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Spatial Analysis of Composition and Species Interactions with Temporal Variation of Zooplankton Community of Shallow Tropical Lake: Thol Bird Sanctuary, India

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Abstract:

Spatial and temporal patterns in the distribution of the zooplankton in a tropical Man-made reservoir- Thol Bird Sanctuary were investigated for two consecutive years from September 2007 to August 2009. The zooplankton was sampled at two different zones of Thol wetland located 23°15'N and 72°30'E near Ahmedabad city of Gujarat state, India. Sixteen species of Rotifers rich in number of individuals, density were dominant throughout the seasons in two sampling sites among the other groups. The main species were *Polyarthra vulgaris, Keratella tropica, K. cochlearis* and *Brachionus forficula*. Eleven species of Cladocera were more abundant in spring with the occurrence of *Daphnia* sp. and *Macrothrix rosea* at site 1 (feeder canal of the lake). Whereas, *Diaphanosoma birgei*, the most abundant Cladoceran, mainly occurred at site 2 (littoral zone of the lake). Peaks of tinted Protozoan were observed at site 1 during winter and spring. Variation in spatial distribution was noticeable, the abundance of zooplankton was significantly higher (P< 0.05) at the site 2 than the site 1 as a result of preponderance of the small Rotifers and Cladocerans particularly *Bosmina longirostris.* The analysis of one way ANNOVA between the sites for the first year showed the F′(5.84) value is greater than critical F value (4.30), whereas in the second year P' value (0.0005) is lesser than alpha (α) value 0.05.

Keywords: Density, Spatial-temporal distribution, Thol bird sanctuary, Zooplankton community

1.0 Introduction

Zooplankton plays an important role in energy transfer and occupies a central position in the trophic link between primary producers and higher trophic levels (Tunde, 2009). The influence of environmental factors, chemical conditions of hydro-geology of aquatic ecosystem cause changes in the composition of zooplankton and influence their densities, and so, they are also termed as bioindicators of the physical and chemical conditions of aquatic environments. The members of zooplankton are important for their role in the aquatic food chain (Cadjo *et al.*, 2007). Protozoan, Cladocera, Copepoda, Rotifera serves as indicators of water quality. The factors on the basis of bioindicators are evaluated through the qualitative and quantitative condition, relative success, community structure (composition) trophic structure or environmental heterogeneity and species interactions (Holyoak *et al*., 2005). The shallow lakes are much influenced by the intensive exchange of nutrients between their water columns and sediments (Vicente *et.al.,* 2006). Due to the excessive nutrient condition the loss of structural diversity and decrease in biodiversity at upper trophic levels generated. The variation of spatial and temporal of zooplankton biomass do not considered with the well-developed generated accepted body of knowledge (Clark *et al.*, 2001). Phytoplankton, zooplankton, macrophytes, macro-microbenthos and tertiary consumers are considerably undertaken for the biomonitoring of lakes ecosystem.

According to Ferrar *et.al,* (2002) the primary productivity fluctuates with changes in environmental factors and grazing by zooplankton. Trivedi *et al*., (2003) disclosed that places of low zooplankton population usually have rapidly multiplied phytoplankton population. Zooplankton distribution is non homogenous. Some are mainly found in the littoral waters while others are in selected limnetic waters. Hakanson (2003) attributed this to food availability and avoidance of predators. Zooplanktons are globally recognized as pollution indicator organisms in the aquatic environment (Sunkad *et al*., 2004). The review of limnological literature indicates limited information available on the ecology, diversity and role in aquatic productivity of inland aquatic environs of India (Sharma and Sharma, 2008). The dominant species and their seasonality are highly variable in different ecosystem according to their nutrient status, age, morphometry and other location factors (Rajashekher, 2009).

In Gujarat, although some information are available on the zooplankton community of marine ecosystem, studies are sparse and restricted to mere short term taxonomic observation reports of lentic ecosystem without any real quantitative analysis. Several studies have been done on different aspects of lentic ecosystems. The floral and faunal diversity of aquatic ecosystem and the major industrial development pressures posed by the mangrove and coastal ecosystem of Gujarat observed by Oswin (2004). Kumar *et al.,* (2005, 2008) explored physico-chemical characteristics of water and sediments, diversity of macrophytes. Temporal and spatial variations, with reference to community composition of zooplankton had been studied by Soni (2007) for two community reservoirs (Pariyej and Kanewal), Central Gujarat for a yearlong study period. Influence of water quality on composition and seasonal abundance of phytoplankton community in Thol Wetland of Gujarat studied by Kumar and Verma (2011). Kamini (2011) investigated the quality of surface water deteriorating due to rapid industrialization, population growth and urbanization of Ahmedabad city by weighted arithmetic index method.

The ecology of composition and spatial- temporal variations among plankton community of shallow lakes, in spite of its significant role in food web of aquatic ecosystem, is poorly understood. Hence, the present study undertaken in western India carries special significance. The study aims to provide a baseline data on the zooplankton of Thol Lake Bird Sanctuary and analyzed the spatial composition, species interaction with temporal variations of shallow tropical lake.

2.0 Materials and Methods

2.1 *Study Area*

The Thol Wildlife Sanctuary is situated 40 km away from Ahmedabad on the north side of Gujarat, in Kadi taluka, Mehsana district. It lies in between (23° 15' to 23°30' and 72°30' to 72°45' E).Sampling was carried out in the manmade Thol Lake Bird Sanctuary (Fig. a). The wetland was declared as "Bird Sanctuary" in November 1988 by Department of forest, Government of India which is a habitat of 150 of bird species, of which, 100 bird species are water bird and 30 bird species are migratory. The site is important for pre-breeding congregation and nesting of Indian Sarus Crane (*Grus Antigone antegone*). Gopi Sunder *et al*., (2000) have seen 35 cranes in May 1998. Wetland Thol is characterized by alkaline water, good oxygenation of surface water, for decades the wetland has been used for irrigation purposes. Rural settlement is found towards the North East and North West direction of the wetland.

As the wetland come under the Natural Conservation Area for birds of Gujarat the anthropogenic activities such as washing, poaching, cattle wading, bathing and illegal entry are strictly restricted. Birds such as *Common coots, Shelduck, Common pochards, Flamingoes, Painted stork, Spoonbills, Ibis* are dominated species throughout the investigated period and *Spot Billed Duck, Eurasian Wigeon, Asian openbill* are found mostly seasonal and appeared only during in winter season. In the present study, samples were collected from two sites of the wetland area: one shoreline site and one deep area. Site 1 is the major inlet of the wetland as stream of river Narmada canal drains into the wetland. Site 2 is one of the deepest outlets of the wetland. The water is then used for irrigation and drinking purpose by the villagers. The shoreline vegetation comprises predominantly of the following macrophytes *Ipomea aquatica, Polygonum sp., Typha angustata, T. domengensis, Eichhornia crassipes* and *Salvinia natans. T. angustata, Ipomea aquatic* were observed as the dominant vegetation at the site 1.

2.2 *Sampling and Analysis*

Zooplankton was sampled monthly during two different annual cycles (September 2007- August 2009) and at the two sites of the Wetland (Fig.a). Surface samplings were carried out with a 25 cm diameter and 75 cm length net of 20 µm mesh size. The volume of water filtered has been determined indirectly assuming that the net filters the whole volume of the column of water traversed by the net (De Bernardi, 1984). All samples were immediately fixed with 4% formalin and examined in the laboratory with light invertscopes (Olympus, CKX31) with magnification varying from 100 to 400×. The most abundant organisms and rotifers were identified and counted on sedimentation chambers and 1ml subsample from the final sample were chosen so that organisms did not pile up on one another (APHA, 2000). The less frequent or larger organisms (e.g., predatory

Cladocera) were counted with a long working distance objective at 40x after sedimentation of larger subsamples (10 ml) on petri dishes. Identification of species was made according to Edmondson (1959) for Copepoda, Wetzel (2001); Biswas (1949) for Rotifera, and other published literature.

Basic statistical methods on variance of spatial distribution patterns of the zooplankton were studied through analysis of variance (ANOVA). The zooplankton counts were analyzed for differenced between habitats (littoral and deep area). Whereas significant values ($P< 0.005$) were obtained by dominant species with the other members of the groups.

Fig. a: Geographical Representation of Lake Thol Bird Sanctuary

3.0 Results and Discussion

3.1 Zooplankton special abundance and Diversity:

A diverse planktonic assemblage in both the samples with a total of thirty identifiable species being recorded across the study area (16 Rotifera, 11 Cladocera and three Protozoa). Relative species distribution of abundance (ind. X 10^5 μl^{-1}) of both the sites for each year is shown in Table 1.

3.2 Zooplankton Spatial Abundance and Diversity:

Diverse planktonic assemblages in both the samples with a total of thirty identifiable species being recorded across the study are (16 Rotifera, 11 Cladocera and three Protozoa). Relative species distribution of abundance (ind.x 10^5 μl^{-1}) of both the sites for each year is shown in Table 1. Rotifera are the most abundant and the most constant accounting 16 species, this settlement has rather great specific richness and high diversity. The most abundant and dominant group during the study period, ranging from 16.4 x 10^5 μl^{-1} and 19.2

x 10^5 µl^{-1} at both the sites in first year and 34.6 x10^5 µl^{-1} at site 2 in both the years. A spatial variability is less noticed in the settlement of this group among the two sites. The main species of rotifers were *Polyarthra vulgaris*, *Keratella tropica*, *K. cochlearis* and *Brachionus forficula.* The most numerically dominant species Keratella *cochlearis* accounting 7.6 x 10^5 µl^{-1} at site 2 were recorded in first year followed by *Keratella tropica* 4.64 x 10^5 µl^{-1}.

Rotifer probably sensitive to some limiting factors (pollution and predation) on the other hand presents a relative decrease in abundance in the rainy season. Rotifers react less to different trophic levels given that some species, e.g. *Keratella cochlearis*, which is typically predominant in eutrophic lakes (Gliwicz, 1969), were observed both in eutrophic and oligo-mesotrophic lakes (Maier and Buchholz, 1996). *Brachionus calyciflorus* and *Keratella tropica tropica Aspein* were able to maintain high population during the wet season suggesting that they are resistant to suppression by the cladocerans. Cladocera are more clearly distributed according to the season and are more abundant in the rainy season and present a dynamics clearly related to the sites of the wetland. Eleven species of Cladocera were more abundant in spring with the occurrence of *Daphnia sp. Macrothrix rosea* at site 1. Whereas, *Diaphanosoma birgei*, the most abundant Cladoceran, mainly occurred at site 2. The species richness and density of Cladoceran were low at both the sites in two years. Average minimum density (8.64· X 10^5 µl^{-1}) of Cladocera recorded at site 1 in first year and maximum density (18.56 x 10^5 µl^{-1}) at site 2 in second year.

However, in the present study we noticed the maximum density of cladoceran at site 2 shows the spatial variation among the two sites. Similar observation is made by Dejen *et al. (*2004), who reported that in Lake Tana, the Cladocerans were most abundant in the sub-littoral zone and least abundant in the littoral zone, because the littoral zones sampled were devoid of aquatic macrophytes. Site 2 of the lake is the outlet, and found to the deepest point of the wetland. In the rainy season, water arriving in the reservoir drives a great quantity of organic and inorganic matters (Kabre, 2001) dissolved or in suspension, which brings about an expansion of phytoplankton and bacteria. These matters together with the phytoplankton and the bacteria constitute the essence of the food of the zooplankton which accounts for the significant development of the Cladocera (Wetzel, 2001). The other possible factor explaining the high density of zooplankton in the deeper part of the lake could be the less predation pressure in this zone.

Table 1: Zooplankton Species Average Density for Each Site of Both the Years from Thol Bird Sanctuary (Measured in individual (ind.) x 10^5 µl^{-1})

Species Name	First Year		Second year	
	Site 1	Site 2	Site 1	Site 2
	ind.x10^5 µl^{-1}			
Protozoa				
Chilomonas paramecium	1.04	1.36	1.28	1.84
Difflugia lebes	0.16	1.52	0.16	1.36
Difflugia oblong	1.92	1.28	2.24	2.4
Total ind· x10^5 µl^{-1}	3.12	4.16	3.68	5.60
Rotifera				
Asplanchna sp.	0.00	0.96	0.00	0.56
Brachionus sp.	1.12	1.12	1.36	1.28
B. calyciflorus	0.96	1.36	1.12	1.44
B.forficula	1.04	1.52	1.44	1.68
B.quadridentata	1.12	0.96	1.36	1.04
B.mirabilis	0.64	1.52	0.56	1.84
Filinia longiseta	1.44	3.28	1.68	4.88
F. opolienses	1.12	1.68	1.2	1.84
F. terminalis	0.64	2.32	0.72	2
Monostyla decipiens	0.96	0.96	1.12	0.8
Keratella tropica tropica	2.32	4.64	2.24	4.8
K. cochlearis	1.68	7.6	2	4.16
K. procurva	0.8	1.36	1.04	2.32
Keratella valga	0.64	0.48	0.96	0.08
K.tropica (Apstein)	0.4	1.2	0.4	1.36
Polyarthra vulgaris	1.52	3.2	1.92	4.08
Total ind· x10^5 µl^{-1}	16.40	34.16	19.12	34.16
Cladocera				
Alona monocantha	0.72	0.96	0.96	1.6
Bosmina longirostris	1.12	3.44	2.4	3.76
Macrothrix rosea(By Birge)	1.12	0.72	0.72	2.16
Ciliophora	1.12	1.12	1.36	2.32
Daphnia sp.	1.76	0.32	1.6	0
Diaphanosoma birgei	1.12	1.2	1.2	1.6
Plagiocampa mutabilis	1.04	0.48	1.28	1.68
Phyllodiaptomus blanci	0.08	0.56	0.32	2.08
Nemata sp.	0	0.72	0.08	1.6
Halophrya simplex	0.16	0.88	0.16	1.76
Coleps hirutus	0.4	0.99	0.48	0.88
Total ind.x105 µl-1	8.64	11.39	10.56	19.44

However, the density of individual species of Cladocera were low when compared with Rotifera occurrence*, Bosmina longirostris* were the most occurred species with the maximum density 3.76 x 10^5 µl^{-1} and 3.4 x 10^5 µl^{-1} at site 2 in both the years and 2.4 x 10^5 µl^{-1}at site 1 in second year. The distinct variability in the settlement and abundance of Cladocera and Protozoa were noticed that represents a seasonal dynamics.

Protozoa were the least occurred species in both the years at two sites contributing mainly *Difflugia species.* Maximum density recorded among the species of protozoa at site 2 with 2.4 x 10^5 µl^{-1} of Difflugia oblong in second year. The species abundance of Protozoa ranged between 0.25 to 7.36 x 10^5 µl^{-1} at site 1 and 2 in both the years.

3.3 Zooplankton Temporal Distribution

The analyse of Box Whisker Chart (Fig. b) clearly shows the significant difference among the average values, medians and standard deviation among the zooplankton density according to the factor season. This population presents an increased variation in October, November and April, May, June of first year and then decreases to relatively low levels in July and August of the first annual cycle, whereas, total plankton population shows two increased trends during September to January and March to May of the second year.

Fig. c shows the spatial and temporal trends of Rotifera, Cladocera of both the sites. Regarding the two groups of organism, Cladocera and Rotifera, we note that the distribution of Rotifera is independent with the sites but dependent on the seasons, showing decrease in abundance in rainy seasons, whereas two peaks were equally noticed in both the years in summer seasons. As for Cladocera distributions, it is not independent in any of the two cases. These results show that the Cladocera zooplankton have very important seasonal variability in contrast with Rotifers. This population presents a drastic increase in July (1.2), September (1.36) and January (2.08) x 10^5 µl^{-1} at site 2, (0.72, 0.64 x 10^5 µl^{-1}) in October and June at site 1.

In the present study it was found that in Lake Thol, rotifers have contributed the maximum densities of zooplankton composition in two years. Rotifers are the nutrient tolerant species and good competitor of survival, and are found with maximum densities in summer seasons. Whereas, Cladocera and Protozoa densities are quite low in this season but contribute good density in October and November. The relative density and compositions of the various groups of zooplankton show that the small sized zooplankton dominated the community. These high values were mostly due to small-bodied nauplii stages, high densities of small rotifers and cladocerans which are characteristic of lakes with planktivorous fishes. Densities of large bodied Cladocera were low during the study period probably as a result of predation pressure. Rotifers are regarded as bio indicators of water quality (Sladecek, 1983 ; Saksena, 1987) and high rotifer density has been reported to be a characteristic of planktivore fish eutrophic lakes (Sendaczz, 1984). The impact of predation on zooplankton abundance is also indicated by Whittaker *et al.* (2001), where significantly lower plankton density was associated with the presence of the planktivore fish.

3.4 Predictions among the Group

The analysis of one way ANOVA in Table 2.1 among the sites for the first year showed the F(5.84) value is greater than critical F'value (4.30) with the means of population aims to believe there is no such significant spatial difference in between the two sites density of zooplankton for the first year, whereas in the Table 2.2 second year P' value (0.0005) is lesser than (α) value 0.05, supports a significant difference in between the two samples, believed there is difference between the two samples and density/occurrence of zooplankton due to hydro –geochemical properties and depend on the geo-morphology of the wetland.

According to the total density of zooplankton (Fig. c) occurred high at site 2 could represent a bias analysis if, as commonly reported, species number depends on lake geomorphology (Walseng, 2006). However, to resist this bias relationship with the application of One-way ANOVA (Table 2.1 and Table 2.2), our study does not reveal any correlation between lake geo-morphology and density of zooplankton F'5.84, greater than critical F'value (4.30) of the first year, but, the results of the second year considering P'0.0005, least value than P'0.05, representing correlation between site location and density of zooplankton. The significantly higher density of zooplankton at site 2 (one of the outlet of the lake-littoral zone) supports the findings of Dodson (2000). There is also a shift in the species composition of rotifers, which was represented by 16 species of different genera. Taxonomic dominance of rotifers was reported in several water bodies (Nogueira, 2001; Cavalli *et al.,* 2001; Sampaio *et al.,* 2002; Neves *et al.*, 2003). This pattern is common in tropical and subtropical freshwaters, whether in lakes, ponds, reservoirs, rivers or streams (Neves *et al.,* 2003).

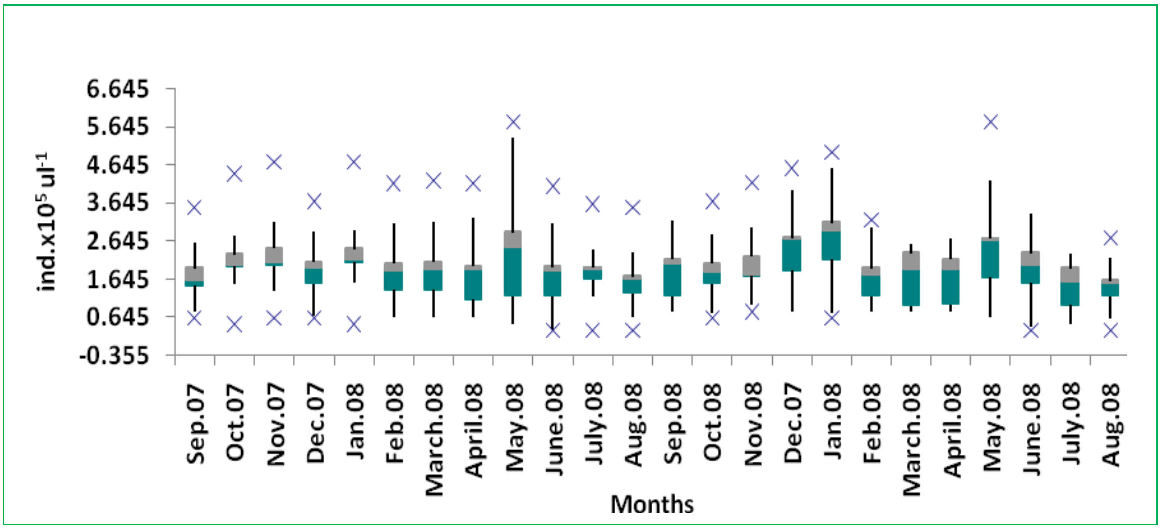
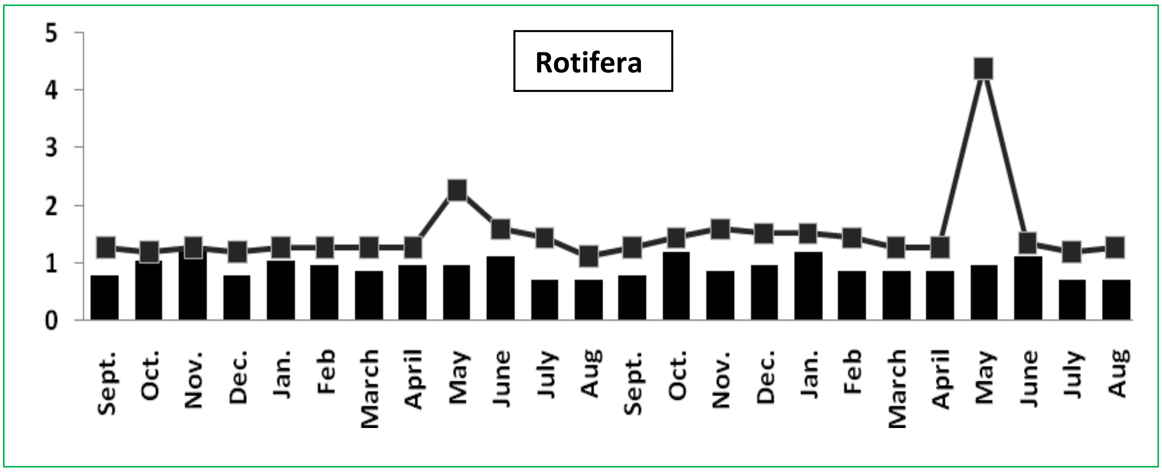
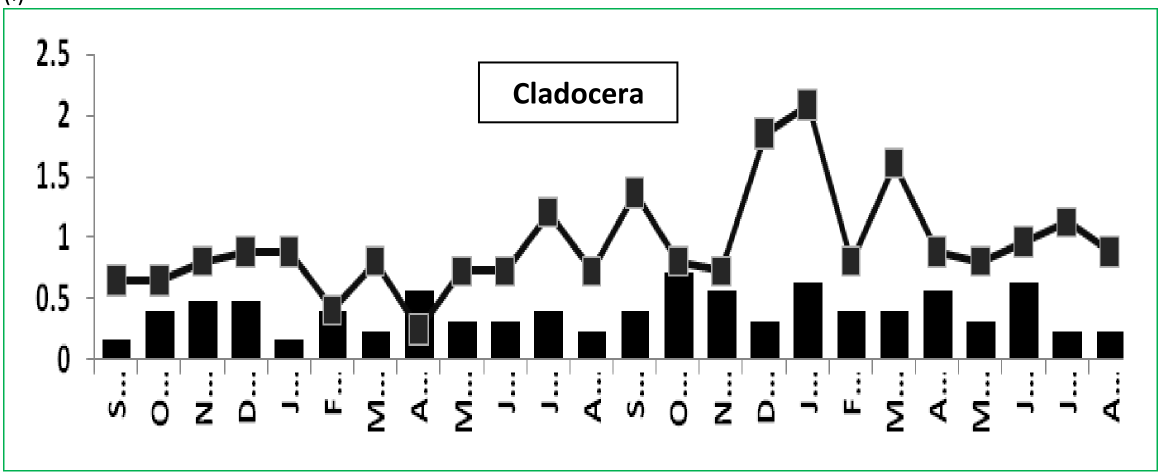


Figure b. Box and whisker plot of total species numbers from both the sites of two years. Vertical line is median of all observations, dark boxes within boxes is median of the category, extension of boxes represents 25th and 75th percentiles and extension of lines is 10th and 90th percentiles.



(i)



(ii)

Figure c. (i, ii) Temporal Abundance Patterns for Rotifera, Cladocera of Two Sites for Both the Years

Table 2.1 .P-Values of Single Factor ANOVA of the Two Sites, According to Group of Organisms Density and Season Factor of the First Year September 2007-August 2008

Source of Variation	df	F-value	P-value	F critical
Between Groups	1	5.84	0.024	4.30
Within Groups	22			
Total	23			

Table 2.2 P-Values of Single Factor ANOVA of the Two Sites, According to Group of Organisms Density and Season Factor of the Second Year September-2008 to August 2009

Source of Variation	df	F-value	P-value	F critical
Between Groups	1	16.93	0.0005	4.35
Within Groups	20			
Total	21			

This may be due to their special characteristics, i.e., less specialized feeding, high fecundity and frequent parthenogenesis reproduction, constellation of life traits that make them opportunist and typical r-strategist, favoured in unstable and eutrophic environments (Rocha *et al.,* 1995). This may be also due to a wide spectrum of food particles exploited by this group, which display the ability to consume bacteria, algae and detritus of different sizes, which allows quite distinct diets for the many species simultaneously present in the water body (Starkweather, 1980). *Brachionus* and *Keratella* was the prominent genus represented by five species each. The genus *Brachionus* and *Keratella* is the index of eutrophic water (Sladecek, 1983) and its abundance is considered as a biological indicator for eutrophication (Nogueira, 2001). The species *B. calyciflorus* is considered to be a good indicator of eutrophication (Sampaio *et al*., 2002). Qualitative dominance of zooplankton in net plankton communities of Loktak Lake concurs with the findings of Sharma and Sharma (2010) but differs from higher phytoplankton richness observed by Sharma and Hussain (2001).

In the present study 11 Cladoceran species are recorded and the most frequent Cladocerans were *Diaphanosoma birgei* and *Bosmina longirostris*. These two members represented major part of Caldocerans; these organisms usually associate with macrophytes, periphyton and sediment (Wisniewski *et al*., 2002). According to Uttangi (2001) Cladocerans prefer to live in clear waters. It was observed that more number of Cladocerans species were in monsoon season in both the years at site 2. In the absence of low organic pollution during monsoon seasons may have contributed the maximum abundance of Cladocerans. In conclusion, our study demonstrates that the zooplankton community structure of the wetland Thol has features typical of shallow lakes with high productivity. The seasonal variations among the abundance, spatial difference between the densities of zooplankton and prevailing Rotifers over other groups both in total number and diversity are seen to be typical for high productivity and eutrophic wetland.

4.0 Conclusion:

Three main zooplankton groups were identified in the study (Rotifera, Cladocera and Protozoa) with 30 identified forma. The maximum zooplankton density peaked in October, November and April, May, June of first year and in months of September to January and March to May of the second year, then decrease relatively low during rainy season. Spatially, the highest levels occurred at the outlet (Site 2). Seasons are the important factor influencing zooplankton assemblages. A noticeable decrease in density and species richness of zooplankton was noticed at site 1. With the one way ANOVA application, the community composition do not show any relationship with site specific and found highly changed with time series. Several species of Rotifers were present throughout the study period.

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