__Original Research Article__

Relationships between Land Use Changes and Benthic Macroinvertebrates' Community Structure in an East African Riverine Environment.

Abstract

Land use activities determines the health status of river ecosystems in supporting aquatic biodiversity. Undisturbed wetlands ensure water bodies are ecologically healthy for community livelihoods. Recent years have witnessed degradation of aquatic ecosystems due to intensification of riparian land use activities and these changes could create devastating effects on the environment and community livelihoods. One of such wetlands is river Isiukhu of western Kenya. This study analysed water physicochemical parameters and benthic macroinvertebrates' assemblages of River Isiukhu between August to November, 2022. Four sampling stations were selected along the longitudinal river gradient based on anthropogenic impact and dominance of land use activities. Sampling stations were classified as 'very high', 'high', 'moderate' and 'low' and rated 4,3,2 and 1 respectively, depending on the anthropogenic impact. Macroinvertebrates were sampled using D-frame net and classified using appropriate keys. Anthropogenic activities and habitat characteristics were noted and recorded. Water quality parameters were determined in situ. Macroinvertebrates' population indices were calculated to determine community structure. Sorenson's Coefficient quantified similarities of species in different stations. Pearson correlation coefficient and ANOVA tested the study hypothesis. About 1,391 invertebrates were collected belonging to 12 orders, 32 families and 30 genera. Orders Ephemeroptera, Hemiptera, Diptera and Coleoptera recorded highest percentage taxonomical composition. Upper pristine stations (F and G) supported more species richness and diversity than lower stations (L and T). Macroinvertebrates' communities in terms of diversity, abundance, richness, evenness, and functional feeding groups responded differently to impacts of anthropogenic activities, due to their varied adaptation traits. Water quality varied significantly between sampling stations ($\rho < 0.05$). Close relationship was realised between land use activities and species diversity ($r=0.8$; $\rho < 0.05$); richness ($r=0.8779$; $\rho < 0.05$); evenness ($r=0.1067$; $\rho < 0.05$); and abundance ($r=0.962$; $\rho < 0.05$). The study recommends the need to conserve riparian vegetation as a way of mitigating and adapting to the impact climate change on stream ecosystem processes in order to guarantee sustainability of species and community livelihoods.

Keywords: Anthropogenic activities; Macroinvertebrates; Riparian land use; Water quality; Wetland.

Introduction

Land-use change involves the organizations, and activities that people make in a particular land cover type to produce or maintain change. Globally, land use changes have been increasing at a high rate and the associated negative impacts creating a lot of concerns (Lambin & Meyfroidt, 2011). Land-use changes may involve the enlargement of one land use and reduction of another land-use type. This changes may affect biodiversity and livelihoods of communities relying on the ecosystem. One of the main causes of changes in land uses is increase in population that increases the demand for agricultural production (Berihun *et al*., 2019) and this affect wetlands. MEA 2005 indicated that wetlands are among the most threatened ecosystem across the globe and are continually being degraded.

Globally, ecosystems are adversely changing due to population growth and related human activities and this often leads to climate change, biodiversity loss and fragmentation of riparian vegetation (Meraj *et al*., 2018). Gagne and Fahrig, (2007) indicates that land-use change was the major driver of the loss of wetlands and associated ecosystem services during the 20th century. In Spain, land-use change for agriculture and urbanization was reported to be the major driver of biodiversity loss leading to the conversion of 60% of the original wetland area which acted as a habitat for various animal species.

Loss of wetlands to other land uses has also been reported in various studies in sub-Saharan Africa. Wondie (2018) and Assefa *et al*., (2020) attributed urban encroachment, agricultural expansion, sedimentation, and agriculture to wetlands loss in Ethiopia. These changes consequently affect the ecological and economic values of various ecosystem services by altering wetland hydrology and water quality (Ethiopian Wildlife and Natural History Society (EWNHS) 2018) which in turn results in biodiversity loss.

In East Africa, wetlands are majorly converted to agriculture to mitigate food insecurities (Ondiek *et al*., 2020). In Uganda, Isunju and Kemp (2016) reported 62% of the wetland vegetation loss in Nakivubo wetland, between 2002 and 2014, 30% of which was due to agriculture. In Kenya the Anyiko wetlands declined by 55% between 1966 and 2018 of which 43% was converted to agriculture (Ondiek *et al*., 2020). Masese *et al*., (2020) reported that anthropogenic activities coupled with climate change impact are responsible for the overuse and degradation of wetlands and riparian areas in Kenya. Little seems to be known about the relationship between land uses changes and macroinvertebrates community structure along river Isiukhu which is one of the main tributary of river Nzoia, which drains its waters in Lake Victoria.

Despite wetlands being known for the delivery of essential ecosystem services, they are among the ecosystems facing greatest transformations worldwide. Rivers and streams provide water that is essential for survival of organisms (Pablo *et al.*, 2017; Masese. *et al*., 2020). Riparian vegetation regulates wetland water quality, provides instream primary production through light interception, and also provides organic matter used as food by aquatic organisms (Monoury, Gilbert, & Lecerf, 2014; Entrekin *et al.*, 2020 & Sitati *et al*., 2021).

Macro invertebrates are among the key species that inhabit the streams and wetland regions across the globe. Their distribution and assemblage's changes in a predictable way in relation to changes in water quality due to influence of human activities, thus they can be used as indicators of changes in stream water quality (Masese *et al*., 2014; Buss *et al*., 2015). Physicochemical changes associated with agricultural activities exert stress on stream ecosystem by enriching nutrients and enhancing sedimentation (Magbanua *et al*., 2010), thus affecting Macro invertebrates' population. Wang *et al.*, (2019) confirms that the degradation of habitat quality and elevated pollution can alter resource availability, thereby affecting stream biological communities. Use of macroinvertebrates' communities in assessing response of river ecosystem to anthropogenic impact is vital in environmental monitoring (Buss *et al*., 2015). Environmental Protection Agency (2013) indicated that the assessment and monitoring of river health calls for an integrative approach that takes into account measurement of biological, chemical and physical attributes of ecosystem. Monitoring and assessment of land use patterns and changes over time is required in understanding environmental mechanisms and informing environmental management decisions (Meraj *et al.*, 2013).

In Kenya, Lake Victoria and its tributaries have been experiencing increased levels of eutrophication since 1960s, thus making parts of water anoxic in supporting biota (Aura *et al*., 2010). Phosphorus and other nutrients from agricultural activities in the catchment areas are responsible for increased eutrophication of Lake Victoria basin, and this has attracted international concern (GEF, 2004). Lake Victoria basin need to be conserved and managed since it's a crucial ecosystem hub that support various aquatic and terrestrial life forms. Eutrophication threat in Lake Victoria basin exposes how river Isiukhu, a tributary of Lake Victoria is affected by land use activities.

The river transverses through areas with various land use activities like agriculture, settlement and urbanisation (Rop, 2011). Increased land use activities along river Isiukhu underscored the need for this study, since the river is economically and ecologically important to the wildlife and adjacent local community's livelihoods. Within this context, the main aim of the study was to establish the relationship between land use changes and benthic macroinvertebrates' community structure in River Isiukhu. Specifically, this research sort to determine if there was a significant difference in water quality variation and land use changes along Isiukhu River. Secondly, the study determined if there was a significant relationship between macroinvertebrates diversity indices and land uses changes. Lastly, the study sort to establish if there was a relationship between Functional Feeding Groups (FFGs) and land use changes along River Isiukhu, Kenya. We hypothesised that the water quality would not vary significantly with land use changes along the river, there was no significant relationship between macroinvertebrates diversity indices and land uses changes along river Isiukhu and that there is no significant relationship between Functional Feeding Groups (FFGs) and land use changes in the study area. The results are key mechanism of providing fundamental information for use by local environmental protection agencies in order to ensure sustainable conservation of the wetland ecosystem.

2. Materials and Methods

River Isiukhu catchment lies in Kakamega County, Western region of Kenya. The area is located between geographical coordinates of latitude 0° 15' - 0° 25' N and longitude 34° 40' - 34˚ 50' E. The elevation of area varies between 1240 metres and 2000 meters above the sea level. River Isiukhu is a tributary of River Nzoia that drains its water in Lake Victoria. The river lies in Kakamega County that experiences tropical humid climate, with well distributed rainfall (1300mm to 2200mm per annum) and high temperatures (18 to 29 c per annum) throughout the year. This county has a population density of 618 persons/km^2 and a population growth rate of 1.2 percent per year (KNBS, 2019). The river transverse land use gradient with varying human population densities and pressures. The river drains forested and grassland areas at its upper reaches, before entering farmland and urban settlement at its downstream areas. Understanding benthic macroinvertebrates communities' structure and functions is vital in conservation of fresh water resources in this region.

2.1 Data Collection and Analysis

The research adopted a cross sectional and longitudinal research design. Sampling was done once per month between August and November 2022. Stratified random sampling was employed. Four sampling stations were selected based on dominance and characteristics of existing land use activities along the river Isiukhu. Macro invertebrates and water samples were collected from four sampling sites on every of the four sampling stations, leading to a total of 16 sampling sites. The land use and in stream habitat characteristics were observed and recorded to give a summarized description of each station as indicated in table 1. Forest station (F) had minimal human impacts and thus was selected as a reference point.

Table 1: Physical and land use characteristics of sampling stations in River Isiukhu during the study period.

Station	GPS Coordinates	Land Use Characteristics in the Catchment Area
F	0˚18ˊ00″N ; 34˚50ˊ46″E	**Natural Forest** (Dense continuous natural vegetation cover) Minimal anthropogenic impact (Reference station)
G	0˚17ˊ04″N ; 34˚48ˊ33″E	**Riparian Grasslands** (Continuous grass cover with scanty short trees cover. Used for grazing domestic animals)
L	0˚16ˊ07″N ; 34˚46ˊ17″E	**Agricultural Zone** (Intensive small scale mixed farming and agroforestry)
T	0˚15ˊ24″N ; 34˚45ˊ1″E	**Urbanisation Zone**, (Kakamega Town)

The land use cover was classified as being very high, high, medium or low in relation to dominance and characteristics of land use cover and rated as 4 (very high), 3 (high), 2 (medium) and 1 (low) respectively. Use of Global Positioning Systems (GPS) helped to ensure samples are collected in same place on every sampling occasion. Macroinvertebrates' were sampled in four replicates of each station, using D-frame net (0.25m×0.25m size with 0.5mm pore sizes). Sampling involved disturbing macroinvertebrates by kicking upstream bottom substrate in an area of $1m^2$ for every 60 seconds for a representative sample. Dislodged organisms were then swept into D-frame net by natural water flow (Ligeiro *et al.*, 2020). Sampling was done in undercut banks, leaf packs and under snags, riffles, and tree roots. Collected macro invertebrates' samples were transferred into labelled plastic containers that had 10% formalin solution and taken to the laboratory. Dissecting microscope (×6 magnification) helped in sorting and counting organisms, while identification was done using relevant identification keys to the lowest taxonomic level in relation to local conditions. Habitat characteristics observed included nature of river bank, channel morphology, nature of riparian cover, riffles and snags.

Water samples were collected and measured in situ over 100 m stretch on each sampling occasion before macroinvertebrates were collected. Water quality parameters namely temperature, electric conductivity (EC), hydrogen-ion concentration ($_{P}{}^{H)}$, and Total Dissolved Solids (TDS) were measured using a water proof $_{P}{}^{H}$ / EC/TDS and Temperature tester while turbidity was measured using a Turbidity Meter (Model WZB -170). Dissolved oxygen (DO) was detected using a DO Analyser portable meter (Model JPB-607A).

Data was statistically analysed using SPSS software and a $P < 0.05$ confidence level was considered statistically significant. Mean values for physicochemical parameters from four sampling sites were averaged to give a summarised data that is a representative of water quality measure for each of the four sampling stations. ANOVA tested significant differences among sampling stations and to locate stations of significant difference. Pearson's correlation coefficient was used to describe relationships between variables. Parametric tests (ANOVA and Pearson Correlation) were used because the sample sizes of the study were small and the data passed normality test. The Shannon-Weiner Diversity Index, evenness index, species richness and mean abundance were done to describe the organism ecological characteristics. Sorenson Coefficient described quantitative similarities/dissimilarities between stations.

3. Results

3.1 Physicochemical Water Parameters

Water quality varied significantly among sampling stations ($p < 0.05$) (Figure 1). Temperature varied across sampling stations ($F = 498.5429$, $\rho < 0.05$). Forest recorded the lowest temperature 19.3˚C, which increased successively downstream in other sampling stations with G (20.9 ˚C), L (21.5 ˚C) and T (21.8 ˚C). A strong negative correlation existed between water temperature and sampling stations ($r = -0.9381$, $\rho < 0.05$). This indicates that changes in land use could explain the variability in water temperature in the study area.

Electric Conductivity (EC) significantly differed among the sampling stations ($F= 578.4059$, $\rho < 0.05$). EC generally increased down the sampling stations except for station G. The EC for Forest (F) was 91 µs, G (90 µs) L (95 µs) and T (100 µs) (Figure 1). A strong negative relationship existed between EC and sampling stations ($r = -0.9087$, $\rho < 0.05$). The results reveal that land use changes could also explain the variability in the water electric conductivities in the study area.

There was a significant variation between water pH and land use activities ($F= 3.292887$, $p <0.05$), and that, pH was similar in three stations with 6.0 for F, G and L stations. Water pH at T was 6.2. However, a negative correlation existed between water pH and sampling stations ($r = -0.7746$, $\rho < 0.05$). The results reveal that urbanisation negatively affects water pH by mainly increase water pH in adjacent area. Dissolved Oxygen (DO) significantly decreased downstream ($F=1950.33$, $\rho < 0.05$) with station F recording the highest (6.8 mg/l), G (6.4 mg/l), L (5.7 mg/l) and T (5.0 mg/l) (Figure 1). A strong positive relationship existed between water DO and sampling stations (r = 0.9928, ρ < 0.05), an indication that land use changes led to decline in DO with urbanisation and agriculture having the highest effect.

Total Dissolved Solids (TDS) increased downstream across the sampling stations, and that, stations differed significantly (F= 283.6032, ρ < 0.05). Station F had the highest TDS with 44 mg/l, G (45 mg/l), L (48 mg/l) while T had the highest (49 mg/l). A strong negative correlation existed between water TDS and sampling stations (r = -0.9762, ρ < 0.05). Likewise, water turbidity increased downstream and significant variation existed between sampling stations and turbidity (F= 64.94485, ρ < 0.05). Natural Forest (F) had the turbidity of 52 NTU, Grasslands (G) (90 NTU), Agriculture (L) (102 NTU) and Urbanization (T) (131 NTU) (Figure 1). Variation in water turbidity was significant (F= 64.94485; ρ < 0.05). A strong negative correlation existed between water turbidity and sampling stations (r = -0.9824, ρ < 0.05).

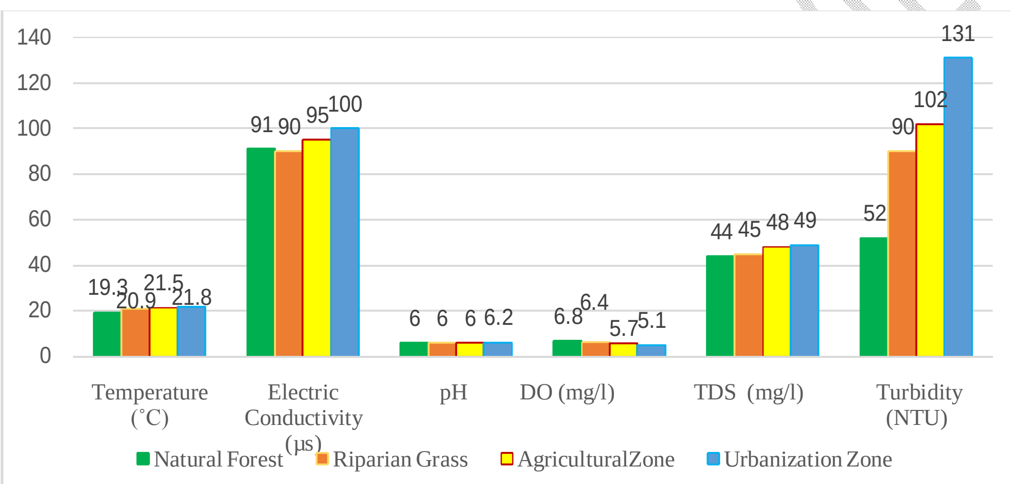

Figure 1: Water quality trends on sampling stations.

3.2 Macro Invertebrates Community Structure

3.2. 1 Taxonomic Composition

About one thousand three hundred and ninety-one (1391) macroinvertebrates were sampled. They belong to 12 orders, 32 families and 30 genera. In terms of diversity, Order Hemiptera was most diverse (5 families) while Diptera, Trichoptera and Ephemeroptera had four families each. Orders with low diversity include Odonata (3 families), Coleoptera (3 families), Plecoptera (2 families), Decapoda (2 families), Oligochaeta (2 families), Hirudinea (1 family), Sphaeriida (1 family) and Gastropoda (1 family).

In terms of relative order abundance in the entire study area, Ephemeroptera had the highest (18.70%; n = 260), followed by Hemiptera (17.54%; n =244), Diptera (17.25%; n = 240) and then Coleoptera (12.87%; n = 179). The least abundant orders were Trichoptera (7.70%; n =

107), Odonata (6.54%; n = 91), Oligochaeta (6.33%; n = 88), Plecoptera (5.32%; n = 74), Decapoda (4.39%; n = 61), Sphaeriida (1.58%; n= 22), Hirudinea (0.93%; n = 13) and Gastropoda (0.86%; n = 12) (Figure 2).

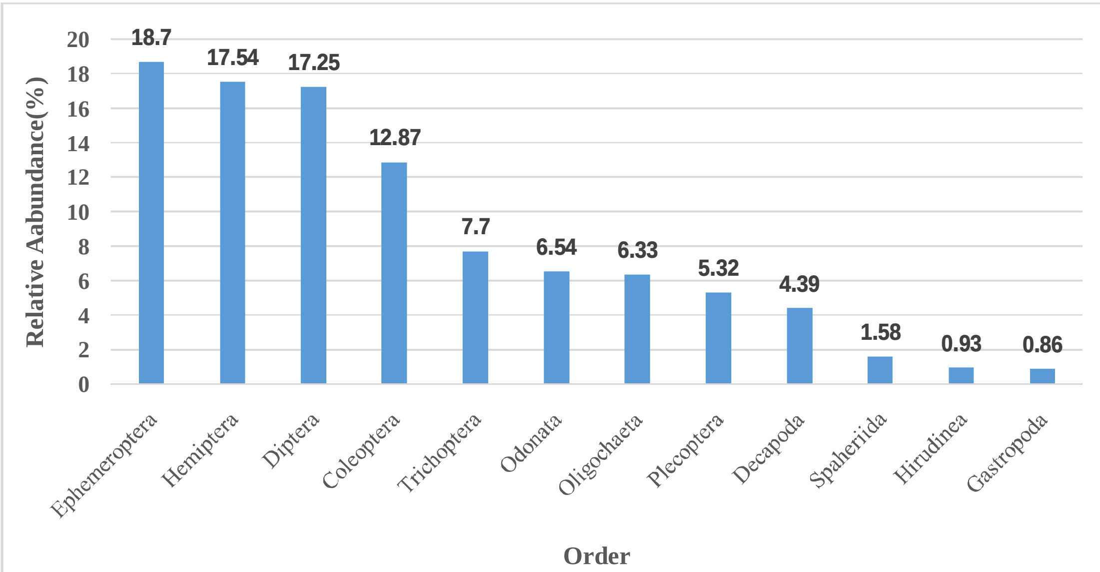

Figure 2: Trends in relative abundance of macro invertebrates' orders in the study area.

Diptera dominated area under urbanization T (28.75%; n = 69) while a fair distribution of the same occurred at F, L and G (24.58%; n =59, 24.17%; n = 58 and 22.5%; n = 54) respectively. Hemiptera was more abundant at natural forest F (32.79%; n = 80) and least abundant in G (17.62%; n = 43). L had 29.1%; n = 71 while T recorded 20.49%; n = 50. Coleoptera was more abundant in natural forest F (43.57%; n = 78) than L (15.08%; n = 27), while G and T recorded 21.23%; n = 38 and 20.11%; n = 36 respectively. Trichoptera dominated at F (34.58%; n = 37) and less at T (13.08%; n = 14), while G and L had 26.17%; n = 28 each. Plecoptera was uniformly dominant in G and L (32.43%; n = 24 each) while F and T recorded (24.32%; n = 18 and 10.81%; n = 8) respectively. Ephemeroptera was dominant at G (41.92%; n = 109) and least at T (11.54%; n = 30), while F and T recorded 30.77%; n = 80 and 15.77%; n = 41 respectively. Odonata was more in L (46.15%; n = 42) and least at G (8.79%; n = 8) while T and F had 32.97%; n = 30 and 12.09%; n = 11 respectively. Decapoda was dominant at riparian grasslands G (57.38%; n = 35) and absent at agricultural land L. F and T had 32.79; n = 20 and 9.84%; n = 6 respectively. Oligochaeta dominated at urbanization area T (50%; n = 44) and least G (9.09%; n = 8). L and F had 25%; n = 22 and 15.91%; n = 14 respectively. Hirudinea was only present in L (100%; n =13) and absent in all other sampling stations. Sphaeriida was present at L and F (54.55%; n = 12 and 45.45%; n = 10) respectively, and absent in G and T. Gastropoda was only present at L (100%; n = 12) (Figure 3).

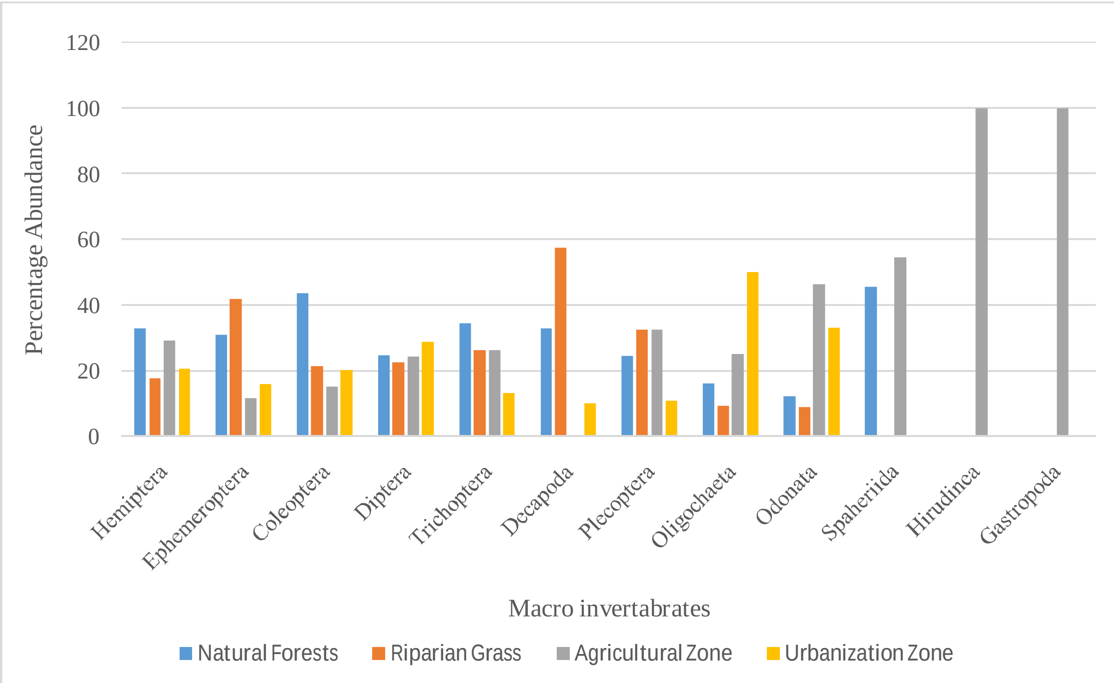

Figure 3: Trends in percentage species order abundance among sampling stations

3.22 Functional Feeding Groups and Species Indices

All the five functional feeding groups were present in all sampling stations. Predators dominated the area of study (26.1%; n = 488), followed by Collector Gatherers (24.1%; n = 451), Shredders (21.3%; n = 398), Scrapers (18.7%; n = 350) and lastly Collector Filters (9.7%; n = 187). Shredders were abundant at F (26.1%; n = 141), followed by Predators (23.1%; n = 125), Collector Gatherers (20.4%; n = 110), Scrappers (18.5%; n = 100) and Collector Filters (11.9%; n = 64). A positive significant correlation existed between Shredders abundance and sampling stations ($r=0.9646$; $\rho < 0.05$). Scrapers were more dominant at G (28.1%; n = 131), followed by Shredders (24.9%; n =116), Collector Gatherers (24.2%; n = 113), Predators (14.4%; n =67) and Collector Filters (8.4%; n=39). Significant positive relationship existed between Scrapers and sampling stations ($r=0.6492$; $\rho < 0.05$). Predators were more abundant at L (40.8%; n = 178), followed by Collector Gatherers (20.6%; n = 90), Shredders (16.7%; n = 73), Scrapers (11.7%; n = 51) and Collector Filters (10.1%; n = 44). Furthermore, Collector Gatherers were more abundant at T (32.2%; n =

137), followed by Predators (27.8%; n = 118), Shredders (16%; n = 68). Scrapers (15.8%; n = 67) and Collector Filters (8.2%; n = 35). A negative correlation existed between Collector and sampling station ($r= -0.3887$; $\rho < 0.05$), though not significant. Collector filter dominated in F (11.9%; n= 64) than other stations (Figure 4). Predators recorded a negative correlation with sampling stations ($r= -0.2559$; $\rho < 0.05$) while Collector Filters recorded a positive significant correlation with sampling stations ($r= 0.8225$; $\rho < 0.05$). This results indicates that changes in land use water quality could explain the variability in among Functional Feeding Groups of different species in the study area.

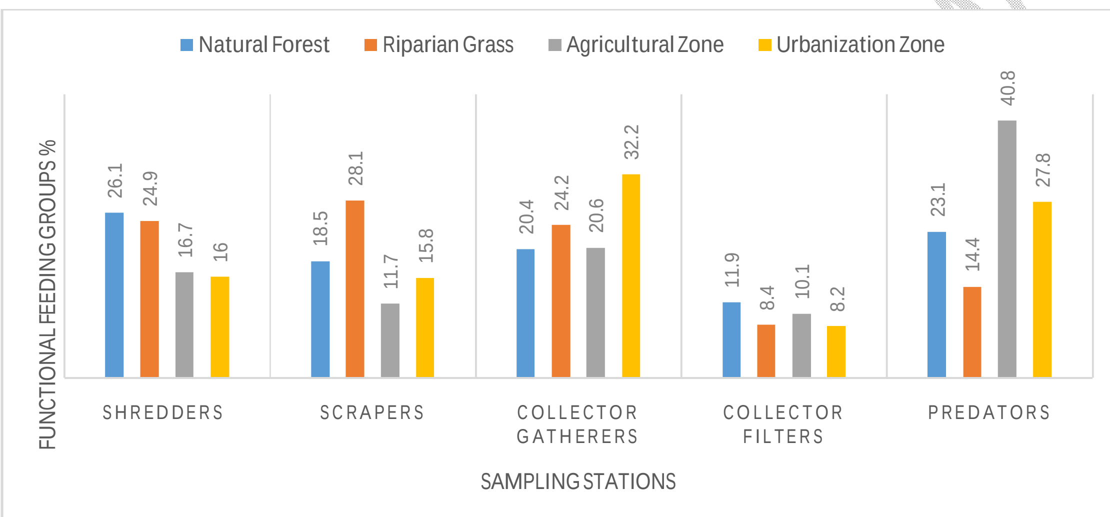

Figure 4: Trends in FGGs of species in different sampling stations.

However, functional feeding groups of some macro invertebrates overlapped between two feeding groups. For instance, *Chironomous sp.* and *Derenectes sp.* were classified as Collector Gatherer and predator, *Antocha sp.* (Shredder and Collector Filter), *Corixa sp*. and *Elmis sp*. (Shredder and Scraper), *Enochrus sp.* (Shredder and predator) and lastly *Baetis sp.* and *Ephemerrela sp.* (Collector Gatherers and Scrapers).

Species collected from study areas had a quite similarity since they all recorded Sorenson's coefficient values above 0.5. Highest similarity existed between G and T (0.857), followed by F and G (0.833), F and T (0.826), F and L (0.735), G and L (0.622) and lastly, Land T (0.605). F recorded the richness index (26), L (23), G (22) and lastly T (20). A significant relationship existed between macro invertebrates' richness and sampling stations ($r=0.8779$; $\rho < 0.05$).

Highest species richness occurred at F (26), followed by L, G and T (23, 22 and 20) respectively. Macro invertebrates were more abundant at F (407), followed by G, L and T

(347, 339 and 298) respectively. In terms of means species abundance, L was the highest (15.8), followed by F, T and L (15.7, 14.9 and 14.7) respectively (Figure 5). This indicates that changes in land use and water quality could explain the variability in species indices in the study area.

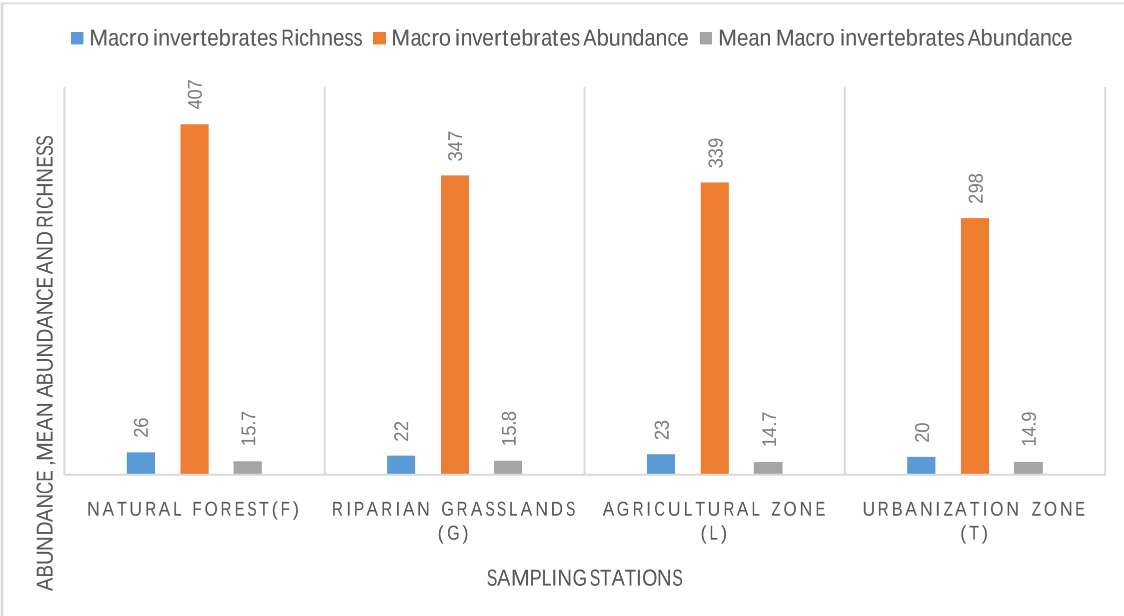

Figure 5: Species abundance, mean abundance and richness in various sampling stations.

Evenness Index values was high at Riparian Grasslands G (0.971), followed by Urbanization zone T (0.968), Natural forest F (0.952) and lastly Agricultural Zone L (0.893). A positive correlation existed between species evenness and sampling station, though it was not much significant ($r=0.1067$; $\rho < 0.05$). Highest diversity index was recorded at Natural Forest F (3.1), followed by Riparian Grasslands G (3.0), Urbanization Zone T (2.9) and lastly Agricultural Zone L (2.8). A significant relationship existed between macro invertebrates' diversity and sampling stations ($r=0.80$; $\rho < 0.05$). In terms of species abundance, station F recorded the highest abundance (407), followed by G (347), L (339) and lastly T (298). A significant relationship existed between macro invertebrates' abundance and sampling stations ($r=0.962$; $\rho < 0.05$).

4. Discussions

Macroinvertebrates' diversity, richness, evenness, abundance and functional feeding groups displayed spatial variation in relation to anthropogenic activities that also altered physicochemical composition of river water. Generally, higher shredders abundance was recorded at forest station, while predators dominated agricultural and urbanization stations. Sampling stations were impacted differently depending on their physical characteristics and degree of anthropogenic activities along the river. Intense anthropogenic activities along agricultural zone and urbanization zone led to degraded water quality, which negatively affected ecological integrity of the river. Conversely, pristine waters at natural forest and riparian grasslands resulted in flourishing of aquatic life. Urban runoffs and increased river bank erosion due to farming and decimation of riparian vegetation degraded water quality thus altering physicochemical parameters of the river. Conversely, natural forest vegetation and minimal anthropogenic activities at riparian grass could be responsible for pristine waters present at those respective places.

All water quality parameters significantly varied with adjacent land uses ($p < 0.05$). As a result, the null hypothesis of the study was rejected as there was a significant water quality variation along land use gradient of river Isiukhu. Anthropogenic land use activities influenced water quality as indicated by water physicochemical properties such as water temperature, EC, DO, TDS and turbidity. Water turbidity and TDS progressively increased downstream.

Downstream stations such as agricultural zones and urbanization zone recorded highest water turbidity. High organic and inorganic sediments from farms and urban wastes runoffs contributed to high suspended solids and turbidity at disturbed sampling stations comparable to low levels of the same realised at protected forest vegetation and grassland. According to Bernstein (2004), there is high degradation river water passing through urbanised areas, since they are close to pollution sources such as urban runoffs and urban solid wastes. According to Emere and Nasiru (2007), macro invertebrates are affected by high turbidity since it reduces water transparency, thus limiting primary productivity. Upper stations recorded low TDS and turbidity due to dense riparian vegetation. According to Fierro *et al.*, (2017), vegetation improves stream water quality by regulating surface runoffs, strengthening and filtering sediments.

Dissolved Oxygen significantly decreased downstream. A significant difference existed between stations ($\rho > 0.05$), where upper stations recorded high DO than lower stations an indication that runoffs from farms and Kakamega town drained organic wastes into the river causing water to become anoxic (Majule, 2010). Electric conductivity levels were higher at downstream stations comparable to upper stations. EC significantly differed among the sampling stations ($\rho < 0.05$). However, forest vegetation recorded high conductivity compared to riparian grass. This can be attributed to river bedrock chemical composition and not anthropogenic activities, since forest vegetation had minimal human impact. Higher conductivity at lower stations could be due to increased urban and farmland runoffs (Mwaijengo *et al*., 2020).

There was a significant variation between water pH and sampling stations ($\rho > 0.05$), and that, pH was almost neutral in most stations. However, a slightly higher pH at T could be attributed draining of urban waste runoffs with high basic content at the station. Temperature significantly varied across sampling stations. Upper stations recorded the lowest mean temperature compared to downstream stations. Dense vegetation at F contributed to low water temperature. Forest canopy limit solar insolation from reaching the water, thus leading to low water temperature (Aura *et al*., 2010; Masese *et al.*, 2017). Conversely open canopy and increased urban and farm runoffs could have increased river water temperatures at downstream stations.

4.2 Macro Invertebrates Community Structure

Macroinvertebrates' community composition spatially varied with water quality changes along land use gradient of river Isiukhu. Predators such as *Chironomous sp. Corixa sp*. and all species in order *Odonata* increased with disturbance. They dominated L and T since they are highly tolerable to highly degraded water quality of such areas, resulting from intensification of anthropogenic activities. Disturbance at station L and T created a degraded habitat condition that could only tolerate tolerant macro invertebrates. According to Welch 1992, Chironomids dominate degraded areas since they have more haemoglobin content. Insensitive orders and species, mainly in EPT group dominated F and G areas since such areas experienced minimal anthropogenic interferences on their riparian areas. For this reason, *Similium sp., Hexatoma sp., Belostoma sp., Elmis sp., Lepidostoma sp., Baetis sp.,* and *Heptagenia sp*. dominated station F and G.

Species richness, diversity, evenness and abundance indices differed from one station to the other depending on respective site conditions. Diptera and Hemiptera dominated the study area. Upper stations were dominated by Ephemeroptera, Plecoptera and Trichoptera (EPT) group, which declined down the river. High species Shannon-wiener diversity Index and abundance was realised at station F. The station was found in a protected indigenous forest that improved stream quality, regulated water temperature and provided a wider habitat diversity to aquatic organisms. Low species diversity downstream was associated by environmental stress propagated by array of human activities in form of agriculture and urbanisation (Wang and Lyons 2003).

Shredders dominated station F compared to other stations. This can be attributed to forest cover that provides leaf litters and other course particulate organic matter which is major source of food for shredders. Therefore, they help in processing course particulate organic matters from allochthonous organic matter which are found within riparian corridors. Furthermore, shredders increase in areas with dense canopy. Such canopy improves water quality that aid their survival. Low dominance of shredders at T and L can be attributed to decimation of natural riparian vegetation for agriculture; intense stream pollution and dominance of exotic vegetation (Aura *et al*., 2010). According to Masese and Raburu (2017), scrapers and shredders are highly sensitive and intolerable to habitat disturbance when compared to predators and collectors. According to Miserendino and Masi (2010), forested regions are typically characterised by high abundance and richness of shredders while scrappers dominate grasslands. Predators, collector gatherers and collector filters dominated station T and L. Generally, predators thrive in areas with open canopy and they prey on other consumers and animal tissues. Predator dominance in richness and abundance at station T can probably be because of taxa tolerable to degraded water conditions of urban areas (Masese *et al*., 2020). Collector gatherers utilize fine particulate organic matters found and in river bottom. As result, they dominate urban and farmland sites with more nutrients and organic matter. Conversely, collector filters filter and utilize fine particulate organic matter in both stream column and bottom.

5. Conclusion

Overall, macroinvertebrates' communities responded differently to water quality changes induced by varying degrees of disturbance. Water quality parameters, species indices and functional feeding groups significantly varied with sampling stations. Upper stations were dominated by intolerant taxa to habitat disturbance like EPT while tolerant taxa to pollution dominated lower stations. Therefore, macro invertebrates' are good biological indicators of stream water quality.

8. Data Availability and Statement

The data that support the findings of this study are available on request from the corresponding author. The data is not publicly available due to privacy or ethical restrictions

9. References

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