3+8.00(May)	65.23+3.04(Dec.)
Magnesium(mg/l)	16.95+0.92(June)	45.22+2.98(Jan.)	22.65+2.38(June)	47.33+1.94(Dec.)
Nitrates(mg/l)	0.117+0.009(Jan)	0.971+0.04(June)	0.092+0.01(Jan)	0.939+0.05(June)
Phosphates(mg/l)	0.043+0.01(Jan)	0.925+0.09(June)	0.045+0.01(Jan)	1.01+0.22(June)
Sulphates(mg/l)	0.005+0.003(Jan)	0.397+0.16(June)	0.05+0.04(Jan)	0.441+0.11(June)

**Table 3.** Mean and standard deviations of Physico-chemical parameters at all the three study sites of Barnai Pond from July-2013 to June, 2015

	(2013-2014)			(2014-2015)		
	St-I	St-II	St-III	St-I	St-II	St-III
Air Temp.(°C)	27.25±17.32	27.9±16.82	27.35±17.61	26.5±19.09	27.5±19.09	26±19.09
Water Temp.(°C)	22.25±10.25	22.55±9.97	22.1±9.76	20±14.14	20.75±13.78	19.25±13.79
water depth(cm)	22.9±11.46	28.25±15.20	31.6±18.95	26.5±19.09	28.5±17.67	33.5±20.51
Transparency(cm)	21.2±12.31	20±12.02	17±9.19	22.5±10.61	19.5±12.02	17.5±10.61
p H	6.6±1.31	6.55±1.06	6.45±1.06	6.5±1.31	6.4±1.13	6.35±1.06
Dissolved Oxygen (mg/l)	4.7±2.54	4.0±2.48	1.85±2.33	5.5±3.46	4.8±2.96	2.35±2.62
Free Carbon dioxide(mg/l)	38.5±21.92	41.5±23.33	43.5±23.33	38.5±17.68	41.5±20.51	43±19.79
Carbonates(mg/l)	0±0	0±0	0±0	0±0	0±0	0±0
Bicarbonates(mg/l)	288.05±238.37	295.95±246.57	301.7±249.61	288.05±251.09	292.95±250.81	308.35±265.66
Chloride(mg/l)	23±16.97	23.5±19.09	26.5±17.68	21±16.97	24±19.79	26.5±19.09
Calcium(mg/l)	44.63±27.43	46.67±27.94	48.78±26.16	42.26±28.19	45.21±28.31	52.83±21.84
Magnesium(mg/l)	29.09±18.45	31.17±20.15	33±21.35	32.95±17.77	34.76±17.41	37.26±17.15
Nitrates(mg/l)	0.518±0.58	0.551±0.62	0.564±0.62	0.493±0.59	0.509±0.579	0.546±0.63
Phosphates(mg/l)	0.426±0.57	0.487±0.62	0.538±0.68	0.428±0.57	0.503±0.643	0.654±0.84
Sulphates(mg/l)	0.142±0.19	0.166±0.23	0.296±0.41	0.167±0.22	0.252±0.277	0.699±0.21

of maximum size in a very short period of time (Moreira *et al.*, 2016). Apart from this, more availability of food and optimum temperature also favoured the growth of Rotifers (Bottrell *et al.*, 1976). In context to the present findings, George

(1966) has also considered a numerical superiority of rotifera over other zooplankton groups, while the observations of Koli and Muley (2012), Jose and Sanal (2012) and Kadam *et al.* (2014) also recorded similar order of dominance.

**Table 4.** Drinking water standards

S.No.	Parameters	Standard Value	Units	Recommended
1.	pH	6.5-8.5	-	ICMR/BIS
2.	DO	4.0-6.0	mg/l	WHO
3.	Ca	75	mg/l	BIS
4.	Mg	30	mg/l	BIS
5.	Chloride	45	mg/l	ICMR/BIS
6.	Sulphate	5.99	mg/l	ICMR
7.	Nitrate	150	mg/l	ICMR

**Table 5.** Seasonal abundance (no./l) of different groups of Zooplankton at all the three study sites of Barnai from July, 2013-June 201

2013-2014	Stations	July	Aug	Sep.	Oct	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Total
Protozoa	I	0	0	0	0	0	0	0	0	0	0	2	4	6
	II	0	0	2	6	0	0	0	1	0	10	18	3	40
	III	0	1	2	0	0	0	0	0	0	0	0	0	2
Rotifera	I	41	20	70	139	21	16	10	10	112	112	153	151	855
	II	38	29	76	67	37	21	9	44	20	37	193	160	731
	III	19	16	53	100	12	43	24	3	9	46	14	106	445
Cladocera	I	14	0	0	5	0	0	0	5	9	0	72	10	115
	II	0	1	0	0	0	0	0	0	2	8	109	0	120
	III	0	0	2	0	0	0	1	10	23	9	128	18	191
Copepoda	I	9	0	22	3	0	0	0	14	8	44	93	91	284
	II	4	5	4	20	2	4	1	11	11	28	39	35	164
	III	8	8	21	2	0	4	6	0	1	11	44	61	166
Ostracoda	I	0	0	0	3	0	0	0	0	0	0	0	0	3
	II	0	0	0	0	0	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	2	1	0	0	0	0	3
2014-2015 Protozoa	I	0	0	1	9	0	0	1	0	0	5	9	0	25
	II	0	0	4	29	0	0	0	9	5	119	4	14	184
	III	0	0	0	9	10	0	2	9	7	0	5	9	51
Rotifera	I	30	66	163	106	69	18	37	8	80	36	189	155	957
	II	87	26	160	180	80	15	30	52	86	65	407	418	1606
	III	12	26	37	227	32	75	30	29	41	25	163	193	890
Cladocera	I	16	2	25	72	11	0	18	5	0	53	154	50	406
	II	13	6	0	123	0	0	0	1	3	37	104	0	287
	III	0	8	0	2	0	0	0	5	0	0	70	0	85
Copepoda	I	26	24	61	71	8	0	5	3	341	12	49	51	651
	II	26	16	51	13	5	4	24	15	50	5	69	36	314
Ostracoda	II	21	46	1	26	8	2	11	1	-	4	34	-	154
	I	0	0	0	2	0	0	0	0	0	0	0	0	2
	II	1	0	0	0	0	0	0	0	0	0	0	0	1
	III	0	0	0	0	0	0	1	1	0	0	0	0	2

**Seasonal variations****Seasonal variations in water quality parameters**

Monthly variations in physico-chemical

parameters of Barnai pond revealed well marked fluctuations with maxima and minima during specific seasons. Mean standard deviations of

**Table 6.** Distribution of zooplankton fauna along various stations of Barnai pond during the study period (2013-2015)

Zooplankton species	Station-I		Station-II		Station-III	
	2013-2014	2014-2015	2013-2014	2014-2015	2013-2014	2014-2015
Protozoa						
<i>Centropyxis aculeata</i>	+	+	+	+	+	+
<i>C.ecornis</i>	-	+	+	+	-	+
<i>Diffugia oblonga</i>	+	+	+	+	-	+
<i>Arcella dentata</i>	-	+	+	+	-	-
<i>Arcella megastoma</i>	-	-	-	+	+	-
<i>Paramecium caudatum</i>	-	+	+	+	-	+
Rotifera						
<i>Brachionus calyciflorus</i>	+	+	+	+	+	+
<i>B.quadridentata</i>	+	+	+	+	+	-
<i>B.bidentata</i>	+	+	-	+	-	+
<i>B.fulcatus</i>	+	+	-	+	+	+
<i>B.plicatilis</i>	+	-	+	+	-	-
<i>B. forficula</i>	-	-	+	-	-	-
<i>B.angularis</i>	-	-	-	+	+	-
<i>Platyias patulus</i>	+	+	+	+	+	+
<i>Platyias quadricornis</i>	+	+	+	+	+	-
<i>Keratella tropica</i>	+	-	-	-	-	-
<i>K. cochlearis</i>	-	-	+	-	-	-
<i>Lepadella sp.</i>	-	+	+	+	-	-
<i>Mytilina sp.</i>	+	-	+	+	-	-
<i>Cephalodella sp.</i>	+	-	+	+	-	-
<i>Colurella sp.</i>	-	+	+	+	-	-
<i>Lecane luna</i>	+	+	+	+	+	+
<i>Monostyla sp.</i>	+	+	-	+	-	+
<i>Trichocera sp.</i>	-	-	-	-	+	+
<i>Asplanchna sp.</i>	+	+	+	+	+	+
<i>Filinia longiseta</i>	+	-	-	-	-	-
<i>Philodina sp.</i>	+	+	+	+	+	+
Cladocera						
<i>Ceriodaphnia sp.</i>	+	+	+	+	+	-
<i>Diaphanosoma brachyurum</i>	-	+	+	+	+	+
<i>Chydorus sphaericus</i>	+	-	+	+	+	+
<i>Alona sp.</i>	+	+	+	+	+	+
<i>Alonella sp.</i>	-	+	-	-	-	-
<i>Scapholeberis sp.</i>	-	+	-	+	+	+
Copepoda						
<i>Nauplius larva</i>	+	+	+	+	+	-
<i>Cyclops sp.</i>	+	+	+	+	+	+
<i>Mesocyclops leukartii</i>	+	+	+	+	+	+
<i>Tropocyclops sp.</i>	+	+	-	+	+	+
Ostracoda						
<i>Oncocypris pustulosa</i>	+	+	-	-	+	+
<i>Stenocypris sp.</i>	-	-	-	+	-	-
Total species	25	27	26	32	22	20

each parameter of all the stations of pond in which air temperature, water temperature, free carbon dioxide, chloride, nitrates, phosphates and sulphates showed summer hike in their values. Their summer maxima might be attributed to the accelerated decomposition of organic matter with rise in temperature and release of excessive nutrients (Chourasia and Adoni, 1985 and Ahwange *et al.*, 2012) and increased respiratory activity of the aquatic organisms at high temperature (Singh *et al.*, 1999; Harney *et al.*, 2013 and Bharama and Korgaonkar, 2015) while Transparency, pH, dissolved oxygen, bicarbonates, calcium, and magnesium reflected winter hike in their values (Table 2). Maxima in dissolved oxygen during winters might be attributed to the decreased

rate of decomposition of organic matter at low temperature (Singh, 2004) and low metabolic activity of aquatic organisms (Sharma, 2002). Moreover, accumulation of bicarbonate ions in water, as the rate of their uptake is declined due to reduced photosynthetic activity in winters (Naik *et al.*, 2015) might be responsible for maxima of bicarbonates. Further, increased solubility of calcium and magnesium ions at low temperature (Singh and Gupta, 2010 and Chowdhary, 2011) and run off loaded with calcium and magnesium ions enter directly or indirectly into the pond during winter rains (Kumar, 1990) may be plausible reason for maximum concentration of calcium and magnesium during winters. Other parameter like water depth revealed maximum values during

**Table 7.** Correlation coefficient (r) between the zooplankton fauna and various physico-chemical parameters of water of Barnai pond

Parameters	Protozoa	Rotifera	Copepoda	Cladocera	Ostracoda
Air Temp.	0.198	0.586**	0.367	0.396	-0.408*
Water Temp.	0.210	0.555**	0.448*	0.364	-0.295
pH	-0.279	-0.573**	-0.432*	-0.414*	0.394
Water depth	-0.225	-0.213	-0.189	-0.247	0.60
Transparency	-0.35	-0.248	-0.226	-0.185	0.175
Dissolved oxygen	-0.250	-0.544**	-0.474*	-0.428*	0.409*
Free carbon dioxide	0.232	0.612**	0.473*	0.476*	-0.430*
Bicarbonate	-0.315	-0.572**	-0.378	-0.458*	0.447*
Carbonate	0	0	0	0	0
Calcium	-0.237	-0.603**	-0.402	-0.518**	0.383
Magnesium	-0.009	-0.451*	-0.276	-0.271	0.345
Chloride	0.210	0.593**	0.458*	0.399	-0.319
Nitrate	0.095	0.449*	0.226	0.237	-0.200
Phosphate	0.197	0.682**	0.348	0.202	-0.316
Sulphate	0.128	0.729**	0.391	0.306	-0.332

\*\*Correlation is significant at the 0.01 level (2-tailed)-reflects the confidence level is 99% and the two parameters show very strong correlation with each other

\*Correlation is significant at the 0.05 level (2-tailed)- reflects the confidence level is 95% and the two parameters show strong correlation with each other but less than (0.01 level)

**Table 8.** Diversity indices used of zooplankton community structure at various stations of Barnai pond from July, 2013- June, 2015

Index	2013-2014			2014-2015		
	I	II	III	I	II	III
Margalef's Richness Index(d)	3.36	3.59	3.13	3.41	3.98	2.68
Simpson's Index(D)	0.24	0.22	0.17	0.15	0.23	0.22
Shannon-Wiener Index(H)	2.05	2.23	1.98	2.27	2.11	2.01
Evenness Index(J)	0.61	0.63	0.72	0.69	0.61	0.67



monsoon and it was due to the surface runoff from the catchment area and inflow of rain water (Chowdhary, 2011). However, station wise analysis did not reveal much differences among these parameters but Station-III of the pond depicted

slightly high values of depth, free carbon dioxide, bicarbonates, calcium, magnesium, chlorides, nitrates, phosphates and sulphates and low values of transparency, dissolved oxygen (Table 3). As per WHO, the standard value of DO is between

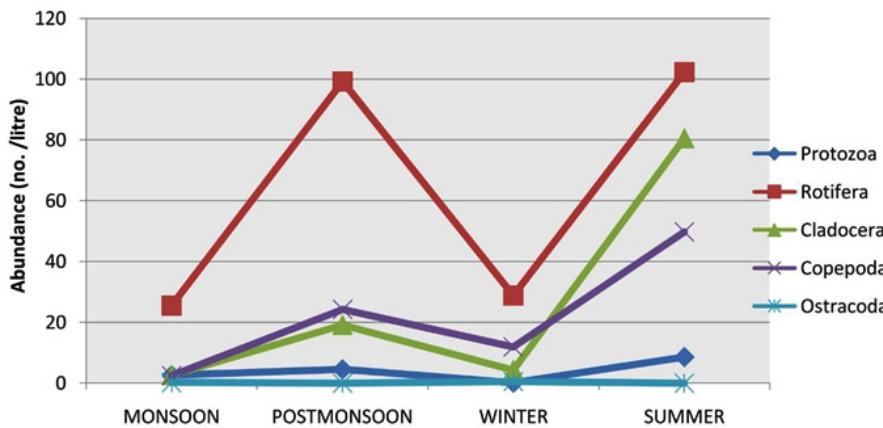


Fig.1. Graphical representation of seasonal variations of different groups of zooplankton in Barnai pond (July, 2013 - June, 2015)

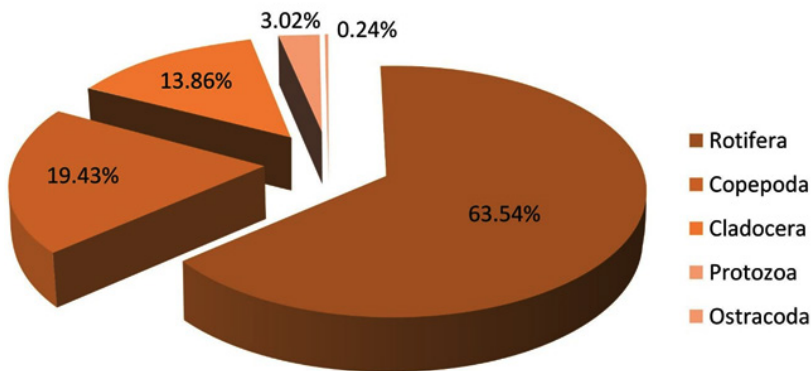


Fig.2. Overall percent contribution of different groups of zooplankton in Barnai pond from July, 2013 - June 2015

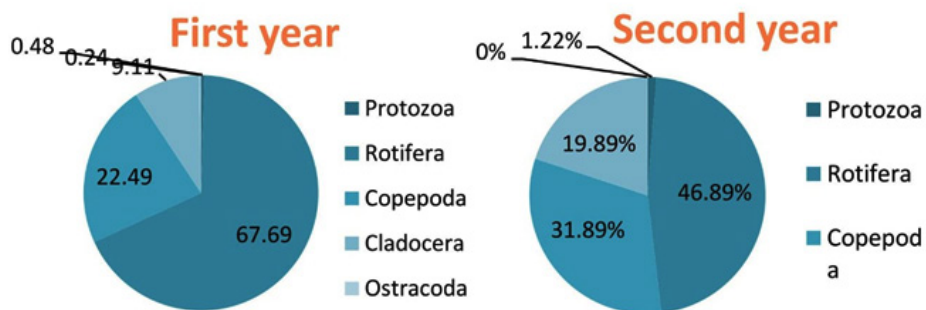
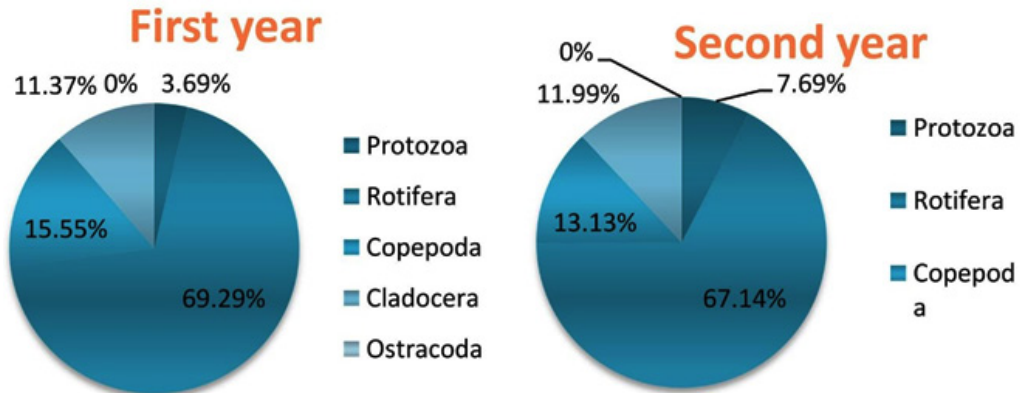
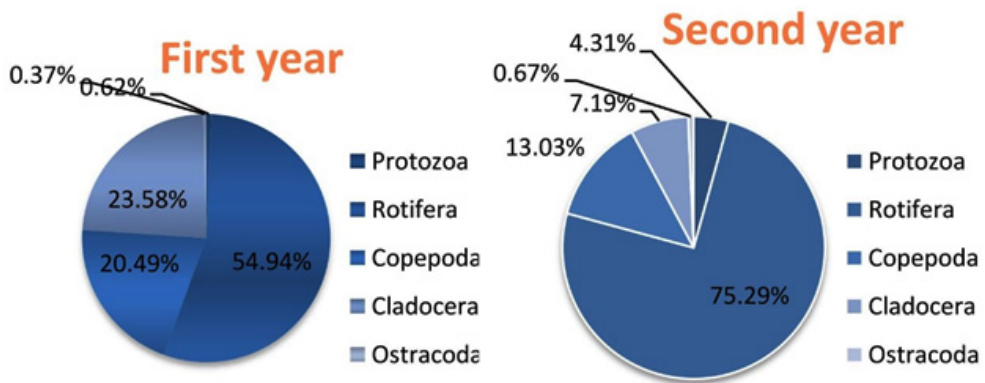


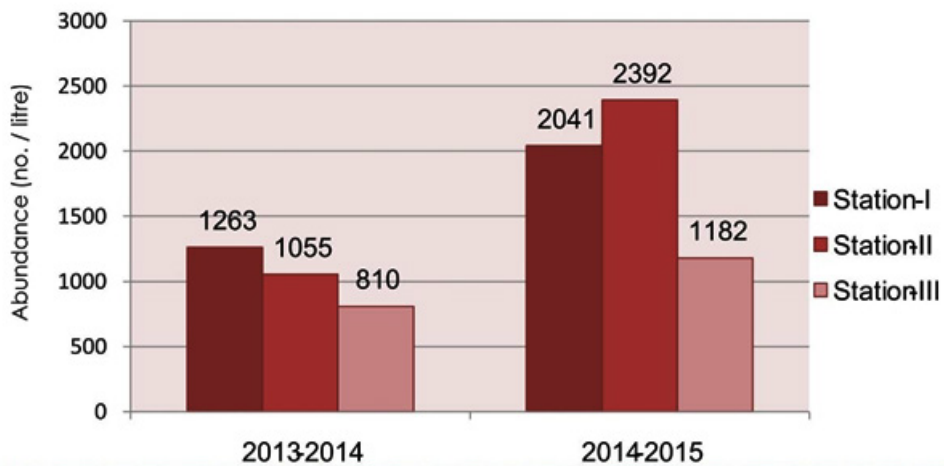
Fig.3. Annual percent contribution of different groups of zooplankton of Station - I in Barnai pond during the first year (2013-2014) and second year (2014-2015) respectively



**Fig.4.** Annual percent contribution of different groups of zooplankton of Station - II in Barnai pond during the first year (2013-2014) and second year (2014-2015) respectively



**Fig.5.** Annual percent contribution of different groups of zooplankton of Station - III in Barnai pond during the first year (2013-2014) and second year (2014-2015) respectively



**Fig.6.** Comparative account of quantitative abundance of zooplankton of all the three stations of Barnai pond during the study period (2013-2015)

4.0-6.0mg/l(Table-4)which reflected the polluted nature of the Station III as it was a victim of huge waste water inflow and domestic sewage from the human locality. Moreover, Site III was shady as compare to Site I and Site II due to the presence of huge marginal tree (*Ficus religiosa*) which might restrict the photosynthetic process of aquatic weeds, thereby causing less production of dissolved oxygen and more production of free carbon dioxide in water. However, Carbonates remained absent at all stations throughout the study period.

#### Seasonal variations in Zooplankton

The density of zooplankton revealed well marked seasonal variations in Barnai pond, with an increase during summer and a fall during winter and monsoon season. However, during post monsoon season, their abundance (147.03 no./l) remained moderate (Fig.1). Varied distribution during different seasons seemed to be greatly influenced by different environmental factors like water temperature, presence of nutrients and physico-chemical factors (Ahmed *et al.*, 2011)

Maximum abundance(241.19 no./l) of zooplankton faunal assemblage in Barnai pond during the summer season was primarily contributed by Rotifera(102.3no./l), Copepoda(49.79no./l) and Cladocera(80.5 no./l) which may be due to favourable environmental conditions (Dede and Deshmukh, 2015), maximum temperature during summer stimulates the rate of decomposition of organic matter (Mishra *et al.*, 2009), availability of more food due to decomposition of organic matter, less predation pressure(Shivashankar and Venkataramana, 2013), increase in nutrient load (nitrate and phosphate) which cause an increase in phytoplankton productivity(Breitburg *et al.*, 1999) and prolific growth of macrophytes during summer may serve as a better refuge for zooplankton (Bozkurt and Guven, 2009).

Similar trend of summer rise in zooplankton abundance has also been put forth by Godhantaraman (2001), El- Sherbiny *et al.*(2011), Sarma *et al.*, 2011), Pradhan (2014), Dede and Deshmukh (2015), Vasanthkumar *et al.*(2015) and Golmarvi *et al.* ( 2017).

The moderate abundance (147.03 no./l) of zooplankton fauna observed during post monsoon may be due to high nutrient flow during this season, maximum abundance in food supply in the form

of bacteria, suspended detritus and senesced macrophytes with withered leaves floating on the surface of water may provide more space and shelter to the zooplankton population (Ahmed *et al.*, 2010 and Rathod *et al.*, 2016).

The characteristic fall in zooplankton population during rainy season i.e. monsoon (July-August) (33.15 no./l) and winter (Jan-feb)( 45.64 no./l) (Fig.1) could be attributed to dilution factors (Rathod *et al.*, 2016) which destabilize the pond ecosystem, thereby affecting the habitat of zooplankton fauna, regular flush out of pond water during rains (Kumar *et al.*, 2011), increased flow of water during rains reduces the detritus, which may disturb the feeding habitat of zooplankton (Sawhney, 2004), high turbidity interferes with the photosynthesis of phytoplankton thus inhibiting their multiplication and ultimately reducing the zooplankton population due to food scarcity (Viroux, 2002 and Kumar *et al.*, 2011).

Similar trend of monsoon decline in zooplankton population has also been put forth by Godhantaraman (2001), Karuthapandi *et al.* (2013), Sharma (2013), Dede and Deshmukh (2015), Manjare (2015), Vasanthkumar *et al.*( 2015) and Rathod *et al.* (2016).

Quantitative abundance of zooplankton population recorded at different stations of the pond revealed maximum abundance(1263no./l at St-I (Ist year-2013 to 2014) and at St-II(2392no./l) (2<sup>nd</sup> year-2014 to 2015) (Table-5 and fig. 6) which might be due to prolific growth of emergent aquatic macrophytes especially during summer which provide day time refuge against predators, better habitat and better feeding ground to the zooplankton fauna Crowder and Cooper,1982; Walsh, 1995; Jeppesen *et al.*, 1998; Burks *et al.*,2006 and Cazzanelli *et al.*,2008), comparatively high DO(Table 3) at both these sites (Kemdirim, 2000) and favourable environmental conditions (Rathod *et al.* 2016) with special reference to the favourable temperature which may directly be responsible for the abundant growth of phytoplankton on which zooplankton are known to feed (Patil *et al.*, 2002).While Station III recorded the lowest abundance(First year-810 no./l; Second year-1182 no./l) both qualitatively and quantitatively (during both the years of study) (table 5,table 6 and fig. 6) which could be attributed

to highly polluted nature of this station as reflected by very less DO (Table 3), absence of sunlight and less abundance of phytoplankton.

Correlation coefficient ( $r$ ) between the zooplankton and physico-chemical parameters exhibited significant positive and negative correlation (Table 7).

Rotifera recorded a positive and significant correlation with air temperature ( $r=0.586$ ), water temperature ( $r=0.555$ ), free carbon dioxide ( $r=0.612$ ), chloride ( $r=0.593$ ), nitrates ( $r=0.449$ ), phosphates ( $r=0.682$ ), sulphates ( $r=0.729$ ) while negative and significant correlation with pH ( $r=-0.573$ ), dissolved oxygen ( $r=-0.544$ ), bicarbonates ( $r=-0.572$ ), calcium ( $r=-0.603$ ) and magnesium ( $r=-0.451$ ). Tidame and Shinde (2012), Bera *et al.* (2014) and Sivalingam *et al.* (2016) also recorded a significant positive correlation of rotifers with temperature and free carbon dioxide.

Copepods recorded a positive and significant correlation with water temperature ( $r=0.448$ ), free carbon dioxide ( $r=0.473$ ) and chloride ( $r=0.458$ ) while negative and significant correlation with pH ( $r=-0.432$ ) and dissolved oxygen ( $r=-0.474$ ) (Bera *et al.*, 2014). Positive correlation with water temperature and negative correlation with pH coincides with the investigation of Koli and Muley (2012) in Tulsi Reservoir, Maharashtra.

Cladocerans recorded a negative and significant correlation with pH ( $r=-0.414$ ), dissolved oxygen ( $r=-0.428$ ), calcium ( $r=-0.518$ ) while positive and significant correlation with free carbon dioxide ( $r=0.476$ ).

Ostracods recorded a positive and significant correlation with dissolved oxygen ( $r=0.409$ ) and bicarbonate ( $r=0.447$ ) while negative and significant correlation with air temperature ( $r=-0.408$ ) and free carbon dioxide ( $r=-0.430$ ). Significant positive correlation of Ostracods with dissolved oxygen and bicarbonate coincides with the findings of (Sivalingam *et al.*, 2016).

Various diversity indices viz; Shannon-Wiener diversity (H), Margalef's richness (d), Pielou's evenness index (J) and Simpson's dominance index (D) were derived to analyse zooplankton community structure in Barnai pond

and the results of statistical analysis revealed marked variability at different stations (Table 8). During the first year (2013-2014), the values of various diversity indices i.e. (H), (d), (J), and (D) were 2.05, 3.36, 0.61 and 0.24 at Station-I; 2.23, 3.59, 0.63 and 0.22 at Station-II and 1.98, 3.13, 0.72 and 0.17 at Station-III respectively. Similarly during the second year (2014-2015), the values of (H), (d), (J), and (D) were 2.27, 3.41, 0.69 and 0.15 at Station-I; 2.11, 3.98, 0.61 and 0.23 at Station-II and 2.01, 2.68, 0.67 and 0.22 at Station-III respectively.

Perusal of the table 8 further depicted high values of Shannon-Wiener index at Station-II (H=2.23) during the first year (2013-2014) and at Station-I (H=2.27) during the second year (2014-2015), thus indicating more species diversity at these study sites. Values of Margalef's richness index was higher at Station-II (d= 3.59; d= 3.98) during both the years of study indicated quantitative richness, while high values of Pielou's evenness indicated even distribution of organisms at Station-III (J=0.72) during the first year and at Station-I (J=0.69) during the second year. Values for Simpson's dominance index close to zero indicate satisfactory diversity status (Hazarika, 2013) and in the present studies, these values were observed to be more satisfactory at Station-III (First year) and at Station-I (Second year).

## CONCLUSION

The present study indicated that summer is the most favourable season for the maximum abundance of zooplankton followed by post monsoon, winter and monsoon and their distribution was greatly influenced by different environmental factors and physico-chemical parameters viz; temperature, pH, dissolved oxygen, free carbondioxide, carbonates, bicarbonates, calcium, magnesium, chloride, nitrates, phosphates and sulphates. Moreover, the maximum abundance of Rotifera both qualitatively and quantitatively at all stations indicated the eutrophic status of the studied water body.

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