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Dynamics of Zooplankton Diversity in Freshwater Ecosystems across Seasons: Impact of Phosphate and Other Factors

Banerjee Ka [a*], Adhikary Sa [a] and Bhattachryya Pa [a]

[a] Department of Law, Brainware University, Barasat, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

When it comes to aquatic habitats, the diversity of species is a good indicator of their quality. This study was conducted to analyze the impact of seasonal changes on the zooplankton biodiversity of Tavarekere Lake (latitude 12.4555° N, Longitude 75.9570° E.) in Kodagu, Karnataka, India. This study was conducted between June 2020 and May 2021. Sixteen species belonging to Rotiferal, Cladocera, Copepods, and Nematodes were documented. At this site, rotifers were abundant at 50%, followed by Copepods at 31%, Cladocera at 13%, and nematodes at 6%. The population density followed the order Rotifers>Copepods> Cladocera> Nematodes, with the highest population in the pre-monsoon season (summer) and the lowest population recorded in the monsoon season. The CCA plot showed a positive correlation between zooplankton and surface water temperature. This study shows that zooplankton diversity is seasonal and changes in response to environmental

**Corresponding author: Email: Kaushik.phd@gmail.com;*

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parameters, as it was observed that, with increasing temperature, the species diversity varies, which will impact the balance of the food chain and can be utilized as a potential tool to monitor and maintain water quality.

Keywords: Zooplanktons; bioindicators; canonical correspondence assay; fresh water; physicochemical analysis.

1. INTRODUCTION

Freshwater ecosystems have been significantly affected in the past few decades because of habitat degradation, water pollution, and invasive species [1]. Natural bioindicators of pollution, such as phytoplankton and zooplankton, play important roles in protecting freshwater habitats [2]. Zooplankton are heterotrophic plankton that range in size from microscopic to large species. Zooplankton are nutrient and energy transmitters between primary producers and consumers of aquatic communities [3]. Zooplankton is important to ecosystems as each organism performs a set of functions (nutrient cycling, an integral part of food chains) in the ecosystem, and any variation can lead to ecosystem imbalance [4]. Zooplankton are sensitive to environmental change [5]. Any variation in their abundance and diversity is an indicator of changes in the trophic state and water quality [6]. The distribution of zooplanktons majorly depends upon its ability to adjust with abiotic factors (DO, BOD, TDS, surface water temperature, pH) and biotic factors (nutrient availability, algal bloom toxins), etc. [7], (Pinto et al., 2023). The growth of zooplankton is also dependent on the phytoplankton abundance in the community (Liu et al., 2023). Eutrophication in lakes severely affects the zooplankton habitats (Cabarel et al. 2020; Le Quesne et al. 2020). Increased eutrophic conditions lead to small species in a community (Derevenskaia, Borisova, & Unkovskaia, 2021). in Rotifera Branchionus sp., Keratella sp., and Cladocera Ceriodaphnia sp., which have algal toxins that are detrimental to the survival of zooplankton (Pawlick & Bownick, 2021) [8-10]. The species richness and species evenness of a community are the two components that make up the species diversity of that community. The ratio of the number of distinct species (S) to the total number of species (N) in the community was established as the definition of species richness. A measurement of the distribution of species is referred to as species evenness. The purpose of the study was to 1) investigate the number, variety, and distribution of zooplankton at the sample location. 2) To assess the physical and chemical factors that are responsible for eutrophication and the influence that these factors have on the distribution of zooplankton. This study suggests that some species might be used as bioindicators to evaluate the trophic state of freshwater ecosystems.

2. MATERIALS AND METHODS

2.1 Study Area

Samples were taken from Tavarekere Lake in Kodagu District, Karnataka State, India (Fig. 1) (12.4555° N, 75.957° E). Sample sites were selected based on the influence of anthropogenic activities in and around the region. Furthermore, water levels and nutrient sources of the lakes were considered as parameters. The geographical locations of the sites were noted using GPS, and the depths of the lakes were measured using a weighted line.

2.2 Physicochemical Analysis of The Water

Water samples were collected monthly during the morning period from 7 AM to 9 AM from June 2020 to May 2021. Parameters such as water temperature were measured on-site. Parameters such as pH, TDS, and EC were measured immediately upon reaching the laboratory. Parameters such as D.O. and nitrates were measured according to the guidelines of the APHA [11].

2.3 Sampling Method

The use of a zooplankton net allowed for the collection of water samples. After the samples were collected, they were promptly preserved in a solution of 4% formalin and Lugol's iodine [12]. In addition, the samples were then transported to the laboratory for further examination. To determine the identity of the samples, centrifugation was used to concentrate them, and then they were examined under a microscope. To enumerate the number of cells, the Sedgewick rafter technique was utilized, and the

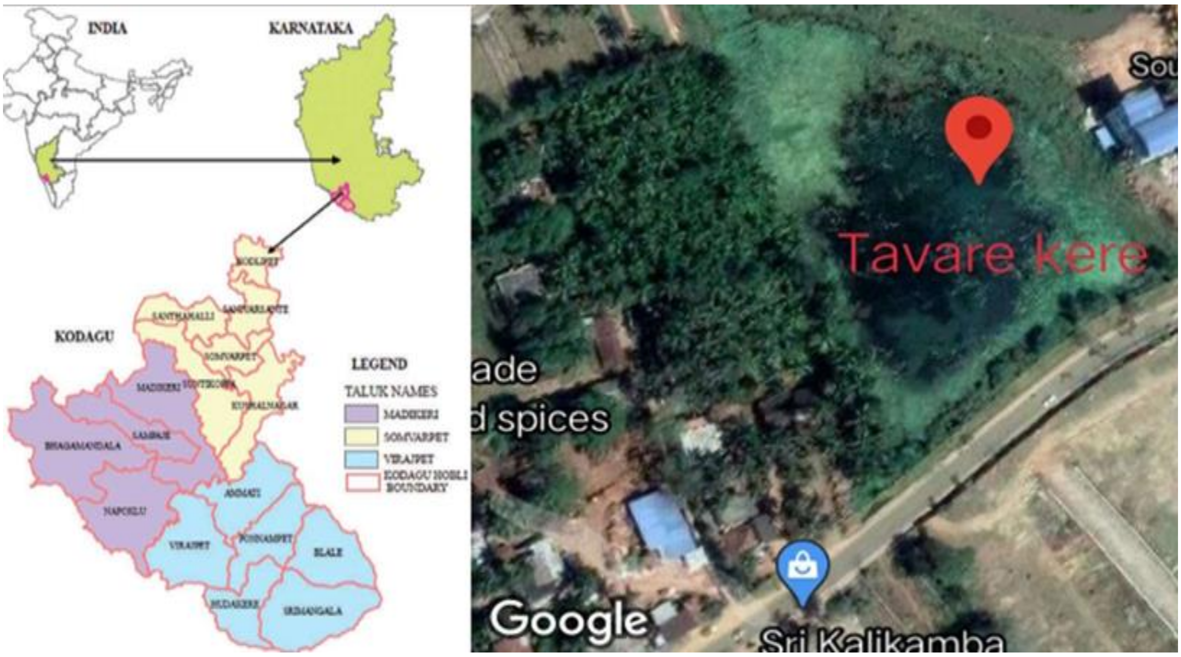


Fig. 1. Google image for our experimental site

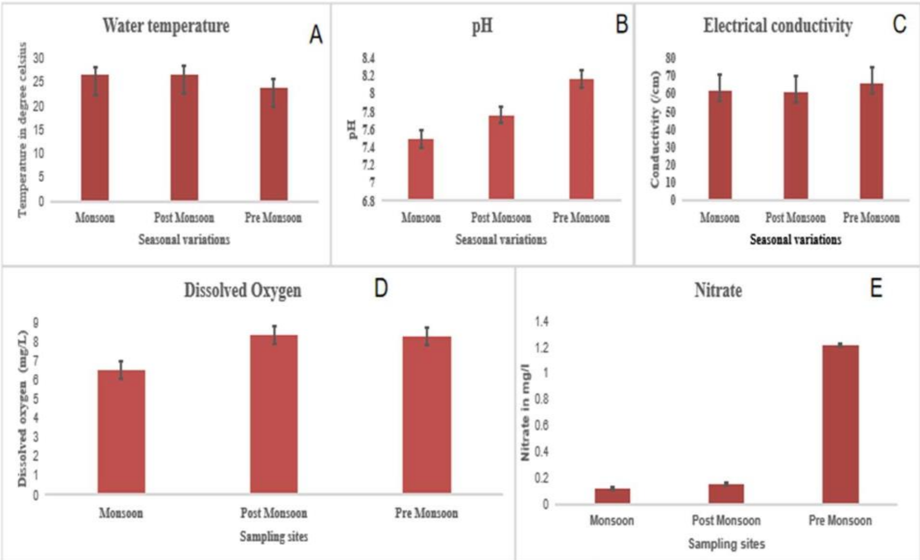
resulting value was recorded as org/L. The count was carried out three times to ensure accuracy. According to Goswami [13], the formula that was utilized was N= nxv/V, where N represents the total number of zooplanktons per liter, n represents the average number of planktons that are present in 1 mm of the sample, v represents the amount of plankton that is concentrated, and V represents the volume of the water sample. It was determined that zooplankton were present by employing conventional techniques [14,15,13].

2.4 Statistical Analysis

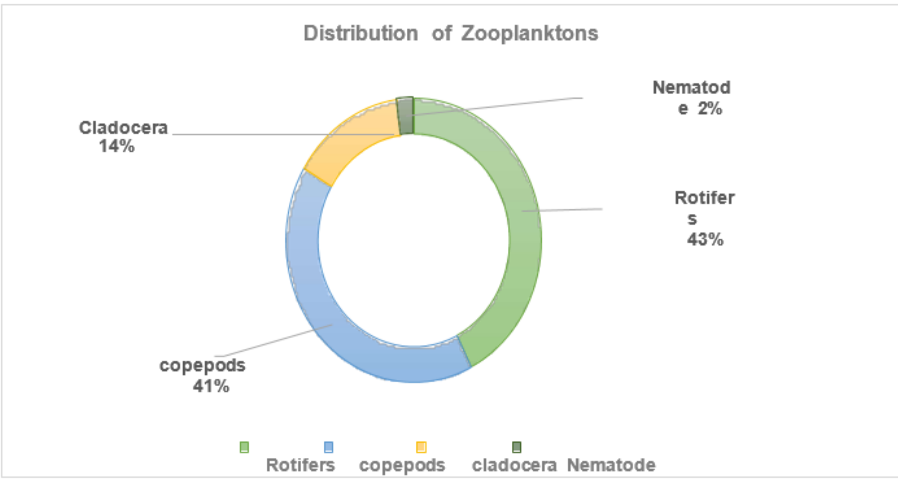
The physicochemical water parameters were calculated using Microsoft Excel, and the graph was plotted using GraphPad Prism 10. Diversity indices, Pearson Correlation Analysis, and Canonical Correspondence Assay were calculated using PAST 4.03.

3. RESULTS

The research was conducted during the months of June 2020 and May 2021. A small number of water parameters were selected to investigate the relationship between the physicochemical analysis of water and the variety of zooplankton. Fig. 2 illustrates the temperature of the water level. In the post-monsoon season, the surface temperature ranged from 21.50 degrees Celsius to 30.10 degrees Celsius. Throughout the course of the season, the pH readings ranged from 6.2 to 8.1 overall. Conductivity ranged from 52.28 to 70.94 µS cm-1 throughout the experiment. A range of 5.8 to 8.9 mg l-1 was observed for the concentration of dissolved oxygen. Between 0.11 and 2.4 mg l-1, the concentration of nitrate was found to be variable. It was during the post-monsoon time that the concentration of dissolved oxygen was at its maximum, while it was at its lowest during the monsoon season. During the pre-monsoon period, the concentration of nitrate was at its greatest, whereas during the monsoon season, it was at its lowest. Using plankton nets, the zooplanktons were captured for scientific study. Over the course of the research, a total of sixteen taxa were documented (Table 1). Recordings were made of zooplanktons that belonged to four different classes: rotifers, cladocerans, copepods, and nematodes. There was a seasonal variation in the number of species and diversity, with the lowest taxon number (one taxon) occurring in the month of December and the maximum taxo-number (five taxon) occurring in the month of June. The species that have been documented are as follows: Diphanosoma sarsi, Branchionus falcatus, and Branchionus angularis are the other species. Ptygura pilula, Keratella cochlearis, Monostyla bulla, Philodena citrina, and Philodena roseola are the species that are involved. In addition to nematode, Ceriodaphina chorata, Moina brachyata, Maxillopoda species, Mesocyclops leukarti, Cyclops species, Diaptomus castor, and Naupilis species are also included. The distribution of zooplankton is as follows: rotifers make up 43% of the total, copepods make up 41%, cladocera make up 14%, and nematodes make up 2% (graph 2). The diversity indices of the sampling site are stated in Table 1. The Shannon diversity index (Shannon H) value is 2.66, the Simpson diversity index (Simpson_1-D) value is 0.92, whereas, the Pieolous evenness index is 0.89, the Magarleif index is 1.58, the Menhinick index is 0.14. Canonical Correspondence analysis plot showing the relation between the environmental parameters like Temperature, EC, pH, TDS and nitrate with zooplankton species diversity (Graph 3). Axis 1 shows a correlation of 64.29% and axis 2 shows a correlation of 35.71%. In CCA plots, the length of the variable (Physicochemical water parameters) determines their significance and is equal to the rate of change of variables. The positions of species distribution show their preferred habitats. In our study all the 5 parameters chosen shows a spatial distribution, which corresponds to their significance to the study. However, out of 16 species, 4 preferred a higher temperature condition (*Nematodes, Cyclops sp., Diaptomus castor, and Monostyla bulla*), 3 species (*Branchionus falcatus*, *Philodena citrina* and *Naupilis sp.,*) showed a preference to moderate pH and nitrate concentration. The remaining 9 species preferred the moderate concentration of environmental parameters.



Graph 1. A. Water temperature, B. pH, C. Electrical conductivity, D. Dissolved oxyzen, E.Nitrate



Graph 2. Zooplaktons Distribution

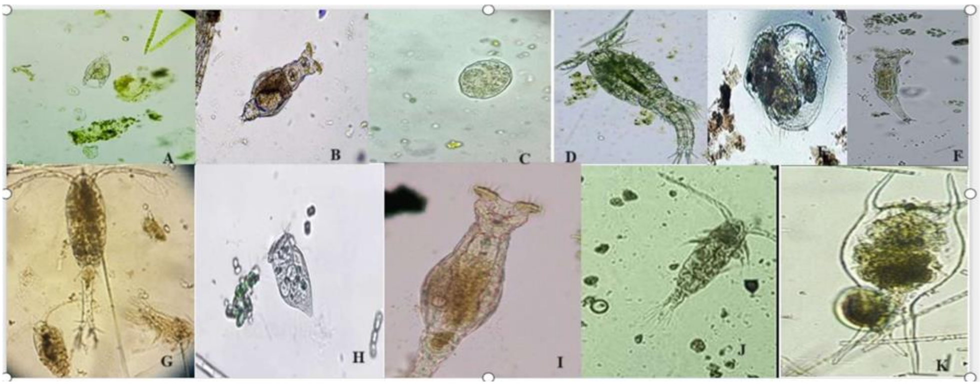
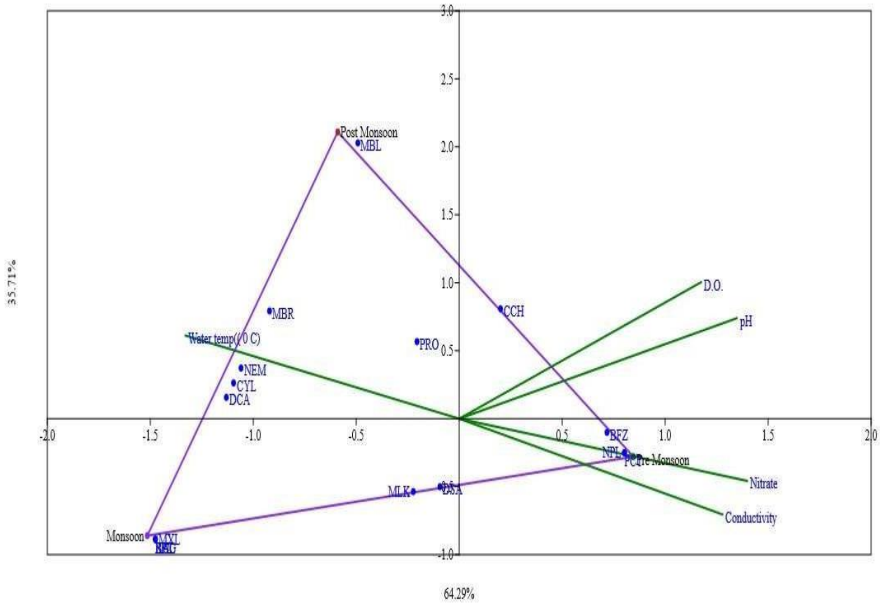


Fig. 2A. chiomis falcatus, B. Philodena citrina, C. Ptygura pilula, D. Diaptomus castor, E. Moina brachiyata F. Diapanosomuus sarsi, G. Maxillopoda sp., H. Monostyla bulla, I. Philodena roseola „J. Cyclops sp., K. Keratella cochliaris



Graph 3. Canonical correspondence analysis plot shows a correlation between the phyco-chemical water parameters and distribution of zooplankton

Table 1. The different diversity index values

Diversity Index	Values
Taxa S	16
Individuals	12970
Dominance D	0.0752
Simpson_I-D	0.9248
Shannon H	2.662
Evenness e^H/S	0.8953
Brillouin	2.657
Menhinick	0.1405
Margalef	1.584
Equitability J	0.9601
Fisher alpha	1.801
Berger-Parker	0.1203
Chao-I	16

4. DISCUSSION

The importance of assessing water parameters to understand the quality of freshwater habitats has been established by many workers [16,17,18], (Sunkad 2008) The water surface temperature values were found to be within the permissible limit set by WHO (2008). However, it has been reported that the increasing rate of temperature, influences the increase of chemical and biological parameters of a water body [19]. pH is one of the important water parameters to be assessed to understand the trophic state of any water body, as low pH indicates to a corrosive nature of water, and pH also has a positive correlation with electrical conductivity

[20], (Bhalla and Waykar,2012). Electrical conductivity is the measure of the ability of a solution to conduct electricity. It's the measure of quality and reported that the diversity and population of zooplanktons are correlated to the biotic and abiotic factors (pH, temperature, dissolved oxygen) (Vagas et al., 2015) [21,22,23], (Xiong et al., 2020). Similar species have been reported by workers in freshwater habitats with similar physicochemical measurements, rotifers [24,25,26,27], Cladocera [27,28], (Das et al., x2016) [24,29, 25,30-41].

5. CONCLUSION

This study shows that zooplankton diversity is seasonal and changes in response to environmental parameters. The results indicate that zooplankton species are vulnerable to environmental changes and can be used as a prospective bio-monitoring tool, to predict the water quality. It was observed that, with increasing temperature, the species diversity varies, which will impact the balance of the food chain. To conclude, the water body contains bio indicators of eutrophication, giving anticipation of deterioration in the forthcoming days. Hence, regular monitoring, assessment, and remediation measures are needed to prepare and protect the water body. However, standardized protocols are necessary to conclude the biomonitoring tools. Furthermore, this study also establishes baseline data for documentation of the study area, more spatiotemporal work needs to be conducted, to elaborate on the biomonitoring species. The diversity indices for the sampling site are presented in Table 1. The Shannon diversity index (Shannon_H) is recorded at 2.66, the Simpson diversity index (Simpson_1-D) is 0.92, the Pielou's evenness index is 0.89, the Margalef index is 1.58, and the Menhinick index is 0.14. Zooplanktonic distribution can be influenced by various factors, including phosphate levels. Phosphate is a key nutrient for phytoplankton growth, which serves as food for zooplankton. Therefore, higher phosphate concentrations often lead to increased phytoplankton abundance, subsequently attracting more zooplankton. Conversely, low phosphate levels can limit phytoplankton growth and, consequently, zooplankton populations. This relationship is well-documented in marine and freshwater ecosystems.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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