Seasonal variability and Diversity of Zooplanktons in three treated sewage water fed ponds in CHRIST (Deemed to be University), Bengaluru, Karnataka, India.

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Abstract

Monthly and seasonal variances in zooplankton composition, abundance and diversity suggest the current ecological state of the three treated sewage water fed ponds at Main Campus (MCP: 12.555°N, 77.361° E), Bannerghatta Campus (BCP:12.523°N, 77.354°E) and Kengeri Campus (KCP:12.514°N, 77.261°E) of CHRIST(Deemed to be University), Bengaluru, Karnataka , India. The Present research predicts that changes in zooplankton compositions appear seasonally and location wise in treated sewage water discharged ponds. The population of zooplankton represent 26 genera belong to *Rotifera*, *Copepoda*,*Cladocer*, *Ostracoda* and Nauplii of various species. The Dominance of genera was in order of Rotifer>Copepoda> Cladocera>Ostracoda. Seasonal changes and monthly changes in abundance were found to be distinct, highest abundances of populations were observed in the order of summer>post-monsoon> winter >monsoon.

The minimum and maximum values of Shannon-Wiener index(H)were observed in the sites during the seasons as MC(Winter):2.39238; KC(Summer):3.10467,Jaccard Evenness Index**:** KC(Summer): 0.048077; MC(Winter):0.106648,Index of Dominance: KC(Summer): 0.048077; MC(Winter):0.106648. The percentage contribution of each group of zooplankton was found to be: 74% *Rotifera>14%Ostracoda>7* % *Copepod*> 6% *Cladocera*.
Keywords: Treated sewage water, Zooplankton *Rotifera, Copepoda, Claodcera, Ostracoda.*

Introduction

Limnology is an interdisciplinary science which entails extensive field and laboratory research to obtain an extensive understanding of the structural and functional aspects and problems associated with the freshwater environment(Cole & Weihe, 2015)(Agrawal, 1999; Lind, 2016; Moss, 2013; Wetzel, 2001)(Ruttner, 2020). Human abuse and mismanagement of both living resources and the ecosystems that support them are the principal dangers to aquatic biodiversity. The major part of ponds are polluted by domestic waste, sewage, industrial and agricultural effluents(Parisara, 2022; Shekhar *et al.*, 2008)(Chapman, 1996)).The need for water in all life forms, from microorganisms to life forms, is a significant matter today, as all water resources have reaches critical point as a direct consequence of unplanned urbanization and industrialization. Characterize zooplankton as one of the most essential biotic components regulating all functional elements of an aquatic ecosystem, including food chains, food webs, energy flow, and matter cycling. (K. Sharma *et al*., 2012). Zooplankton is an essential component of the aquatic ecosystem, serving a wide range of critical functions. First and foremost, it purifies water by feeding on phytoplankton and microorganisms. We can assess water quality based on the dominant species in zooplankton communities. As a result, zooplankton can be used to predict saprobity. Zooplankton, on the other hand, is a source of food for fish fry and some species of mature fish**(Hudson, 1886; Santhanam *et al.*, 2018)(Hulyal and Kaliwal, 2008; Shekhar et *al.*, 2008)**. Furthermore, the diversity, abundance, and biomass of zooplankton determine fish production in the aquatic ecosystem. Fish resources are affected by zooplanktons reproductive cycles, growth, reproduction, and survival rates(Duhamel & Hureau, 1985).On the other hand, zooplankton assemblages have been used to track environmental changes over time, such as hydrographic events, eutrophication, pollution, global warming, and environmental concerns (Omori & Ikeda, 1984). Zooplankton biomass is ecologically important since the composition and abundance of zooplankton differs depending on the aquatic environment. According to(Lansac-Tôha *et al*., 2009)(Y. Zakaria *et al.*, 2019)(Duggan *et al.*, 2001a)(Joseph &Yamakanamardi, 2011).zooplankton plays an essential part as a bioindicator and is an excellent tool to determine the state of water pollution..Because zooplankton has a short life cycle and reacts to the environment more quickly, plankton communication changes in terms of tolerance, abundance, diversity, and dominance in the ecosystem. As a result, zooplankton communities from a variety of reservoirs, lakes, and shallow water bodies have been employed as markers of lake health(Hulyal&Kaliwal, 2008)(Chapman, 1996)(Duggan *et al.*, 2001a)(Sun *et al.*, 2023).

Seasonal studies of zooplankton abundance in a given water body not only explain the mechanisms that cause the presence or absence of certain taxa, but also interpret variations in species diversity patterns. They will also aid in the assessment of a water body's current status. Because there are no studies on zooplankton species richness, variety, abundance, or seasonal variations in treated and untreated sewage water ponds, as a result, the current study aims to look at the richness, diversity, and evenness of zooplankton species in relation to one another.

Materials and methods

Study Area

Sewage treatment plants located on all three campuses of CHRIST (Deemed to be University) in the heart of Bangalore, Karnataka, India, receive waste water primarily from toilets, housekeeping, laboratories, laundries, restaurants, washrooms, hostels, and construction works that are present on these massive campuses that provide space for more than 35 thousand of students to study and live in. Wastewater is collected and sent to one or more centralized Sewage Treatment Plants via sewage networks (underground sewage pipelines) (STPs). The fundamental concept behind sewage treatment is to convert waste water generated by the institute into a useable form that may be used for a variety of applications such as plant irrigation, rest rooms, animal husbandry, fish culturing, and vehicle washing, among others. MT, BT and KT were the three-water sample collecting sites. i.e. Main campus Treated sewage water (MT), Bannerghatta campus Treated sewage water (BT) and Kengeri campus Treated sewage water (KT). The ponds were found between the latitudes of 12°5' and 12°56'N and the longitudes of 77°26' and 77°36'E in the Campuses.

Table.1 Study Areas in CHRIST (Deemed to be University) Campuses, Begaluru, Karnataka, India.

Sl.No	Study Area	Abrev,	Latitudes	Longitudes
1	Main campus	MCP	12°55'59.9" N	77°36'14.7" E
2	Bannerghatta Campus	BCP	12°52'39.5" N	77°35'45.4" E
3	Kengeri Campus	KCP	12°51'40.5" N	77°26'18.4" E

Sampling Sites

MC (12.555°N, 77.361° E) BC (12.523°N, 77.354°E) KC (12.514°N, 77.261°E)

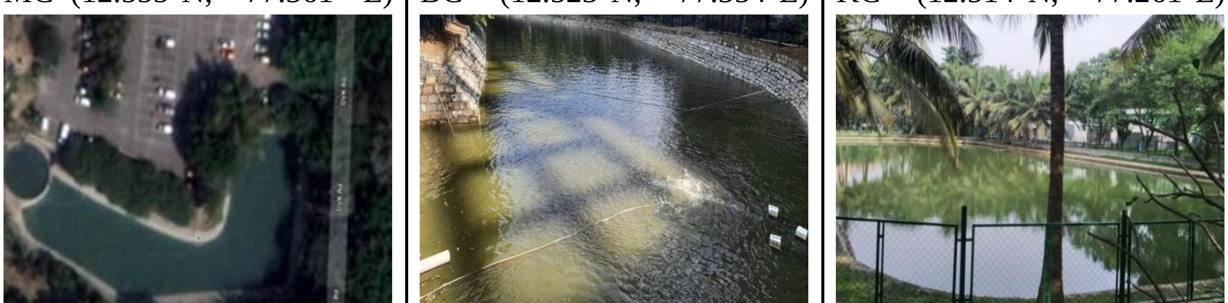


Fig:1. Images of study sites and their geographical Co-ordinates of CHRIST(Deemed to be University),Bengaluru, Karnataka, India.

Sampling Procedure

Collection, Preservation, Identification, and Density Analysis of Zooplankton. For one year(Nov-2019-Dec2020), zooplankton samples were collected from each selected study site of these selected Treated sewage water ponds,with sampling taking place between 7 and 10 a.m. Zooplanktons were gathered at 1m intervals in the water column, and zooplankton populations were concentrated using a planktonic net with a mesh size of 90cm long, 78cm wide, 50mm pore size, and a 25 ml container to hold the zooplanktons. After collecting, zooplanktons were brought to the laboratory and a few drops of lugol's iodine solution were added, followed by 4% formaline(Zhang *et al.*, 2022)(Harris *et al.*, 2000; Johnson & Allen, 2012)(Manuri *et al.*, 2022; Unesco, 1968)(Lansac-Tôha *et al.*, 2009; Manuri *et al.*, 2022; Unesco, 1968)(Dar &Khuroo,

2020). The plankton net was towed in the open water area of each site three times to collect zooplankton precisely (horizontally, vertically and obliquely). Zooplankton samples were first classified into major taxonomic groups, and enumeration was accomplished compound microscope (labovision) (Medstar) as well as a phase contrast microscope (Lawrence Hamyo) under the power of 4X, 10X, 20X, 40X, and 60 X, respectively, for the estimation and identification of zooplankton populations. (Altaff . K (2004) (Akindele, 2014; Sadashivappa *et al*., 2011).Using stereo microscopes adult individuals were separated from the sub-samples and preserved in small glass bottles using 70% ethyl alcohol for species identification using zooplankton keys(Harris *et al*., 2000)((Todd *et al*., 1996)(Goswami, 2004) . For quantitative estimation of zooplankton, The net is dragged horizontally and obliquely in surface water of the study region. Two buckets of water (one bucket = 10 litres) were collected from each sampling site and filtered out through the net for quantitative examination. Following the transfer of the material into airtight plastic bottles, it was carefully labeled and stored.A Sedgewick-Rafter counting cell 50mm long, 20mm wide, and 1mm deep was used to evaluate quantitative samples for zooplankton abundance (ind.l-1) and its constitutive entities. 1 ml of concentrated sample from each sampling site was transferred into the Sedgwick Rafter counting chamber, and air bubbles were avoided during the transfer. Furthermore, before counting the zooplankton, it was made certain that all of the organisms had settled down. During the one year period 2019-2020, each sample was counted for zooplankton at least five times, and an average was taken for the samples of each month. Samples were used to conduct qualitative and quantitative analyses of zooplankton. The abundance of zooplankton was calculated using the formula: No: of Organisms/m3 = C x V 1 / V2 xV3 Where, C= No: of organisms counted V1= Volume of concentrated sample (25 ml) V2= Volume of sample counted (1 ml) V3= Volume of grab sample (0.1m3) Finally, to obtain organisms/ L, the number of organisms per m3 was divided by 1000.

Ecological indices such as Shannon-wiener index(Zhang *et al*., 2022; Zhao *et al.*, 2022), Jaccard (1942) Evenness Index (Czerniawski & Pilecka-Rapacz, 2011; Lansac-Tôha *et al.*, 2009) and Index of Dominance(Rajagopal *et al*., 2010; Shrestha & Shrestha, 2013) were analyzed.

Result and Discussion

During the 12 month study, a total of 26 species belong to four taxonomic groups such as *Rotifera*,*Copepoda*, *Cladocera and Ostracoda* were observed. Rotifera was the dominant group represented with 12 species followed by, Copepoda with 8 species and only three species were recorded from Cladocera as well as ostracoda. Seasonal variations in zooplankters reveals that, maximum number of individuals were recorded during summer>post-monsoon> winter >monsoon.

Rotifera

Rotifers or tiny wheel animalcules, are known as nature's water purifiers because they perform an important cleanup service in the still or slow-moving waters in which they live. Because of their limnetic origin, capacity to adapt to changes in the physical-chemical characteristics of the water, resistance of certain species to hypoxia and anoxia conditions, suspension feeders, benefits from short life cycles, parthenogenetic reproduction, and the capacity to develop resistant cysts rotifer populations thrive in freshwater habitats. The density of *rotifers*(Fig:2-9) is found to be lowest in the winter and largest in the summer proves their love for warm temperatures resulted in higher populations of rotifers during the summer, results justified with values of (Jiménez-Contreras *et al.*, 2018)(Joseph &Yamakanamardi, 2011; Rajagopal *et al.*, 2010). Also hyper tropical circumstances of the water body, which include high temperatures and low water levels, can be attributed to higher rotifer assemblages in the summer(Jiménez-Contreras *et al.*, 2018; Rajagopal *et al.*, 2010). The dominance and quantity of rotifers are related to an increase in trophic circumstances because of their capacity to consume smaller creatures like bacteria and other organic debris, which are numerous in eutrophic habitats. It is believed that *Brachionus calyciflorus* is a highly reliable indicator of eutrophication. *Brachionus angularis*, *Filinalongiseta, and Lecane sp*. are indicators of semi-polluted waterways. Among the various species *Brachionus quadridentatus*, *B.rubens*, *B.calyciflorus*, *B.rotundiforms*, *Rotifer nauplii(Rotifer), Asplanchna intermedia(Rotifer),Habrotrocha bryce(Rotifer)*,were the most abundant forms.

Concentrations of *Rotifers*

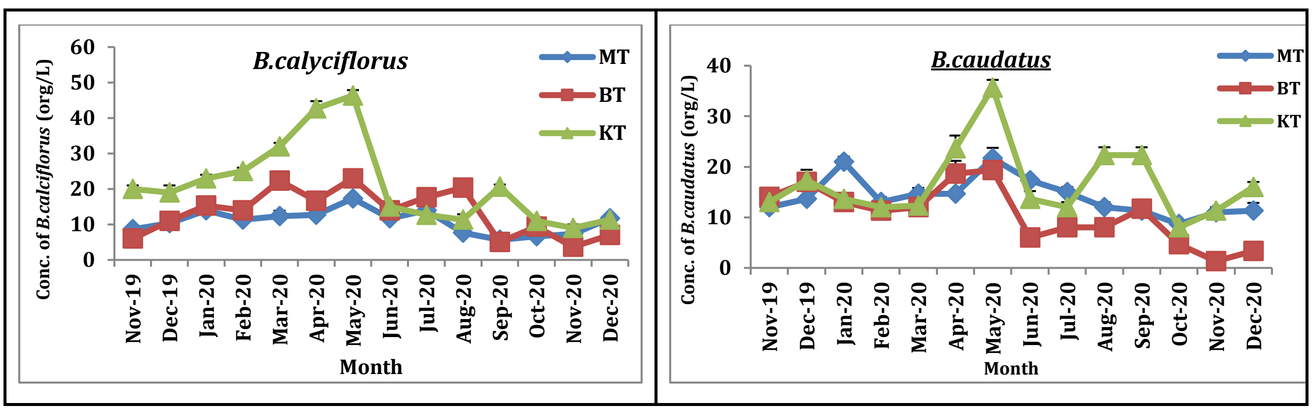


Fig:2 Conc.of (a) *B. calyciflorus* (b) *B.caudatus* from the treated sewage water samples.

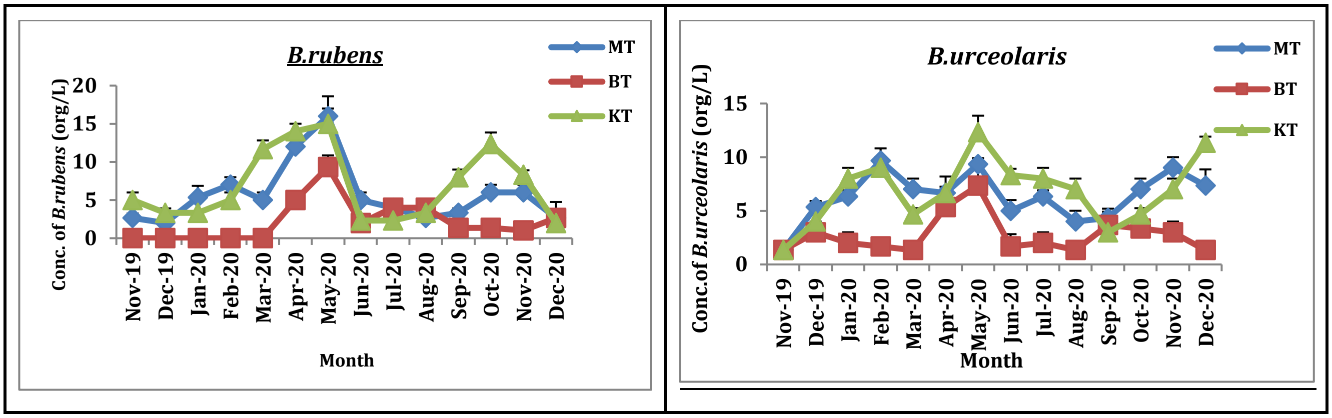


Fig:3 Conc.of (a) *B.rubens* (b) *B.urceolaris* from the treated sewage water samples.

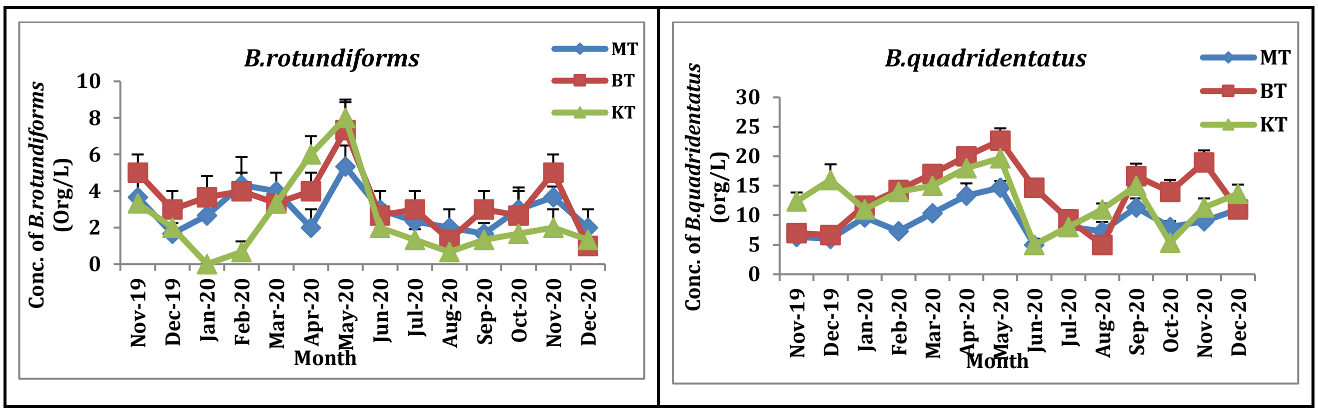


Fig:4 Conc.of (a) *B.rotundiforms* (b) *B.quadridentatus* from the treated sewage water samples.

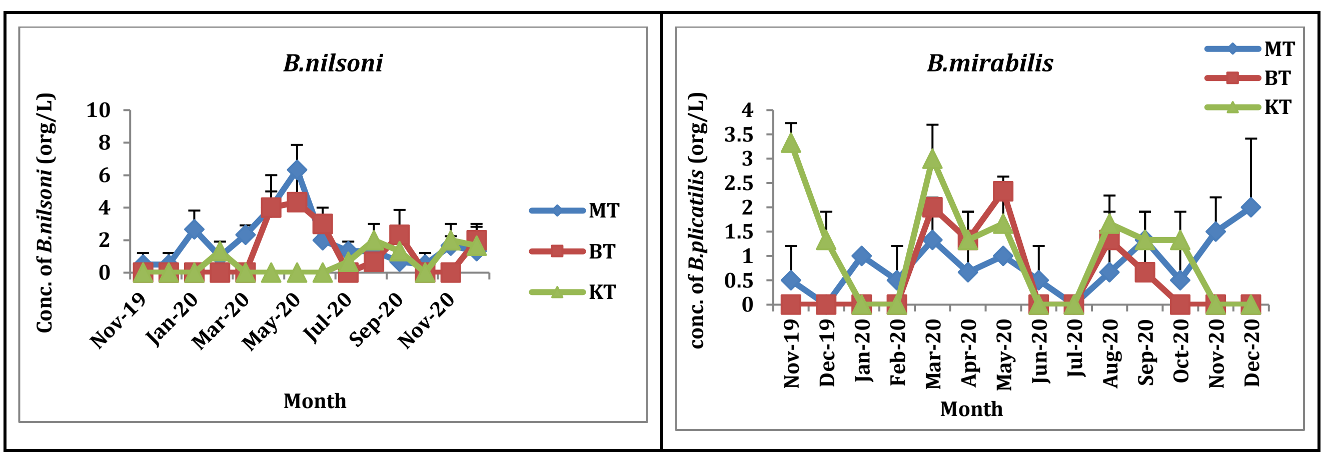


Fig:5 Conc.of (a) *B. nilsoni* (b) *B.plicatilis* from the treated sewage water samples.

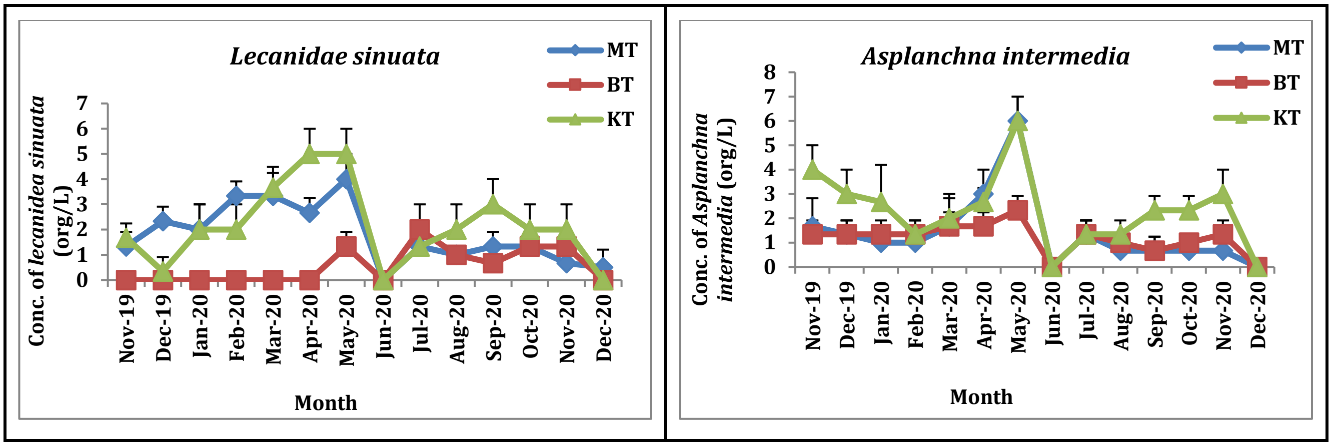


Fig:6 Conc.of (a) *Lecanidae sinuata* (b) *Asplanchna intermedia* from the treated sewage water samples.

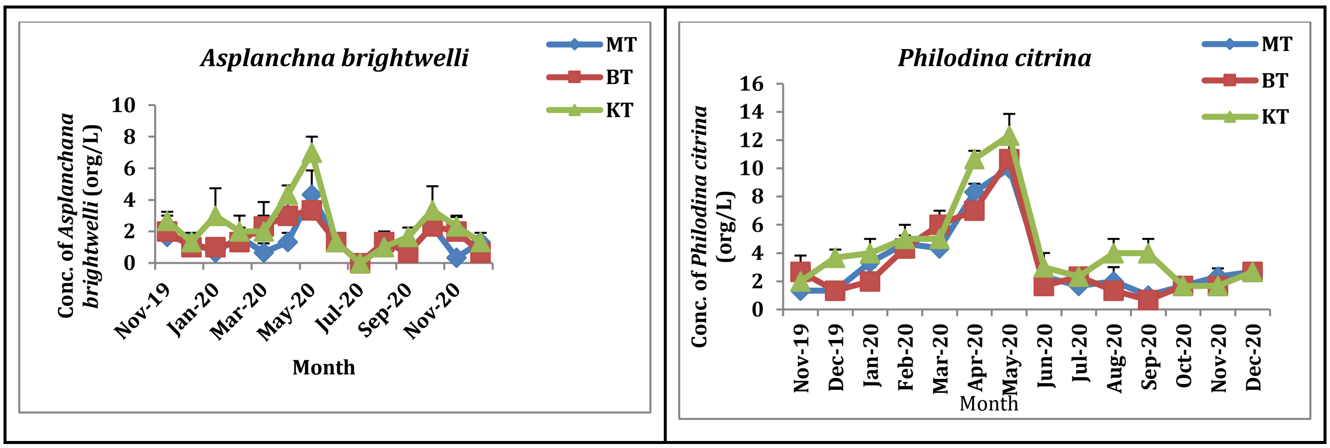


Fig:7 Conc.of (a) *Asplanchna brightwelli* (b)*Philodina citrina* from the treated sewage water samples.

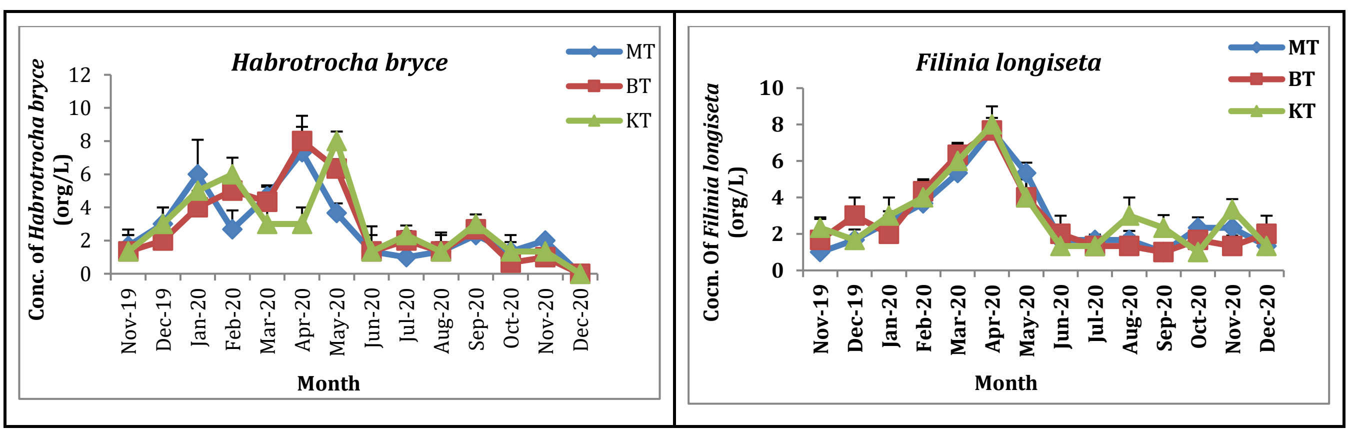


Fig:8 Conc.of (a) *Habrotrocha bryce* (b) *Filinia longiseta* from the treated sewage water samples.

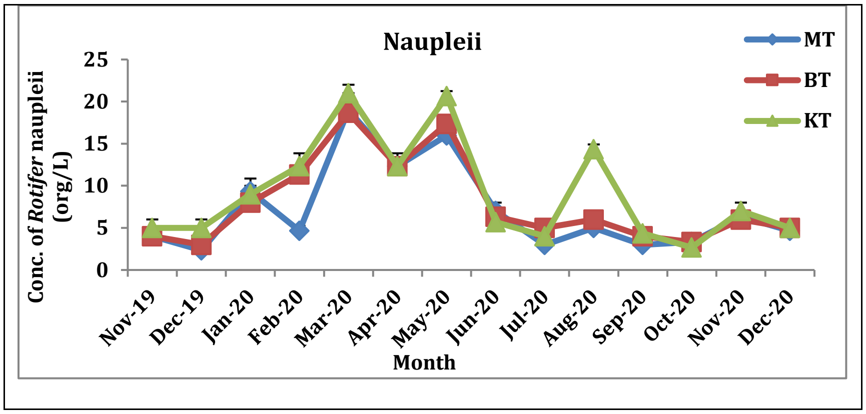


Fig:9 Conc.of *Rotifer* naupleii from the treated sewage water samples.

Copepoda

One of the main zooplankton populations found in all kinds of water bodies is made up of copepods. They are a fundamental component of ecological pyramids and provide food for a variety of fishes, during the investigation of my study I observed 8 species of copepods(Fig:10-13) and pond's high level of organic matter sustains more Cyclopoids, which suggests that they dominate in waters with higher trophic levels, explaining the abundance of copepods in the summer and winter(Rajagopal *et al*., 2010). Low population density of copepods during the monsoon season may result from their lack of a parthenogenetic form. Among all the copepods *Thermocyclops hyalinus (copepod, cyclopoid),Sinodiptomus indicus(copepod, cyclopoid),Microcyclops varicans(copepod, cyclopoid)* most abundant.

Concentrations of *Copepods*

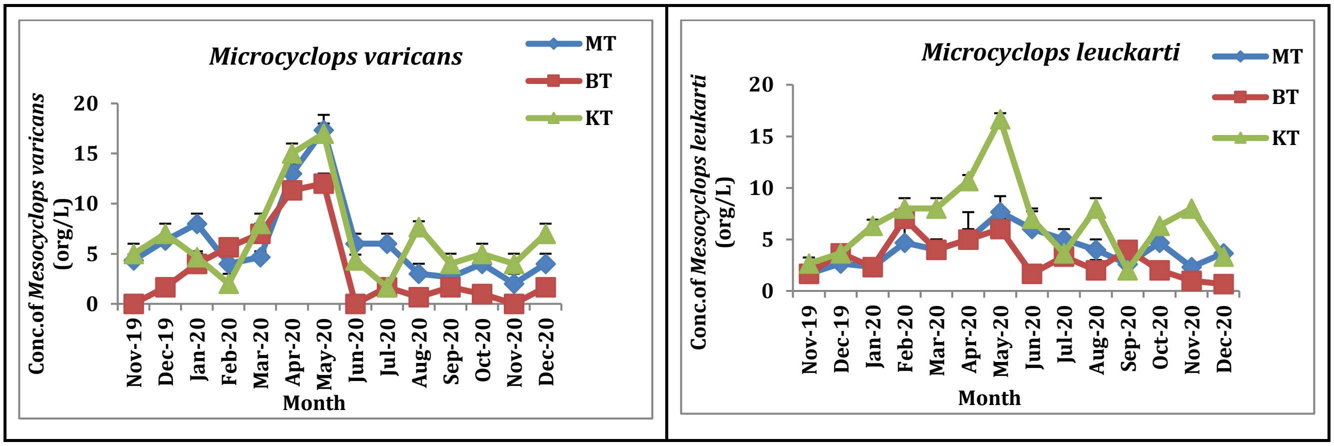


Fig:10 Conc.of (a) *Mesocyclops varicans* (b) *Mesocyclops leuckarti* from the treated sewage water samples.

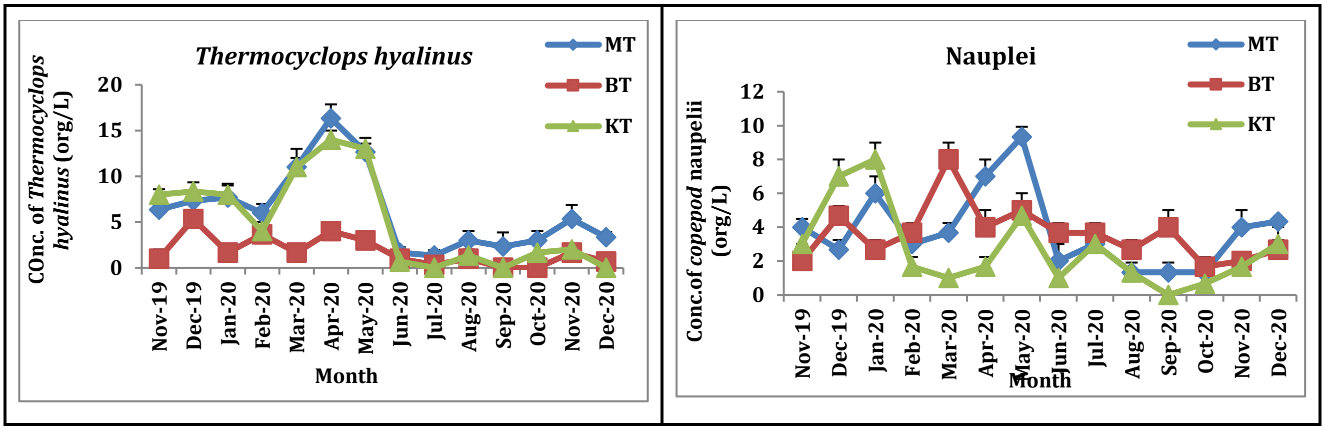


Fig:11 Conc.of (a) *Thermocyclops hyalinus* (b) Copepod naupleii from the treated sewage water samples.

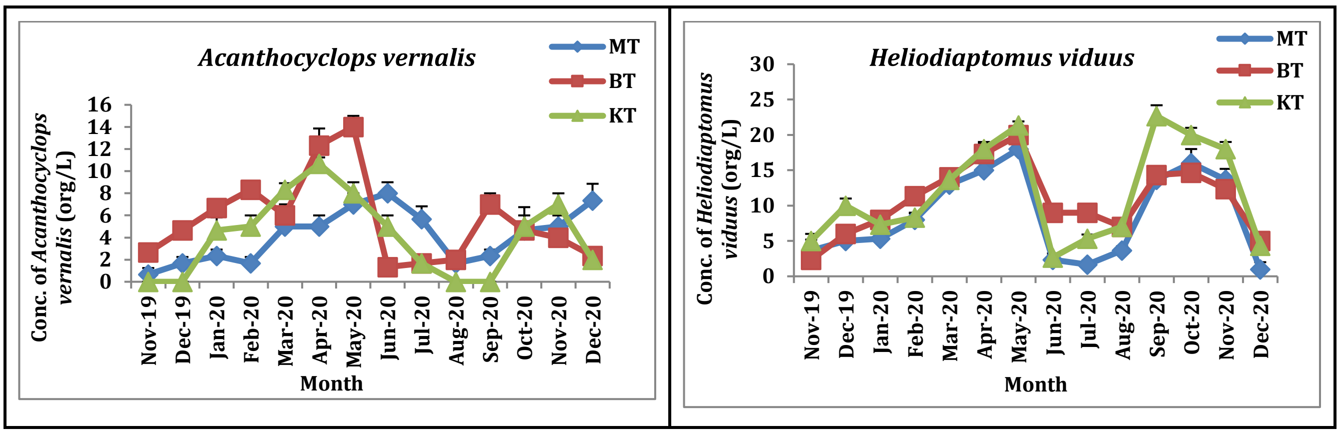


Fig:12 Conc.of (a) *Acanthocyclops vernalis* (b) *Heliodiaptomus viduus* from the treated sewage water samples.

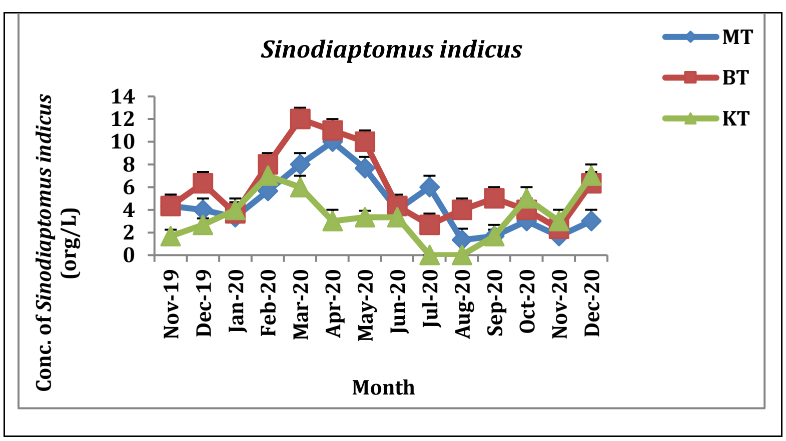


Fig:13 Conc.of *Sinodiaptomus indicus* from the treated sewage water samples.

Cladocera

A wide variety of small crustaceans known as cladocera are found in a variety of aquatic settings, from shallow temporary ponds to deep lakes and wide rivers. Cladocerans are a vital source of food for crustaceans, tiny fish, and aquatic insects. In the above study there were 3 species *Cladoceras*(Fig:14-15) observed from all the three study sites of treated sewage water. Family of Daphnidae and Moinidae were mainly seen. The research period's quantitative analysis revealed that the family Daphnidae had the greatest species diversity(Rajagopal *et al.*, 2010). The family Daphnidae, which was determined to contain the majority of the species among the recognized cladocerans, includes *Ceriodaphnia cornuta*, *Diaphanosoma excium*

(Cladocera)(Joseph &Yamakanamardi, 2011).

Concentrations of Cladocera

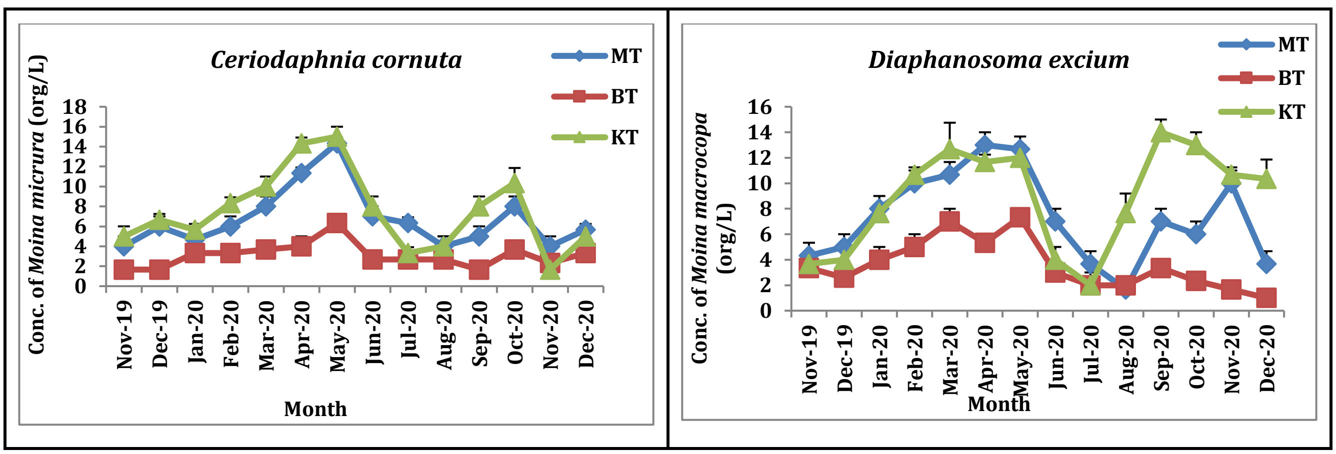


Fig:14 Conc.of (a) *Ceriodaphnia cornuta*

(b) Diaphanosoma excium from the treated sewage water samples.

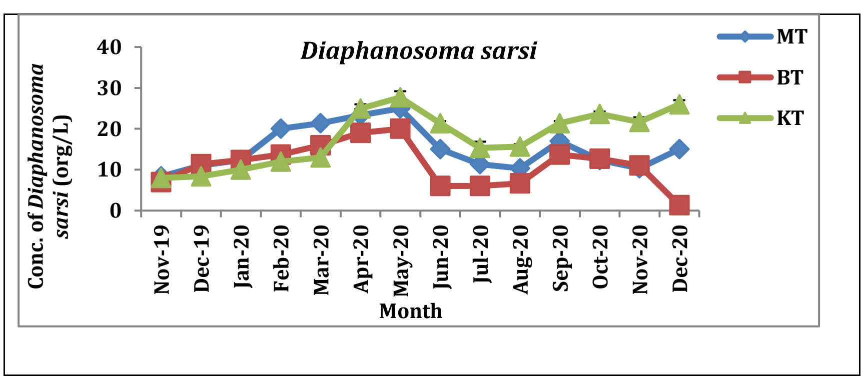
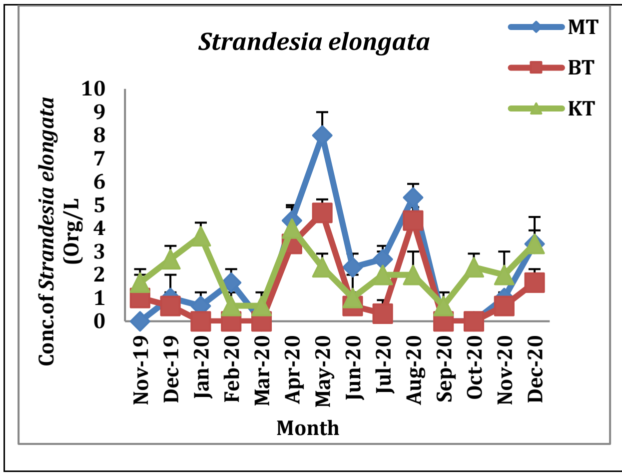


Fig:15 Conc.of *Diaphanosoma sarsi* from the treated sewage water samples.

Ostracoda

In comparison to other zooplankton species, ostracod(Fig:16-17) had a very low diversity and population density. Three different ostracod species such as *Cyprinotus nudus,Strandesia elongate and Eucypris bispinosa* were identified in the current investigation. The population density was higher in the summer and lower in the winter. Sukand and Patil (2004) in Belgaum's Fort Lake and Kedar *et al*. (2008) in the Washim district's Rishi freshwater lake also noted this conclusion.

Concentrations of Ostracoda



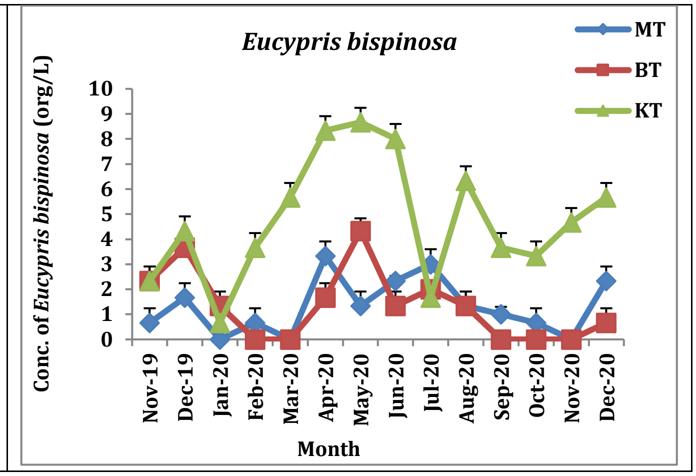


Fig:16 Conc.of (a) *strandesia elongata* (b) *Eucypris bispinosa* from the treated sewage water samples.

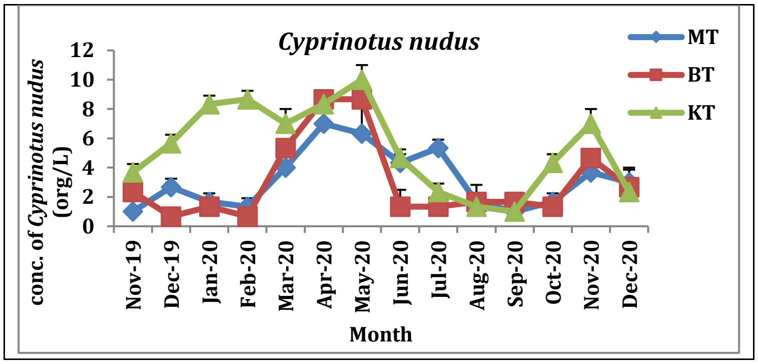


Fig:17 Conc.of *Cyprinotus nudus* from the treated sewage water samples.

Diversity Indices

While at MT Pond the order was summer>post-monsoon>winter>monsoon, the Shannon Wiener Species Diversity Index results showed that H'=2.91, 2.75, 2.65, and 2.37. Similar ordering was seen at the BT and Kt locations, with summer having the greatest values. In the summer, according to Jaccard (1942) Evenness Index, all MT, BT, and KT had lower Evenness Index values

(JE:0.061-0.063), while winter, post-monsoon, and monsoon seasons all showed slightly fluctuating values. For all of the study locations, including MT, BT, and KT, the values for the Index of Dominance were found to be highest in the summer, followed by post-monsoon, winter, and monsoon.

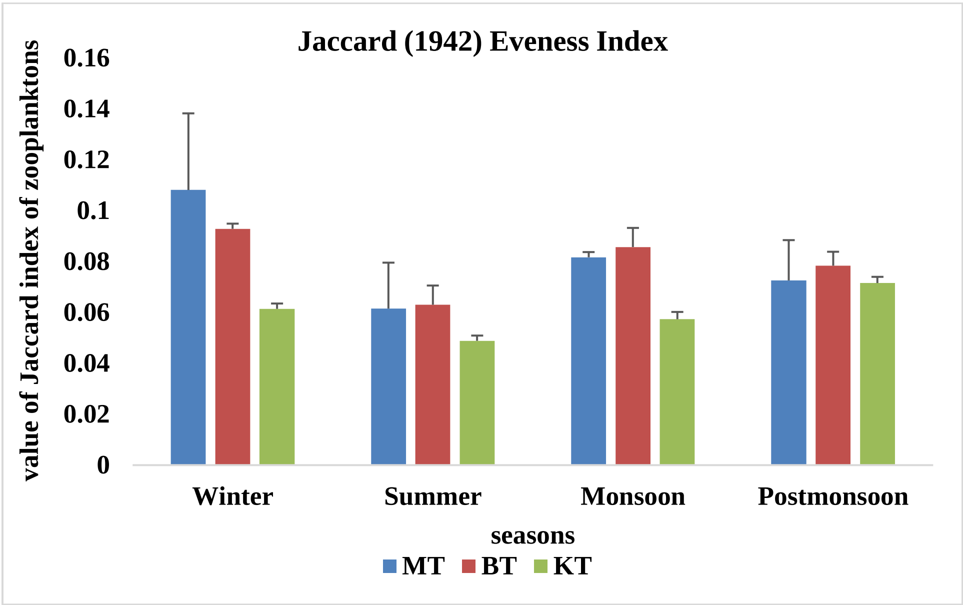


Fig:17 Jaccard (1942) Evenness index values of zooplanktons from the treated sewage water samples.

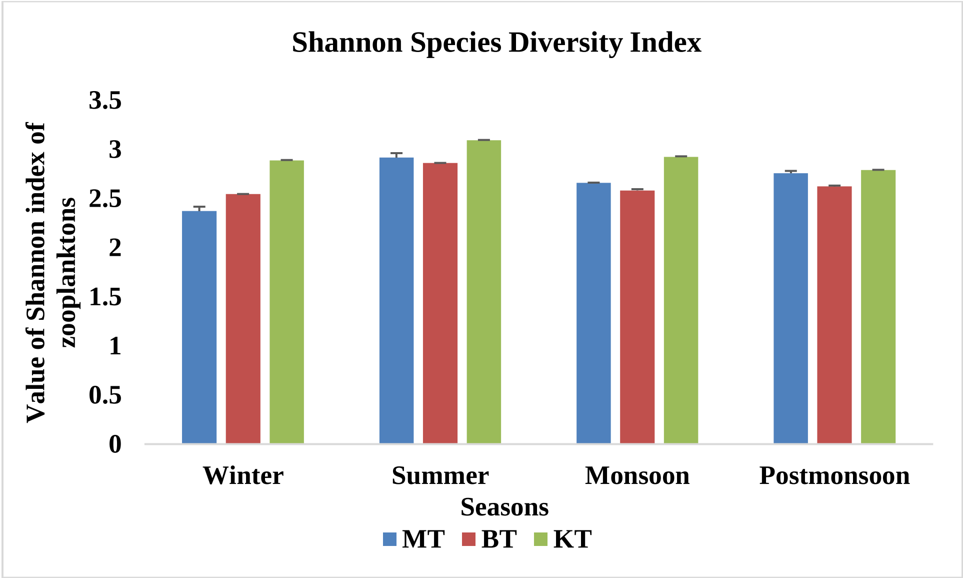


Fig:18 Shannon Species Diversity index values of zooplanktons from the treated sewage water samples.

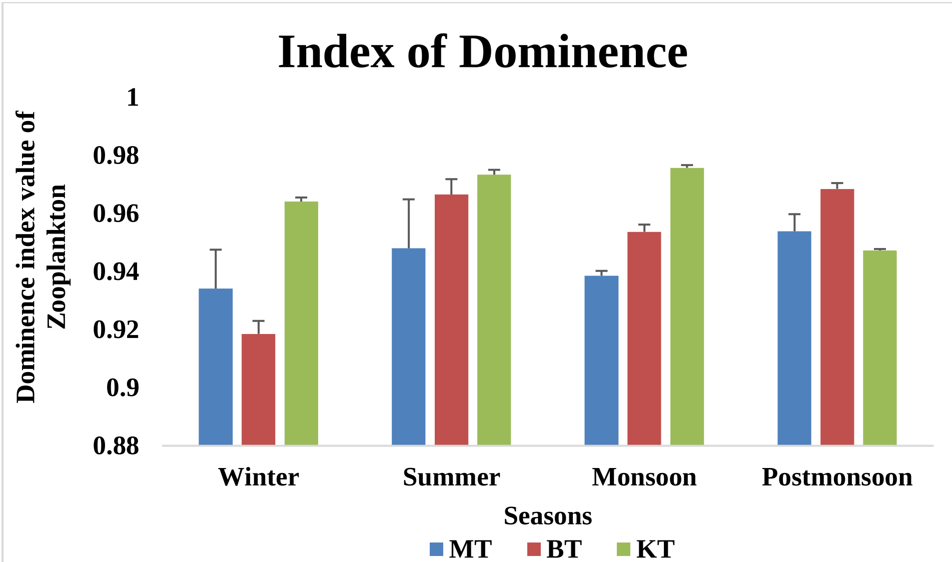


Fig:19 Index of Dominance values of zooplanktons from the treated sewage water samples

Percentage level of Zooplankton

The treated waters of Main campus(MT),Bannerghatta Campus (BT) and Kengeri campus (KT) percentage contributions of zooplankton populations were showed up very minor fluctuations. Winter Percentage contribution of each group of zooplankton was in the following order 74% *Rotifera>14%Ostracoda>7* % *Copepod*> 6% *Cladocera*,in Summer 49% *Rorifera>* 29 *%Cladocer>13%Copepoda>9%* *Ostracoda*, theMonsoonseason 73% *Rotifera>27 %Clodocera>21%* *Copepoda>6%* *Ostracoda* and post monsoon season the order was 79% *Rotifera*>9%*Copepoda*>9% *Ostracoda*>3% *Cladocera.*

Conclusion

Rotifers have the greatest diversity as well as population density of all the zooplanktons present among all the study areas and across all the seasons. Because of the constant availability of food, rotifers predominated in the ponds, which in turn shows that the ponds were eutrophic (Sukand and Patil, 2004). The average number of Copepods was observed throughout the summer and winter, but the monsoon season saw too few. Cladocera and ostracod population densities were extremely low in comparison to *rotifera* and *copepoda* in all seasons, and they did not exhibit the striking seasonal variation. In this study, total zooplankton population was highest in the summer and winter, and lowest during the monsoon season. Over the entire year, rotifers and copepods outnumbered Cladocera and ostracod in terms of population, Das(2002) has made similar observations**.** The summertime increase in zooplankton population density is caused by primary production and worm temperatures of the habitat. Monsoon typically results in lower population densities because of its diluting effect and lowered primary production photosynthetic activity. Salve and Hiware (2010) reported comparable outcomes at the Wan reservoir in Nagpur. It has been claimed that an abundance of some zooplanktons in the aquatic food chain is a sign of eutrophication (Halbach *et al*., 1983). The results of this investigation showed that *Rotifera* and *Copepoda* predominated, indicating eutrophication of the treated sewage water at MT and KT**.** The lack of aquatic vegetation, shallowness, short hydroperiod, thin bottom sediment deposits, erratic manual flushing and washing of big tanks, and short hydroperiod all contributed to the poor faunal diversity in BT.

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