Chapter: 5

Zooplankton

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Introduction

Zooplankton (Greek: Zoon – animal; Planktos – wanderer/drifter) are minute, mostly microscopic drifting creatures mainly inhabiting the surface layers of aquatic ecosystems like seas, oceans, lakes, rivers, and ponds. The zooplankton along with phytoplankton form the lower tiers of aquatic food chains and thus are fed upon by animals of higher tropic levels like fishes. The zooplankton comprises of wide range of organisms that are classified based on their size, depth at which found, geographical distribution and mainly in relation to their life cycle (Santhanam *et al*., 2019). Zooplankton are the most heterogenous, microscopic and important biotic components of all the functional aspects of an aquatic ecosystem, such as food chain, food web, energy flow and cycling of nutrients present in the form of organic matter (Mallanagound *et al*., 2017). Freshwater zooplankton in the tropics comprises predominantly of Rotifers and microcrustacea which includes Cladocerans, Copepods and Ostracods (Fernando, 2002). These most common organisms often govern the entire consumer communities.

The zooplankton play a key role of converting energy trapped by phytoplankton into food, suitable for fish and aquatic animals and hence have acquired importance in fishery research (Kadam, 2014). Zooplankton form an inter-remedial link between primary and tertiary production as fishery potential is enormously coupled with the presence of zooplankton (Dubey *et al*., 2006; Goswami and Mankodi, 2012; Pradhan, 2014; Kar and Kar, 2016). They act as main source of food for many fishes and also play an important role in early detection and monitoring of pollution in water (Singh and Talpade, 2018). Changes in the aquatic environment accompanying anthropogenic pollution are one of the major causes of growing concern and require monitoring of surface waters and organisms inhabiting them (Vandysh, 2004). Zooplanktons are also capable of concentrating large quantities of heavy metals from water bodies (Sharma *et al*., 2013, Verma *et al*., 2013) and these metals may be passed on and concentrated at higher trophic levels through the food chain. The nutrients mainly nitrogen and phosphate act as bio-stimulants causing eutrophication or enhancement of the growth of zooplankton and phytoplankton.

In the last two decades much attention has been paid in tropical countries towards the study of biology, ecology and toxicology of zooplankton due to their important role in rapidly emerging concepts in environmental management like Environmental Impact Assessment (EIA), biomonitoring of pollution and biological monitoring (Salve and Hiware, 2010). The most significant feature of zooplankton is its immense diversity over space and time (Sing and Talpade, 2018) which is one of the major ecological parameters in water quality assessment. Hence qualitative and quantitative studies of zooplankton are of great importance in water reservoirs. In spite of convergent similarities, zooplankton species have different types of life histories influenced by seasonal fluctuations of physico-chemical parameters, feeding ecology and predation pressure (Pathani and Upadhayay, 2006). Thus, dissimilar assemblages of organisms vary in species composition and biomass.

Zooplankton have short life span than phytoplankton (Chen, 1982) and there is usually a natural compensatory provision for the zooplankton to enhance reproductive capacity and hence they are always present in large numbers (Goldman and Horne, 1983). Zooplanktons are crucial elements of freshwater lake ecosystem as they occupy central position of aquatic food web and are important food for almost all freshwater species at some stage in their life history (Lampert and Sommer, 1997). Identification of zooplankton species in food web is essential part of managing aquatic bodies whereas diversity of zooplanktons can be used to mediate chronic water pollution problems (Bashini *et al*., 2017).

The occurrence of zooplankton depends on the status of productivity of water body. Photosynthesis plays significant role in increasing some algae which pass through the nutrient rich alimentary canal of zooplankton in visible condition. Ecologically, zooplanktons are one of the most important biotic components (Dadhik and Saxena, 1992; Sinha and Islam, 2002). Zooplankton associated in particular with macrophyte beds may act as a positive feedback mechanism that contributes in maintaining the clear water state (Stefanidis and Papastergiaou, 2010). However, some disadvantages include competition with other zooplankton, food scarcity, chemical inhibition, adverse abiotic conditions and increased predation pressure from macrophyte-related invertebrates (Burk *et al*., 2001; 2002). These authors have reported that significant higher density of zooplankton indicate the clear state of water while high value of species richness reflects the suitability of habitat for varied organisms. This is also correlated with longer food chain and relative more stable community.

Among all freshwater aquatic biota, zooplankton population is able to reflect the nature and potential of any aquatic systems (Kumar *et al*., 2010). As a group, they have worldwide distribution, species composition and community structure, nutrient enrichment and they respond differently to different level of pollution (Jha and Barat, 2003). High species density and numerical abundance of zooplankton population is reported in natural wetland as compared to man-made wetland (Pal *et al*., 2015), but on the contrary higher density of zooplankton are observed in man-made wetland as compared to natural wetland. Zooplankton diversity and density refer to variety within the community which are often important links in the transformation of energy from producers to consumers due to their high density, drifting nature, high group as well as species diversity and different tolerance to the stress (Kapoor, 2015; Chopra and Jakhar, 2016).

Zooplankton communities are known to be highly susceptible to a wide range of factors like environmental changes, temporal abundance and seasonal variations, and their diversity is a marker of water quality in trophic conditions in cold, temperate and tropical waters (Gannon and Stemberger, 1978). Further, they are of enormous value as they are primary consumers of phytoplankton and also regulate the nutrients (Ramachandra *et a*l., 2006; Manickam, *et al*., 2014; Kapoor, 2015; Malik and Pamwar, 2016; Manickam, 2017). Thus these are most important biotic components influencing all the functional aspects of an aquatic ecosystem, such as food chain, food web, energy flow and cycling of nutrient which is present in the form of organic matter (Mallanagound *et al*., 2017).

Due to their short life span, the zooplankton community often exhibits quick and dramatic changes in response to the changes in the physicochemical properties of the aquatic environment (Dar and Dar, 2009) and dependent on many physicochemical and environmental factors such as rainfall, air and water temperature, nutrient concentration and salinity of lake, change of climatic conditions, physical and chemical parameters and vegetation cover (Neves *et al*., 2003). The physicochemical parameters and nutrient status of water body play an important role in governing the production of plankton which in turn provides the necessary amount of protein for rapid growth of larval fishes (Rahman and Hussain, 2008). Availability and quality of food resources in the aquatic ecosystem directly affect the phytoplankton abundance, which in turn induces the change in distribution pattern of zooplankton species (Chandrashekhar and Kodarkar, 1997). In addition, their diversity has assumed added importance during recent years due to the ability of certain species to indicate the deterioration in the quality of water caused by pollution or eutrophication. Zooplankton community poor in species but dominated by small sized organisms is generally typical sign of eutrophic and disturbed ecosystems (Kagalon and Kosiori, 2010). Certain species of zooplankton are good indictors of water quality and hence referred to as biological indicators (Arora, 1961; Abdulwahab and Rabee, 2015; Pavan *et al*., 2016). They determine the quantum of fish stalk. Hence, zooplankton communities based on their quality and species diversity, are used for assessing the productivity VIZ, fishery resource, fertility and health status of the ecosystem (Sharma *et al*., 2013).

The study of freshwater fauna especially zooplankton of a particular area are extensive and complicated due to environmental, physical, geographical and chemical variations involving ecological and extrinsic factors (Majagi and Vijaykumar, 2009; Majumdar *et al*., 2015). On the basis of large number of studies covering a wide variety of ecosystems and organisms it has been suggested that species richness tend to vary strongly with ecosystem productivity and habitat heterogeneity (Rosenzweig, 1995). The study of freshwater fauna especially zooplankton even in a particular area is extensive and complicated phenomenon. Sanyal *et al*., (2015) studied ecosystem of four selected watlands located along East Kolkata Wetlands of International significance (Ramsar site) and computed biotic indices like species pollution value (SPV) and community pollution value (CPV) based on the basic ecological information on zooplankton taxa. The freshwater zooplanktons comprise of Protozoa, Rotifera, Cladocera, Copepoda and Ostracoda. Among zooplankton, rotifers dominate the community structure qualitatively as well as quantitatively (Arora and Mehra, 2009). Most of them depend on a large extent, on various bacterioplankton and phytoplankton for food.

In India, zooplankton communities have been investigated in numerous reservoirs, lakes and shallow water bodies (Gopal and Zutshi, 1998; Jana, 1998Zooplanktons are globally recognized as pollution indicator organisms in the aquatic environment (Yakubu *et al*., 2000). Many of the larger zooplanktons are secondary consumer, while some of them are detritivore feeders, browsing and feeding on organic matter particles attached to substrate or lying on the bottom sediments (Patil, 2011).). Higher population of rotifer is usually reported in reservoirs with higher eutrophication (Goswami and Mankodi, 2012). Zooplankton are considered to be most important in terms of population density, biomass production, grazing and nutrient regeneration in any aquatic ecosystem (Omudu and Odeh, 2006). Hence, in present study of reservoir investigation of zooplankton density and diversity is considered for three wetlands Malpur dam, Baldane reservoir and Krishna park in rain deficient North Maharashtra State.

Results

Four different groups, rotifer, cladocera, copepod and ostracoda representing zooplankton community are considered during present study of three water bodies namely Malpur dam, Baldane reservoir and Krishna park reservoir.

At Malpur dam total 48 species belonging to 35 genera were recorded during the two year study of which 25 species (11 genera) belonged to rotifer, 9 species (9 genera) to cladocera, 7 species (7 genera) to Copepoda and 7 species (7 genera) to ostracoda. (Annexure-2).

Similarly at Baldane reservoir total 44 species belonging to 30 genera were recorded of which 23 species (11 genera) belonged to rotifer, 8 species (6 genera) belonged cladocera, 6 species (6genera) to Copepoda and 7 species (7 genera) to ostracoda (Annexure-2).

At Krishna Park Total 39 species belonging to 29 genera were recorded with 21 species (11 genera) belonging to rotifera, 7 species (7 genera) to cladocera, 6 species (6 genera) to Copepoda and 5 species (5 genera) to ostracoda (Annexure-2). The rotifers were the dominant zooplankton recorded at all the three water bodies, whereas Ostracodes were minimum during the study period.

At Malpur dam maximum deensity (2400 ± 108 no./l) of total zooplanktons were recorded in summer, which decreased to 1870 ± 107 no./l in monsoon and 1320 ± 79.3 no/l in winter. Almost similar trends were noted at other two water bodies with maximum 2547 ± 118.5 no/l in summer at Baldane dam which decreased to 2014±120 no/l in monsoon and 1392± 72.67 no/l in winter. At Krishna Park this trend was with 2197 ± 97.24 no./l in summer decreasing to 1733±65.9 and 1232±84.21no./l in monsoon and winter respectively. The seasonal trends were highly significant with $P<0.0001$ with $F_{2\ 21}$ 26.9 at Malpur dam, $F_{2\ 21}$ 29.6 at Baldane and $F_{2\ 21}$ 33.51 at Krishna Park.

Among the different groups of zooplankton, rotifers constituted the largest group at all the three water bodies with maximum density in summer and minimum in winter. At Malpur dam 1020±64.5 rotifers /l were recorded in summer which decreased to

647±59.1 in monsoon and 446±37.4 in winter (p<0.001 $F_{2\ 21}$ 24.1). At Baldane, this trend was with 1067±66.18 rotifers/l in summer declining to 735.1±76.41 in monsoon and 482.6±39.2 in winter (p<0.001 $F_{2\ 21}$ 23.13) and at the third reservoir Krishna Park it was 934.9±44.2, 631.3 ± 28.87 and 422.4±36.13 rotifers/l over the three seasons respectively.

The second dominant group cladocera also showed similar trends to that of rotifers with 700±17.2 no/l in summer, 580±23.4 no/l in monsoon and 442±30 no/l in winter with Significant seasonal variations (P< 0.0001 $F_{2\ 21}$ 25.88) at Malpur dam. At Baldane dam these values were 750.4±28.91 no/l, 601.9±23.21 no/l, and 455.6±29.39 no/l during summer, monsoon and winter respectively (P< 0.0001 $F_{2\ 21}$ 30.12). At the smaller reservoir Krishna park the values were 653.8±29.76 no/l, 520.6±23.12 no/l and 410.8± 30.77 no/l respectively (P< 0.0001 $F_{2\ 21}$18.77).

The third dominant group of zooplankton was copepoda. At Malpur dam 585.9 ± 21.7 no./l Copepoda were recorded in summer, 500 ± 25.5 no./l in monsoon and 362 ± 14.7 no./l in winter. At Baldane reservoir also maximum Copepoda density were recorded 617±21.58 in summer followed by 529.4 ± 20.36 no./l in monsoon and minimum 386 ± 16.34 no./l in winter (P< 0.0001 $F_{2\ 21}$ 35.57). The density of Copepoda at Krishna park 513.1±29.17 no/l in summer, 443.8 ±22.05 no/l in monsoon and 338.1± 16.9 no/l in winter (F P< 0.0001 $_{2\ 21}$ 14.6).

Ostracoda, the fourth quantitative component among the four zooplankton groups at all the three reservoirs also showed significant seasonal variations at Malpur dam (P < 0.0001 $F_{2\ 21}$ 25.71) Baldane reservoir (P < 0.0001 $F_{2\ 21}$ 31.59) and Krishna park reservoir (P < 0.0001 $F_{2\ 21}$ 31.66). At Malpur dam summer density was 96.13±7.42 no./l which increased to 139±7.86 no./l in monsoon and decreased to minimum 69.13±6.85 no./l in winter. At Baldane reservoir it was 107±6.85 no./l , 147.6±6.18 no./l and 67.25± 8.27 no./l while at Krishna park these values were 95.63±4.27 no./l, 137.5 ±5.59 no./l and 602.5±9.6 no./l respectively.

The two year biannual percentage density in decreasing order rotifera, cladocera, copepoda and ostracoda for Malpur dam were 36.86%, 30.79%, 25.88% and 5.45% respectively. For Baldane reservoir it was 38.4%, 30.45%, 25.74% and 5.4% while for Krishna Park these values were 38.5%, 30.7%, 25.1 % and 5.86% respectively.

Species richness of total zooplankton:

Species richness was also maximum in summer, declined in monsoon and was found to be minimum during winter at all the three reservoirs. At Malpur dam the mean values for total zooplankton were 22.75±0.77 in summer, 20.25±0.65 in Monsoon and 12.50±0.50 in winter ($P<0.001$ $F_{2\ 21}$ 63.1). At Baldane reservoir the mean values were 20.5±0.87 for summer, 17.63±0.05 for monsoon and 10.63±0.71 for winter ($F_{2\ 21}$ 51.75). For species richness rotifers were the dominant group with mean species richness of 10.75±0.64 for summer, 8.25±0.49 for monsoon and 4.88±0.44 for winter ($F_{2\ 21}$ 19.20). At Baldane reservoir these values were 11.38±0.38, 8.75±0.53, 4.88±0.44 respectively ($F_{2\ 21}$ 52.45) and at Krishna park 9.5±0.42, 7.37±0.18 and 4.13± 0.35 respectively ($F_{2\ 21}$ 65.66). The mean species richness for cladoceran was 6±0.2, 5.26±0.16 and 4.12±0.27 respectively for Ma;lpur dam, 6.5±0.19, 5.5±0.18 and 4.25±0.25 for Baldane dam and 5.13±0.23, 4.5±0.12, and 3.37±0.18 respectively for Krishna Park.

The mean species richness of copepode at Malpur dam in summer was 4.75±0.76, in monsoon 3.50±0.2 and 2.75± 0.16 in winter ($P< 0.0001$ $F_{2\ 21}$ 7.54). At Baldane dam it was 5±0.19 for summer, 3.5±0.18 for monsoon and 2.88±0.23 ($P< 0.0001$ $F_{2\ 21}$ 29.15). At Krishna Park mean copepode richness was 4.38±0.18 for summer, 3.25± 0.16 for monsoon and 2.37±0.18 for winter ($P< 0.0001$ $F_{2\ 21}$ 32.17). The mean species richness of ostracode was lowest among the four groups with 1.25±0.31 in summer, 3.25±0.16 in monsoon and 0.75±0.16 in winter at Malpur dam. The values for Baldane dam were 1.5±0.19, 3.25±0.16 and 0.88± 0.13 for summer, monsoon and winter respectively and at Krishna park 1.5±0.19, 2.5±0.19 and 0.75±0.16 respectively.

The two year percentage species richness showed similar trend to density in decreasing order of rotifera, cladoceran, copepod and ostracoda. For Malpur dam it was 43.01%, 27.5%, 19.81% and 45% respectively, for Baldane dam 42.9%, 27.9%, 19.53 and 96.5 and for Krishna park it was 43.07%, 23.66%, 20.51% and 9.74 respectively.

Pearson correlation

When correlation with physicochemical parameters (Chapter 1) is considered at Malpur dam, cladoceran and copepod density were positively correlated with AT, Cl, CO_2, MgH, TDS, TS, TH and WT while negatively correlated to DO, PO_4, transparency and WC. When ostracodes were considered, similar results were noted except no correlation with Cl, MgH, TH, PO_4 and WC and positive correlation with pH. Similarly rotifers in addition showed positive correlation with pH, SO_4 and transparency. When total zooplankton were considered they showed almost similar correlations to that of cladoceran, copepod and rotifer, whereas ostracodes showed different results. None of the group showed any significant correlation with Ca, NO_3 and TSS except ostracoda.

For Baldane dam almost similar correlations were found for the zooplankton groups and physicochemical parameters except cladoceran showing positive significant correlation with SO_4 and TS and negative with TSS, copepods also showed correlation with SO_4, and ostracodes showed no correlation with NO_3 while showed negative correlation with Calcium hardness. Rotifers showed no correlation with transparency while total zooplankton showed no correlation only with pH.

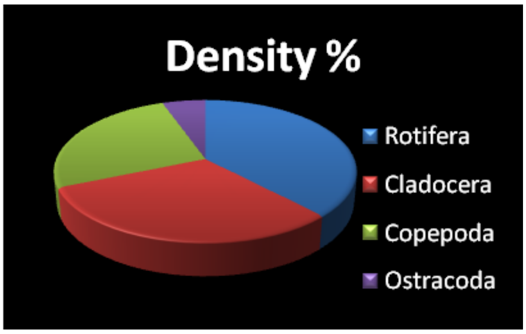
For Krishna park also various groups of zooplankton and physicochemical parameters showed similar correlation except cladoceran and copepod showing positive correlation with CaH and SO_4 and no correlation with transparency. The later did not show any correlation with PO_4 too. Ostracoda showed positive correlation with chlorides and no correlation with NO_3. Rotifers showed positive correlation with calcium and no correlation with SO_4 and negative correlation with SO_4, and negative correlation with transparency. While the total zooplankton additionally exhibited positive correlation with calcium hardness.

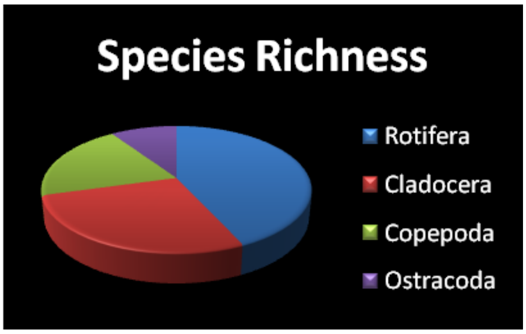
Table: 5.1 Two Years Percentage density and species richness of different groups of Zooplankton at Three wetlands during October 2011 – September 2013.

	Rotifera	**Cladocera**	**Copepoda**	**Ostracoda**
Malpur Dam				
Density	37.86	30.79	25.88	5.45
Sp.Rich	43.01	27.5	19.81	9.45
Baldane reservoir				
Density	38.4	30.45	25.74	5.4
Sp.Rich	42.9	27.9	19.53	9.6
Krishna Park				
Density	38.5	30.7	25.1	5.68
Sp.Rich	43.07	26.66	20.51	9.74

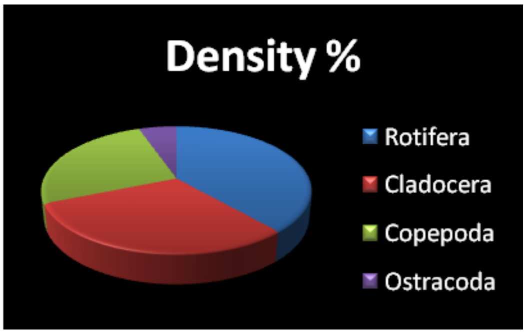
Fig. 5.1 Biannual Percentage density and Species Richness of different groups of Zooplankton at three wetlands during October 2011 – September 2013.

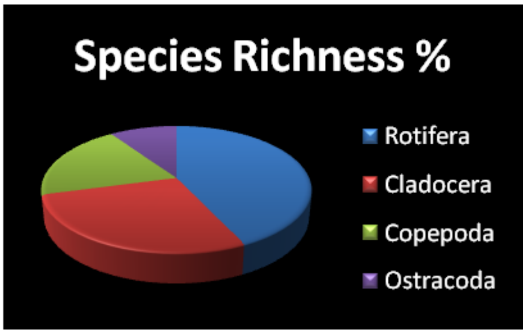
Malpur Dam



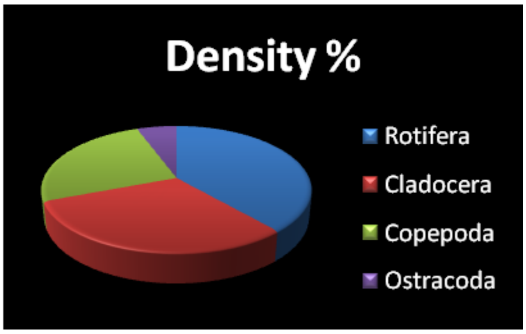


Baldane Reservoir





Krishna Park



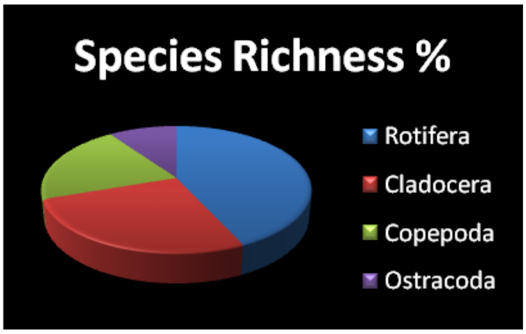


Table5.2a: Seasonal Variations in density (No/l) of different groups of Zooplankton

(Malpur dam)

Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years %
1	Tot. zoo.	$F_{2\,21}$26.9	1320 ± 79.8	2400 ± 108	1870 ± 107	
2	Rotifera.	$F_{2\,21}$ 24.1	446 ± 37.4	1020 ± 64.5	647 ± 59.1	37.86 %
3	Cladocera.	F_{221} 25.88	442 ± 30.0	700 ± 17.2	580 ± 23.4	30.79 %
4	Copepoda.	F_{221} 14.27	362 ± 14.7	585.9± 21.7	500 ± 25.5	25.88 %
5	Ostracoda	$F_{2\,21}$ 25.71	69.13 ± 6.85	96.13± 7.42	139 ± 7.86	5.45 %

Table5.2b: Seasonal Variations in species richness (no. of species) of different groups of Zooplankton (Malpur dam)

Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years %
1	**Tot. Zoo.**	$F_{2\ 21}$ 63.10	12.50 ± 0.50	22.75 ± 0.77	20.25± 0.65	
2	**Rotifera.**	$F_{2\ 21}$ 19.20	4.88 ± 0.44	10.75 ± 0.64	8.25 ± 0.49	43.01 %
3	**Cladocera.**	$F_{2\ 21}$ 11.82	4.12 ± 0.27	6.00 ± 0.20	5.26 ± 0.16	27.5 %
4	**Copepoda.**	$F_{2\ 21}$ 7.54	2.75 ± 0.16	4.75 ± 0.16	3.50 ± 0.20	19.81 %
5	**Ostracoda**	$F_{2\ 21}$19.73	0.75 ± 0.16	1.25 ± 0.31	3.25 ± 0.16	9.45 %

Table5.3a: Seasonal Variations in density (No/l) of different groups of Zooplankton (Baldane reservoir)

Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years %
1	**Tot. zoo.**	$F_{2\ 21}$ 29.6	1392 ± 72.67	2547 ± 118.5	2014 ± 120.7	
2	**Rotifera.**	$F_{2\ 21}$ 23.13	482.6 ± 39.2	1067 ± 66.81	735.1 ±76.41	38.4 %
3	**Cladocera.**	F_{221} 30.12	455.6± 29.39	755.4± 28.91	601.9 ±23.21	30.45 %
4	**Copepoda.**	F_{221} 35.57	386 ± 16.34	617 ± 21.58	529.4 ±20.36	25.74 %
5	**Ostracoda**	$F_{2\ 21}$ 31.59	67.25 ± 8.27	107 ± 6.85	147.6 ± 6.18	5.4 %

Table5.3b: Seasonal Variations in species richness (no. of species) of different groups of Zooplankton (Baldane reservoir)

Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years %
1	**Tot. Zoo.**	$F_{2\ 21}$ 87.95	12.88 ± 0.58	24.38 ± 0.59	21.00± 0.71	
2	**Rotifera.**	$F_{2\ 21}$ 52.45	4.88 ± 0.44	11.38 ± 0.38	8.75 ± 0.53	42.9 %
3	**Cladocera.**	$F_{2\ 21}$ 28.47	4.25 ± 0.25	6.5 ± 0.19	5.5 ± 0.18	27.9 %
4	**Copepoda.**	$F_{2\ 21}$ 29.15	2.88 ± 0.23	5.00 ± 0.19	3.5 ± 0.18	19.53 %
5	**Ostracoda**	$F_{2\ 21}$58.2	0.88 ± 0.13	1. 5 ± 0.19	3.25 ± 0.16	9.6 %

Table 5.4a: Seasonal Variations in density (No/l) of different groups of Zooplankton (Krishna Park)

Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years %
1	**Tot. zoo.**	$F_{2\ 21}$ 33.51	1232 ± 84.21	2197± 97.24	1733 ± 65.9	
2	**Rotifera.**	$F_{2\ 21}$ 48.67	422.4± 36.13	934.9 ± 44.2	631.3 ± 28.87	38.5 %
3	**Cladocera.**	F_{221} 18.77	410.8± 30.77	653.8± 29.76	520.6 ± 23.12	30.7 %
4	**Copepoda.**	F_{221} 14.6	338.1± 16.09	513.1± 29.17	443.8 ± 22.05	25.1 %
5	**Ostracoda**	$F_{2\ 21}$ 31.66	60.25 ± 9.60	95.63± 4.27	137.5 ± 5.59	5.68 %

Table 5.4b: Seasonal Variations in species richness (no. of species) of different groups of Zooplankton (Krishna Park)

Sr. No.	Parameters	F value	Winter	Summer	Monsoon	Two Years %
1	**Tot. Zoo.**	$F_{2\ 21}$ 51.75	10.63 ± 0.71	20. 5 ± 0.87	17.63± 0.50	
2	**Rotifera.**	$F_{2\ 21}$ 65.66	4.13 ± 0.35	9.5 ± 0.42	7.37 ± 0.18	43.07 %
3	**Cladocera.**	$F_{2\ 21}$ 15.1	3.37 ± 0.18	5.13 ± 0.23	4.5 ± 0.127	26.66 %
4	**Copepoda.**	$F_{2\ 21}$ 32.17	2.37 ± 0.18	4.38 ± 0.18	3.25 ± 0.16	20.51 %
5	**Ostracoda**	$F_{2\ 21}$23.55	0.75 ± 0.16	1.5 ± 0.19	2.5 ± 0.19	9.74 %

Fig.5.2a Seasonal Variations in density of different groups of Zooplankton (No./l) at Malpur Dam during October 2011 – September 2013.

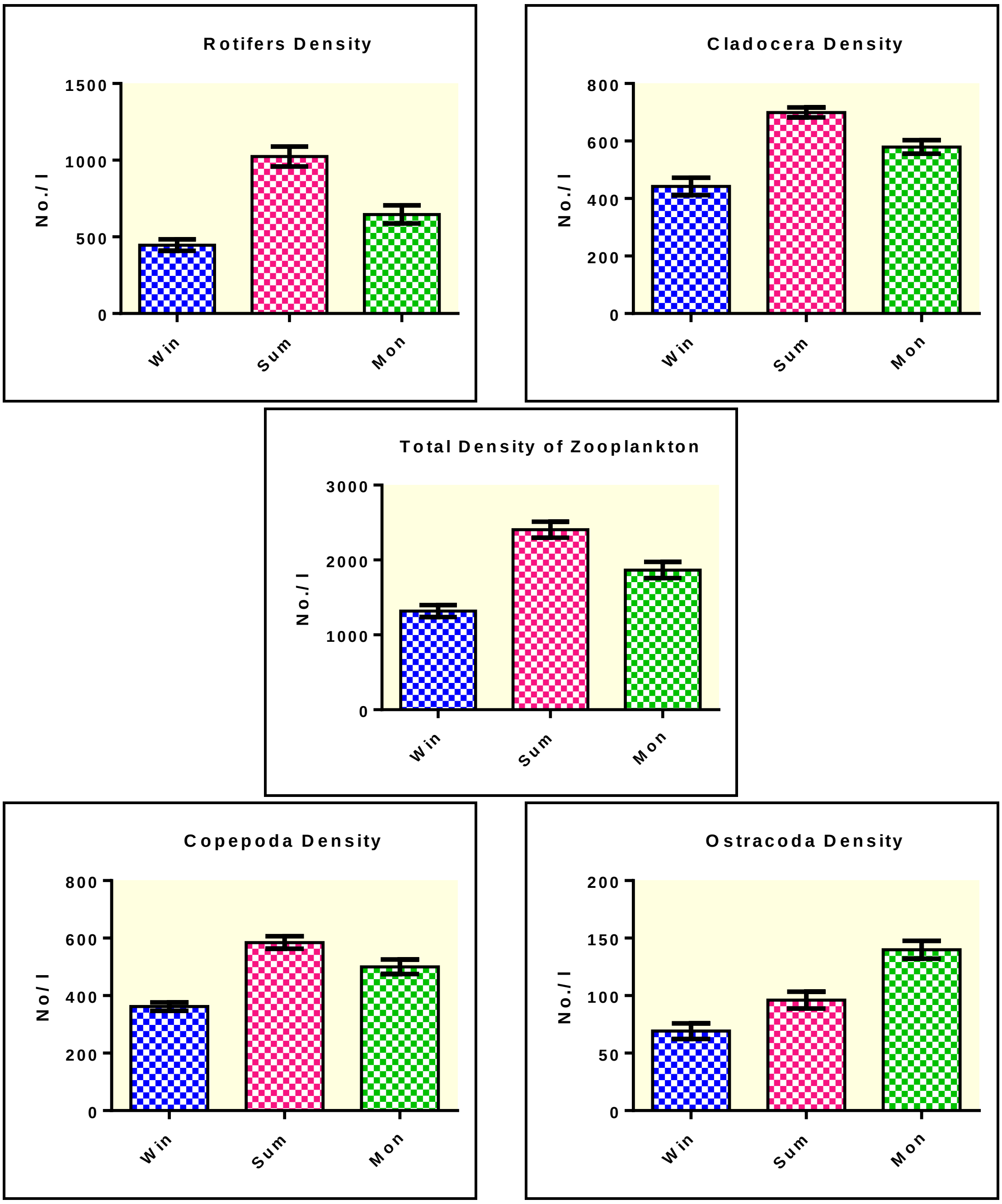


Fig.5.2b Seasonal Variations in Species Richness of different groups of Zooplankton at Malpur Dam during October 2011 – September 2013.

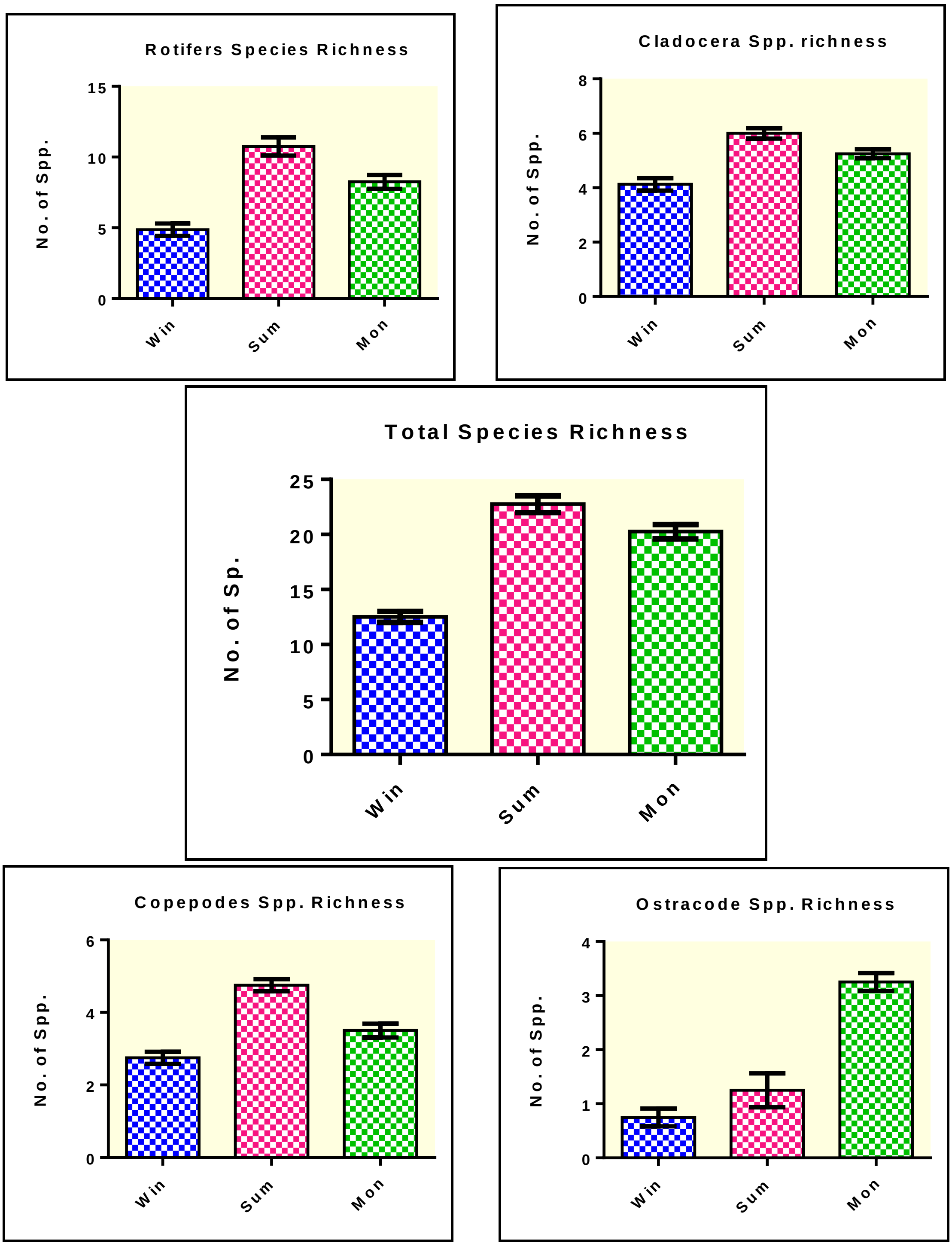


Fig.5.3a Seasonal Variations in density of different groups of Zooplankton (No./l) at Baldane Reservoir during October 2011 – September 2013.

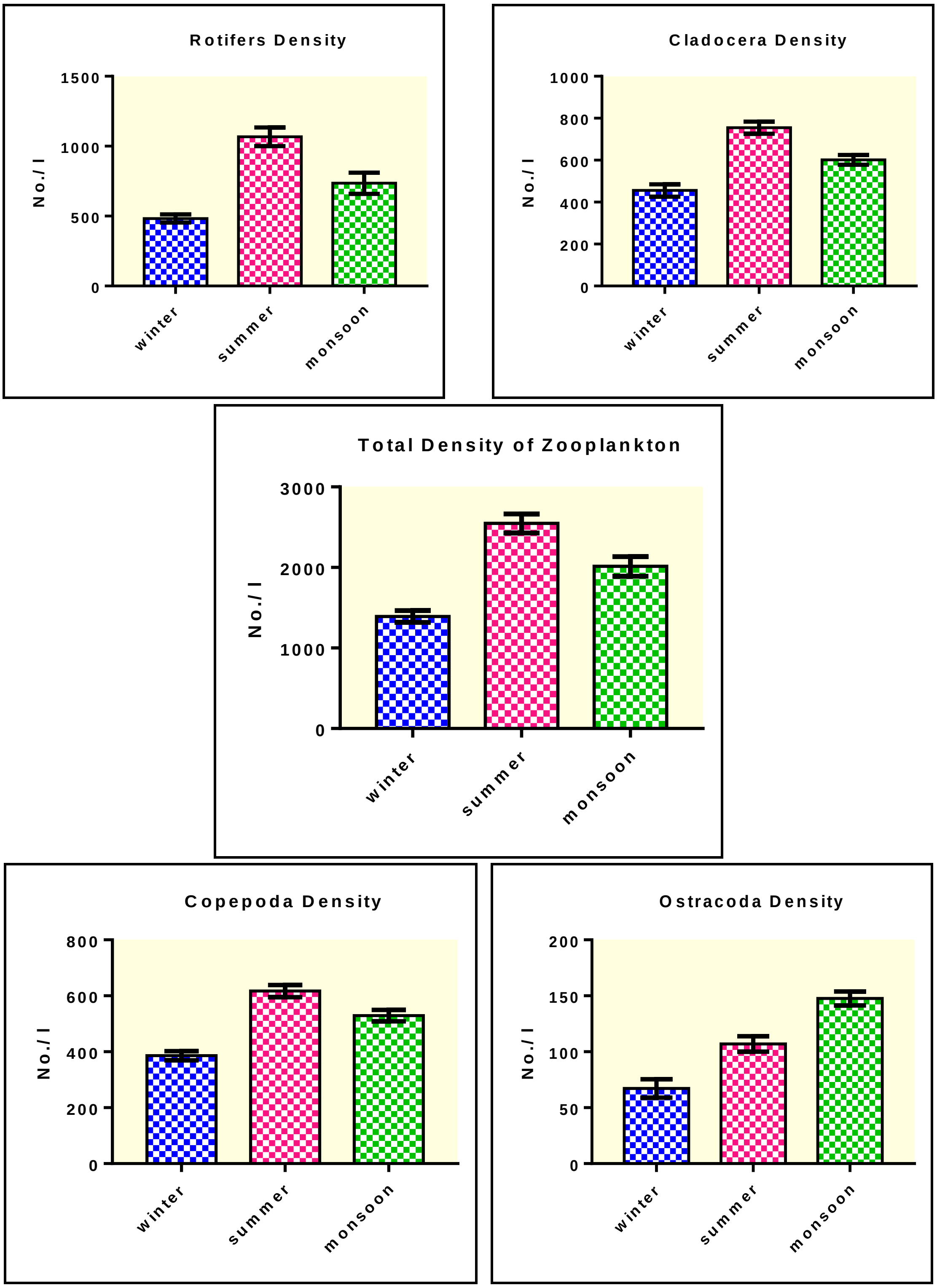
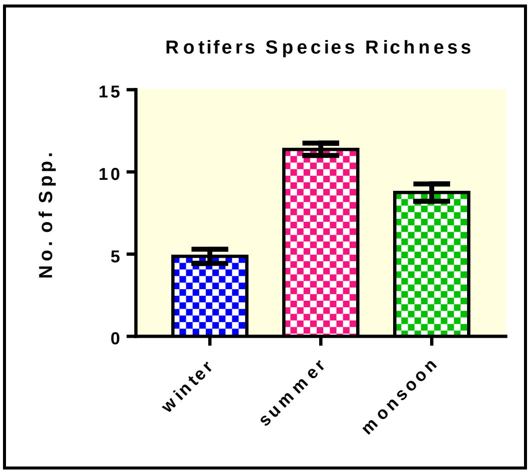
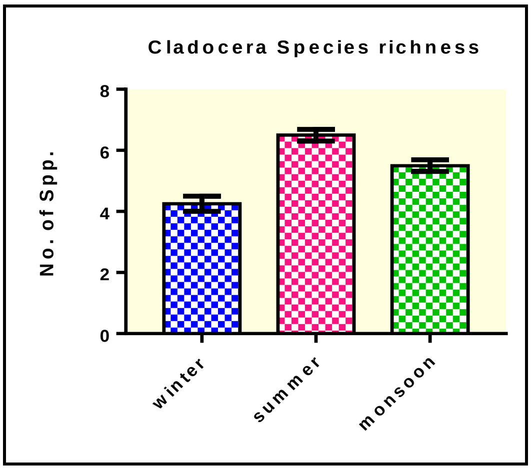
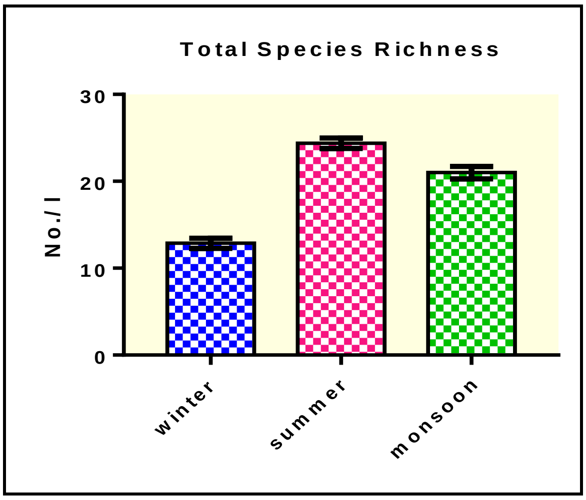
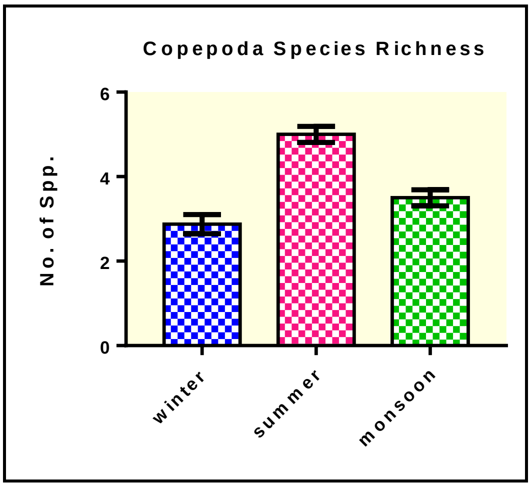


Fig.5.3b Seasonal Variations in Species Richness of different groups of Zooplankton at Baldane Reservoir during October 2011 – September 2013.


Rotifers Species Richness
No. of Spp.
15
10
5
0
winter
summer
monsoon


Cladocera Species richness
No. of Spp.
8
6
4
2
0
winter
summer
monsoon


Total Species Richness
No./l
30
20
10
0
winter
summer
monsoon


Copepoda Species Richness
No. of Spp.
6
4
2
0
winter
summer
monsoon

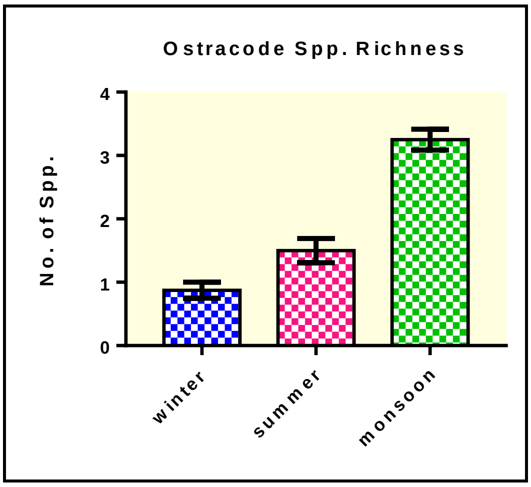

Ostracode Spp. Richness
No. of Spp.
4
3
2
1
0
winter
summer
monsoon

Figure: 5.4a Seasonal variation in density of different groups of Zooplankton (No./ l) at Krishna Park during October 2011 – September 2013.

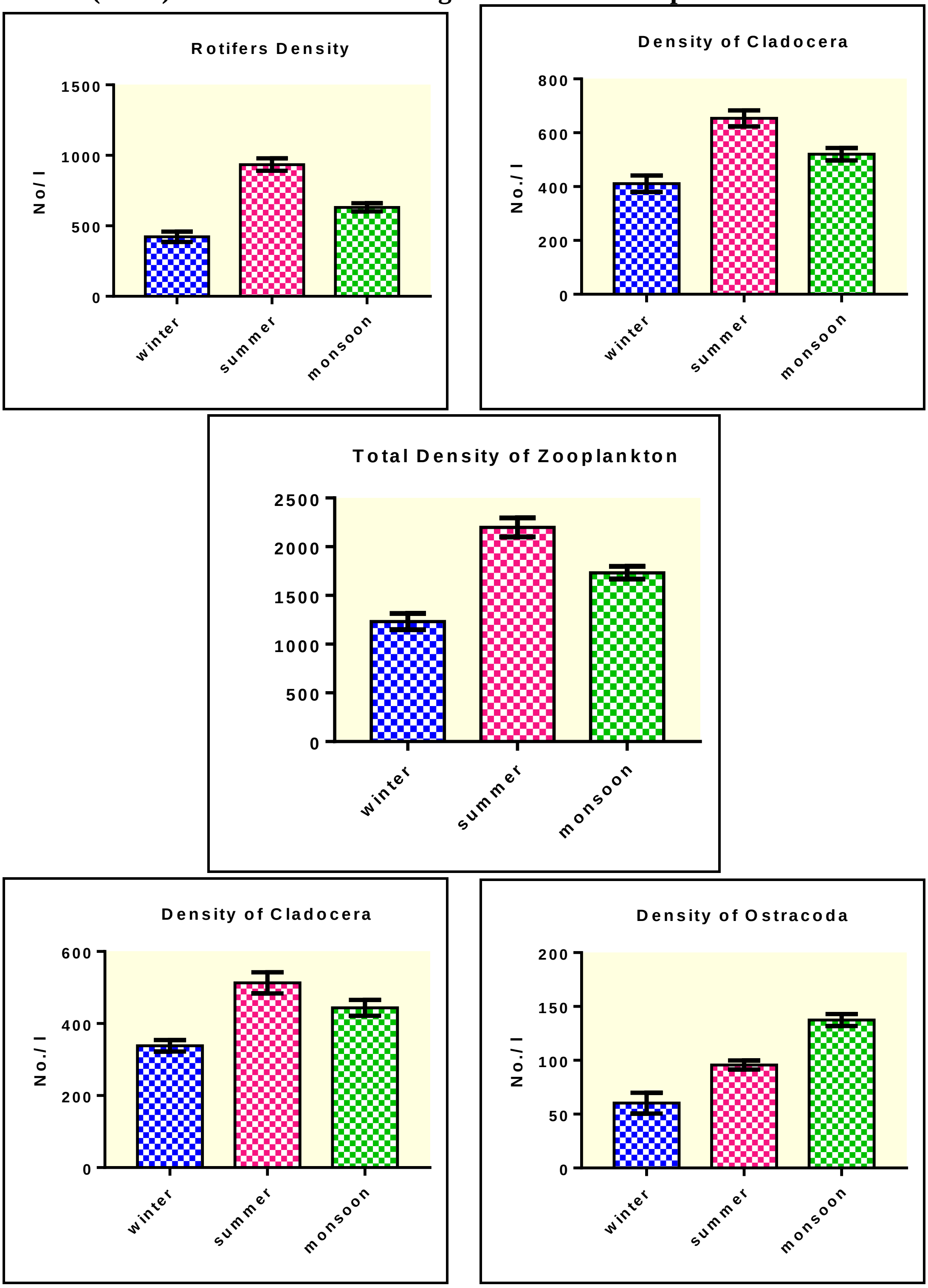


Figure: 5.4b Seasonal variation in Species Richness of different groups of Zooplankton at Krishna Park during October 2011 – September 2013.

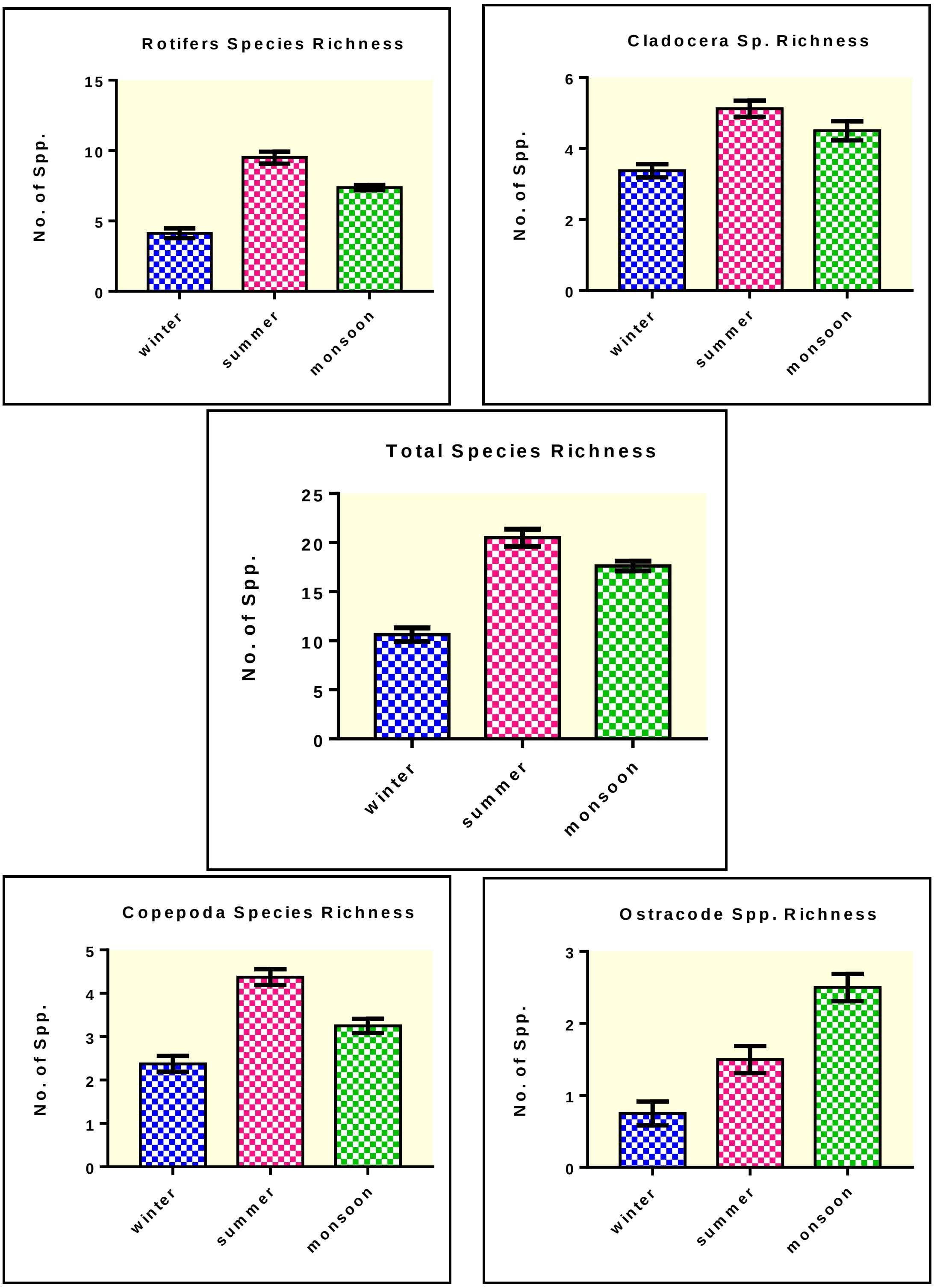


Table 5.5

Pearson Correlation- Physicochemical Parameters and Zooplankton Density of Malpur Dam

	Cladocera	Copepoda	Ostracoda	Rotifera	Tot. Zooplank
AT	.658**	.796**	.482*	.786**	.784**
CA	-.305	-.258	-.274	-.195	-.252
CL	.678**	.556**	-.136	.780**	.693**
Cladocera	1.000	.906**	.450*	.946**	.973**
CO2	.807**	.906**	.548**	.845**	.879**
Copepoda	.906**	1.000	.509*	.916**	.958**
Ostracoda	.450*	.509*	1.000	.341	.468*
DO	-.853**	-.878**	-.438*	-.862**	-.886**
MG	.676**	.631**	-.078	.792**	.719**
NO3	-.242	-.104	.615**	-.375	-.242
PH	.364	.314	-.539**	.543**	.411*
PO4	-.537**	-.427*	.254	-.651**	-.554**
Rotifera	.946**	.916**	.341	1.000	.985**
SO4	.365	.390	-.178	.583**	.474*
Tot. Zooplank	.973**	.958**	.468*	.985**	1.000
TDS	.590**	.544**	-.165	.704**	.626**
TH	.514*	.490*	-.319	.687**	.577**
TRAN	-.498*	-.524**	-.932**	-.363	-.489*
TS	.674**	.687**	.890**	.574**	.677**
TSS	.193	.236	.901**	.027	.171
WC	-.626**	-.547**	.008	-.747**	-.670**
WT	.750**	.864**	.552**	.834**	.851**

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.6

Pearson Correlation- Physcochemical Parameters and Zooplankton Density of Baldane Reservoir

	Cladocera	Copepoda	Ostracoda	Rotifera	Tot. Zooplan
AT	.627**	.739**	.504*	.696**	.709**
CA	-.124	-.199	-.418*	-.074	-.139
CL	.540**	.466*	-.163	.689**	.582**
CO2	.902**	.906**	.472*	.858**	.895**
Cladocera	1.000	.965**	.464*	.936**	.973**
Copepoda	.965**	1.000	.601**	.948**	.986**
Ostracoda	.464*	.601**	1.000	.429*	.533**
Rotifera	.936**	.948**	.429*	1.000	.984**
Tot. Zooplan	.973**	.986**	.533**	.984**	1.000
DO	-.853**	-.909**	-.611**	-.883**	-.906**
MG	.580**	.530**	-.098	.708**	.620**
NO3	-.136	-.121	.117	-.211	-.162
PH	.403	.280	-.511*	.466*	.369
PO4	-.515*	-.427*	.271	-.633**	-.532**
SO4	.554**	.512*	-.146	.645**	.573**
TDS	.760**	.736**	.268	.858**	.811**
TH	.569**	.518**	-.205	.714**	.610**
TRAN	-.431*	-.542**	-.945**	-.359	-.472*
TS	.611**	.688**	.853**	.618**	.677**
TSS	.136	.254	.858**	.062	.177
WC	-.610**	-.554**	.069	-.755**	-.659**
WT	.702**	.782**	.471*	.737**	.755**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5.7

Pearson Correlation- Physicochemical Parameters and Zooplankton Density of Krishna Park

	Cladocera	Copepoda	Ostracoda	Rotifera	Tot. Zooplank
AT	.655**	.680**	.510*	.714**	.729**
Ca	.628**	.480*	-.261	.710**	.616**
Cl	.739**	.734**	.445*	.894**	.851**
CO2	.832**	.807**	.504*	.939**	.919**
Cladocera	1.000	.912**	.371	.903**	.958**
Copepoda	.912**	1.000	.471*	.868**	.942**
Ostracoda	.371	.471*	1.000	.410*	.491*
Rotifera	.903**	.868**	.410*	1.000	.975**
Tot. Zoop	.958**	.942**	.491*	.975**	1.000
DO	-.823**	-.829**	-.489*	-.893**	-.897**
MG	.630**	.539**	-.235	.746**	.650**
NO3	-.104	-.160	.188	-.175	-.136
PH	.377	.205	-.599**	.433*	.320
PO4	-.548**	-.401	.387	-.585**	-.503*
SO4	.534**	.532**	-.257	.627**	.559**
TDS	.772**	.675**	.136	.835**	.793**
TH	.546**	.427*	-.308	.640**	.543**
TRANP	-.388	-.479*	-.934**	-.415*	-.495*
TS	.584**	.614**	.802**	.625**	.674**
TSS	.119	.231	.875**	.121	.213
WC	-.583**	-.473*	.162	-.664**	-.587**
WT	.743**	.769**	.541**	.802**	.820**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Discussion

Zooplanktons are microscopic free swimming animals which represent a major part of aquatic fauna and are known to be crucial link between the primary producers and consumers of lake ecosystem (Malik and Panwar, 2016) and are highly susceptible to wide range of factors like environmental changes, seasonal abundance and temporal variations (Gannon and Stemberger, 1978) as was reported at all the three water bodies namely Malpur Dam, Baldane reservoir and Krishna Park reservoir during the two year study. The distribution, type and number of these organisms present in any aquatic ecosystem/ habitat provide a clue on the environmental condition prevailing in that particular habitat.

The zooplankton community represented by four different groups reservoirs at all three water bodies namely Malpur dam, Baldane tank and Krishna park in decreasing order in density as rotifera>cladocera>copepod>ostracoda as reported in other studies too (Basuet *et al*., 2009; Salve and Hiware, 2010; Joshi,2011; and karthika*etal.,* 2017).

During warmer months (summer) when water temperature was higher maximum density of total zooplanktons was recorded at Malpur dam as is also advocated by Jose and Senthilkumar (2015; and (Salve and Hiware, 2010). Temperature is one of the important factors among the physical factors which has profound influence and direct or indirect effect on biota of an ecosystem (Basu*et.et al.*, 2010). The season wise atmospheric average temperature fluctuation was recorded between minimum to maximum (20.88±1.17 C to 20.25±0.75 C) at Krishna park and Malpur Dam.

The total zooplanktons showed positive significant correlation with atmospheric temperature, chloride, carbon dioxide, Magnesium and water temperature while significantly negative correlation with dissolved oxygen, phosphate and water cover at Malpur dam. Almost similar correlations were recorded at Baldane reservoir and Krishna park reservoirs.

The physicochemical parameters such as temperature, light, pH, organic and inorganic components and interrelationship with other organisms play an important role in determining the nature and pattern of alterations of population densities of zooplankton in an ecosystem (Jadhav *etal*.,2012). The higher density of phytoplankton of Lotus lake in summer created a favorable niche for herbivorous zooplanktons, thus increasing the density of these primary consumers (Patil,2011) and in turn increase the density of secondary consumer zooplankton increasing the total zooplankton density. Similar findings with higher density of zooplankton in summer are reported at Krishna park reservoir and Malpur dam and Baldane reservoir, in comparison with higher densities of phytoplankton. The above results are also advocated (Kumar *etal.*,2011) in tropical wetlands with zooplankton peak in summer. Malik and Panwar, (2016) showed temperature, salinity, water, dissolved oxygen and pH of lake as critical factors in development of zooplanktons. Chloride, carbon dioxide, pH, Mg, sulphate and physical factors like ambient temperature and water temperature, total hardness, total solids, total dissolved solids showed positive correlation with total zooplanktons while negative correlation with dissolved oxygen, phosphate, water cover and transparency at Krishna park and Baldane reservoir.

The higher summer population densities of zooplanktons at all three reservoirs were coincided with the peak of phytoplankton density, high temperature and low rainfall (Jagadishappa and Vijaya Kumar, 2013) indicating that the density and diversity of different groups of zooplanktons were remaining high in pre monsoon. Since all the wetlands are located under semi arid zone/region, the prevailing temperature and a nutrient load by various factors enhance the population abundance of plankton.

The Summer population maxima of zooplanktons were correlated with higher temperatures, low transparency and a high standing crop of primary producers and decomposition of organic matter leading greater availability of food (Joshi, 2011) as was recorded during the present study at all the three reservoirs. The summer maxima were also advocated by (Sharma *et.al*.,2013) where zooplanktons population was shared mainly by rotifers, and was seen maximum in March and minimum in August; due to abundance in food.

At lower temperature, some of the species may enter diapause condition (Wetzel, 2001). However, contrasting results have been recorded of higher zooplankton density during winter season with 2437no/l at Safilguda tank, Hyderabad (Karuthapandi*etal.*,2013). The zooplankton composition, abundance and distribution are very sensitive to ecological changes; therefore, they are considered as more ideal indicators of tropic state and aquatic ecosystem Gunn and May (1997).

Among zooplanktons, rotifers are most dominant groups reported at all three water bodies as was also depicted by Arora and Mehra, (2009), Dhembare, (2011), Thirupathaih *et al*. (2011), Akindele and Olutona, (2014),. Sanyal *et al*. (2015) during their investigations. Dominance of rotifer were, also reported (Manickam *et.al.,* 2017) with top rank in percentage composition in Surur and Ukkadam lake. Although

Rotifera dominated the fauna qualitatively, their quantitative contribution was much lower (Akindele and Olutona, 2014) than that of Copepoda, a greater percentage of which was recorded between November and March when flow velocity was greatly reduced.

The summer maxima of all major groups of zooplanktons were observed, correlated with higher temperature, lower transparency and a high standing crop of primary producers leading to greater availability of food (Sharma *et al*., 2013) as also depicted in present investigation at all the three water bodies. However, high rotifer species in the water body indicates enrichment due to direct inflow of untreated domestic sewage from adjacent areas into the wetland (Arora,1966).

Cladocera were the second in order of abundance in freshwaters. Their population was comparatively higher in high temperature, (Kapoo, 2015). It is an order of small crustaceans commonly called as water fleas. In the present investigation seasonal occurrence of maximum cladoceras mean density varied from (700±17.2no./l) in summer to (442±14.7no./l) in winter with relative density percentage of 30.79% at Malpur Dam. Similar trends of cladoceran density was recorded in other two water bodies viz. Baldanereservoir& Krishna Park reservoir. Hence, distinct seasonal fluctuations in Cladoceran density were recorded.

Cladocerans commonly known as water fleas, constitute one of the major groups of animals of great economic importance in freshwater ecosystems. They are also widely used in aquaculture as large filter feeding cladoceran species and have an indirect economic impact as important fish food or phytoplankton controlling group (Padate, *et al.,* 2014). In present investigation distinct seasonal fluctuations of cladoceran density were recorded. Cladocerans at Malpur dam showed positive significant seasonal correlations with atmospheric temperature, chloride, carbon dioxide, magnesium, total dissolved solids, total hardness, total solids and water cover whereas significant negative correlation was showed by dissolved oxygen, phosphate, transparency and water cover. Though Malik and Panwar, (2016) reported positive correlation between cladocera growth with water temperature and pH and negative correlation with oxygen and alkalinity. This group showed its quantitative abundance in summer and the least number was seen in the monsoon (Kaur *et al.,* 2016).

During the present investigation minimum cladoceran density reported in winter season at all three water bodies, as was recorded at Lotus lake, Toranmal (Padate *et al.,* 2014). Shah *et al.* (2013) recorded high seasonal variability due to the undulation of parthenogenesis. However, contrastingly maximum abundance of cladocera reported during winter season and minimum during summer season (Dipthi and Yamakanamrdi, 2014) at Varuna and Giribettethe lakes of Mysore. The summer maxima may be attributed to favorable temperature and availability of food in the form of bacteria, nanoplankton and suspended detritus and factors like DO, water. The seasonal succession of the cladocera is quite variable, both among species and within a species living in different lake conditions.

Temperature and turbidity also play an important role in controlling the density of cladocera (Edmondson, 1965) and Naik *et al.* (2017) reported higher density and diversity of cladocera in the month of May, June and July where the density started increasing in spring and reached to its peak in early summer and lowest in winter thereby revealing the unimodal pattern of seasonal fluctuations, as was advocated in the present study at all three water bodies.

With respect to species richness also this group appeared second dominant component in all three water bodies with two years average percentage species richness of 27.5% at Malpur dam, 27.9% at Baldane reservoir respectively. In fresh waters, the truly planktonic crustacean; cladocerans and copepodas; dominate almost completely (Wetzel, 2006).

Increase in temperature results in an immediate effect by increasing the rate of moulting and brood production, whereas increase in food supply, within limits, affects rate of development of the population by increasing survivorship and fecundity (Wetzel, 2001). Among cladoceran zooplanktons population in general, low populations in winter among perennial species and a near absence in winter among aestival species are common With increasing food supply from algae, detritus and bacteria with rising temperatures in (spring), cladoceran population increase from overwintering adults or resting broods (Wetzel,2006). Temperature increases the rate of molting and brood production, while rising food supply results in increasing number of eggs per brood. The herbivorous populations can increase exponentially to the point where the community filtrations rates crop the phytoplanktons at the rates exceed the reproductive rates of the phytoplankton community.

According to Deepthi and Yamakanamrdi, (2014) water temperature, COD and conductivity are the major factors affecting the abundance of cladocera, whereas the abundance of cladocerans seem to be correlated on phytoplankton density (Nerves,2016). The density of cladocera was seen positively significantly correlated with density of Bacillariophaceae, density of copepods, density of rotifers, total zooplankton, at Malpur dam.

Copepoda

Freshwater copepods constitute one of the major zooplankton communities occurring in all types of water bodies and also reported in all the three water bodies selected for the study during the two years. They qualitatively as well as quantitatively remained dominant in summer al all three water bodies. Their quantitative as well as qualitative abundance in summer as they prefer warm conditions to flourish and multiply in number is also advocated (Kaur *et.al*., 2016) in perennial pond Jonu of subtotal regions of Jammu. They are able to resist the harsh conditions of higher temperatures and even the flushing with water due to their comparatively bigger size. During the present study their positively significant correlation was recorded with AT,CaH,Cl,CO_2,MgH,SO_4,TDS,TS,TH and water temperature and negatively significantly correlated with DO and transparency during study at Krishna park reservoir. Almost similar correlations were also recorded at Malpur dam and Baldane reservoir. With phytoplanktons, copepodas were seen to positively significantly correlated with Chlorophyceae and cyanophyceae at Malpur dam. Among copepodas some of the species are planktonic, some are benthic, and some continental species may live in limno-terrestrial habitats and other wet terrestrial places, such as swamps, bogs, springs, ephemeral ponds and poodles, damps moss or water filled recesses of plants such as bromeliads and pitcher plants.\

Seasonally higher population densities of copepodes were found in summer. Similar summer maxima were also advocated by Jagadishappa *et al*. (2013) in wetlands of Tumkur of Karnataka. Copepodas were reported dominant (Kapoor, 2015) at sites where macrophytes were more. Among copepod species cyclops species (62.50%) show its greatest abundance (Pal, 2015) in manmade wetlands during warmer months at Cooch Behar.

The positive correlation between the copepod with water temperature, pH and negative with dissolved oxygen and alkalinity were depicted in Bhimtal Lake of Kumaun region of Uttarakhand (Malik and Panwar, 2016). In floodplain wetland of West Bengal copepods dominated the zooplankton population in terms of numerical density, as compared to Rotifers and Cladocerans(Ganesan and Khan,2008). During summer the density of copepod and cladocera were recorded higher than rotifers

(Karuthapandi *et al*., 2013) and found dominant in oligotrophic lakes (Kurasawara, 1975).

Ostracoda

Ostracods are calcified and bivalve group having shape like small seeds. The freshwater ostracods inhibits lakes, tanks, ponds, pools, swamps, streams and even polluted waters. Ostracods are the common group of micro benthos in aquatic ecosystem with adult typically 0.5 to 3.0 mm long. Many freshwater ostracods live among the macrophytes in the littoral and sublittoral zones of lakes for food and shelter (Altinsach *et al.,* 2014). Ostracods are of benthic nature and play a role of converting phytoplankton to food for fish and other aquatic animals. They are found in almost every aquatic environment and their distribution is controlled by hydrobiological, biological and sedimentological features (Faiz *et al*., 2017). When different environments (Parana river, tributaries and lakes) were analyzed together, turbidity, pH, water temperature, dissolved oxygen, electrical conductivity and total phosphorus were the factors that showed significant influence on ostracod distribution (Higuti *et al*., 2017). Atmospheric temperature, water temperature, carbon dioxide, total solids, total suspended solids showed significant positive correlations while DO, Calcium, pH, transparency showed negative correlations with ostracodes at Malpur dam. Nearly similar observation were recorded at Baldane reservoir and Krishna Park reservoirs. Shah *et al*. (2013) the density of ostracods also showed significant positive correlation with density of Euglenophyta, while negatively correlated with the density of Bacillariophyceae, chlorophyceae and Cyanophyceae at Malpur dam during study period. Ostracoda abundance and species diversity vary independently and their distribution is defined by different environmental factors (Faiz *et al.,* 2017). During the study the *Cypris subglobosa, Eucypris species, Standesiala biata, Hemicypris anomala, Cypris notuscingalensis* and *India cyprisdispar* were reported commonly from all the three water bodies, while *Stenocypris major* was reported rarely during the study period at Krishna Park reservoir while not reporting at Malpur dam and Baldane reservoirs. Maximum 7 species of ostracoda were reported from all the three water bodies with two year average percentage composition of (9.74 %, 9.6 % and 9.4 %) at Krishna park reservoir, Baldane reservoir and Malpur dam respectively. Altinsach *et al*. (2014) reported 8147 ostracodes of 24 species from nine wetlands (lakes and lagoons) Kocaeli and Sakarya of Turky. 44 species of ostracods recorded in the river flood plain system of upper Parana river of south central Brazil where higher species richness and densities were recorded in the lentic environment as compared to lotic environment (main channel of Parana river and tributeries). This difference has been attributed to the lower waterflow and higher stability within the lentic environments.

Ostracods revealed the seasonal variations during the study period. Shah et al. (2013) recorded significant seasonal positive correlation with temperature ($P < 0.05$), indicating temperature has strong influence on crustacean abundance in two ways, as directly to hasten the growth rates, thereby increasing population densities while indirectly by stimulating growth of phytoplankton providing nutrients.

Karthica *et al*. (2017) reported 4 species of ostracoda with mean density ranging between maximum in summer 164.6 ± 41.5 org/l and minimum 20.6 ± 9.2 org/l. recorded in monsoon at Perur lake in Tamil Nadu but during present study maximum density (139 ± 7.86 org/l) of ostracodes were recorded in monsoon and minimum (69.13 ± 6.85 org/l) in winter with two year percentage (5.45 %) at Malpur dam. Almost similar trends of ostracode density were recorded at Krishna park and Baldane reservoirs.

Looking at the Data collected it may be said that the three ma made water bodies have established themselves with healthy population of zooplankton which depend on various physical, chemical biological as well as geographical factors.