International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133, Print ISSN: 2664-7125
Received: 29-06-2021, Accepted: 14-07-2021, Published: 30-07-2021
Volume 3, Issue 3, 2021, Page No. 65-71

Zooplankton diversity and physico-chemical conditions in bommanahalli reservoir of Uttara Kannada district Karnataka, India

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Abstract
A study on zooplankton diversity and physicochemical conditions at Bommanahalli reservoir located in Kali tiger reserve was undertaken from July 2017 to September 2018. Water parameters like Atmospheric temperature, Water temperature, pH, Transparency, Conductivity, Suspended solids, Total solids, Hardness, Alkalinity, Chloride, Sulphate, and BOD were studied. A total of 31 zooplankton species were recorded. Rotifera was the dominant group represented with 11 species. Cladocera was the most abundant group with the highest number of individuals. *Tropocyclopsprasinus* was the most abundant species. Shannon's and Simpson indices were found highest to Rotifera, while lowest for Ostracoda. Evenness was highest in Copepoda but Dominance was maximum for Ostracoda. Canonical Correspondence Analysis (CCA) indicates Cladocera and Rotifera show negative response to Water temperature were as Copepoda shows a positive response to Air temperature, EC and Turbidity.

Keywords: bommanahalli, zooplankton, water quality, diversity, CCA

Introduction
The aquatic ecosystem plays an important role in balancing environmental changes. The water cycle is essential to sustain every life on earth. As the environment is the interaction of biotic and abiotic components, an ecosystem is a part of this environment that comprises producers and consumers where the energy transfer takes place in the form of a food chain through the tropic levels. Plankters play a major role in energy transfer at different trophic levels of an aquatic ecosystem [1]. Zooplanktons take the intermediate level in tropic status that passes energy from lower to higher tropic level in the food web [2] and they are also considered as biological indicators of eutrophication [3, 4, 5]. To understand the trophic dynamics of an aquatic ecosystem it is necessary to consider the water quality parameters [6]. Abiotic factors comprise physical and chemical variables that can be correlated with biotic factors to specify the condition of the given water body. Water quality parameters like DO, Free CO2, Chlorides, Hardness, Alkalinity, pH, Temperature, Turbidity, Salinity, Conductivity and many play a significant role in balancing the aquatic ecosystem.

Uttar Kannada is one of the ecologically sensitive districts situated in the Western Ghats of Karnataka State with the higher vegetation cover in India [7]. Due to factors like growing population and mega developmental projects, much of its natural landscape and the natural resource are under severe pressure. Deforestation, encroachment, submergence, forest fragmentation, river pollution, and other impacts are already being witnessed. It has a total area of about 10, 24, 679 hectares with an annual rainfall of 2, 427 during 2017. It has four big reservoirs, 81 small reservoirs, and 2,290 tanks with less than 40 hectares of area and four canals [8]. The studies on lentic habitats of Uttara Kannada are limited to few reports [9, 10, 11]. However, the ecological studies concerning water quality and zooplankton diversity in this area are scanty and on water bodies that are located within and surrounding the protected area are almost nil. Therefore the present work was undertaken to investigate the water quality and zooplankton diversity of the Bommanahalli reservoir.

Materials and methods
1. Study area
Bommanahalli reservoir is the third dam site built across the Kali river situated in Halyal Taluka of Uttar Kannada District of Karnataka (Latitude 15°10'5.2 ''N; longitude 74°42'37.4 ''E). It has a catchment area of 1683 sq Km, The dam is 1024.8m in length and 30.45m in height, having a water capacity of 84.8 million m^3.

2. Collection of sample and Analysis
Samples were collected at a specific point at Bommanahalli reservoir monthly between 06:00 to 09:00 hrs from July 2017 to September 2018. Collection and analysis of samples were conducted according to standard methods. Few physicochemical parameters were analysed at the sample collection point and the rest were analysed in the laboratory. Eutech PCS Tester 35 probe was used to measure pH, Electric conductivity, TDS, and Salinity. A digital thermometer was used to record the water and atmospheric temperature. A nephelometer was used to determine turbidity. Chemical parameters like Hardness, Alkalinity, Chloride, Sulfide, BOD, Dissolved oxygen were analysed in the laboratory using standard methods [12]. For zooplankton studies, samples were collected using plankton net (68µm). 100 liters of water was sieved to collect one liter of sample. 4% formalin was used to preserve the samples. A subsample was used to analyse the zooplanktons with the help of the Olympus CH 20i microscope. For quantitative analysis of planktons, Sedgwick Rafter chamber was used. Zooplankton were identified to

possible taxonomic level with the help of Specialised bibliography [13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28].

3. Statistical Analysis

Pearson correlation was used to study the interrelation between water quality variables using SPSS software (IBM) version 21 (Table-3). The data were analysed with a software program Past, which generates diversity indices with the help of zooplankton abundance count (Table-5). CCA was also done using Past software.

Result and Discussion

1. Abiotic factors

Physico-chemical parameters recorded at Bommanahalli reservoir are presented in Table-1. Water temperature was recorded minimum in December 2017 (16 °C) and maximum during July 2018 (26 °C). Water temperature always remained lower than the air temperature. The air temperature was minimum during May 2018 (18 °C) and maximum during July 2017 (28.8 °C). However, during July 2018 water temperature was more than the air temperature. Similar observations were made at Mudageri and Hotgali tank of Uttara Kannada District, Karnataka State [29], and Gajoldoba and Domohani Beel wetlands at West Bengal [30]. Suspended solids remained in the range of 10 mg/l to 28 mg/l, higher values were observed during July 2018. Dissolved solids ranged between 22 and 38 mg/l. The maximum dissolved solids were observed during June and July 2018. The higher values of suspended solids, dissolved solids, and total solids during rainy months are due to the influx of runoff water caused by rains. The dissolved solids showed a positive correlation with suspended solids (Table-3). Hardness is caused by compounds of calcium and magnesium and by a variety of other metals. In the present study, the hardness was ranged between 20 mg/l and 38 mg/l with its maximum value recorded during June 2018. Hardness was positively correlated with suspended solids and total solids. The total alkalinity of freshwater lakes is generally low, thus making them poorly buffered and susceptible to acidification [31]. The alkalinity in the present study varied between 24 mg/l and 46 mg/l with its highest value observed during rainy days indicate nutrient richness [32]. Chloride was having a maximum value of 7.8 mg/l in September 2018 and a minimum of 6 mg/l in April 2018. Chloride levels depict the effects of decomposition [33]. In the present study chlorides values were significantly correlated with suspended solids, total solids, dissolved solids, and hardness. The maximum value for Sulphate was 16.4 mg/l during September 2018 and a minimum value of 14 mg/l was observed during March 2018. A similar trend of highest values of sulfate in the rainy season and lowest in the summer season was also observed at Banglore [34]. Sulfate showed a positive correlation with alkalinity (Table-3). BOD values ranged from 1 mg/l to 2.4 mg/l in the present study and are positively correlated with pH. Dissolved oxygen levels ranged between 7 and 8.5 mg/l. The highest value was recorded in August 2018. Dissolved Oxygen was positively correlated with pH (Table-3). Similar observations were reported at the nearby Supa reservoir [33]. Electric conductivity values varied throughout the study period. Maximum conductivity of 516 µS/cm was recorded in September-2017 and a minimum value of 136 µS/cm was observed in April 2018. A high concentration of ionic constituents in the water body during rainy days is the reason for high values of conductivity [35]. In the present study, conductivity was negatively correlated with pH and BOD. The turbidity value was highest in June 2018 (800NTU) and it was lowest in December 2017 (20NTU). The higher values of turbidity during the rainy season are due to the silt brought into the reservoir which later declined during the winter and summer months. A similar trend was noted at Khanapur freshwater reservoir from Ajara Tahsil, Kolhapur district, Maharashtra, India [36].

Table 1: Monthly variations in physico-chemical parameters at Bommanahalli reservoir.

Sl. No	Parameter	Jul 17	Aug 17	Sep 17	Oct 17	Nov 17	Dec 17	Jan 18	Feb 18	Mar 18	Apr 18	May 18	Jun 18	Jul 18	Aug 18	Sep 18
1	AT ° C	28.8	27	26	27	26	24	26	27	28	27.3	18	26	25	24	26
2	WT ° C	25	24	16	16	17	16	17	20	19	24	25	24	26	21	19
3	pH	7.3	7.1	7.1	7.4	7.3	7.3	7.4	7.3	7.3	7.5	7.4	7.4	7.4	7.7	7.4
4	S.S mg/l	13	12	14	12	10	12	12	10	10	10	14	22	28	26	24
5	D S mg/l	32	26	32	30	24	22	36	26	24	22	28	38	38	34	38
6	T.S mg/l	45	38	46	42	34	34	48	38	34	32	42	60	66	60	62
7	Hardness mg/l	26	30	30	22	24	26	20	24	22	26	22	38	36	38	36
8	Alkalinity mg/l	46	36	36	26	26	44	24	32	28	32	36	30	38	36	34
9	Chloride mg/l	7	6.4	6.6	7.2	6.4	6.4	6	6.4	6.2	6	6.8	7.2	7.8	7.6	7.8
10	Sulfate mg/l	15.8	15.2	15	14.2	15	15.6	14.6	14.4	14	14.6	14.6	14.6	15.4	16	16.4
11	BOD mg/l	1.1	1	1.4	1.8	1.8	1.8	1.4	1.6	2	1.8	1.2	2.2	1.8	2.4	1.6
12	DO mg/l	7	7	7	7.8	7.8	7.4	7.4	7	7.3	7.3	7.6	7.4	7.8	8.5	7.8
13	EC µS/cm	516	420	516	186	148	151	223	161	159	136	174	234	236	210	236
14	Turbidity NTU	300	200	200	200	50	20	50	50	30	30	50	800	300	200	500

AT= Atmospheric temperature, WT=Water temperature, S.S =Suspended solids, D.S= Dissolved solids. DO=Dissolved oxygen, EC=Electric conductivity

Table 2: Correlation between Physico-chemical parameters at Bommanahalli reservoir (July-2017 to September-2018).

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	pH														
2	Suspended solids Mg/L	.48													
3	Dissolved solids Mg/L	.27	.78**												
4	Total solids Mg/L	.4	.95**	.94**											

5	Hardness $CaCO_3$ Mg/L	.27	.87**	.60*	.78**										
6	Alkalinity $CaCO_3$ Mg/L	-.13	.23	-.02	.11	.31									
7	Chloride Cl Mg/L	.39	.88**	.71**	.85**	.73**	.28								
8	Sulphate SO_4 Mg/L	.17	.58*	.37	.5	.61*	.63*	.57*							
9	Turbidity NTU	.08	.65**	.73**	.72**	.74**	.08	.65**	.3						
10	B O D Mg/L	.64*	.41	.1	.28	.4	-.29	.28	-.05	.21					
11	Dissolved O_2 Mg/L	.77**	.61*	.32	.49	.37	-.18	.59*	.33	.1	.62*				
12	*Cond* µS/cm	-.55*	.04	.29	.16	.21	.47	.11	.33	.28	-.57*	-.47			
13	Air temperature °C	-.25	-.24	-.04	-.14	-.02	-.15	.18	-.07	.13	.04	-.38	.29		
14	Water temperature °C	.19	.35	.19	.29	.35	.38	.27	.12	.32	-.17	-.08	.16	-.15	

Note: N=15, *P<0.05, **P<0.01.

Table 3: Monthly variations of Zooplanktons at Bommanahalli reservoir from July 2017 to September 2018

Planktons	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep
Cladocera															
Alona pulchella	24	25	20	22	15	13	8	20	21	25	30	34	35	30	20
Daphnia carinata	48	-	47	-	28	18	-	-	13	17	17	13	-	-	-
Moina oryzae	-	-	-	-	-	15	-	40	28	34	31	47	49	48	52
Alona monocantha	16	29	-	24	21	15	-	-	-	18	-	-	-	-	19
Bosminopsis dietersi	32	35	30	-	-	20	-	9	7	-	26	32	30	29	-
Macrothrix goeldi	5	-	-	-	7	4	4	-	-	-	-	-	-	8	9
Diaphanosoma excisum	32	31	36	24	15	13	-	-	19	-	33	36	37	-	-
Leidigia ssspacanthocercoides	2	3	8	-	3	4	-	2	2	1	-	-	5	-	2
Chydrous reticulatus	39	32	34	39	-	12	-	-	21	28	22	26	17	16	-
Total	198	155	175	109	89	114	12	71	111	123	159	188	173	131	102
Copepoda															
Heliodiaptomus viduus	36	39	32	22	18	11	8	-	16	18	27	26	-	29	33
Paracyclops fimbriatus	22	17	-	8	-	10	-	18	21	-	-	21	-	24	22
Neodiaptomus strigilipes	43	41	25	18	15	10	-	-	-	-	12	15	18	-	-
Tropocyclops prasinus	55	53	46	45	-	33	-	-	33	30	-	50	-	43	-
Rhinodiaptomus indicus	39	38	35	33	29	22	-	15	19	-	-	22	26	35	38
Mesocyclops leucarti	22	-	21	29	31	25	18	-	16	12	26	23	21	-	-
Mesocyclops hyalinus	-	35	37	-	39	-	-	-	26	28	29	31	33	-	-
Total	217	223	196	155	132	111	26	33	131	88	94	188	98	131	93
Rotifera															
Brachinus. calyciflorus	12	14	15	14	8	13	-	7	9	11	12	13	8	9	-
B. caudatus	2	-	3	5	4	-	5	-	7	-	9	9	8	7	7
B. diversicornis	1	3	2	-	5	-	-	1	2	-	1	2	1	3	1
B. quadridentatus	21	13	15	25	-	-	-	-	3	-	-	14	17	19	21
B. falcatus	29	31	-	12	17	16	-	-	19	21	-	27	-	26	-
Platias quadricornias	3	7	-	4	-	-	-	-	-	-	-	-	-	-	-
Keratella cochlearis	42	43	34	-	23	-	15	-	12	-	14	-	-	-	-
Polyarthra sps	33	31	-	25	-	18	-	-	-	25	29	38	36	31	-
Lecane sps	-	-	-	-	8	-	-	-	10	16	12	12	13	8	-
Keratella tropica	35	38	40	42	40	33	-	-	31	-	28	22	21	18	18
Lecane luna	8	7	9	11	8	9	-	8	-	11	8	12	9	8	-
Total	186	187	118	138	113	89	20	16	93	84	113	149	113	129	47
Ostracoda															
Hemicypris fossulata	25	28	30	31	28	-	-	26	27	28	32	31	29	31	-
Darwinula sps	32	30	26	-	25	20	19	-	-	32	36	34	37	-	-
Stenocypris hislopi	11	19	21	-	25	25	25	-	18	21	24	26	28	31	33
Ilyocypris gibba	8	9	13	12	13	8	-	10	-	7	10	8	6	7	8
Total	76	86	90	43	91	53	44	36	45	88	102	99	100	69	41

2. Biotic factors

A total of 31 taxa were recorded, which include 11 Rotifera, 9 Cladocera, 7 Copepoda, and 4 Ostracoda. The highest species richness and abundance was observed during July 2017 with 28 species and 677 ind/l. The highest species richness during the monsoon period was also reported in riverine waters [37]. Species richness and abundance were at their lowest during January 2018 with 8 species and 102ind/l (Table-4). In the present study, Rotifera was the dominating group represented with the highest species richness. *Tropocyclops prasinus* was the most abundant species in the present study. The maximum number of rotifers is due to their special ability to filter suspended materials to obtain food [38]. Similar observations were reported at Doddavaddarahalli lake, Bangalore [39], and Thoppaiyar reservoir, Dharmapuri District, South India [40]. Copepoda was the most abundant group in the present study represented with

30% of the total zooplanktons (Fig.2). In this group, *Paracyclops fimbriatus* was the least registered species. Cladocera was the second most abundant group after Copepoda. *Alona pulchella* member of this group was the only zooplankton that was recorded throughout the study period. In Bommanahalli reservoir, Ostracods were represented with minimum species richness and abundance. *Ilyocypris gibba* was the least abundant species in the present study. Similar observations were recorded in the nearby Supa reservoir [8].

Table 4: Diversity indices for Zooplanktons of Bommanahalli reservoir.

	Cladocera	Copepoda	Rotifera	Ostracoda
Taxa_S	09	07	11	04
Individuals	1910	1916	1595	1063
Dominance_D	0.1422	0.1538	0.1349	0.2768
Simpson_1-D	0.8578	0.8462	0.8851	0.7232
Shannon_H	2.022	1.907	2.146	1.324
Equitability_J	0.9202	0.9801	0.895	0.9549
Evenness_e^H/S	0.8391	0.9619	0.7774	0.9394

3. Diversity indices

Shannon's diversity index was found highest for Rotifera (2.14) while it was least for Ostracoda (1.32). Simpson diversity was highest for Rotifera (0.8651) and lowest for Ostracoda (0.7232). Species richness and diversity indices exhibit an identical pattern.

4. Evenness

Species evenness values ranged from 0 to 1, where 1 is the maximum species diversity. In the present study, the evenness index ranged between 0.77 and 0.96. The highest evenness was observed for Copepoda (0.9619) and the lowest for Rotifera (0.7774). As the sampling site of the study area was shallow we found benthic forms (Ostracodes) whose species richness was low but dominance was highest (0.2768) compared to other groups.

5. CCA

Canonical Correspondence Analysis (CCA) was used to analyse and evaluate the relationships between the physical factors like Temperature (°C), Turbidity (NTU), and Electric conductivity (µS/cm) and the zooplankton groups in Bommanahalli reservoir suggest that Cladocera and Ostracoda show positive response to EC and Turbidity. Rotifera shows a positive response to Water temperature. Copepoda shows a negative response to Air temperature (Figure-3). The Eigenvalues for Axis -1 = 0.026252, P = 0.24 and Axis - 2 = 0.0055381, P = 0.158. Percentage of Axis 1 = 82.58% and Axis 2 = 17.42%.

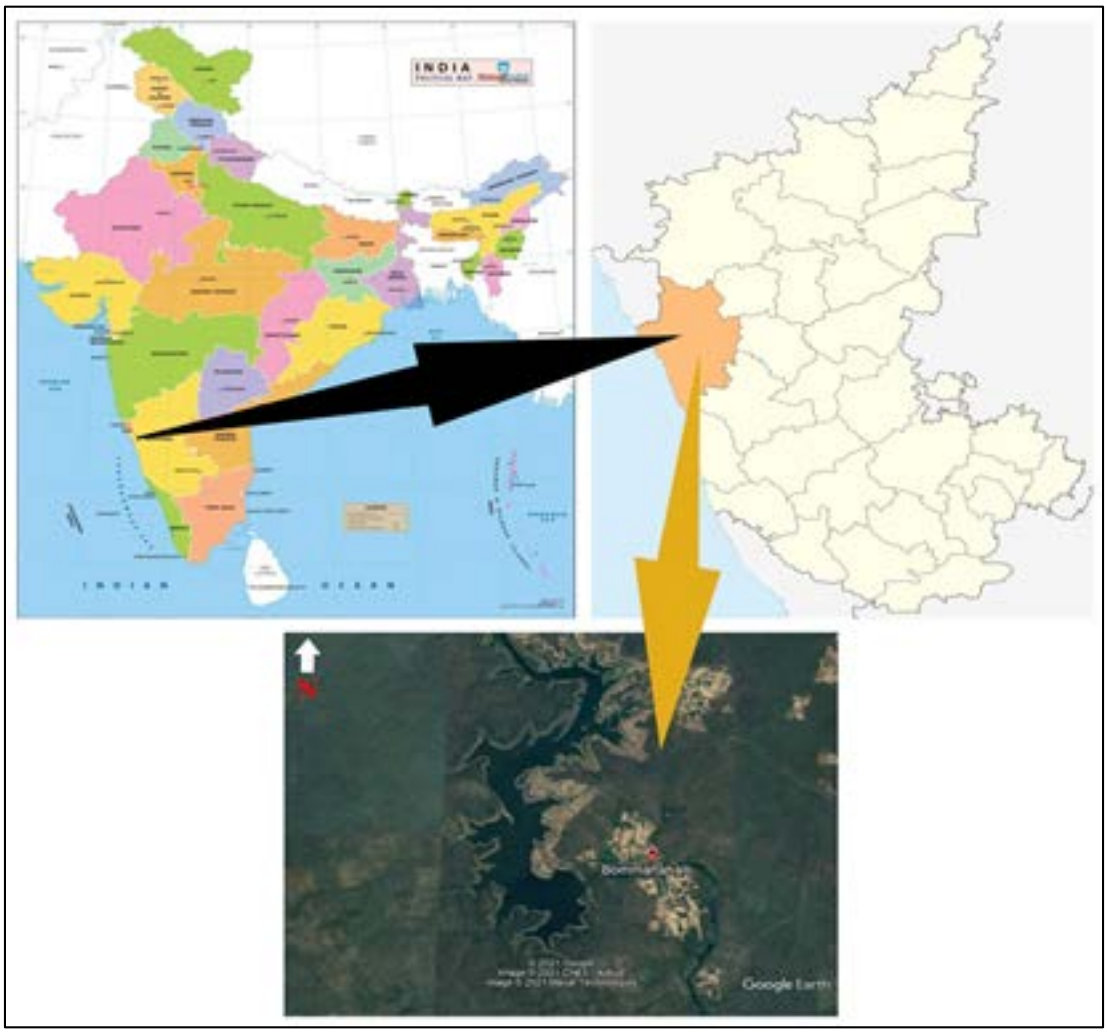

Fig 1: Map showing the study area at Uttara Kannada district, Karnataka State, India (Latitude 15°10'5.2" N; longitude 71°42'37.4"E)

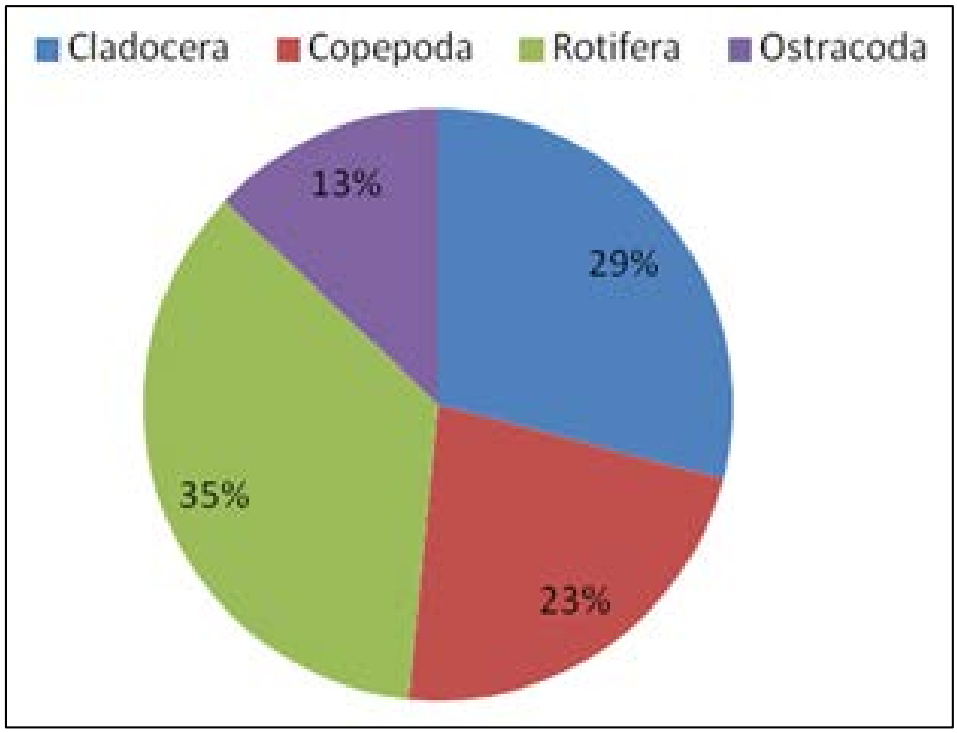

Fig 2: Graph showing percentage of Zooplankton abundance at Bommanahalli reservoir.

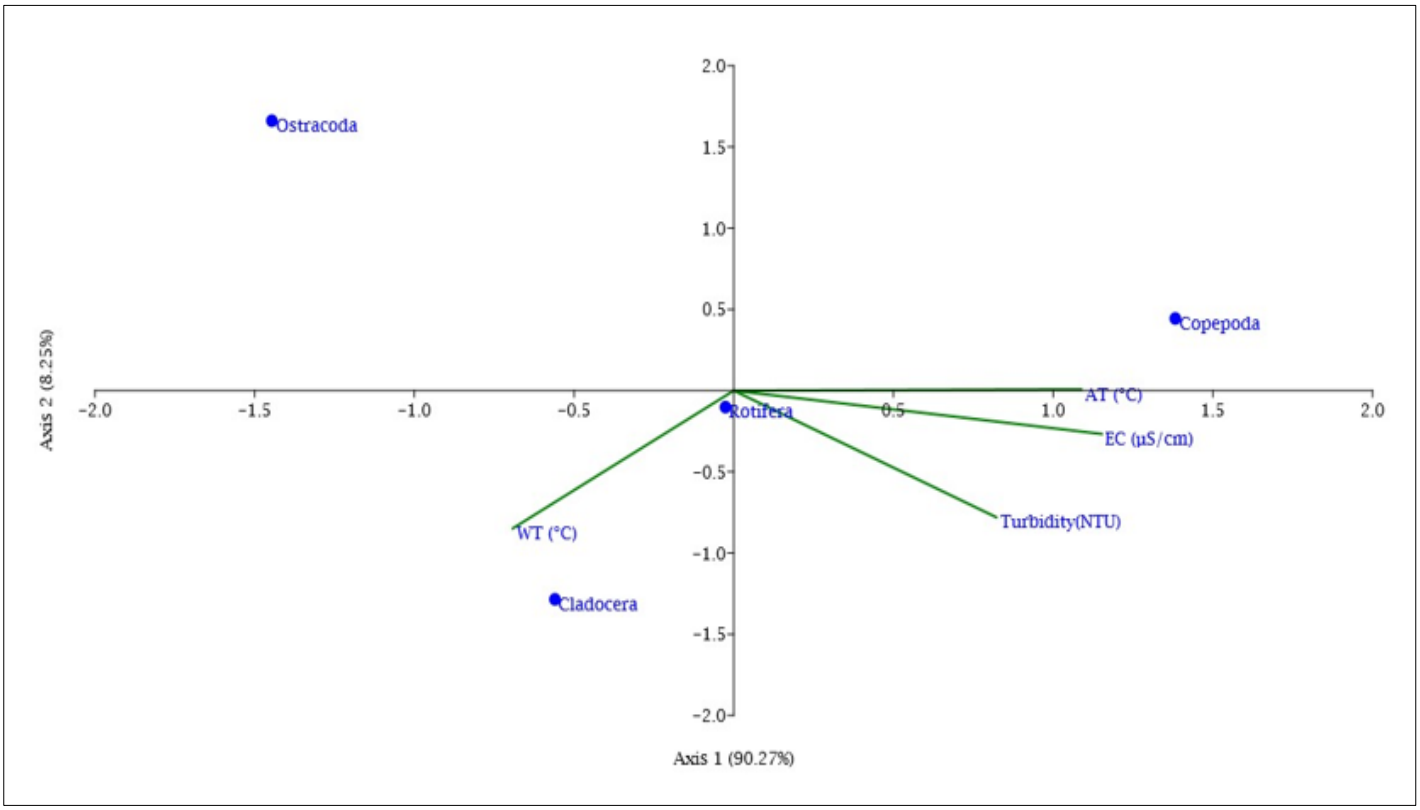

Fig 3: CCA to determine the response of different plankton groups to environmental variables like EC (µS/cm), Turbidity (NTU), WT (°C), and AT (°C) at Bommanahalli reservoir.

Conclusion

Bommanahalli reservoir shows varied zooplankton diversity. Rotifers represented with highest species richness and Copepoda with the highest abundance. The Cladocera was the second highest abundant group with a good number of individuals that are found throughout the year and served as good sources for fish. As the reservoir is shallow and accumulates the silt by runoff water the suspended solids, dissolved solids, and total solids

increase and the transparency is affected. Regular monitoring and examination of water quality is essential to protect and conserve the water body for its intended use.

Acknowledgements
The authors are thankful to the Chairman, Department of Zoology, Karnatak University, Dharwad for providing the necessary facility to conduct the study. Nayan Revankar thank Principal, B.N Degree College, Dandeli for encouragement and support. Thanks to Manjunath Hosamani for the statistical analysis.

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