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Zooplankton Diversity and Seasonal Variability in Kalmadu Reservoir, Northern Sri Lanka

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ABSTRACT

Zooplankton play a crucial role in freshwater ecosystems by contributing to energy transfer and nutrient cycling. This study assesses the diversity and of zooplankton in the Kalmadu Reservoir, Northern Sri Lanka, over a six-month period (August 2024–January 2025). Water samples were collected from ten locations using a 5L bucket and filtered through a 64-µm mesh plankton net. Standard taxonomic keys were used to identify species, and Lackey's drop count method was applied for population density estimation. A total of 10 zooplankton species were recorded, including *Paramecium aurelia*, *Vorticella citrina*, *Moina brachiata*, and *Mesocyclops leukarti*. Species abundance varied monthly, with higher counts observed during periods of increased water levels. The Simpson index ranged from 0.9664 to 0.9993, indicating species dominance, while the Shannon index (0.0031–0.1108) suggested low species evenness. The dominance of protozoan species, particularly *Vorticella citrina*, suggests eutrophic conditions in the reservoir. These findings highlight the importance of zooplankton diversity in ecosystem functioning and fisheries productivity. Seasonal shifts in community structure emphasize the need for long-term monitoring and further investigation into environmental drivers such as dissolved oxygen, pH, and nutrient levels to inform conservation and water resource management strategies.

Keywords: Environment, Diversity, Plankton, Shannon index, Simpson index, Zooplankton diversity

1. INTRODUCTION

Plankton comprising both phytoplankton and zooplankton forms the foundation of aquatic ecosystems and plays a pivotal role in energy transfer and nutrient cycling. Phytoplankton, as primary producers, are responsible for nearly 45% of global annual food production through photosynthesis, underscoring their ecological significance[5]. Zooplankton, on the other hand, are primary consumers that mediate energy flux within aquatic food webs, linking primary producers to higher trophic levels, including commercially important fish species. These organisms include protozoans, rotifers, cladocerans, copepods, and ostracods and they are predominantly found in the photic zone where food resources are abundant, though they also inhabit deeper waters[18]. Their heterotrophic nature and role in biogeochemical cycles such as carbon and nitrogen cycling further highlight their ecological importance[15]. Zooplankton are critical in maintaining the balance of aquatic ecosystems as they regulate phytoplankton populations and serve as a primary food source for fish and other aquatic organisms[18].

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The biodiversity of aquatic ecosystems, particularly zooplankton communities, is increasingly threatened by pollution, eutrophication, habitat degradation, and climate change. Freshwater reservoirs such as the Kalmadu Reservoir in Kilinochchi, Northern Sri Lanka, are critical for local fisheries and water resource management. However, the ecological health of these systems is often compromised by anthropogenic activities, including agricultural runoff, industrial discharge, and overfishing. Eutrophication driven by excessive nutrient inputs leads to algal blooms and oxygen depletion, which can drastically alter zooplankton community structure and reduce biodiversity[26]. Studies have shown that nutrient enrichment in freshwater systems often results in the dominance of a few zooplankton species, reducing overall diversity and ecosystem resilience[14]. Understanding the diversity and dynamics of zooplankton in such reservoirs is essential for assessing ecosystem health, predicting fish stocking rates, and informing conservation strategies. Zooplankton density and diversity are key indicators of water quality and trophic status, making their study crucial for sustainable fisheries and biodiversity conservation[11].

Globally, biodiversity loss is accelerating due to the combined pressures of pollution and climate change. Freshwater systems are particularly vulnerable because they concentrate contaminants from agricultural runoff, pesticides, and industrial effluents, which reduce water quality and threaten zooplankton and other sensitive taxa[6]. Climate change further intensifies these impacts by altering rainfall patterns, increasing water temperatures, and shifting hydrological regimes, thereby affecting the survival, reproduction, and distribution of aquatic species[28]. The synergistic effect of pollution and climate variability can exacerbate eutrophication, favor opportunistic species, and undermine ecosystem resilience[10]. For reservoirs like Kalmadu, which support both biodiversity and fisheries livelihoods, these stressors pose a serious risk to ecological balance and long-term sustainability.

This study aims to assess the zooplankton diversity in the Kalmadu Reservoir focusing on species composition, abundance, and seasonal variations. By employing standardized sampling and identification methodologies, the research seeks to provide insights into the ecological dynamics of the reservoir, particularly in relation to environmental factors such as water temperature, nutrient availability, and hydrological changes. The findings will contribute to a broader understanding of freshwater ecosystem functioning and inform management practices aimed at preserving biodiversity and enhancing fishery productivity in the region. Zooplankton populations directly influence fish stocking rates and overall productivity in the inland fishery sector, making their conservation essential for sustainable resource management[9].

2. MATERIALS AND METHODOLOGY

2.1.Study Area

The Kalmadu Reservoir, situated approximately 18 km east of Kilinochchi in the Northern Province of Sri Lanka was selected as the study site due to its ecological and socio-economic significance. The reservoir, with a catchment area of approximately 68 km², serves as a vital freshwater resource for local fisheries, irrigation, and water supply. Its susceptibility to environmental changes, such as eutrophication and seasonal hydrological fluctuations, makes it an ideal location for investigating zooplankton diversity and its role in aquatic ecosystem dynamics.

2.2. Sampling Design

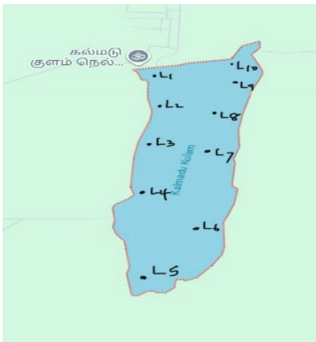

Figure 1. Sample Collected Locations (L1-L10)

To ensure a comprehensive assessment of zooplankton distribution, ten sampling locations (L1–L10) were strategically selected across the reservoir. These locations were chosen to cover the entire water surface area, including areas near the dam, mid-reservoir, and inflow/outflow regions. Sampling was conducted monthly from August 2024 to January 2025 to capture monthly variations in zooplankton abundance, diversity, and community structure.

2.3. Sample Collection

Zooplankton samples were collected using a 5-L white polythene bucket, which was thoroughly rinsed with distilled water before each use to prevent cross-contamination. At each sampling location, five replicate samples were collected by performing five complete horizontal tows of the bucket from left to right in a clockwise direction. This method ensured a representative sample of the water column, including both surface and subsurface layer. The collected water was then filtered through a 64-micron mesh zooplankton net to concentrate the plankton biomass. The residue retained in the net's cone was carefully transferred into 10 ml glass specimen bottles containing 25% ethanol for preservation and subsequent laboratory analysis (Edmondson, 1959; UNESCO, 1968).

2.4. Laboratory Analysis

In the laboratory, the preserved zooplankton samples were processed for taxonomic identification and enumeration. Each sample was homogenized and a 1 ml subsample was transferred using a wide-mouthed pipette into a Sedgewick-Rafter counting chamber. The chamber was allowed to settle for 10–15 minutes to ensure even distribution of zooplankton. Identification and counting were performed under a binocular microscope at 40× magnification. Taxonomic identification was carried out using standard taxonomic keys, including those by Rajapaksa and Fernando (1984) and Mendis and Fernando (1962), which are widely recognized for zooplankton identification in tropical freshwater systems.

2.5. Quantification of Zooplankton Density

The population density of zooplankton was quantified using the drop count method (Lackey, 1938). The formula used for calculation was:

$$\mathrm{N} = \frac{\mathrm{n} \times \mathrm{v}}{\mathrm{V}}$$

Where:
N = Total number of organisms per liter of filtered water
n = Number of zooplankton counted in 1 ml of the plankton sample
v = Volume of the concentrated plankton sample (ml)
V = Total volume of water filtered through the net (liters)
This method ensured accurate estimation of zooplankton density, accounting for variations in sample concentration and volume.

2.5.1. Diversity Indices

To evaluate the zooplankton community structure, two widely used ecological indices were calculated:
Simpson's Diversity Index (D): This index measures the dominance of species within the community, with values ranging from 0 to 1. Values closer to 1 indicate low diversity and high dominance of a few species, while values closer to 0 suggest higher diversity and evenness.
Shannon-Wiener Index (H'): This index quantifies species diversity and evenness, with higher values indicating greater diversity and evenness in the community. The index is calculated using the formula:

$$H' = -\sum_{i=1}^{S} (p_i \ln p_i)$$

Where pi is the proportion of individuals belonging to the i^{th} species, and S is the total number of species.

2.6. Environmental Parameters

Although the primary focus of this study was on zooplankton diversity, environmental factors such as water temperature, nutrient availability, and hydrological changes were recorded during sampling. These factors are known to influence zooplankton community dynamics and were noted to provide context for the observed patterns.

2.7. Statistical Analysis

Data were analyzed to determine monthly variations in zooplankton abundance and diversity. Descriptive statistics, including mean, standard deviation, and total counts, were calculated for each species. The Simpson and Shannon diversity indices were computed for each sampling month to assess changes in community structure over time. Results were presented in tabular and graphical formats to facilitate interpretation.

3. RESULTS AND DISCUSSION

3.1. Composition and Abundance of Zooplankton Species

A total of 10 zooplankton species were identified during the study period (August 2024 to January 2025) in the Kalmadu Reservoir. The species included protozoans (*Paramecium aurelia* (Figure 2(a)), *Vorticella citrina* (Figure 2(b)), *Amoeba proteus* (Figure 2(c)), rotifers, cladocerans (*Moina brachiate*) (Figure 2(d)), *Ceriodaphnia reticulate* (Figure 2(e)), *Moinadaphnia mecleayi* (Figure 2(f)), and copepods (*Mesocyclops leukarti* (Figure 2(g)), *Sinodiaptomus indicus* (Figure 2(h)), *Gonium formosum* (Figure 2(i)), *Didinium faurei* (Figure 2(j)). The monthly abundance of these species varied significantly, with protozoans dominating the community during most sampling periods, particularly *Paramecium aurelia* and *Vorticella citrina*, which showed the highest densities (Table 2(a) & Figure 2(j)).

Seasonal fluctuations in abundance, with higher .in contrast, *Sinodiaptomus indicus*, a copepod, showed a gradual increase in abundance from August (4 organisms/L) to January (14 organisms/L).

3.2. Monthly Variations in Zooplankton Abundance

The zooplankton community exhibited significant seasonal variations in abundance. The highest total abundance was recorded in August 2024 (141 organisms/L), while the lowest was observed in December 2024 (55 organisms/L). The abundance of *Paramecium aurelia* peaked in August (40 organisms/L) and declined steadily until January 2025 (16 organisms/L). In contrast, *Sinodiaptomus indicus* showed a gradual increase in abundance from August (4 organisms/L) to January (14 organisms/L). Seasonal variations in zooplankton abundance are commonly observed in freshwater ecosystems and are influenced by factors such as water temperature, nutrient availability, and hydrological changes (Lampert & Sommer, 2007).

3.3. Monthly Variation of Zooplankton Abundance

The zooplankton community in the Kalmadu Reservoir exhibited significant monthly variations in abundance over the study period from August 2024 to January 2025. Notably, *Paramecium aurelia* peaked in August (40 organisms/L) and showed a steady decline through to January 2025 (16 organisms/L). Conversely, *Sinodiaptomus indicus* demonstrated a gradual increase from 4 organisms/L in August to 14 organisms/L in January 2025. For instance, the high *Paramecium aurelia* abundance in August may be linked to lower water volumes concentrating nutrients, while the increase of some copepods like *Sinodiaptomus indicus* during later months may reflect favorable cooler and oxygen-rich water conditions (Williamson et al., 2009). The observed monthly variation underscores the dynamic nature of zooplankton populations and highlights the importance of continuous monitoring to capture short-term ecological shifts in tropical freshwater ecosystems.

Although the introduction highlights the importance of zooplankton as a primary food source for fish and their influence on fisheries productivity, this study did not include direct fisheries data or fish population assessments. Therefore, claims related to fisheries impacts are based on ecological reasoning and existing literature rather than direct observation or measurements in the Kalmadu Reservoir. To maintain scientific rigor, it is recommended either to: include fisheries data or fishery-related observations in future studies to provide empirical evidence supporting the link between

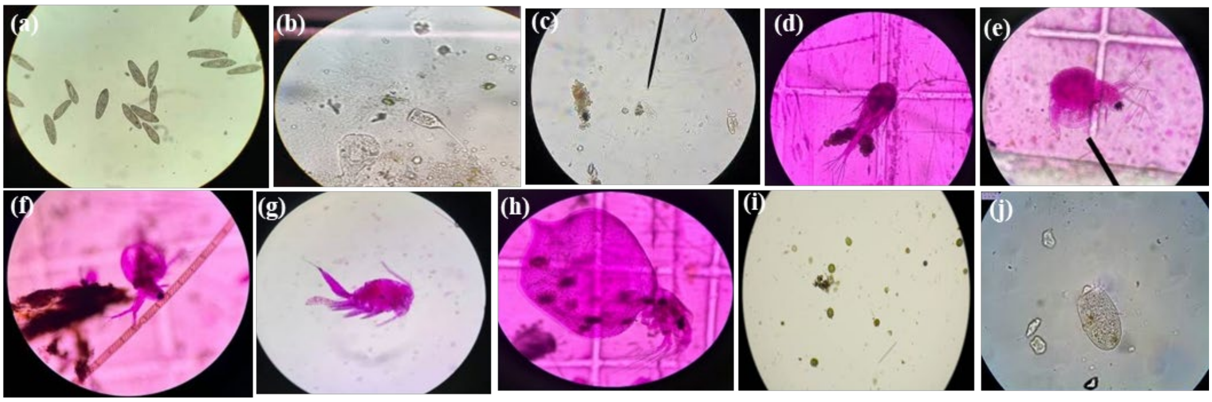

Figure 2. (a)*Paramecium aurelia* (b)*Vorticella citrina* (c) *Amoeba proteus* (d) *Moina brachiate* (e) *Ceriodaphnia reticulate* (f) *Moinadaphnia mecleayi (g) Mesocyclops leuckarti* (h) *Sinodiaptomus indicus* (i) *Gonium formosum* (j) *Didinium faurei*

zooplankton dynamics and fishery productivity, or remove or soften fisheries-related claims from the current study's objectives and discussion, clarifying that fisheries implications are inferred based on zooplankton roles in aquatic food webs as established in referenced research (De Silva et al., 2001).

3.4 Trophic Interactions and Ecological Implications

The presence of both herbivorous (e.g., *Moina brachiata*) and carnivorous (e.g., *Mesocyclops leukarti*) zooplankton species indicates a complex trophic structure within the reservoir. Herbivorous zooplankton, such as cladocerans, play a crucial role in controlling phytoplankton populations, while carnivorous copepods regulate the abundance of smaller zooplankton.

The coexistence of herbivorous and carnivorous zooplankton highlights the reservoir's role in energy transfer and nutrient cycling within the aquatic food web[4]. The high abundance of herbivorous species (*Moina brachiata*) during the wet season suggests increased grazing pressure on phytoplankton, which may help mitigate algal blooms. However, the dominance of protozoans, which are less efficient grazers, could reduce the overall efficiency of energy transfer to higher trophic levels, potentially impacting fish populations [3]. These findings underscore the need for integrated management strategies to maintain a balanced zooplankton community and support sustainable fisheries.

For instance, the decline in *Mesocyclops leukarti* abundance from August (8 organisms/L) to December (2 organisms/L) may reflect the species' sensitivity to changes in prey availability. This trend is consistent with studies showing that copepods thrive in cooler, oxygen-rich waters, which are more prevalent during the wet season [27]. Copepods like *Mesocyclops* are known to feed on smaller zooplankton and protozoans, and their decline may be linked to the reduced abundance of prey during the wet season [19]. These trophic interactions are critical for maintaining the balance of the reservoir's ecosystem, as changes in zooplankton composition can have cascading effects on higher trophic levels, including fish [17].

3.5 Environmental Factors Influencing Zooplankton Dynamics

Although not the primary focus of this study, environmental factors such as water temperature, nutrient levels, and hydrological changes were observed to influence zooplankton dynamics. The higher abundance of zooplankton during periods of increased water levels (January 2025) suggests that hydrological changes play a significant role in shaping the community structure.

Hydrological changes, such as reservoir overflow, can alter nutrient availability and water quality, creating favorable conditions for zooplankton growth [20].

Table 1**.** Monthly variation of Species Diversity Index in Kalmadu aquifer, Kilinochchi.

Species / Month	*Paramecium aurelia*	*Vorticella citrina*	*Moina brachiata*	*Dindinium faurei*	*Mesocyclops leukarti*	*Amoeba proteus*	*Gonium formosum*	*Ceriodaphnia reticulate*	*Ceriodaphnia reticulate*	*Moinadaphnia mecleayi*
Aug-24	40	21	23	5	8	0	5	7	4	13
Sep-24	32	32	9	3	2	0	11	9	6	16
Oct-24	25	30	5	0	7	3	9	5	12	18
Nov-24	17	21	13	3	5	7	4	0	11	5
Dec-24	11	12	15	2	2	4	7	3	8	7
Jan-25	16	17	12	0	4	8	8	2	14	14
Total Species	141	133	77	13	28	22	44	26	55	73
Simpson index	0.9664	0.9701	0.9901	0.9988	0.9993	0.997	0.995	0.991	0.995	0.9911
Shannon index	0.1108	0.1023	0.046	0.0419	0.0031	0.042	0.026	0.039	0.026	0.0389

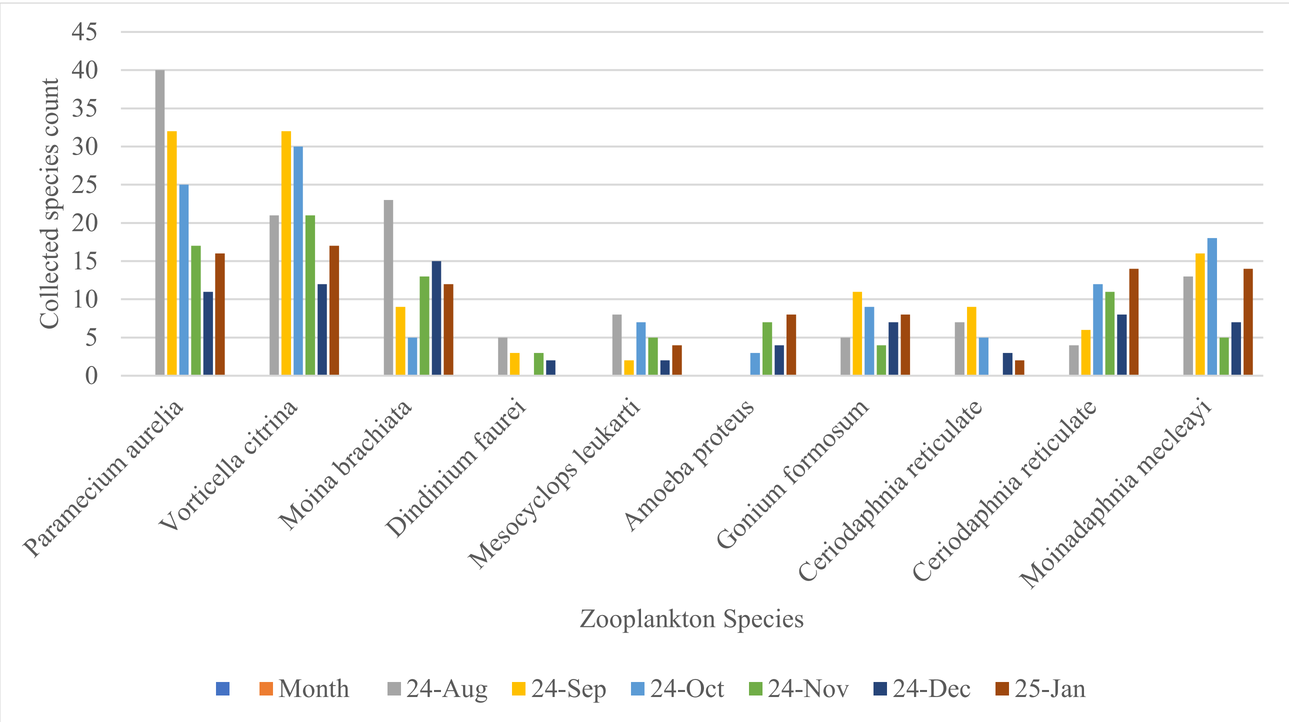

Figure 3. Month-wise Zooplankton Species Count in the Kalmadu Reservoir

The observed increase in copepod abundance during the wet season aligns with studies showing that copepods prefer cooler, oxygen-rich waters [21]. For example, the increase in *Sinodiaptomus indicus* abundance from August (4 organisms/L) to January (14 organisms/L) may be linked to the cooler, oxygen-rich conditions during the wet season

Copepods are known to thrive in such environments, and their increase may reflect the species' preference for these conditions [22].

The decline of *Paramecium aurelia* from August (40 organisms/L) to January (16 organisms/L) may be linked to the dilution effect caused by increased water volume during the wet season, which reduces nutrient concentration and limits protozoan growth [23]. Similarly, the decline in *Moina brachiata* abundance from August (23 organisms/L) to December (15 organisms/L) may reflect the species' sensitivity to changes in water temperature and nutrient availability [24]. These seasonal shifts in zooplankton abundance have significant implications for the reservoir's food web, as changes in zooplankton composition can alter energy transfer to higher trophic levels, including fish [25].

3.6 Implications for Fisheries and Water Resource Management

The zooplankton community in the Kalmadu Reservoir plays a critical role in supporting local fisheries, as zooplankton serve as the primary food source for commercially important fish species. The observed fluctuations in zooplankton abundance and diversity could directly impact fish stocking rates and overall fishery productivity.

The dominance of protozoans and low species diversity may reduce the availability of high-quality food resources for fish, potentially impacting fish growth and reproduction [25]. The presence of *Vorticella citrina*, a bioindicator of eutrophic conditions, suggests that the reservoir may be experiencing nutrient enrichment, which could lead to algal blooms and oxygen depletion, further threatening fish populations [24].

These findings highlight the need for regular monitoring of zooplankton communities to inform sustainable fisheries management and water resource conservation. For instance, the decline in *Ceriodaphnia reticulata* abundance from August (7 organisms/L) to December (3 organisms/L) may reflect the species' sensitivity to changes in water quality [23]. These findings underscore the importance of implementing conservation measures to protect the reservoir's zooplankton community and ensure the sustainability of local fisheries.

4. CONCLUSION

This study highlights the fundamental role of zooplankton in maintaining the ecological balance of the Kalmadu Reservoir, serving as key mediators in energy transfer and nutrient cycling within the freshwater ecosystem. The observed dominance of a few tolerant species and the low diversity indices indicate possible ecological stress, likely associated with eutrophication and environmental disturbances. Such shifts not only reduce species evenness but also weaken the overall resilience of the aquatic ecosystem, potentially compromising fisheries productivity and the stability of higher trophic levels.

The findings emphasize the urgent need for effective water quality management and the implementation of sustainable conservation strategies to mitigate the impacts of nutrient enrichment and habitat alteration. Long-term monitoring of zooplankton communities, along with integrated assessment of environmental parameters such as dissolved oxygen, pH, and nutrient concentrations, is essential to fully understand the drivers of community dynamics and to inform adaptive management practices.

Protecting zooplankton diversity is crucial not only for maintaining ecosystem functionality but also for supporting the livelihoods of local communities that depend on the reservoir’s resources. Overall, this study contributes to a broader understanding of freshwater ecosystem functioning and highlights the importance of proactive measures to ensure the long-term sustainability and ecological health of the Kalmadu Reservoir and similar freshwater systems. Future research should incorporate detailed physicochemical analyses and broader biological assessments, including fish population studies, to strengthen ecosystem-based management approaches.

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