Abundance and Diversity of Macroinvertebrates in the Main Tributaries of Mindu Dam in Morogoro, Tanzania

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Abstract

Freshwater ecosystems support biodiversity but are threatened increasingly by human activities. Limited information exists on how land-use affects macroinvertebrate communities in Mindu Dam, the main water source for Morogoro. This study assessed the abundance and diversity of macroinvertebrates across three tributaries (Mlali, Lukulunge, and Mugera) representing cropping, settlement, and grazing land uses. A total of 444 individuals from seven orders and 12 families were recorded. Hemiptera dominated (> 76%), with Veliidae (191) and Gerridae (122) most abundant. While Mlali showed the highest abundance, Shannon measuring the greatest diversity, and Lukulunge clocking the lowest number of variants, statistical analyses revealed no significant differences in overall abundance or diversity across tributaries or land-use types. However, tolerant taxa dominated disturbed sites, whereas sensitive families were rare or absent, indicating subtle compositional shifts due to land-use. These findings suggest that land-use does influence macroinvertebrate community structure but without strongly affecting overall abundance or diversity; thus it provides baseline data for biomonitoring and pollution management in the Mindu Dam catchment. Future investigation is needed to capture seasonal dynamics, to identify specific pollutant influences, and to develop localized bioassessment indices that strengthen long-term monitoring.

***Keywords*:** macroinvertebrates, anthropogenic activities, pollution, diversity, tributaries, Mindu Dam, water quality, abundance

1. Introduction

Freshwater ecosystems are essential for sustaining a wide range of organisms and providing critical ecosystem services that support biodiversity, human well-being, and environmental sustainability (Bănăduc et al., 2022). Mindu Dam is the primary freshwater supply for Morogoro urban and peri-urban areas, contributing approximately 80% of the total water demand (Mdegela et al., 2009). The dam also supports a wide range of aquatic organisms, including macroinvertebrates that play vital ecological roles and are widely used as indicators of water quality (Arimoro & Keke, 2017). Mindu dam catchments areas support various human activities including farming and settlement (Mdegela et al., 2009). Farming, settlements, and associated land-use modifications contribute to nutrient enrichment, pesticide inputs, and untreated wastewater discharge (Natkhin et al., 2015). These expanding anthropogenic activities around the dam play a great role in degrading water quality, and in threatening the ecological health of Mindu Dam (Makarius et al., 2015; Ojija & Kavishe, 2016a; Omary et al., 2023). Additionally, climate variability and changing land-use patterns intensify environmental stress through altering hydrological processes, vegetation cover, and pollutant pathways (Gobry et al., 2023; Kibena et al., 2014; Mzuza et al., 2019; Namugize et al., 2018). Such disturbances have significant implications for the ecological functioning of dam tributaries, particularly for sensitive biological communities such as macroinvertebrates.

Aquatic macroinvertebrates are small aquatic animals without backbones that spend some period of their lives, or the entirety of their lives, in and around water bodies. They are recognized by researchers as effective bioindicators due to their sensitivity to ecological stressors, their rapid response to pollution gradients, their wide distribution across freshwater habitats, and their ready accessibility for sampling (Ojija & Laizer, 2016; Shimba & Jonah, 2016). Changes in the diversity, abundance, and community composition of aquatic microinvertebrates provide reliable insights into environmental disturbances and shifts in water quality conditions (Siddig et al., 2016; Tampo et al., 2021). Based on previous studies, polluted freshwater systems are expected to typically exhibit reduced macroinvertebrate diversity and shifts in genetic development toward pollution-tolerant taxa. These developments are further assumed to reflect a decline in ecological integrity (Makumbe et al., 2022; Omary et al., 2023).

Despite the ecological importance of Mindu Dam and its role in sustaining the Morogoro community, there remains a limited amount of scientific information about the diversity, abundance, and distribution of aquatic macroinvertebrates in its tributaries. Existing studies have primarily focused on water quality assessments and pollution sources (Mdegela et al., 2013; Ngonyani, 2007; Raphael, 2022); but there is no comprehensive evaluation that has been conducted to link the macroinvertebrate community's structure with human-associated pollution in the dam's main feeder rivers. This lack of ecological data constrains effective monitoring and management of environmental changes occurring in the catchment area.

To address this gap, the present study examined the macroinvertebrate communities along the major tributaries of Mindu Dam to determine how human activities may have influenced their distribution patterns. The study was guided by the hypothesis that aquatic macroinvertebrate diversity and abundance decrease along tributaries exposed to higher levels of anthropogenic disturbance and degraded water quality. The overall aim of this research was to characterize aquatic macroinvertebrate assemblages in the Mindu Dam tributaries and to assess how their ecological patterns may have reflected the impacts of pollution from surrounding human activities. Findings from this study are expected to provide essential baseline information for guiding management strategies, supporting ecological monitoring, and enhancing conservation efforts within the Mindu Dam catchment.

2. Material and methods

2.1 Study area

The study was conducted between May and June 2024 within the Mindu Dam catchment, located at approximately 6.82°S and 37.66°E in Morogoro Region, eastern Tanzania (Fig 1). The catchment covers about 303 km^2 and forms part of the larger Ngerengere River basin (Ngonyani, 2007). Mindu Dam receives inflow primarily from four tributaries Lukulunge, Mugera, Mlali and Mzinga as well as runoff from the Uluguru Mountain ranges.

The catchment experiences a bimodal rainfall pattern, with long rains occurring from March to May and short rains from September to November. Annual rainfall ranges between 800-1500 mm, averaging about 890 mm. Temperatures fluctuate seasonally, with cooler months in June-August averaging 18-22°C, and hotter months between October-March reaching 30-33°C (Melchioly, 2021).

Vegetation in the area consists mainly of cultivated land, fallow fields, patches of riv1§erine vegetation, and degraded forest areas influenced by human activities.

2.2 Sampling of macroinvertebrates

A total of 9 sampling stations were chosen from three pre-determined main tributaries, three sampling sites were selected from each individual tributary and divided based on the surrounding main anthropogenic activities taking place in the area nearby which are cropping area, settlement area and grazing area. Macroinvertebrates were collected from 30m pre-determined sampling station at each site, using a dip net coupled with hand picking. Sampling method was according to Shimba & Jonah, (2016) with some modifications. Dip net was swung in water from one point to another within 30m area, large debris and aquatic plants were washed and observed of any organisms. Macroinvertebrates were then counted, picked, collected into plastic bottles containing 70% alcohol for preservation before taken to the lab for identification. In the lab all macroinvertebrates were identified to family level using standard keys with the aid of light microscope (Zahraddeen et al., 2019). Mapping of the study area was conducted through GIS system to depict the area map and the sampling stations.

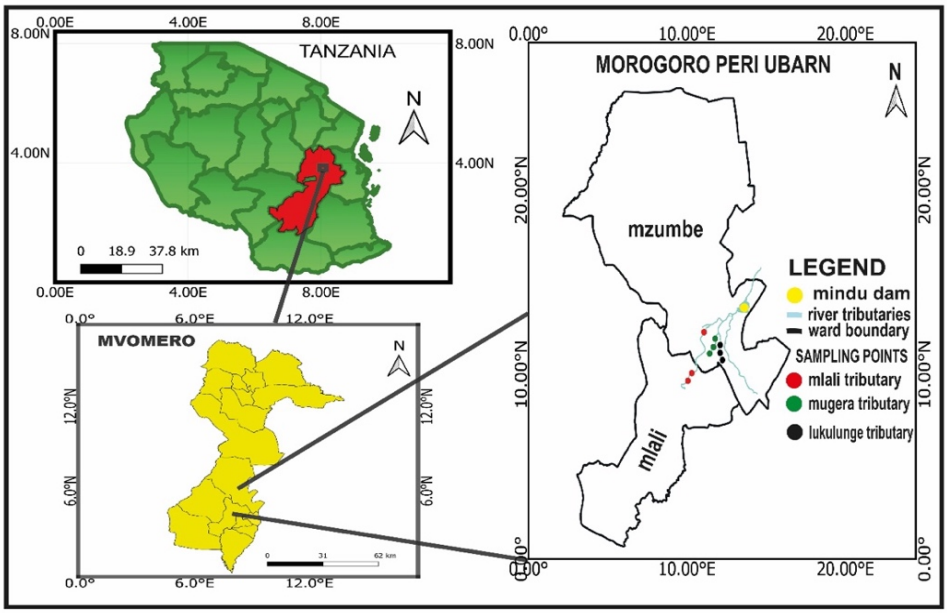


Figure 1: Study area map showing the sampling stations in main tributary of mindu dam. Made from google earth and qGIS desktop by author.

2.3 Data analysis

All data were analyzed using R-software (R v4.4.3), Species abundance was determined through counting the number of every species in the tributaries of Mindu dam, species diversity was determined through measure of Shannon diversity index (H), Simpson (1-D) and Margalef's index to account the species richness and evenness. Mean distribution and abundance of macro-invertebrates were compared by Kruskal-Wallis test to analyze the statistical significance variation across the tributary and land use.

3. Results

3.1 Abundance of macroinvertebrates

A total of 444 macroinvertebrate individuals, belonging to 12 families and 7 orders, were collected from the three tributaries of Mindu Dam. Abundance varied across tributaries: Mlali recorded the highest abundance (206 individuals), followed by Lukulunge (124 individuals) and Mugera (114 individuals). Across land-use categories, settlement sites (SMT) contributed the highest abundance (247 individuals), while cropping (115 individuals) and grazing (82 individuals) had comparatively lower counts (Figure 1).

Hemiptera dominated the assemblage, contributing over 76% of all individuals, with Veliidae (191) and Gerridae (122) being the most abundant families. In contrast, sensitive taxa such as Planorbidae, Haplotaxidae, and Brachyura were rare ($\leq$ 5 individuals). A Kruskal-Wallis test performed on family-level abundance across tributaries revealed no statistically significant difference in macroinvertebrate abundance among Mlali, Lukulunge and Mugera ($H = 0.855$, $p = 0.652$). This indicates that although numerical abundance varied, overall family-level distribution patterns were statistically similar across tributaries.

The taxonomic composition across the sites showed that, Hemiptera was the dominant order, followed by Coleoptera and Araneae. Order-level richness differed slightly among tributaries, with Mlali supporting the greatest richness (7 orders), followed by Mugera (6 orders) and Lukulunge (5 orders). Lukulunge lacked several rare or sensitive families that appeared in the other tributaries, including Planorbidae and Haplotaxidae (Table 1) following figure 2 below.

3.2 Diversity of aquatic macroinvertebrates

Diversity analysis revealed moderate variation across tributaries and land-use types (Table 2). Mlali recorded the highest Shannon diversity (H' = 1.462) and Simpson diversity (1-D = 0.734), indicating greater ecological balance. Mugera showed intermediate Shannon diversity (H' = 1.324) but the lowest evenness (E = 0.637), implying stronger dominance by tolerant taxa. Lukulunge had the lowest Shannon value (H' = 1.211).

Across land-use types, cropping sites (CRP) showed the highest Shannon diversity (H' = 1.482), followed by grazing sites (H' = 1.405). Settlement sites exhibited the lowest diversity (H' = 1.291) due to strong dominance by Hemipterans. Statistical analysis using Kruskal-Wallis tests on Shannon, Simpson and evenness values across tributaries showed no statistically significant differences in diversity ($p > 0.05$ for all indices). This indicates that statistically uniform diversity patterns across the tributaries. This uniformity is consistent with the observed dominance of few tolerant families (Veliidae, Gerridae, Gyrinidae) across all sites and the low presence of sensitive groups point to reduced habitat heterogeneity, suggesting comparable environmental pressures and levels of disturbance across the catchment.

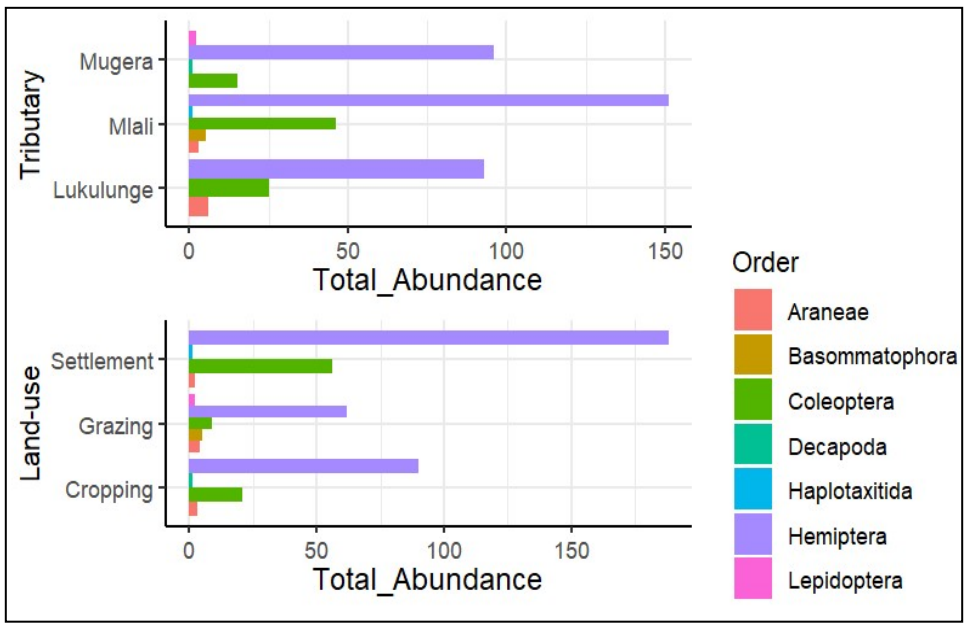


Figure 2: Total abundance of macroinvertebrates across the tributary and land use

Table 1: Macroinvertebrates abundance of the three studied tributaries (Key: CRP = Cropping, SMT = Settlement, GRZ = Grazing)

Order	Family	Mlali			Lukulunge			Mugera			Total
		CRP	SMT	GRZ	CRP	SMT	GRZ	CRP	SMT	GRZ	
hemiptera	Veliidae	23	29	22	12	34	10	11	34	16	191
hemiptera	Gerridae	22	32	3	0	31	6	14	14	0	122
hemiptera	Naucoridae	5	13	2	0	0	0	0	1	3	24
hemiptera	Hebridae	0	0	0	0	0	0	3	0	0	3
Coleoptera	Gyrinidae	8	29	9	11	14	0	0	13	0	84
Coleoptera	Haliplidae	0	0	0	0	0	0	2	0	0	2
Araneae	Dictynidae	1	0	2	0	0	1	0	0	0	4
Araneae	Psauridae	0	0	0	2	2	1	0	0	0	5
Basommato-phora	Planorbidae	0	0	5	0	0	0	0	0	0	5
Haplotaxida	Haplotaxidae	0	1	0	0	0	0	0	0	0	1
Lepidoptera	Crambidae	0	0	0	0	0	0	0	0	2	2
Decapoda	Brachyura	0	0	0	0	0	0	1	0	0	1
Total		59	104	43	25	81	18	31	62	21	444
Total / tributary		206			124			114			

Table 2: Diversity indices (family-level) per tributary and per land-use. (H' = Shannon; 1–D = Simpson; E = Pielou's evenness)

Group	H' (Shannon)	1–D (Simpson)	Evenness (E)
Mlali (tributary)	1.462	0.734	0.751
Lukulunge (tributary)	1.211	0.665	0.752
Mugera (tributary)	1.324	0.638	0.637
Cropping (CRP)	1.482	0.711	0.675
Settlement (SMT)	1.291	0.694	0.720
Grazing (GRZ)	1.405	0.624	0.676

4. Discussion

The findings reveal a clear presence and distribution of diverse macroinvertebrates across the Mindu Dam tributaries, providing strong biological evidence of the ecological conditions within this hydrological network. The results demonstrate that macroinvertebrate assemblages are indeed significantly influenced by anthropogenic activities, particularly cropping, settlement and grazing within the catchment. These patterns support the initial hypothesis that increased human disturbance reduces

macroinvertebrate diversity and alters community structure, consistent with our prior expectations.

The dominance of moderately pollution-tolerant taxa such as Veliidae, Gerridae, and Gyrinidae indicates that the ecological conditions within the tributaries are suboptimal and moderately degraded. These groups are well-documented for their ability to persist in disturbed or organically enriched waters, and their prevalence aligns with findings from similar tropical freshwater systems (Rodrigues Capítulo et al., 2001; Xu et al., 2014). Their abundance across all tributaries suggests that tolerant taxa have replaced sensitive groups, a common response to cumulative watershed disturbances highlighted in the introduction. This is consistent with the results by Sharma & Behera, (2022) who stated that, taxa with greater diversity and abundance offers a wide range of tolerant to pollution.

Consistent with expectations for polluted systems (Makumbe et al., 2022; Omary et al., 2023), no highly sensitive macroinvertebrate groups (such as Ephemeroptera and Plecoptera) were recorded. These taxa require elevated dissolved oxygen, stable substrates, and minimal organic pollution (Arimoro & Keke, 2017; Elias et al., 2014). Their complete absence provides strong biological evidence that water quality has been compromised across the tributaries, confirming the ecological stress linked to expanding land-use activities. This confirmation further reinforces the usefulness of macroinvertebrates as reliable bioindicators for assessing environmental degradation (Siddig et al., 2016; Tampo et al., 2021).

Spatial variation among tributaries further demonstrates the role of land-use intensity in shaping community patterns. The higher diversity and abundance in Mlali tributary suggest comparatively lower pollution pressure, allowing for a broader range of taxa to persist. Conversely, Lukulunge and Mugera tributaries, which are surrounded by more intensive human activity, exhibited reduced diversity – consistent with the hypothesis that disturbance negatively affects macroinvertebrate communities. These observations closely align with previous regional studies showing that agricultural expansion, grazing pressure, and settlement discharge degrade stream habitats, leading to declines in sensitive taxa (Gobry et al., 2023; Ojija & Kavishe, 2016b).

The variation among land-use types across sites provides additional insights. Grazing areas consistently showed the lowest macroinvertebrate abundance and diversity, likely due to increased bank erosion, livestock trampling, and nutrient inputs, all of which modify substrate structure and reduce habitat suitability. Cropping areas, though also impacted by agrochemical and sediment runoff, showed slightly higher

diversity than grazing sites did, possibly reflecting mixed habitat conditions. Settlement areas supported relatively more individuals than expected, potentially due to heterogenous microhabitats that allow moderate-tolerance taxa to persist. These site-specific trends agree with the documented influence of land-use gradients upon macroinvertebrate distributions globally, as well as in East African watersheds (Makumbe et al., 2022; Ojija & Laizer, 2016).

Overall, the patterns observed across the tributaries support the central hypothesis introduced in this study: land-use activities around the Mindu Dam catchment significantly influence macroinvertebrate community structure, leading to assemblages dominated by tolerant taxa and the loss of sensitive indicators. These changes signal ongoing ecological degradation and water-quality deterioration within the dam's hydrological network. Given the dam's central role in supplying water to Morogoro, the results underscore the necessity for strengthened pollution control, catchment management, and continuous biomonitoring to mitigate further ecological decline.

5. Conclusion

This study provides clear evidence that the presence and distribution of macroinvertebrate bioindicators in the tributaries of Mindu Dam effectively reflect the ecological conditions of the catchment. The overwhelming dominance of moderately pollution-tolerant taxa such as Veliidae, Gerridae and Gyrinidae, combined with the complete absence of highly sensitive groups including Ephemeroptera and Plecoptera, indicates that the tributaries are experiencing moderate ecological degradation. Spatial patterns observed in the assemblages further support this assessment, with Mlali showing comparatively higher diversity, while tributaries exposed to more intensive settlement, cropping and grazing activities exhibited reduced richness in the variety of microinvertebrates, and a shift toward tolerant taxa.

Overall, the macroinvertebrate communities observed in this study demonstrate that ongoing land-use pressures are altering habitat quality; for these pressures are reducing the presence of sensitive bioindicator groups across the Mindu Dam hydrological network. These findings confirm the usefulness of macroinvertebrates as reliable biological indicators for detecting ecological stress. Such results highlight the importance of continuous biomonitoring to track environmental change; they also indicate the value in management of this critical water resource. Continued investigation is needed to capture seasonal dynamics, to identify specific pollutant

influences, and to develop localized bioassessment indices that strengthen long-term monitoring, which will in turn improve our understanding of ecosystem change within this critical freshwater system.

6. Conflicts of interest

The authors declare that there are no conflicts of interest regarding this research or the publication of this paper.

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