



Ecological Health Assessment of Lukosi River Using Macroinvertebrate and Riparian Vegetation Indicators in Iringa, Tanzania

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Received Date: 28/11/2024 // Published Date: 30/12/2025

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Abstract

The health of river ecosystems is increasingly threatened by human activities such as agriculture, urbanization, and industrialization. This study evaluates the ecological status of the Lukosi River Catchment (LRC) in Kilolo District, Iringa, Tanzania, using macroinvertebrates and riparian vegetation as bioindicators. We employed a cross-sectional design, sampling at upstream, midstream, and downstream sites. Macroinvertebrates were collected via the kicking-bottom method and analyzed using the Shannon–Wiener diversity index and the Average Score Per Taxon (ASPT). Riparian vegetation was surveyed through belt transects and assessed by species distribution and proportional cover. Fourteen macroinvertebrate taxa were identified, dominated by water scavenger beetles and snails. Biodiversity was moderate ($H' \approx 1.98$). ASPT scores declined spatially: upstream (good quality), midstream (moderate), and downstream (poor), indicating worsening water quality downstream. The riparian zone was heavily modified: about 58% grasses, 28% shrubs, and 14% trees, reflecting human disturbance and land-use change. The results reveal progressive ecosystem degradation along the river, strongest downstream, likely driven by pollution and catchment alteration. These results call for integrated catchment management policies, stricter land-use regulation, and community-based riparian restoration programs to enhance water quality, biodiversity, and long-term ecological resilience of the LRC.

Keywords · Ecological health, Lukosi river Catchment, Macroinvertebrates, Riparian vegetation, Bioindicators

1. Introduction

Globally, rivers play a vital role in maintaining ecological balance and supporting human livelihoods by providing essential ecosystem goods and services such as clean water, food, and habitats for aquatic and terrestrial organisms (Rajesh *et al.*, 2024). These

ecosystems also sustain biodiversity and regulate hydrological and nutrient cycles. However, the health of river systems is increasingly under threat from anthropogenic pressures including agricultural intensification, industrialization, and urban expansion (Hoekstra and Wiedmann, 2014). Such pressures alter land use, increase sedimentation and pollution, and

degrade both water quality and ecological integrity (Jun *et al.*, 2016; Ferreira *et al.*, 2017). Contaminants from mining, industrial effluents, agricultural runoff, and domestic waste often enter freshwater systems, adversely affecting aquatic organisms and disrupting ecological functioning (Dalu and Froneman, 2016; Hunt *et al.*, 2017). According to Patten (2016), river health refers to the capacity of a river system to sustain and uphold a balanced, adaptive, and resilient community of organisms under natural conditions.

Traditional assessments of river health have largely relied on physicochemical analyses, focusing on concentrations of pollutants such as nitrates, phosphates, and heavy metals (Keith-Roach *et al.*, 2015). While these measurements are valuable, they offer only a short-term and partial understanding of ecological status. Water quality can fluctuate rapidly, and chemical assessments alone do not capture the cumulative or biological impacts of environmental stressors. Consequently, biological indicators have become increasingly important for evaluating ecological health, as they reflect both current and long-term changes in water quality and habitat conditions (Awoke *et al.*, 2016; Ode *et al.*, 2016). Among these, macroinvertebrates and riparian vegetation have proven to be reliable and cost-effective bioindicators, offering complementary insights into aquatic ecosystem condition.

Macroinvertebrates are widely used in ecological monitoring because of their high sensitivity to environmental variations, limited mobility, and wide distribution across freshwater habitats (Sumudumali *et al.*, 2021). Their community structure reflects cumulative responses to pollution, hydrological alterations, and habitat degradation. Sensitive taxa such as Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) dominate clean, oxygen-rich waters, while tolerant groups like Chironomidae (midges) and Oligochaeta (aquatic worms) thrive in polluted or low-oxygen environments (Pardal *et al.*, 2010; Shimba *et al.*, 2016). These variations in species composition and abundance serve as powerful indicators of ecological

integrity and water quality gradients (Masese *et al.*, 2014; Malakane *et al.*, 2020).

In parallel, riparian vegetation forms an essential component of riverine ecosystems, influencing water quality, hydrology, and biodiversity (Raphael and Lalika, 2022). Vegetation along riverbanks stabilizes soils, reduces erosion, and acts as a buffer zone that filters sediments, nutrients, and pollutants before they reach the main channel (Dosskey *et al.*, 2010; Malan *et al.*, 2018). Through physical, chemical, and biological processes, riparian plants trap sediments, assimilate nutrients, and promote microbial activity that facilitates nutrient cycling (O'Toole *et al.*, 2018; Hofmann *et al.*, 2009). These processes collectively maintain water quality, enhance habitat diversity, and contribute to overall river health, particularly in watersheds exposed to agricultural and urban pressures (Chua *et al.*, 2019).

In Tanzania, river catchments play a central role in supporting economic and ecological systems. The Lukosi River Catchment (LRC) in Kilolo District, Iringa, is a critical tributary of the Great Ruaha River (GRR), which forms part of the Rufiji Basin, an important system supporting hydropower generation, irrigation schemes, and domestic water supply (Seeteram *et al.*, 2019; Gervas *et al.*, 2019). Despite its ecological and economic significance, the LRC faces growing environmental pressures including agricultural expansion, deforestation, and urbanization, which have altered flow regimes, reduced water quality, and contributed to biodiversity loss (Mbungu *et al.*, 2021). Previous studies within the LRC have mainly focused on physicochemical water quality assessments, with limited integration of biological indicators (Nyagongo *et al.*, 2024a, b). This gap in biological assessment constrains a full understanding of how human-induced pressures affect ecosystem health and recovery potential.

Integrating macroinvertebrate and riparian vegetation assessments offers a more holistic approach to evaluating river health.

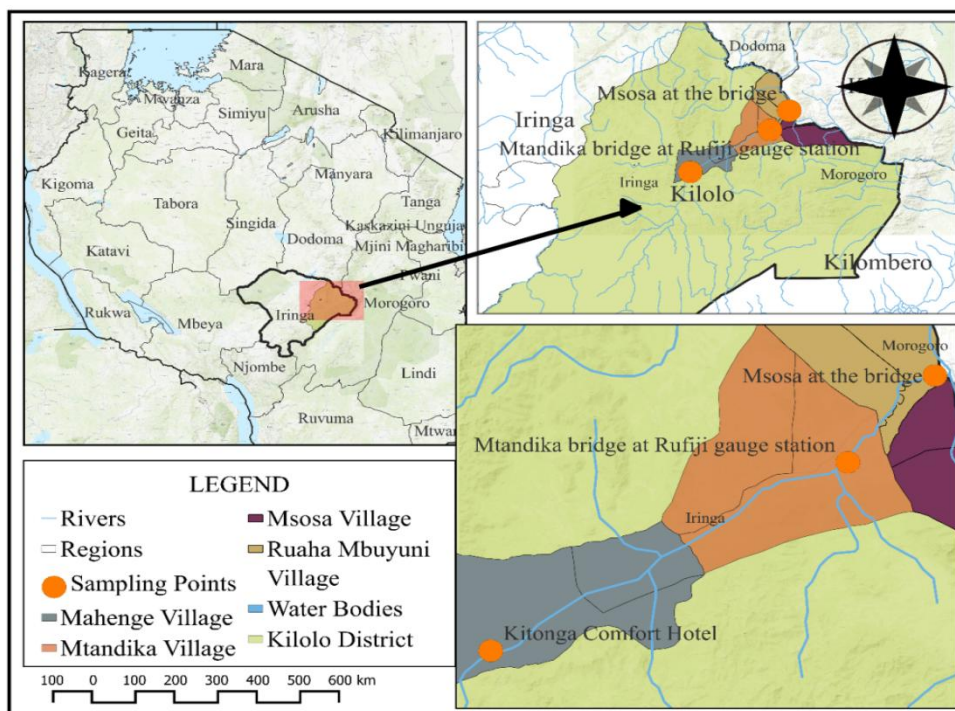


Figure 1: Map showing the location of the study area

Macroinvertebrates provide short-term responses to changes in water quality and substrate conditions, while riparian vegetation reflects long-term effects of land use and watershed management. The combination of these indicators allows for a multi-dimensional understanding of river ecosystem dynamics, linking in-stream biological responses with catchment-level processes (Malan *et al.*, 2018; Chua *et al.*, 2019). Such integration is particularly valuable in tropical catchments like Lukosi, where rapid land-use change and limited monitoring capacity necessitate efficient, biologically based assessment

Therefore, this study aims to assess the ecological health of the Lukosi River Catchment using macroinvertebrates and riparian vegetation as bioindicators. The objectives of these study were to determine the diversity, composition, and distribution of macroinvertebrate and riparian vegetation communities across upstream, midstream, and downstream sites. It is hypothesized that sites exposed to higher human activity will exhibit reduced macroinvertebrate diversity and altered riparian vegetation structure, indicating lower ecological integrity. The outcomes of this study are expected to

Table 1: Sampling stations and their corresponding grid references

Sampling points	Elevation (m)	Coordinates
Kitonga Comfort Hotel (Upstream)	725	36.21 E Longitude 7.677 S Latitude
Mtandika bridge at Rufiji gauge station (Midstream)	564	36.448 E Longitude 7.538 S Latitude
Msosa at the bridge (Downstream)	535	36.506 E Longitude 7.474 S Latitude

tools.

provide essential baseline data for monitoring, inform



Figure 2: Collection and identification of macroinvertebrates

catchment management strategies, and guide sustainable conservation efforts within the Great Ruaha Rufiji Basin system.

2. Materials and Methods

2.1 Study Area

2.1.1 Location

The study was conducted in the Iringa region, specifically within the Kilolo district, which is located in the northeastern part of the region. Kilolo district is situated approximately 37 kilometers away from the regional administrative center (Mbungu *et al.*, 2021). The district lies between latitude $7^{\circ}00'30''$ S and longitude $34^{\circ}00'37''$ E, covering an area of 7,874.6 square kilometers (URT, 2012) (Figure 1).

2.1.2 Forest Cover

Kilolo district currently supports a wide variety of land uses, including both large and small-scale agricultural and forest plantations (PFP, 2017). The presence of these plantations suggests ongoing land

use dynamics in the area. The extensive agricultural activities and the conversion of land for plantation purposes may have led to significant land use changes over time.

2.1.3 Climate

Kilolo district characterized by annual rainfall that ranges from 500 to 1,600 mm. The temperature in the region varies from 15°C to 27°C , contributing to its moderate climate, which is favorable for various agricultural activities (URT, 2012). The elevation of the district, ranging from 900 to 2,700 meters above sea level, likely plays a role in these temperature and rainfall variations, as higher altitudes often correlate with cooler temperatures and distinct precipitation patterns.

2.1.4 Human Activities

Human activities in Kilolo district are primarily centered on agriculture and forest plantations, with both large and small-scale operations present in the area (PFP, 2017). The district is a major producer of

fruits, vegetables, legumes, and maize, contributing significantly to the country's agricultural output (URT, 2012). Alluvial soil predominates.

2.2 Research Design

The study used a cross-sectional research design, which allowed data to be collected at a certain time from a chosen sample that was meant to be representative of the total population.

2.3 Sampling Design and Data Collection

2.3.1 Sampling Design and Data Collection for Macroinvertebrate

2.3.1.1 Macro Invertebrates Sampling

Macroinvertebrates was collected from three sampling sites (upstream, midstream and downstream). Sampling sites was selected in a way that encompasses the human activities that are carried out along the river as well as accessibility. Each sampling site was marked using a Geographical Positioning System (GPS) (Table 1).

2.3.1.2 Data Collection

Kicking bottom technique was used to collect the aquatic macroinvertebrates from sampling sites (Wahizatul *et al.*, 2018). Macroinvertebrates samples were collected with aquatic net in the shape of a D (20 cm in diameter, 40 cm in width, and 300 μ m mesh size) (Wahizatul *et al.*, 2018) (Figure 2). At each sampling site, macroinvertebrates were collected from various biotopes. Sampling from stones involved 2 minutes for stone in-current and 1 minutes for stone out of current. The GSM (Gravel, Sand, and Mud) substrate was sampled for 1 minute. Vegetation was sampled within a 1 square meter area. Macroinvertebrates were collected in dry season in the month of June 2023.

The samples were processed in the field to remove organic debris. Collected macroinvertebrates then were stored in containers with 70% ethanol (Shuman *et al.*, 2020), and taken to the laboratory to undergo additional sorting, counting, and identification, that was done using identification keys

(Ojija and Laizer, 2016). To prevent sample mixing, each container was carefully marked.

2.3.1.3 Sample Classification

Some macroinvertebrates were identified onsite using a hand lens and a field guidebook for common and scientific names. Samples that could not be identified in the field were cleaned to remove debris, preserved in 70% ethanol, labeled carefully to avoid mixing, and transported to the laboratory for further sorting, counting, and identification using a microscope and identification keys.

The sensitivity score, common name, and scientific name of every taxon in each sampling site were recorded using the Aquatic Invertebrates of South African Rivers field guidebook (Omary *et al.*, 2023).

2.3.1.4 Sample Analysis

The diversity of macroinvertebrate was measured using Shannon-Wiener's Species diversity index (H or H'). (Equation 1). To measure sensitivity of the macroinvertebrate, The average score per taxon was calculated by taking the total sensitivity score and the total number of identified groups of species from each sampling site (Omary *et al.*, 2023) (Equation 2). A comparison was made between the obtained value and the ASPT values that correlate to the water quality (Table 2).

$$H' = - \sum_{n=1}^{\infty} (p_i \ln p_i) \quad (1)$$

Where:

H = Shannon Weiner Species Diversity Index;

P_i = the relative proportion (n/N) of the individual of one particular species found;

LN P_i = the natural logarithm (LN) of the value P_i;

$$ASPT = \frac{Sensitivity\ score}{Total\ number\ of\ identified\ group\ of\ species} \quad (2)$$

2.3.2 Sampling Design and Data Collection for Riparian Vegetation

The Belt transects (4 m wide, 1 km long) method was used in this study for vegetation sampling within the riparian zone along LRC. Three sampling stations (upstream, midstream and downstream) were systematically introduced with the aid of a Geographical Positioning (Table 1). This was done in the same area where macroinvertebrate was collected. Samples of the vegetation (grass, shrubs, and larger

2.3.2.1 Analysis of Riparian Vegetation Data

Riparian vegetation data were analyzed by examining species distribution and percent composition. The species counts recorded in the field were cross-tabulated, and the percentage proportions of each species were calculated using Microsoft Excel.

3.0 Results

3.1 Macroinvertebrate species found on the LRC

3.1.1 The Diversity of Macroinvertebrate

Table 2: Average Score per Taxon (ASPT)

Score	Indication
5 and above	Excellent
4-4.5	Good
3-3.5	Moderate
2-2.5	Poor
1-1.5	Very Poor

trees) were taken within a 2 m radius at each station. Plant species were identified on the field by their local names and then taken for technical examination and identification by Sokoine University of Agriculture’s Botanists. This was also done in the

The analysis included a total of 139 macroinvertebrate samples, encompassing 14 species. The most diversity species were water scavenger beetles (32%), followed by snail (28%), Dragonflies (9%), crabs (10%), leeches (4%), predacious diving

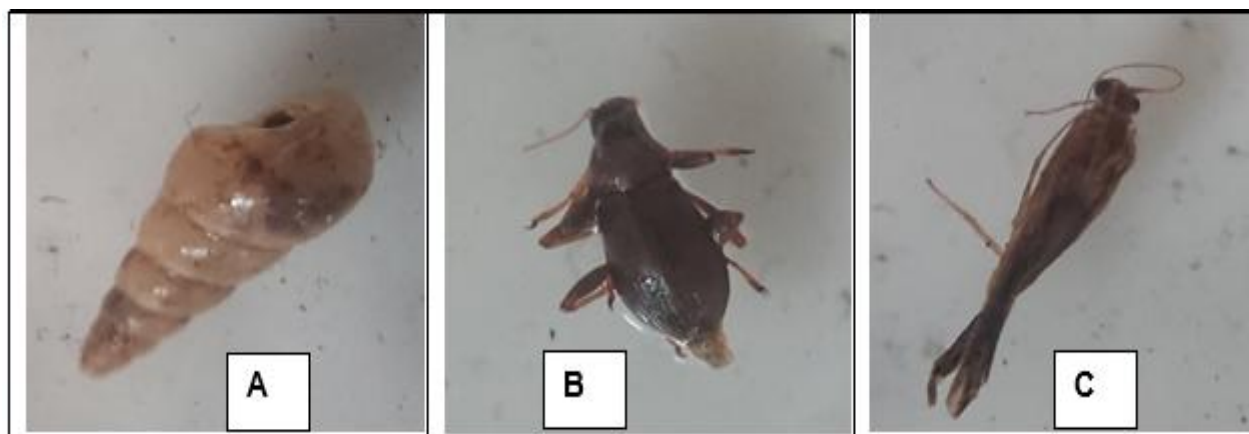


Figure 3. Pictures of selected macroinvertebrate collected from the LRC. (A) *Lymnaea stagnalis* (B) *Hydrophilus triangularis* (C) *Hydropsyche siltalai*

month of June 2023.

beetles (3%), mosquitoes (2%) house flies (3%). brush-legged mayflies (1%), aquatic earthworms (1%), caseless caddisflies (1%), stout crawlers (2%), damselflies (2%) and Pigmy backswimmer (2%)

(Table 3, Figure 3). The Shannon Weiner Species Diversity Index was 1.98, indicating a moderate level of biodiversity within the sampled community, suggesting that the community has relatively low species diversity, as shown in Table 3.

3.1.2 Sensitivity of Macroinvertebrate Community to the Water Quality

The Sensitivity of Macro-invertebrate Community to the Water Quality was measured by calculating the average score per taxon in up-stream, mid-stream and down-stream (Table 3.5). Each taxon has an assigned score that reflects its tolerance to pollution or water quality changes. Pollution-sensitive species have a high score indicating they thrive in clean, unpolluted water while pollution-tolerant

The upstream site has the highest ASPT score (6.75) among the three locations, indicating better ecological conditions. The presence of diverse taxa like stout crawlers, brush-legged mayflies, and dragonflies (Figure 4), many of which are sensitive to pollution suggests a relatively healthy ecosystem. This section likely serves as a vital habitat for many organisms and reflects good water quality, which is essential for the survival of sensitive species.

The midstream location shows a significant drop in the ASPT score to 3.45, indicating a decline in ecological conditions compared to the upstream area. The presence of organisms such as mosquitoes and house flies (Figure 5), which are typically more tolerant of pollution, points to a more degraded

Table 3. Aquatic macroinvertebrate collected from the LRC

Order	Family	Common name	Scientific name	Number	%
Diptera	Culicidae pupae	Mosquitoes	<i>Culex pipiens</i>	3	2
	Muscidae	House flies	<i>Musca domestica</i>	4	3
Coleoptera	Hydrophilidae	Water scavenger beetles	<i>Hydrophilus triangularis</i>	44	32
	Dytiscidae	Predacious diving beetles	<i>Dytiscus marginalis</i>	4	3
Ephemeroptera	<i>Leptophlebiidae</i>	Brush legged mayfly	<i>Tricorythodes minimus</i>	1	1
	Tricorythidae	Stout crawlers	<i>Tricorythodes explicatus</i>	3	2
Annelida	Oligochaeta	Aquatic earthworm	<i>Lumbriculus variegatus</i>	2	1
	Hirudinae	Leeches	<i>Theromyzon tessellatum</i>	5	4
Decapoda	pontamonantidae	Crab	<i>Metacarcinus magister</i>	14	10
Hemiptera	Pleidae	Pigmy backswimmer	<i>Coleopterum maculatum</i>	3	2
Odonata	Coenagrionidae	Damselflies	<i>Ischnura elegans</i>	3	2
	Aeshinidae	Dragonflies	<i>Aeshna juncea</i>	12	9
Basommatophora	Lymnaeidae	Snail	<i>Lymnaea stagnalis</i>	39	28
Trichoptera	Hydropsychidae	Caseless caddisflies	<i>Hydropsyche siltalai</i>	2	1

species have a lower score because they can survive in poorer water quality.

This suggests that midstream conditions

may be affected by anthropogenic influences or alterations in habitat quality.

The downstream area has the lowest ASPT score (2.5), reflecting poor ecological conditions. The

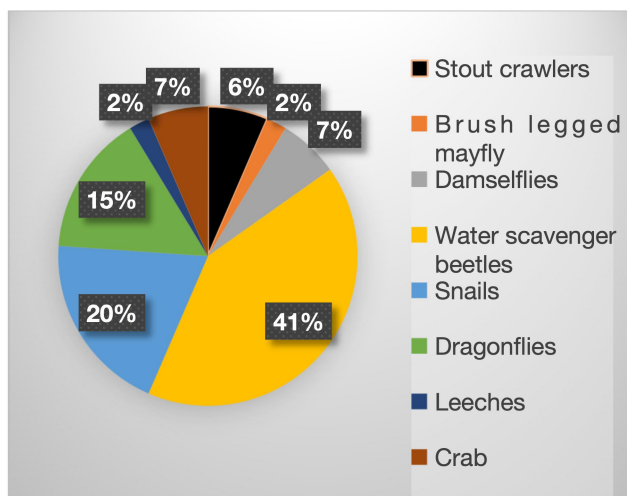


Figure 3: Percentage of macroinvertebrate in
Table 3: Shannon Weiner species diversity index of the LRC

Macro invertebrate species	Number of macroinvertebrate sample	Pi	Lnpi	Pi*Lnpi
Mosquitoes	3	0.021583	-3.83586	-0.08279
Water scavenger beetles	44	0.316547	-1.15028	-0.36412
Brush legged mayfly	1	0.007194	-4.93447	-0.0355
Aquatic earthworm	2	0.014388	-4.24133	-0.06103
Predacious diving beetles	4	0.028777	-3.54818	-0.10211
Leeches	5	0.035971	-3.32504	-0.11961
Crab	14	0.100719	-2.29542	-0.23119
House flies	4	0.028777	-3.54818	-0.10211
Pigmy backswimmer	3	0.021583	-3.83586	-0.08279
Damselflies	3	0.021583	-3.83586	-0.08279
Dragonflies	12	0.086331	-2.44957	-0.21147
Snails	39	0.280576	-1.27091	-0.35659
Stout crawlers	3	0.021583	-3.83586	-0.08279
Caseless caddisflies	2	0.014388	-4.24133	-0.06103
TOTAL	139	1		-1.9759

limited diversity and the predominance of more tolerant species (like mosquitoes and caseless caddisflies) (Figure 6), indicate significant degradation. This could be attributed to accumulated pollutants or changes in habitat due to human activities, leading to a decline in sensitive macroinvertebrate.

3.2 Riparian Vegetation Found Along The LRC

The results on riparian vegetation indicate that 58% of the total vegetation along the river is dominated by grasses. This is significantly higher compared to trees (14%) and shrubs (28%). The grass species include reeds (19%), sedges (22%) and bulrush (17%). The tree species includes fig tree (4%), Tamarind tree (3%), zebra-wood (5%) and paddle-wood (2%). The shrubs species includes Buttonbush (15%) and willow (13), as shown in a table 6. This

suggests an altered ecological condition within the riparian zone, which could be influenced by human

crucial role of riparian zones play in maintaining

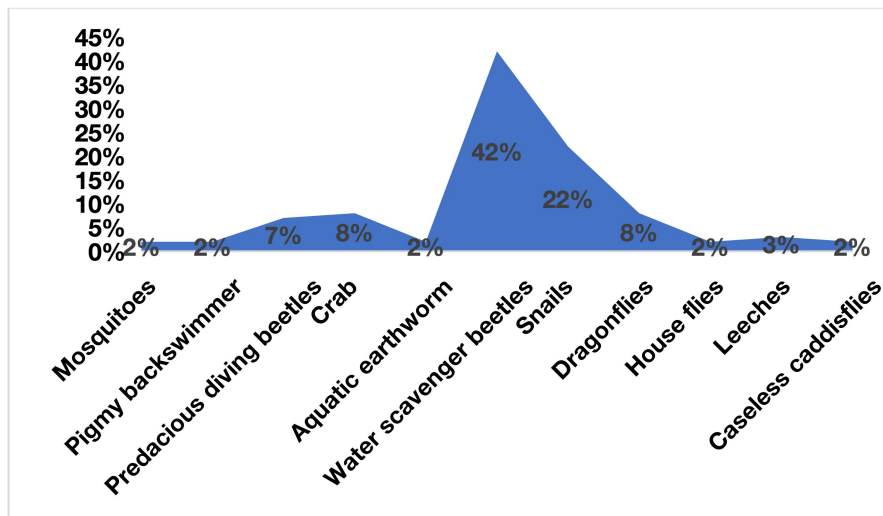


Figure 4: Percentage of macroinvertebrate in midstream

activities.

The study reveals that sites experiencing high rates of riparian vegetation clearance and agricultural activities show significantly worse hydrological conditions. Adverse effects, such as the collapse of

water quality and ecosystem stability.

4.0 Discussion

4.1 Macroinvertebrate Community and Its Implications for Water Quality

The macroinvertebrate community of the LRC, consisting of 14 different species, serves as an important indicator of water quality and habitat health. The most abundant species in the samples were water scavenger beetles (32%) and snails (28%), both of which are generally considered pollution-tolerant. These species dominate in areas of low ecological health, where water quality may be compromised, and their presence suggests that parts of the river may be experiencing reduced water quality. The diversity and abundance of macroinvertebrates are often used as indicators of water quality because these organisms have varying degrees of tolerance to pollution (López, *et al.*, 2015). In the case of LRC, the diversity of macroinvertebrates, revealed a clear ecological degradation from upstream to downstream. The Shannon-Weiner Species Diversity Index (1.98) indicates moderately diverse community, suggesting that the river supports a variety of species, but also points to potential stress factors that might be limiting the community's full potential for biodiversity.

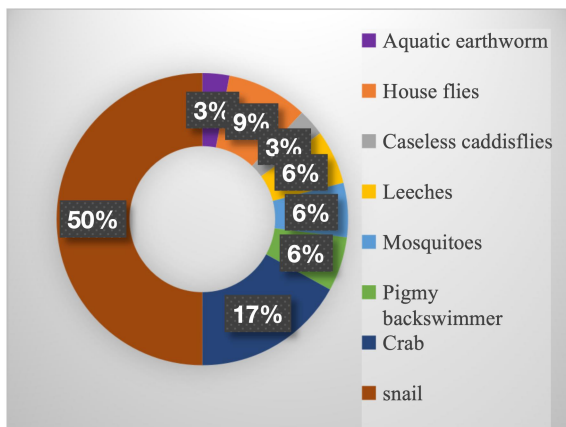


Figure 6: Percentage of macroinvertebrate downstream

riverbanks and sedimentation (Figure 3.7), were observed in these disturbed areas. These findings suggest a clear relationship between land management practices, the conservation of riparian vegetation, and the overall health of the river ecosystem. Conversely, areas with undisturbed or minimally disturbed riparian vegetation exhibited clearer water with less sediment deposition (Figure 3.7), highlighting the

The ASPT score in upstream region of LRC, indicates the best water quality, supporting a variety of species (Everaert *et al.*, 2014; Johnson *et al.*, 1993; Yanai *et al.*, 2018). Similar findings were noted

Table 4: ASP score of the macroinvertebrate along the LRC

Sampling point	Macroinvertebrate	Score	Our score	ASPT Score	Total number	
Upstream	Stout crawlers	9	1		3	
	Brush legged mayfly	15	1		1	
	Damselflies	8	1		3	
	Water scavenger beetles	5	1		19	
	Snails	3	1		9	
	Dragonflies	8	1		7	
	Leeches	3	1		1	
	Crab	3	1		3	
	Total	54	8	6.75	46	
Midstream	Mosquitoes	1	1		1	
	Pigmy backswimmer	4	1		1	
	Predacious diving beetles	5	1		4	
	Crab	3	1		5	
	Aquatic earthworm	1	1		1	
	Water scavenger beetles	5	1		25	
	Snails	3	1		13	
	Dragonflies	8	1		5	
	House flies	1	1		1	
	Leeches	3	1		2	
	Caseless caddisflies	4	1		1	
		Total	38	11	3.45	59
	Downstream	Aquatic earthworm	1	1		1
House flies		1	1		3	
Caseless caddisflies		4	1		1	
Leeches		3	1		2	
Mosquitoes		1	1		2	
Pigmy backswimmer		4	1		2	
Crab		3	1		6	
snail		3	1		17	
	Total	20	8	2.5	34	
		TOTAL			139	

of species, many of which are pollution-sensitive. The presence of species such as dragonflies, brush-legged mayflies, and stout crawlers in this region is indicative of a healthy environment. These species are known to be sensitive to pollution, and their presence in the upstream suggests that this area is undisturbed or low polluted environment. These findings are consistent with previous studies indicating that *Ephemeroptera*, including brush-legged mayflies and stout crawlers, tend to dominate in less polluted areas, whereas more tolerant individuals are found in

in other studies, where the presence of pollution-sensitive taxa was significantly positively associated with higher dissolved oxygen levels and thus found in less impaired river sections (Bonacina *et al.*, 2023; Kaaya *et al.*, 2015).

The midstream and downstream areas of the river demonstrate significant ecological degradation, as evidenced by the decline in the ASPT scores to 3.45 and 2.5, respectively. The midstream site is characterized by a noticeable shift in the community

composition, with an increase in the abundance of species that are more tolerant to pollution, such as mosquitoes and house flies. These species are often

The downstream shift in macroinvertebrate community structure is likely driven by cumulative anthropogenic impacts, such as nutrient loading,

Table 5: Riparian Vegetation along the LRC

Sampling point	Category	Common Name	Scientific Name	Percentage (%)	Group Totals (%)	
Upstream	Tree	Fig tree	<i>Ficus carica</i>	6	30	
		Tamarind tree	<i>Tamarindus indica</i>	7		
		Zebrawood	<i>Brachystegia spiciformis</i>	10		
		Paddle-wood	<i>Pterocarpus angolensis</i>	7		
	Shrub	Buttonbush	<i>Cephalanthus occidentalis</i>	7	20	
		Willow	<i>Salix fragilis</i>	13		
	Grass	Reeds	<i>Phragmites australis</i>	16	50	
		Sedges	<i>Cyperus rotundus</i>	20		
		Bulrush	<i>Typha domingensis</i>	14		
		Total				100
Midstream	Tree	Fig tree	<i>Ficus carica</i>	2	12	
		Tamarind tree	<i>Tamarindus indica</i>	4		
		Paddle-wood	<i>Pterocarpus angolensis</i>	6		
	Shrub	Buttonbush	<i>Cephalanthus occidentalis</i>	12	28	
		Willow	<i>Salix fragilis</i>	16		
	Grass	Reeds	<i>Phragmites australis</i>	18	60	
		Sedges	<i>Cyperus rotundus</i>	22		
		Bulrush	<i>Typha domingensis</i>	20		
		Total				100
	Downstream	Tree	Fig tree	<i>Ficus carica</i>	3	7
Tamarind tree			<i>Tamarindus indica</i>	4		
Shrub		Buttonbush	<i>Cephalanthus occidentalis</i>	11	23	
		Willow	<i>Salix fragilis</i>	12		
Grass		Reeds	<i>Phragmites australis</i>	23	70	
		Sedges	<i>Cyperus rotundus</i>	20		
		Bulrush	<i>Typha domingensis</i>	27		
		Total				100

associated with areas where organic pollution is present, further suggesting a degradation in water quality. Similarly, the downstream area is dominated by more tolerant species such as house flies, aquatic earthworm, mosquitoes and caseless caddisflies, which are indicative of a severely degraded ecosystem. These findings are consistent with those of (Gholizadeh and Heydarzadeh, 2019; Corbi *et al.*, (2010); Rudasingwa & Cho, 2020), who demonstrated that agricultural runoff and organic pollution increase the abundance of tolerant macroinvertebrates.

sedimentation, pesticide runoff, and habitat alteration. These stressors are commonly associated with urbanization, agriculture, and deforestation, which are also cited as major contributors to aquatic biodiversity loss in multiple studies (Arimoro & Ikomi, 2008; Rija *et al.* 2011; Giorgio *et al.*, 2016; Franco-Belussi *et al.*, 2020;). The reduction in sensitive taxa downstream aligns with the findings from Zimbabwe, Thailand, Indonesia, and Rwanda, where lower TARISS or SASS scores and taxa richness were reported in ecologically impaired sites (Makumbe *et al.*, 2022; Deemool & Prommi, 2017; Wimbaningrum *et al.*, 2016; Hyangya *et al.*, 2022).

Such changes in community composition are consistent with findings from other studies, which have shown that downstream sections of rivers often experience the cumulative effects of pollution from upstream sources (Yoon *et al.*, 2015). The reduced diversity of macroinvertebrates in these regions reflects the sensitivity of aquatic ecosystems to environmental stressors, which ultimately impacts their ability to support a healthy and diverse community. Additionally, according to other studies,

4.2 Riparian Vegetation and Its Role in Ecosystem Health

Riparian vegetation is essential for preserving water quality, stabilizing riverbanks, and promoting biodiversity (Dosskey *et al.*, 2010; O'Toole *et al.*, 2018). By acting as a buffer between agricultural fields and waterways, they are acknowledged as the best management strategies for preserving or enhancing stream condition (Dosskey *et al.*, 2010;



Figure 5: Riparian vegetation along the LRC, highlighting disturbed and less disturbed areas

pollutant-sensitive organisms may decline as a result of forest destruction and the introduction of used inorganic contaminants from agriculture that end up in the water through irrigation of agricultural land (Corbi *et al.*, 2010; Gholizadeh and Heydarzadeh, 2019).

O'Toole *et al.*, 2018). Additionally, they have been identified as possible natural filters for nutrients and sediments between streams and upland areas (Vidon 2010; Ou *et al.*, 2016; de Mello *et al.*, 2017, 2018). Furthermore, riparian vegetation stabilizes streambanks, controls river temperature by shading from solar radiation, and offers food and habitat to a variety of aquatic and terrestrial species (Vidon *et al.*,

2010; Li *et al.*, 2012; Guevara *et al.*, 2015; Tonin *et al.*, 2017; Garner *et al.*, 2017). The results of this study indicate that grasses dominate the riparian zone along the LRC, with species such as reeds, sedges, and bulrush making up 58% of the total vegetation. The dominance of grasses, in contrast to the relatively small proportions of trees (14%) and shrubs (28%), indicates that the riparian zone has undergone significant ecological changes, likely due to human-induced disturbance. Such changes in the riparian vegetation structure are commonly associated with land-use alterations, such as agriculture, grazing, and urban development (Raphael and Makarius, 2022). This disrupts the natural vegetation balance and promotes the growth of species that are more tolerant of disturbance.

Grasses are generally more resilient to disturbance and can thrive in environments where soil is disturbed or where tree cover has been reduced. Their prevalence in disturbed riparian areas, often subject to erosion and sedimentation, may be a response to these pressures. However, the proliferation of grasses at the expense of trees and shrubs may have negative implications for the river ecosystem. Trees, particularly those with deep root systems, are essential for stabilizing riverbanks, reducing soil erosion, and maintaining water quality through shading and filtration of runoff (Pollen and Simon, 2005). The loss of tree cover in the LRC's riparian zone could therefore lead to increased sedimentation and a decline in water quality.

The presence of shrubs and trees contributes to the overall biodiversity of the riparian zone and provides important ecological functions such as wildlife habitat and erosion control. As reported by Singh *et al.* (2021), numerous organisms, including plants, algae, insects, fish, migratory birds, and native mammals, can be found in riparian ecosystems. According to McClure *et al.* (2015), they are also acknowledged as crucial locations for migrating and nesting birds. However, the relatively low percentage of trees and shrubs cover in the LRC suggests that the riparian zone may be undergoing a shift towards a more grass-dominated

system. The high percentage of grasses relative to trees and shrubs may be a consequence of land-use changes and human interventions, such as the clearing of trees for agricultural expansion or logging, and the conversion of forested areas into shrub and grassland. Human activities such as deforestation, overgrazing, and agricultural cultivation near the riverbanks could disrupt the natural balance of vegetation types, leading to a decline in tree cover and the proliferation of grasses. These activities often result in increased soil erosion, which in turn can favor the growth of more resilient, fast-growing grass species that can withstand disturbed soil conditions. Furthermore, the replacement of trees with grasses may affect the overall ecological health of the riparian zone, as trees play a critical role in stabilizing riverbanks, providing shade, and supporting a diverse range of wildlife.

The relationship between riparian vegetation and water quality is complex but undeniable. Areas with high vegetation clearance and intense human activity tend to experience poorer hydrological conditions, as evidenced by the increased sedimentation and riverbank collapse observed in the disturbed sites. These findings align with the broader literature that suggests a direct correlation between land-use change, riparian vegetation degradation, and river health (Dufour *et al.*, 2018; Raphael and Makarius, 2022). Conversely, areas with more intact or minimally disturbed riparian vegetation exhibited clearer water and less sediment deposition, reinforcing the critical role of riparian buffers in maintaining the ecological integrity of river systems.

5.0 Conclusion and Recommendations

5.1 Conclusion

This study assessed the ecological conditions of the Lukosi River Catchment (LRC) in Iringa, Tanzania, through the analysis of macroinvertebrate communities and riparian vegetation. The findings reveal important insights into the health of the river ecosystem and the impacts of anthropogenic activities on water quality and biodiversity.

The macroinvertebrate community along the LRC showed a significant decline in biodiversity from the upstream to downstream sections, as evidenced by the Shannon-Weiner Species Diversity Index (1.98) and the decline in Average Score Per Taxon (ASPT) scores. The upstream region exhibited the highest ASPT score (6.75), indicating good water quality and the presence of pollution-sensitive species, such as dragonflies and mayflies. However, as one moves downstream, the ASPT scores decreased, particularly in the midstream (3.45) and downstream (2.5) regions, which showed an increase in pollution-tolerant species like mosquitoes and house flies. This gradient suggests that human-induced disturbances, such as agriculture, urbanization, and deforestation, are negatively affecting water quality, with downstream areas experiencing the cumulative effects of pollution from upstream.

Similarly, the riparian vegetation analysis revealed a significant dominance of grasses (58%), especially species such as reeds, sedges, and bulrush, which are more resilient to disturbances. In contrast, the proportion of trees and shrubs was low (14% and 28%, respectively), suggesting a shift in the riparian ecosystem due to human activities. The alteration of the riparian zone, with the reduction of tree cover, has likely exacerbated erosion, sedimentation, and the degradation of water quality.

Overall, the study underscores the importance of both macroinvertebrate communities and riparian vegetation as vital indicators of the river's health. The findings suggest that the Lukosi River Catchment is experiencing varying degrees of ecological stress, especially in areas where human activities have disrupted natural systems. Furthermore, integrating molecular techniques, as recommended by several recent biomonitoring studies, would improve taxonomic resolution and strengthen the diagnostic power of ecological assessments.

5.2 Recommendations

The following suggestions are offered to enhance the ecological health of the Lukosi River Catchment.

- i. **Riparian zone restoration:** The riparian zone should be actively restored to include more tree and shrub species, particularly in the midstream and downstream sections of the river where human activities have caused significant ecological. Tree planting initiatives, particularly of native species, should be promoted to help stabilize riverbanks, reduce erosion, improve water filtration, and provide habitat for wildlife. The tree species such as Red milkwood, Fever tree, Sycamore fig and African trumpet tree are highly recommended because this species is often found in riparian zones and is well-adapted to withstand periodic flooding. Its ability to enhance soil quality and reduce erosion makes it an excellent choice for riparian restoration projects.
- ii. **Pollution control and monitoring:** Continuous monitoring of water quality and macroinvertebrate communities along the river is essential to detect pollution levels and track changes in biodiversity over time. Efforts should be made to reduce nutrient loading from agricultural runoff, including the use of sustainable farming practices and the reduction of agrochemical inputs near the river.
- iii. **Public awareness and community involvement:** Increasing public awareness about the importance of riparian vegetation and water quality management is crucial for the success of conservation efforts. Engaging local communities in river protection activities, such as tree planting and sustainable farming practices, will create a sense of ownership and responsibility for the river's health.
- iv. **Regulation and enforcement:** Strengthening environmental regulations regarding water quality standards and riparian buffer zones will help prevent further degradation of the

river system. Regular enforcement of land-use policies is crucial for the long-term sustainability of the river's health.

Acknowledgements

The authors would like to express their gratitude to the Zoology Laboratory at the Sokoine University of Agriculture for allowing to conduct laboratory work. Special thanks are also extended to Mr. Rajabu Omary from Ardhi University and Mr. Issa Gomela from Kilolo District for their invaluable assistance in data collection.

Funding Sources

This research was funded by the UNESCO Chair in Ecohydrology and Transboundary Water Management at Sokoine University of Agriculture in Tanzania.

Conflict of Interest

Authors declare the research was conducted in the absence of any conflict of interest.

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