DRY SEASON ABUNDANCE, DISTRIBUTION AND DIVERSITY OF FRESHWATER PLANKTON IN LAKES BABATI AND BURUNGE, NORTHERN TANZANIA

[1]KATONGE, Jackson Henry, [2]KASWAMILA, Abiud Lucas and [3]HAMISI, Mariam Issa

[1]Department of Biology, University of Dodoma, P. O. Box 338, Dodoma, Tanzania.
[2]Department of Geography and Environmental Studies, University of Dodoma, P. O. Box 395, Dodoma, Tanzania.
[3]Department of Crop Science and Horticulture, Sokoine University of Agriculture, P. O. Box 3005, Morogoro, Tanzania.

Corresponding Author: Katonge, J. H. Department of Biology, University of Dodoma, P. O. Box 338, Dodoma, Tanzania. **Email:** jkatonge@gmail.com **Phone:** +255 758304112

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ABSTRACT

This study investigated the abundance, distribution and diversity of planktonic organisms in Babati and Burunge lakes in Manyara region. Field sampling of phytoplankton and zooplankton were conducted in July and August 2022 followed by laboratory analysis. Phytoplankton communities were dominated by Bacillariophyceae (35.90%, 35.40%) and Chlorophyceae (32.10%, 24.00%) for Babati and Burunge lakes respectively. Among the zooplankton, Cladoceridae (37.70%) was most abundant in Lake Babati, while Cyclopidae (36.60%) was most abundant in Lake Burunge. Lake Babati had higher plankton species richness (S = 50) compared to Lake Burunge (S = 45). A slightly higher phytoplankton diversity, H = 3.14 was observed in Lake Burunge compared to Lake Babati, H = 3.04. Lake Babati had slightly higher zooplankton diversity, H = 2.61 compared to Lake Burunge, H = 2.30). Evenness (E) ranged 0.56 – 0.70 for phytoplankton and 0.77 – 0.80 for zooplankton indicating a moderate healthier and more diverse aquatic ecosystem. Phytoplankton and zooplankton typically exhibited a clear inverse correlation during various time intervals in different lakes. Sustainable management practices, protection of water quality and habitat preservation are needed in conservation of planktonic communities for maintaining the ecosystem health.

Keywords: Phytoplankton, Zooplankton, Abundance, Diversity, Lake Babati, Lake Burunge

INTRODUCTION

Lakes are complex ecosystems that play a fundamental role in maintaining biodiversity (Li *et al.*, 2022) and supporting ecological processes (Borics *et al.*, 2021). Plankton, consisting of phytoplankton and zooplankton (Russo *et al.*, 2016; Singh *et al.*, 2021) are integral components of the aquatic ecosystems (Lu *et al.*, 2021). The phytoplanktons are the primary producers (Iniobong *et al.*, 2022), that form essential links and base of aquatic food webs (Asuquo *et al.*, 2022; Declerck and De Senerpont Domis, 2023).

Several studies have investigated the seasonal and spatial variations in plankton abundance in lakes. For instance Adebayo *et al.* (2021) and Frank *et al.* (2023) reported higher plankton abundance during the rainy season due to increased nutrient influx, while (Asuquo *et al.*, 2022) noted variations in abundance between different depths and regions of the lakes. These studies emphasize the dynamic nature of plankton populations and their responsiveness to environmental changes.

The distribution patterns of planktonic organisms are influenced by physicochemical and biological factors that interact in complex ways (Golmarvi *et al.*, 2018; Li *et al.*, 2020). These factors include lake morphology (Asuquo *et al.*, 2022; Matek *et al.*, 2023), water temperature (Henson *et al.*, 2021; Lu *et al.*, 2021; Iniobong *et al.*, 2022), precipitation (Karmakar *et al.*, 2022), nutrient availability and climate change (Ndebele-Murisa *et al.*, 2010), light penetration (Xiao *et al.*, 2020), predation pressure (Wijeyaratne and Nanayakkara, 2020; Henson *et al.*, 2021) and hydrological dynamics (Mbonde *et al.*, 2004; Islam *et al.*, 2020). In addition, human activities, including agriculture and tourism introduce pollutants and alter nutrient inputs (Xiao *et al.*, 2020; Louchart *et al.*, 2023), further affecting planktonic communities (Frank *et al.*, 2023). The spatial and temporal distribution of planktonic organisms varies across lakes of different sizes, depths, geographic locations and climatic zones (Mbonde *et al.*, 2004; Karmakar *et al.*, 2022). Ndikuriyo *et al.* (2021) reported distinct horizontal variations in plankton distribution influenced by higher concentrations near the shorelines compared to open waters. Plankton diversity is an indicator of ecosystem health (Wijeyaratne and Nanayakkara, 2020) and functionality (He *et al.*, 2020; Asuquo *et al.*, 2022). Golmarvi *et al.* (2018), Cervantes-Martínez *et al.* (2023) and Matek *et al.* (2023) focused on zooplankton diversity with regards to various rotifers, copepod, cladoceran and branchiopod species. Iniobong *et al.* (2022) and Ndebele-Murisa *et al.* (2010) highlighted phytoplankton composition, abundance and diversity influenced by several factors. These findings draw attention to the complex interactions between different trophic levels within the planktonic community.

Phytoplankton help regulate water quality by removing excess nutrients, such as nitrogen and phosphorus, from the water column (He *et al.*, 2020; Tikue and Workagegn, 2022). In eutrophic lakes, where nutrient levels are high, the abundance and diversity of phytoplankton influences the development of harmful algal blooms (Golmarvi *et al.*, 2018), which have negative ecological and human health impacts (Talati *et al.*, 2023). The diversity of plankton species contributes to overall biodiversity in freshwater lakes (Matek *et al.*, 2023). Biodiversity is important for ecosystem stability and resilience (Asuquo *et al.*, 2022). A diverse plankton community can better adapt to environmental changes and disturbances (Xiao *et al.*, 2020).

Monitoring the abundance, distribution and diversity of plankton can serve as an indicator of the aquatic ecosystem health (Padua *et al.*, 2023) and condition of a freshwater ecosystem (Borics *et al.*, 2021). Changes in plankton populations signal environmental stressors, such as pollution or climate change impacts (Golmarvi *et al.*, 2018). Plankton abundance and distribution are closely tied to the availability of food for fish (Karmakar *et al.*, 2022). Healthy plankton communities supports a viable fisheries by providing a constant food source for fish populations (Wijeyaratne and Nanayakkara, 2020; Enawgaw and Wagaw, 2023). Monitoring and managing plankton populations are essential for the sustainable management of freshwater ecosystems (He *et al.*, 2020; Asuquo *et al.*, 2022). This study provide baseline data on ecological structure, taxonomic composition and diversity of planktonic species; inform science-based management and conservation strategies that will contribute to the preservation of lakes Babati and Burunge unique ecological heritage for the benefit of present and future generations.

MATERIALS AND METHODS

Study Area: This study was conducted in two freshwater bodies of the Great Rift Valley of East Africa, Lake Babati is located at 4° 15′ 0″ S and 35° 44′ 0″ E (Wikipedia, 2022) and Lake Burunge is located at 3° 52' 28" S and 35° 53' 5" E (Figure 1). Ecological features varied depending on the season, local climate and human activities in the inlet, middle and outlet of lakes resulting to cascading effects throughout the entire ecosystem.

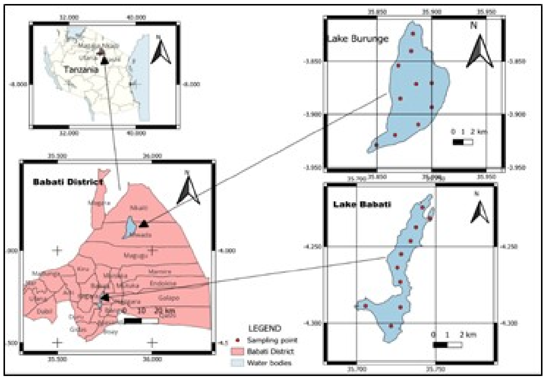

Figure 1: Map of Babati and Burunge Lakes, Tanzania showing the sampled stations (Katonge *et al.*, 2023)

There were variety of aquatic vegetation such as water lilies, reeds and submerged plants providing habitat and food for fish and invertebrates at the inlet. The inlets were also attractive to various bird species, including waterfowl, waders and migratory birds. The presence of these birds indicated the ecological health of the area, as they rely on the lake for feeding and breeding. The middle sections of lakes composed of important fish, plankton and macroinvertebrates' populations. The outlets formed habitat for unique plant and animal species with the diversity of wetland vegetation and wildlife. The outlet area was influenced by human activities particularly agriculture, cattle watering and water drawing but also served as an important site for fish spawning or migration. Furthermore, the lakes hold significant ecological and socio-economic value within the region attracting scientific interest due to their unique characteristics and the interactions between their ecosystems. The area harbors a rich biodiversity, both in terms of aquatic and terrestrial life. The lakes provide important habitat for a variety of bird species, including migratory birds, which use the lakes as stopover sites during their journeys. The lakes support fish populations that are of socio-economic importance to local communities. The lakes' ecosystems are interconnected, with the surrounding vegetation and wetlands providing crucial breeding grounds and foraging areas for various species.

Water Sampling: Water sampling for plankton was conducted in dry season months of July to August, 2022 due to the following reasons that contribute to more accurate and representative data. Firstly, the dry season offer stable environmental conditions and secondly, it offers better visibility, reduced mixing, easy sampling; offer a distinct community composition that allows the assessment of long-term trends and patterns in the plankton community. Three sampling sites; inlet, middle and outlet were sampled for each lake taking into consideration the lake morphology, depth variations and potential sources of nutrient inflow. GPS coordinates were recorded at each of the sampling site. Ten samples were collected between July and August per each sampling site per lake. Plankton net (55 µm) was vertically lowered into the water at 30 cm depth and allowed to move horizontally for a distance of 5 M to capture planktons. The captured planktons were placed in a 100 ml container. Relevant information for each sample, date and time was recorded. 0.5% Lugol's iodine was added to the water samples to prevent degradation of phytoplankton and 5% formaldehyde was used for preserving zooplankton. Sealed sample containers, stored in a cool and dark environment to minimize degradation were transported to the laboratory.

Laboratory Analysis: All standard operating procedures and protocols were observed to ensure data accuracy and comparability. Each sample was concentrated to 10 ml from which 1 mL of sample was taken. Sedgwick rafter cell was used to count individuals, while identification was done under Olympus Vanox Research Microscope Model 230485 with the help of taxonomic keys by (Hötzel and Croome, 1999). The composition of plankton was determined using methods described by Mack *et al.* (2012) and Bellinger and Sigee (2015).

Statistical Analysis: Two diversity indices were used, Shannon-Wiener index (H') to estimate species diversity and species evenness index (E) that indicate species richness and distribution of individuals. $H' = -\Sigma (pi * \ln (pi))$, Where: H' is the Shannon-Weiner index, Σ represents the sum over all species, pi is the proportion (relative abundance) of the i-th species and ln (pi) is the natural logarithm of pi. Simpson's Evenness Index (E) takes into account both species richness (the total number of species) and the distribution of individuals among those species. E = D / S, Where: E = Evenness index, D = Simpson's Diversity Index (1 - D is Simpson's Dominance Index), S = Number of species. SPSS software (Version 12) was used to analyze the dominant planktons. Multiple Correlation Analysis and Principal Component Analysis (PCA) were used to establish the relationship and the dynamics between phytoplankton and zooplankton.

RESULTS AND DISCUSSION

Temporal Phytoplankton Species Composition, Abundance and Distribution: The distribution of phytoplankton in both lakes during July and August was heterogeneous (Table 1). Higher phytoplankton densities were observed in the littoral zone with favorable conditions for growth, such as adequate light and nutrient availability. In July, Bacillariophyceae and Chlorophyceae were more abundant while Cyanophyceae showed a preference for Lake Babati compared to Lake Burunge (Adebayo *et al.* 2021; Frank *et al.* 2023).

The shift in phytoplankton composition between July and August in both lakes Babati and Burunge were likely driven by environmental factors (Iniobong *et al.* 2022). Dominance of Bacillariophyceae and Chlorophyceae in July may be due to favorable conditions for these groups, including nutrient-rich waters (Ndebele-Murisa *et al,* 2010) and optimal temperatures for growth (Lu *et al.*, 2021). The increase in Cyanophyceae dominance in August may be linked to rising water temperatures (Henson *et al.*, 2021), reduced vertical mixing (Adebayo *et al.* 2021), and higher nutrient levels (Xiao *et al.*, 2020), all of which favor cyanobacterial growth. The spatial distribution patterns suggest that phytoplankton abundance is influenced by local conditions, highlighting the importance of monitoring and understanding these patterns for effective lake management.

Spatial Phytoplankton Species Composition, Abundance and Distribution: Tables 1 and 2 showed that phytoplankton communities are highly diverse, comprising 6 classes: Bacillariophyceae, Chlorophyceae, Cyanophyceae, Nitzschiaceae, Dinophyceae and Dictyochophyceae with 38 phytoplankton species in both lakes. The composition of phytoplankton species was not uniform within and between lakes. Phytoplanktons were more abundant in the shallower littoral zones of sites 1 and 2. The most abundant classes were Bacillariophyceae (35.9, 35.4%) followed by Chlorophyceae (32.1, 24.0%), while Dictyochophyceae (1.2, 2.1%) was the least for lakes Babati and Burunge respectively. Harmful algal blooms (HABs) caused by various species of phytoplankton identified in the study area include *Anabaenopsis arnoldii*, *Anabaenopsis elenkinii* and *Anabaenopsis* microcyst. According to Adebayo *et al.* (2021) these species are known to produce toxins during blooms, which harm aquatic life and pose risks to human health through the consumption of contaminated seafood.

Phytoplankton forms the base of aquatic food chains. They are primary producers that convert sunlight and nutrients into organic matter through photosynthesis. Zooplankton, fish and other aquatic animals rely on phytoplankton as a primary food source (Borics *et al.*, 2021). Changes in phytoplankton abundance and distribution have cascading effects throughout the entire aquatic ecosystem (Tikue and Workagegn, 2022). Changes in phytoplankton abundance and composition serve as indicators of the health and condition of aquatic ecosystems (Enawgaw and Wagaw, 2023). Increases or decreases in phytoplankton biomass can reflect changes in nutrient levels, water quality and ecosystem productivity (Padua *et al.*, 2023). The presence of these phytoplankton species suggests the suitability of these lakes to support aquatic life.

The Shannon Wiener diversity index (H'), an indicator of water quality range from 0 to 5, where higher values correspond to greater species diversity or a more evenly distributed species composition (Wijeyaratne and Nanayakkara, 2020). On the other hand, lower values indicate lower species diversity.

Table 1: Abundance and distribution of members of the phytoplankton families: Bacillariophyceae, Chlorophyceae and Cyanophyceae in lakes Babati and Burunge, Tanzania

Class/Species name	Lake Babati stations					Lake Burunge stations				
	1	2	3	Total	%	1	2	3	Total	%
Bacillariophyceae										
Asterionellopsis glacialis	21	1	3	25	9.5	15	3	1	19	13.2
Coscinodiscus excentricus	-	-	22	22	8.4	7	-	-	7	4.9
Eucampia cornuta	31	10	-	41	15.6	-	-	11	11	7.6
Hemiaulus membrenaceus	2	-	1	3	1.1	-	-	2	2	1.4
Navicula spp.	-	1	2	3	1.1	2	-	9	12	8.3
Total	54	12	28	94	35.9	24	3	23	51	35.4
Chlorophyceae										
Chlamydomonas reinhardtii	1	-	13	14	5.3	-	-	-	-	-
Chlorella vulgaris	2	7	-	9	3.4	1	-	1	2	1.4
Euglena ehrenbergii	12	-	2	14	5.3	1	-	-	1	0.7
Eutreptia viridis	4	-	-	4	1.5	2	12	-	14	9.7
Phacus curvicauda	31	-	1	32	12.2	-	2	1	3	2.1
Phacus longicauda	1	1	1	3	1.1	1	7	1	9	6.2
Scenedesmus quadricauda	3	2	5	10	3.8	3	2	2	7	4.9
Total	54	10	22	84	32.1	8	23	5	36	24
Cyanophyceae										
Anabaenopsis arnoldii	1	1	-	2	0.76	-	1	-	1	0.7
Anabaenopsis elenkinii	-	1	2	3	1.1	3	-	-	3	2.1
Anabaenopsis microcyst	12	2	1	15	5.7	1	1	-	2	1.4
Morismopedia convulata	-	-	2	2	0.76	-	1	-	1	0.7
Oscillatoria erythraea	-	-	1	1	0.38	-	-	2	2	1.4
Oscillatoria spp.	1		1	2	0.76	1	1	2	4	2.8
Spirulina platensis	7	1	2	10	3.8	2	3	1	6	4.2
Cyanobacteria spp.	-	1	-	1	0.38	-	-	1	1	0.7
Total	21	6	9	36	13.7	7	7	6	20	14

Table 2: Abundance and distribution of members of the phytoplankton families: Nitzschiaceae, Dinophyceae and Dictyochophyceae in lakes Babati and Burunge, Tanzania

Class/Species name	Lake Babati stations					Lake Burunge stations				
	1	2	3	Total	%	1	2	3	Total	%
Nitzschiaceae										
Nitzschia longissima	3	-	-	3	1.1	1	1	1	3	2.1
Nitzschia pungens	1	-	3	4	1.5	2	-	1	3	2.1
Nitzschia ossiformis	2	-	1	3	1.1	-	-	-	-	-
Nitzschia seriata	1		1	2	0.8	1	2	1	4	2.8
Nitzschia sigma	2	2	1	5	1.9	2	1	1	4	2.8
Nitzschia intermedia	1	-	-	1	0.4	-	-	-	-	-
Phaeodactylum tricornutum	1	-	3	4	1.5	3	-	-	3	2.1
Pleurosigma carpense	-	1	1	2	0.8	-	1	1	2	1.4
Pleurosigma rhombeum	1	3	1	5	1.9	1	-	1	2	1.4
Total	12	6	11	29	11.1	10	5	6	21	14.6
Dinophyceae										
Archaperidinium saanichi	-	-	1	1	0.4	-	1	2	3	2.1
Ceratium furca	1	1	1	3	1.1	-	-	1	1	0.7
Ceratium schmidti	-	2	-	2	0.8	2	-	-	2	1.4
Dinophysis fortii	-	-	3	3	1.1	-	1	-	1	0.7
Gonyaulax polygramma	-	-	2	2	0.8	-	-	-	-	-
Gymnodinium catenatum	-	-	-	-	-	3	-	1	4	2.8
Prolocentrum micans	4	1	-	5	1.9	2	-	-	2	1.4
Total	5	4	7	16	6.1	7	2	4	13	9.0

Dictyochophyceae										
Dictyocha fibula	1	1	-	2	0.8	-	-	-	-	-
Dictyocha spp.	1	-	-	1	0.4	1	1	1	3	2.1
Total	2	1	-	3	1.2	1	1	1	3	2.1
Grand total (Tables 1 and 2)	148	49	77	262	100	57	41	45	144	100

Furthermore, this index evaluates the pollution level in aquatic ecosystem ((Lu *et al.*, 2021). Established H' standards categorize water quality as follows: very good (4 or more), good (3 – 4), moderate (2 – 3), poor (1 – 2) and very poor (less than 1). As for pollution levels based on species diversity, values below 1 means high pollution, between 1 and 3 indicate moderate pollution and values greater than 4 suggest an unpolluted water system (Li *et al.*, 2020).

Phytoplankton results in Table 3, suggest that both lakes have diverse communities. Lake Babati generally exhibited higher species richness (S = 38) and abundance compared to Lake Burunge (S = 35), as evidenced by the higher numbers of species and individuals observed. According to the combined Shannon-Weiner index, both lakes have relatively diverse plankton communities. Lake Burunge tends to exhibit slightly higher diversity (H = 3.14) compared to Lake Babati (H = 3.04). According to Shannon Wiener diversity index (H') scale the two aquatic bodies are not polluted and can harbor various species (Talati *et al.,* 2023). The evenness values obtained indicate how uniformly the individuals are distributed among species. Higher evenness values observed in Lake Burunge (E = 0.70) compared to Lake Babati (E = 0.56) suggest a more balanced distribution of species within a community. A slightly higher combined diversity and evenness observed in Lake Burunge compared to Lake Babati suggest that the differences may be due to ecological conditions (Borics *et al.*, 2021), environmental factors (Wijeyaratne *et al.*, 2020), or anthropogenic influences (Louchart *et al.*, 2023). Both lakes had a consistent number of site visits for each measurement that ensured sampling effort was comparable across the lakes.

Temporal Zooplankton Species Composition, Abundance and Distribution: In July, the zooplankton community in Lake Babati was diverse, with several species (Table 4). Key species from classes Cladoceridae, Cyclopidae, Daphniidae, Keratellidae and Rotiferidae, collectively made up the majority of the community in Lake Babati. Lake Burunges' zooplankton community was also diverse, with similar classes but relatively fewer species compared to Lake Babati. In August, the zooplankton composition in Lake Burunge exhibited changes similar to Lake Babati. Spatially, the distribution of zooplankton in both lakes during July and August was heterogeneous.

The temporal variation in zooplankton composition between July and August in both lakes Babati and Burunge reflected changes in environmental conditions likely temperature (Lu *et al.*, 2021; Iniobong *et al.*, 2022), nutrient availability (Ndebele-Murisa *et al.*, 2010), and predation pressure (Henson *et al.*, 2021). Cladoceridae species often responded positively to increased phytoplankton abundance (Tables 1 and 2), which may have driven their higher abundance (Golmarvi *et al.*, 2018). The decrease in some species abundance in August was associated to changes in food availability (He et al., 2020) and competition with other zooplankton species (Lu *et al.*, 2021). Zooplankton species appeared to be resilient and maintained their presence in both lakes, suggesting their adaptability to changing conditions i.e. Lake Babati, a non saline and Lake Burunge , a saline water body (Katonge *et al.*, 2023). The spatial distribution of zooplankton highlights the importance of the littoral zones for zooplankton communities, where they find optimal conditions for growth and reproduction (Singh *et al.*, 2021). Findings on the temporal dynamics of zooplankton are important for ecosystem management, fisheries and water quality assessment. Long-term monitoring programs help to track changes in these dynamics and understand the health and stability of aquatic ecosystems.

Table 3: Diversity indices of phytoplankton species in lakes Babati and Burunge, Tanzania

Diversity index	Lake Babati				Lake Burunge			
	1	2	3	Combined	1	2	3	Combined
Number of site visited	1	1	1	1	1	1	1	1
Number of species	27	18	26	38	22	18	23	33
Number of individuals	53	24	45	122	37	23	27	87
Shannon-Weiner (H)	2.47	2.50	2.64	3.04	2.69	2.39	2.63	3.14
Evenness (E) e^H/S	0.46	0.67	0.54	0.56	0.67	0.64	0.63	0.70

Table 4: Relative abundance and distribution of zooplankton species in lakes Babati and Burunge, Tanzania

Class/Species	Lake Babati stations					Lake Burunge stations				
	1	2	3	Total	%	1	2	3	Total	%
Cladoceridae										
Bosmina longirostris	-	10	11	21	12.6	1	1	1	3	3.8
Ceriodaphnia dubia	10	2	3	15	9.0	-	10	-	10	12.7
Total	10	12	14	36	37.7	1	11	1	13	16.5
Cyclopidae										
Cyclops scutifer	12	1	2	15	9.0	-	-	12	12	15.2
Monstrilla helgolandica	11	1	1	13	7.8	13	1	-	14	17.7
Total	23	2	3	28	16.8	13	1	12	26	36.7
Daphniidae										
Daphnia magna	-	-	10	10	6	-	-	-	-	-
Daphnia longispina	12	7	-	19	13.5	10	1	2	13	16.4
Total	12	7	10	29	17.4	10	1	2	13	16.5
Keratellidae										
Keratella cochlearis	1	-	1	2	1.2	1	1	9	11	13.9
Keratella cruciformis	13	-	1	14	8.4	4	1	-	5	6.3
Keratella earlinae	-	1	7	8	4.8	-	-	-	-	-
Keratella quadrata	-	1	1	2	1.2	2	-	-	2	2.5
Keratella spp.	17	-	2	19	11.4		1	-	1	1.3
Total	31	2	12	45	27	7	3	9	19	24
Rotiferidae										
Brachionus plicatilis	21	-	-	21	12.6	3	-	-	3	3.8
Filinia longiseta	-	3	1	4	2.4	-	-	-	-	-
Filinia opoliensis	-	1	-	1	0.6	-	1	12	13	16.5
Lepadella vandenbrandei	3	-	-	3	1.8	-	-	2	2	2.5
Total	24	4	1	29	17.4	3	1	14	18	22.8
Grand total	100	27	40	167	100	6	2	28	79	100

In additional, the responses of zooplankton to environmental changes serve as indicators of broader ecosystem shifts, including climate change impacts and anthropogenic disturbances.

Spatial Zooplankton Species Composition, Abundance and Distribution: Five classes with 17 zooplankton species were identified in both lakes, comprising of 17 species in Lake Babati and 13 species in Lake Burunge. Cladoceridae (37.7%) were most abundant for Lake Babati, while Cyclopidae (36.6%) was most abundant for Lake Burunge. There was variation in species composition in some stations during the sampling time and higher zooplankton abundances were observed in the littoral zones of sites 1 and 2 (Table 4).

Zooplankton plays fundamental roles in aquatic ecosystems and has far-reaching implications for both the environment and human activities. Zooplanktons primarily graze on phytoplankton. By doing so, they help control the population of phytoplankton, preventing excessive algal blooms and maintaining water quality (Russo *et al.*, 2016). Zooplankton excretes nutrients in a form that is readily available for phytoplankton to use for growth (Declerck and De Senerpont Domis, 2023; Louchart *et al.*, 2023). Their waste products contribute to nutrient cycling (Karmakar *et al.*, 2022). The significant number of zooplankton noted in this study signifies their ability to controlling and removing the poisonous phytoplankton.

The zooplankton transfer energy from primary producers (phytoplankton) to higher trophic levels, such as small fish and invertebrates, makes them a critical link in the aquatic food web (Sommer and Stibor, 2002; Henson *et al.*, 2021). Many commercially valuable fish species rely on zooplankton as a primary food source during their early life stages (Talati *et al.*, 2023). Healthy zooplankton populations are necessary for successful fisheries and aquaculture operations in lakes Babati and Burunge.

According to Table 5 results, both lakes had diverse communities. While Lake Babati tends to have slightly higher species richness (S = 17) and diversity (H = 2.61), Lake Burunge demonstrated comparable low diversity levels (H = 2.30), with remarkable evenness in species distribution. The combined Shannon-Weiner index suggests that both lakes had moderate to high diversity (Islam *et al.*, 2020). The evenness values were E = 0.80 for Lake Babati and E = 0.77 for Lake Burunge respectively suggesting a more balanced distribution of species within the community (Karmakar *et al.*, 2022).

Relationship and Dynamics of Phytoplankton and Zooplankton Abundance: Results in Table 6 showed the correlation of each independent variable (phytoplankton and zooplankton) in Lake Babati with the dependent variable. In this case, phytoplankton had positive correlation of 0.70 with the dependent variable, while zooplankton had negative correlation of -0.89. Results from PCA analysis with two principal components in Table 7 display the variance ratios, which represent the correlations between the original variables (phytoplankton and zooplankton) and each principal component.

PC1 explained most of the variance and had a strong positive correlation with phytoplankton and a strong negative correlation with zooplankton, while PC2 explained a small fraction of the variance with inverse correlations to the original variables. Results in Table 6 for Lake Burunge, showed phytoplankton had a positive correlation of 0.81 with the dependent variable, while zooplankton also had a positive correlation of 0.74. These findings were in agreement with earlier studies on dynamics and relationship of planktonic species in rural wetlands of Anand and Kheda districts, Gujarat India (Talati *et al.*, 2023) and phytoplankton species in the Yellow River Delta in the northeast of Shandong Province, China (Xiao *et al.*, 2023).

The results further suggested a predator-prey relationship of phytoplankton and zooplankton in both lakes. Phytoplankton populations exhibited seasonal fluctuations, with peaks during the warmer months (e.g., June to August) when light and nutrient availability were favorable for growth (Asuquo *et al.*, 2022). Zooplankton populations followed a similar seasonal pattern but lagged behind phytoplankton abundance. This observation suggested that zooplankton act as predators of phytoplankton, with the abundance of zooplankton influencing the rate of phytoplankton consumption (Wijeyaratne and Nanayakkara, 2020). Conversely, the availability of phytoplankton as a food source affects zooplankton reproduction and growth (Russo *et al.*, 2016). While the model predicted cyclic fluctuations in phytoplankton and zooplankton populations, a true equilibrium did not appear to be reached during the study period. Instead, oscillations in abundance, indicating that populations are not in a steady state, emphasizing the need for monitoring and conservation efforts to maintain the health and resilience of these aquatic ecosystems (Borics *et al.*, 2021). The absence of a stable equilibrium suggested that the phytoplankton-zooplankton interaction is dynamic (Li *et al.*, 2020), influenced by various environmental factors (Majumder *et al.*, 2021), and potentially sensitive to disturbances in lakes Babati and Burunge. Results suggest that, zooplankton grazing reduces phytoplankton abundance, decreasing competition for resources among the remaining phytoplankton, allowing them to grow

Table 5: Diversity indices of zooplankton species in lakes Babati and Burunge, Tanzania

Diversity index	Lake Babati				Lake Burunge			
	1	2	3	Combined	1	2	3	Combined
Number of site visited	1	1	1	1	1	1	1	1
Number of species	11	9	11	17	8	8	7	13
Number of individuals	17	10	15	42	13	8	10	31
Shannon-Weiner (H)	2.16	1.76	1.96	2.61	1.66	1.48	1.51	2.30
Evenness (E) e^H/S	0.79	0.65	0.65	0.80	0.66	0.55	0.65	0.77

Table 6: Multiple correlation analysis of phytoplankton and zooplankton in lakes Babati and Burunge, Tanzania

Lake	Variable	Correlation with dependent variable
Babati	Phytoplankton	0.79
	Zooplankton	-0.89
Burunge	Phytoplankton	0.81
	Zooplankton	0.74

Table 7: Principal component analysis of phytoplankton and zooplankton in lakes Babati and Burunge, Tanzania

Lake	Principal component	Variance ratio	Correlations with original variables
Babati	PC1	0.98	0.83 (Phytoplankton), -0.56 (Zooplankton)
	PC2	0.02	-0.56 (Phytoplankton), -0.83 (Zooplankton)
Burunge	PC1	0.85	0.74 (Phytoplankton), 0.67 (Zooplankton)
	PC2	0.15	-0.67 (Phytoplankton), 0.74 (Zooplankton)

more efficiently, thus leading to another bloom when conditions are favorable (Pomati *et al.*, 2020). On the other hand, increased zooplankton grazing reduces phytoplankton populations, leading to reduced food availability for zooplankton and, in turn, a decrease in their numbers (Cyr and Pace, 1992). The relationship observed is essential for the stability, productivity and health of aquatic ecosystems.

Moreover, regulate nutrient cycling, support food webs, maintain biodiversity, and play a role in climate change mitigation for effective ecosystem management and the sustainable use of aquatic resources.

Conclusion: This study on the abundance, distribution and diversity of freshwater plankton in Lakes Babati and Burunge, has provided valuable insights into the ecological dynamics of these important aquatic ecosystems. Classes Bacillariophyceae, Chlorophyceae, Cladoceridae and Cyclopidae were the dominant planktonic organisms in both lakes. Zooplankton populations increased as phytoplankton abundance increased, conversely, zooplankton exerted top-down control by consuming them, potentially decreased phytoplankton abundance. The findings indicated that lakes support higher trophic levels including various fish species. Despite the progress made in understanding plankton dynamics in lakes, studies are needed to capture the complex interaction between environmental drivers and planktonic responses. The potential impacts of anthropogenic activities on plankton composition and diversity require comprehensive assessment and management. Conservation efforts and sustainable resource management are required to preserve the ecological integrity of these freshwater bodies.

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