ANALYSIS OF SPATIAL AND TEMPORAL DISTRIBUTION OF AQUATIC MACROINVERTEBRATES IN RELATION TO SELECTED ENVIRONMENTAL PARAMETERS ALONG NAIROBI RIVER, KENYA

Abstract

Aquatic diversity in riverine ecosystems is threatened by the intensification of unsustainable human actions in the river catchment areas. Nairobi River is one of the global wetlands that is experiencing high levels of degradation and this has a detrimental effect on the community's livelihood. The study aimed to analyze the spatial and temporal distribution of aquatic macro invertebrates in relation to some environmental parameters in the Nairobi River watershed in Kenya. The study objectives were: to find out macroinvertebrates' diversity in the Nairobi River; to investigate selected water quality parameters in rainy and dry periods along the river; and to analyze the spatial distribution of macroinvertebrates in relation to selected water quality parameters. During the dry days, temperature, electrical conductivity, total dissolved solids, turbidity nitrates, and phosphates had significant differences ($P < 0.05$ and $F > 1$). In the same period, macroinvertebrates were higher in the middle course 1 section of the river (mean 657.00) and in the middle course 2 section (mean 588.00) to upper and lower sections. However, there was no significant difference $(P > .05)$ in the sites. Similarly, during the wet days, macroinvertebrates were noted to be higher in the middle course 2 areas (mean 168) and middle course 1 (mean 155). However, the number of macroinvertebrates was not significantly different $(P > .05)$. Animals such as midge larvae and pupa, aquatic earthworms and mosquito larvae were highly tolerant to pollution due to adaptations to survival while others such as water penny, gilled snails, fingernail clam were sensitive to pollution thus they survived in very few sections of the river and in small numbers. The study recommends the need to conserve the river watershed as well as restore degraded river sections to guarantee the continued future provision of ecosystem services to the adjacent urban river communities and improve the river's biological integrity.

Keywords: Degradation; macroinvertebrates; water quality and wetland

1. INTRODUCTION

The biological integrity of many tropical streams is adversely affected by the activities related to the increasing human population. An increase in urban human population causes expansion of agriculture, industrialization, urbanization, and deforestation in the river watershed [8]. These activities destroy aquatic habitats by interfering with natural stream physicochemical balance and flow characteristics to support diverse aquatic biotas [4]. Additionally, they degrade aquatic habitats by increasing both organic and inorganic pollution that accelerates eutrophication levels thus degrading water quality [29]

Benthic macroinvertebrates are vital species in global wetlands because they act as indicators of water quality changes due to their different tolerance levels to water pollution [15, 13]. They maintain the functional and structural integrity of rivers through degrading particulate organic matter which helps in the decomposition of organic matter and nutrient recycling [4, 13]. Reduced aquatic biota diversity is attributed to toxic waters. Environmental and water quality factors influenced by human activities such as total dissolved oxygen, dissolved oxygen, water temperature, altitude, stream depth, sunlight, water turbidity, phosphate, and nitrate levels influence both the functional and structural composition of macroinvertebrates [13]. These factors interfere with the organisms' colonization, migration, extinction, and reproduction rates. Aquatic biological communities are adversely affected when their habitats are degraded since this alters resource availability for them.

Globally, wetlands and aquatic ecosystems are being destroyed currently at a higher rate and this is causing global concerns due to the expected loss of biodiversity and other associated negative impacts [1]. Water pollution in Latin America has contributed a large percentage to the loss of biodiversity where around 26% of deaths of children have occurred annually. Other causes of death are soil pollution and climate change [9]

Degradation of aquatic ecosystems has also been reported in Africa through various studies undertaken to restore them. In Ethiopia, [4] attributed the massive loss of wetland biodiversity to the unsustainable use of land adjacent to water bodies. Furthermore, linked increased [18] macroinvertebrate diversity to improved water quality. Therefore, an undisturbed water ecosystem supports more aquatic biotas diversity due to its pristine water quality.

Conversion of wetlands to agricultural land in East Africa is on a high rise due high demand for food resources as a result of the increasing population [21] Nakivubo wetland in Uganda has experienced 62% degradation due to unsustainable human activities on the wetland including agriculture [8]. River Rwanda in western Uganda has been faced with degradation risk due to land use activities that have been taking place in the surrounding. People have encroached on the wetlands and runoff from degraded hills due to poor agricultural activities has interfered with water quality. Their biggest polluters are hotels, major industries, and higher institutions of learning. [7]

Many aquatic ecosystems have highly been degraded in Kenya due to human activities and climate change [16]. Nairobi River is the main tributary of the Athi River that drains its water in the Indian Ocean, sourcing of the river is Ondiri swamp. The river transverses through Nairobi city in areas under different unsustainable land use activities such as informal settlement, industrialization, urban waste dumping sites, and inappropriate agricultural activities. These activities have rendered the river to be one of the highly polluted rivers in Kenya thus adversely affecting the stream ecosystem [27]. Rapid population growth is the major cause of the degradation of urban aquatic ecosystems [5]. Several other research have been done on Nairobi River water quality. Some of them are; investigations of physical-chemical parameters and remediation of heavy metals using fish bone by Florence Achieng Masese in the year 2010, general impacts of water pollution by the University of Nairobi in 2022, analysis of biological characteristics on the river by the University of Nairobi in 2023 among others. Among them, none have analyzed the distribution of macroinvertebrates in relation to water physical and chemical parameters. Therefore, understanding how water quality parameters affect species diversity is vital in promoting the conservation and management of aquatic ecosystems. The study findings will be vital in making environmentally informed decisions aimed at conserving and managing wetland ecosystems to ensure future ecosystem services are guaranteed.

MATERIAL AND METHODS

Study Area

This study was carried out in the Nairobi River, which was used as a sample section to represent the whole river at a stretch in Nairobi County, Kenya. The section covers approximately 1.5km running from the upper section (Consolata) to the lower course (Gikomba). This section of the river was selected since it represented an area that had undergone riparian land rehabilitation (Michuki Park) and others that had immersed human negative impact on riparian land in terms of destruction of river line vegetation and pollution. The study area lies between longitude 36°48'0"E and 36°50'0"E and latitude 1°16'0' ´S to 1°18'0' ´S as indicated in Figure 1. The study area receives an average rainfall of 674mm per annum and an average temperature of 18.8 °C. (Climate data 2021) and slopes toward the river. The four major sampling sites are representative of the entire Nairobi river ecosystem, from its source to when it drains to the Arthi River

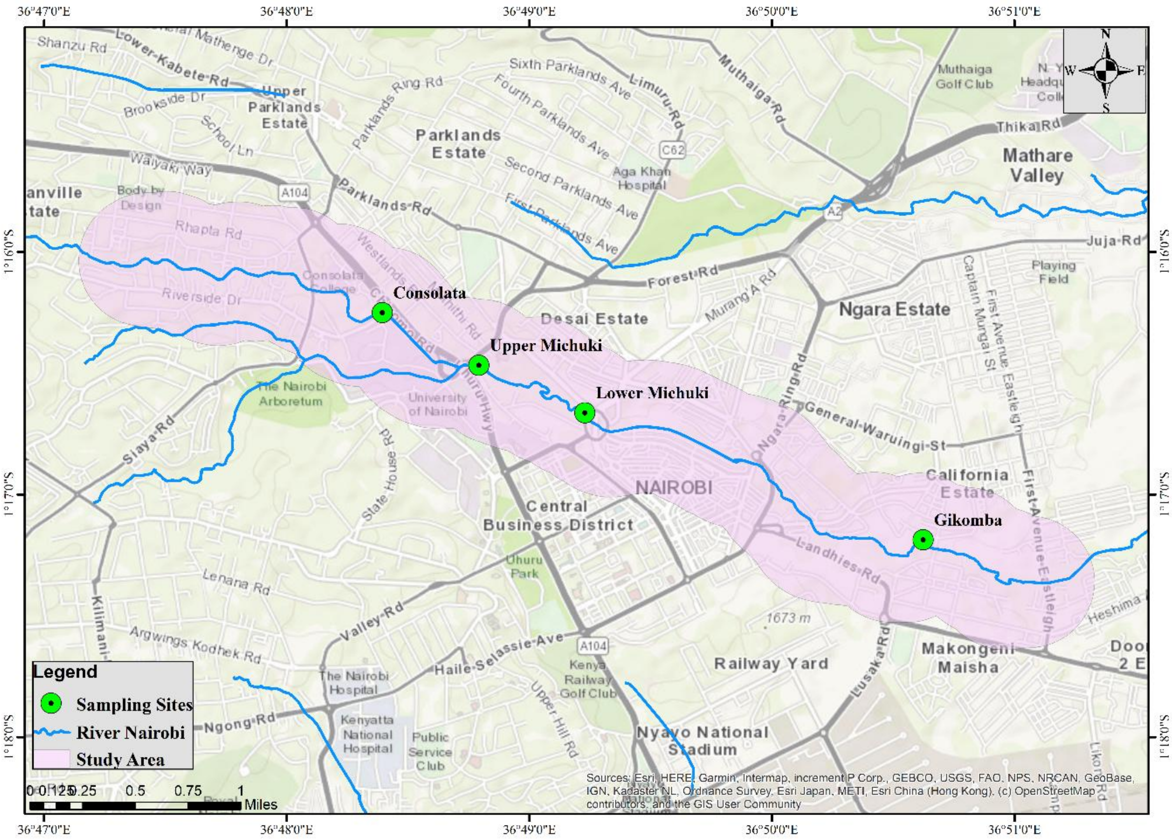

Figure 1: Map of the study area

Conceptual Framework

Macro invertebrates' assemblages were dependent on water quality. Figure 2 above represents a detailed representation of the parameters that were tested during the research period. Both physical and chemical parameters were tested to find out the impact they had on the macro invertebrates' assemblages. Data collection was done both during the dry and wet periods and comparison was done.

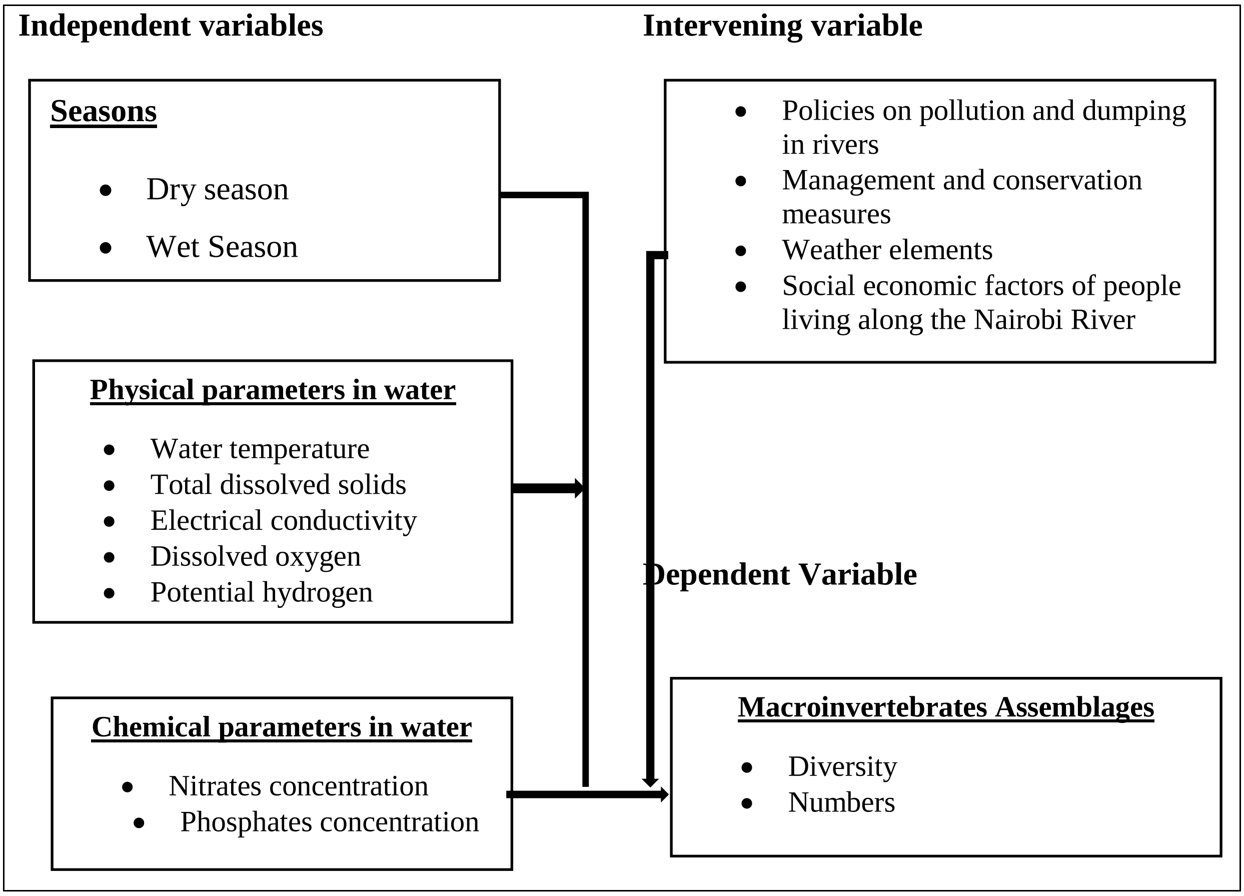

Figure 2: Conceptual framework representing macro invertebrates' assemblages about water quality parameters in different seasons.

The Study Design and Sampling

The experimental research design was the main research design applied during the study. The physical parameters were all tested in the field. The chemical parameters were tested in the lab. The study area was divided into strata where a stratified sampling method was used during the collection of samples. These strata were the upper course, middle course as well and lower course. Lab and field tests gave information that was later used to compare all the sections of the river under study.

Data Collection

Macro invertebrates were collected using a D-frame net (30cm in diameter with a mesh of 0.25mm) which was located on the downstream end of the river section to be tested as the water upstream was disturbed using the feet or a log of wood in deeper sections of the river. The net was bounced backwards and then scooped forward to trap organisms moving downstream. Different sections of the river were sampled to obtain a standard sample that could represent the river. After collection, the organisms were placed on plastic trays for analysis in the field using a biotic index. The collected organisms were returned to the river after analysis.

Chemical parameters were collected and temporarily stored in special sample bottles. Later they were taken to the lab for analysis using an ultra-violet spectrophotometer.

Data Analysis

ANOVA was used to test whether a significant variation existed between water physical-chemical parameters and macroinvertebrates in all sampling plots. The strength of the relationship between the macroinvertebrates obtained and physical-chemical parameters was tested using the Pearson correlation coefficient. Paired T-test was used to test the diversity of macroinvertebrates.

Results and Discussions

4.1 Water Physicochemical Variations of Selected Parameters during Dry Days

In the current study, the highest mean Temperature during dry days was 24.10^0C in the lower course section of the river while the lowest temperature was in the upper course section of the river (mean 20.47^0C). Temperature variation in water bodies occurs due to nature and water disturbance. Some of the human disturbance activities include discharge from power plants, urbanization and deforestation [24]. During the dry days, the middle course 2 section had the highest water pH (mean 5.41) whereas the lower course had the lowest pH (3.15). Variations in pH in water bodies are dependent on three main parameters: nitrogen oxides, acid rain and sulfur dioxide. These compounds emanate from both natural and anthropogenic sources. The anthropogenic sources are industrial plants and power emissions. [12]

A higher level of dissolved oxygen was recorded in the water in the upper course section of the river (0.45). Electrical conductivity was significantly higher in the upper course area than in other areas (F=3.73, *P=.042*). The lowest is in the middle course 2 section (mean 772.5). During this period, Total dissolved solids were significantly higher in the upper course section (70.13) than in other sections (F = 24.04, *P = .0001*). The finding of the study further showed that nitrates and phosphates in the lower course section of the river (112.16 and 917.38 respectively) were significantly higher compared to other sections (F = 22.56, *P = .0001* and F = 15.05, *P = .0001* respectively). Nitrates in water bodies vary depending on factors such as animal feed lots, run-off or leakage from fertilized lands, septic systems, wastewater, urban drainage and landfills [2].

Table 1: Selected Physio-chemical Properties of Water Sample during Dry Days

Site	Temp. (^{0}C)	pH	DO (mg/L)	EC (µS/cm)	TDS (mg/L)	TURB NTU	Nitrates (mg/L)	Phosphates (mg/L)
Upper course	20.47± 0.41^a	3.72± 0.64^a	0.45± 0.09^a	850.3±22.2^b	595.2± 15.5^b	70.13±0.64^b	66.73± 12.7	489.00± 220^b
Lower course	24.10 ±0.62^b	3.15 ±1.62^a	0.40± 0.04^a	843.0±13.7^b	592.1±9.87^b	37.00±1.30^a	112.16± 0.73	917.38± 8.51^c
Middle course 2	22.76 ±0.39^b	5.41 ±1.22^a	0.43± 0.20^a	772.5± 34.3^a	562.8±13.5^{ab}	34.92±3.83^a	13.05± 0.61	14.80 ±2.05^a
Middle course 1	22.27± 0.31^b	3.37 ±0.14^a	0.40±0.07^a	777.3±0.75^a	546.9± 2.25^a	35.38±5.70^a	71.04± 11.5	99.54± 9.74^a
NEMA	**-**	**6.5-8.5**		**2500**	**1200**	**5**	**10**	
WHO	**24-30**	**6.5-8.5**	**< 6**	**1200**	**500-1000**	**0.1-10**	**2.0-50.0**	**0.5**
F- value	**11.32**	**0.93**	**0.04**	**3.73**	**4.15**	**24.04**	**22.56**	**14.05**
P –value	**0.001**	**0.458**	**0.987**	**0.042**	**0.031**	**0.0001**	**0.0001**	**0.0001**

Mean values in the same column denoted by different letters are significantly different at $P \leq 0.05$. Mean separated using Tukey HSD

Table 2: Selected Physio-chemical Properties of Water Sample during Wet Days

Site	Temp. (^{0}C)	pH	DO (mg/L)	EC (µS/cm)	TDS (mg/L)	TURB NTU	Nitrates (mg/L)	Phosphates (mg/L)
Upper course	18.17± 0.29^a	3.74± 0.12^a	0.70± 0.13^b	680.3± 73.3^a	479.6±50.7^a	95.2± 35.7^a	51.33 ± 5.10^b	207.8 ±114^a
Lower course	20.15± 0.48^b	4.06±0.15^a	0.78± 0.09^b	692.8±45.1^a	481.7±29.1^a	85.5± 38.4^a	112.69± 0.60^c	704.2 ± 220^a
Middle course 2	19.15± 0.02^{ab}	4.21± 0.46^a	1.10± 0.00^a	657.8± 52.2^a	462.1± 38.2^a	84.2± 38.6^a	13.03± 0.37^a	241.4 ± 228^a
Middle course 1	18.51±0.11^a	4.31± 0.11^a	1.10± 0.09^a	779.8± 2.84^a	549.3±5.13^a	92.8± 35.9^a	59.99 ±6.31^b	112.7 ± 15.7^a
F- value	**9.43**	**0.96**	**5.27**	**1.13**	**1.20**	**0.02**	**101.76**	**2.45**
P –value	**0.002**	**0.444**	**0.015**	**0.378**	**0.350**	**0.996**	**0.0001**	**0.113**

From the above data in Table 1 above, during the dry days, temperature, electrical conductivity, total dissolved solids, turbidity nitrates, and phosphates had $P < .05$ and F>1. This indicates a significant difference in water quality. We therefore reject the null hypothesis that states that, there is no variation in water quality among the sampling plots and accept the alternate hypothesis that, there is variation in water quality among the sapling plots.

Changes in the physic-chemical parameters in water along the river indicated a trend shown in Figure 3. River water in the lower course (Gikomba area) had the highest levels of Nitrates, turbidity, and phosphates. Levels of nitrates were highest in the lower course and least in the middle course). However, electroconductivity, temperature, dissolved oxygen, and TDS did not have a significant variation in all the sampling points. There were fewer pollutants in the middle section of the river as compared to the upper and lower sections. This was attributed to the high level of protection that is given to the middle course section against sources of pollution. This is because the middle course section lies in Michuki Park which is under conservation thus the area has reduced dumping of wastes which in turn results in a reduction in the number of pollutants.

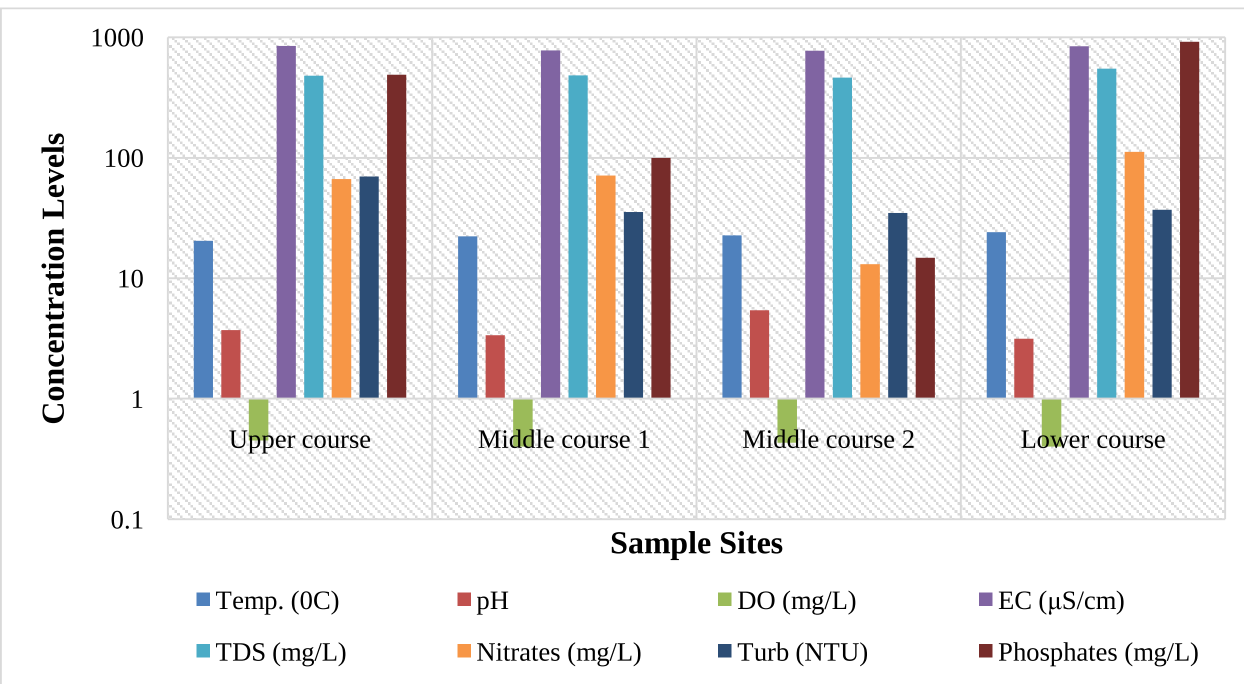

Figure 3: Levels of the physic-chemical elements along the river from the lower course (Consolata) – upper course (Gikomba) section in the dry season.

4.1.2 Physic-chemical variations during wet days

During the wet (rainy) days as indicated in Table 2 above, the mean water temperature was significantly higher in the lower course section (20.15^{0}C) but lowest in the upper course (18.17^{0}C), F= 9.43, $P = .002$. Dissolved oxygen in water was significantly higher in middle course 2 (mean 1.10) and middle course 1(1.10) sections of the river (F = 5.27, $P = .015$). Dissolved oxygen in water bodies varies depending on factors such as plants in the water, obstacles in the water, whether water is in motion or is stagnant, the temperature in water bodies and the nature of rocks over which water is flowing [14]. There was no statistically significant difference in the water pH, Electrical conductivity, total dissolved solids, and turbidity in the different sections of the river ($P > 0.05$). Levels of Nitrates in the water in the lower course section of the river were significantly higher (mean 112.69) compared to other sections (F = 101.76, $P = .0001$). However, phosphate levels were not significantly different in the river sections ($P > .05$), this is represented in Tables 1 and 2.

Considering the flow of the river (from the upper course to the lower course section), the levels of Phosphates and nitrates in the water were higher in the lower course section as compared to other sections of the river. The amount of phosphates in water bodies depends on both natural and human-induced factors. The human-induced factors include urban runoff, fertilizer from agricultural land, industrial effluent, domestic sewage and faulty or overloaded septic systems [30]. Higher levels of dissolved oxygen were detected in the upper course section of the river, reduced slightly in middle course 1, then increased in middle course 2, and finally a decline in the lower course. The variation shows the pollution tread as the river moves through the upper rehabilitated middle and the lower course. Figure 4 below clearly indicates the tread. From the above results on wet days, the majority of the parameters (phosphates, PH, electrical conductivity, total dissolved solids, and turbidity) were not significantly different at P>0.05. Therefore, we accept the null hypothesis that states that, there is no variation in water quality among the sampling plots. Figure 4 below is a comparative bar graph representing the levels of physic-chemical parameters in the sampling points during the wet days.

Results in Tables 1 and 2 above clearly indicate that most pollutants were in the lower course of the river (Gikomba) and fewer pollutants were in the middle courses 1 and 2. This was due to greater exposure of the river section to anthropogenic activities in the lower course which lies in an area with many jua kali industries. [18]. On the other hand, the middle course had fewer pollutants since it lies in a highly protected area that is undergoing rehabilitation with regular garbage collection. [19] Levels of dissolved oxygen also play a significant role since it is a basic requirement for the survival of organisms.

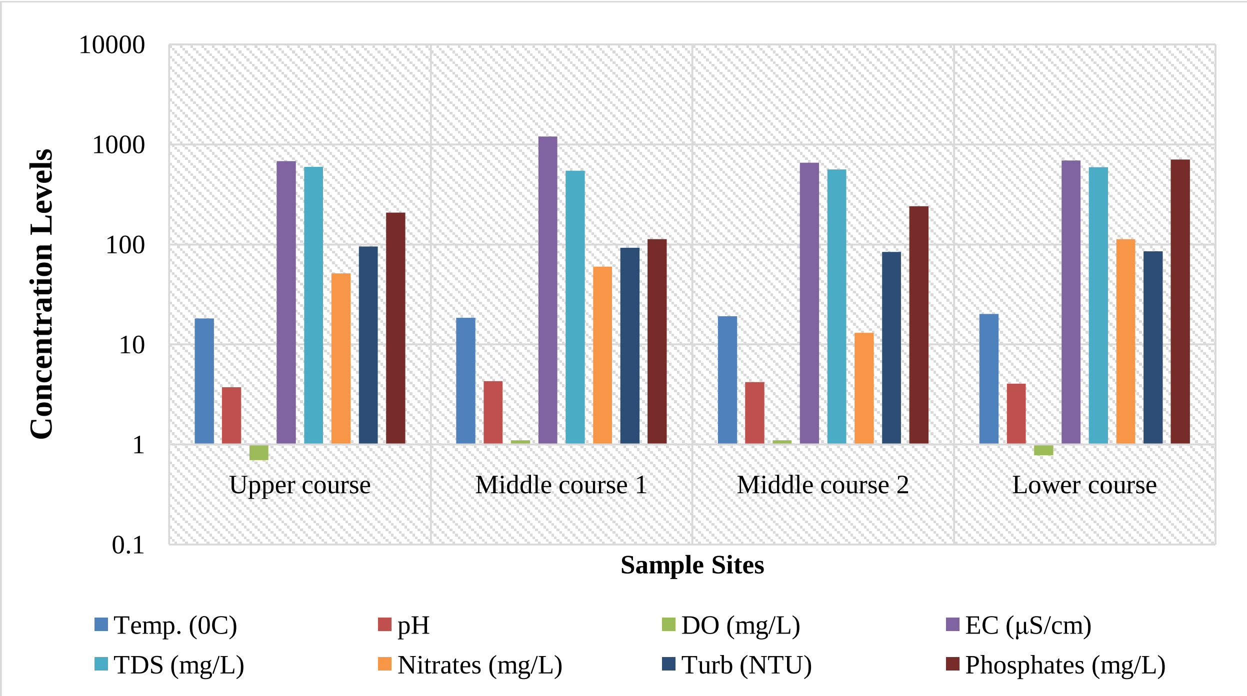

Figure 4: Levels of the physic-chemical elements along sections of the river [Upper course (Consolata) – Lower course (Gikomba)] during the wet period.

4.2 Abundance and diversity of macroinvertebrates along Nairobi River

The number of macroinvertebrates during dry days was higher in the middle course 1 section of the river (mean 657.00) and in the middle course 2 section (mean 588.00) compared to other sections of the river. However, there was no significant difference *($P > .05$)* in the sites. Similarly, during the wet days, a higher number of macro-invertebrates was noted in the middle course 2 areas (mean 168) and middle course 1 (mean 155). However, the number of macro-invertebrates was not significantly different *($P > .05$).* This is shown in Table 3.

Table 3: Number of macroinvertebrates along River Nairobi

Site	Macroinvertebrates in dry days (mean ± SE)	Macroinvertebrates in Wet days (mean ± SE)
Upper course	74.80± 48.5a	109.75 ±34.3a
Middle course 2	588.00 ±449a	168.00±56.3a
Middle course 1	657.00±519a	155.25±26.9a
Lower course	329.00 ±263a	47.00± 8.69a
F- value	0.52	2.33
P –value	0.676	0.126

Mean values in the same column denoted by different letters are significantly different at P ≤ 0.05. Means separated using Tukey HSD

From the results in Table 3 above, it is evident that both during dry and wet days, the number of macroinvertebrates were higher in middle course 1 and 2. This can be attributed to various factors such as water quality parameters and vegetation cover. Vegetation cover affects dissolved oxygen since plants and animals circulate important gases such as oxygen and carbon (iv) oxide among themselves. According to [28] vegetation cover also helps in the moderation of temperature in the atmosphere due to the creation of shade. This makes rehabilitation that has been taking place in the middle course of the river (Michuki Park) an important aspect of the life of macroinvertebrates.

From the results on water quality, the middle course section generally had less concentration of pollutants making it favourable to the majority of the macroinvertebrates. Though distribution of the macroinvertebrates was also determined by the tolerance levels of the organisms towards pollution. Some organisms were more tolerant than others. The most abundant macroinvertebrate in the dry days were midge larvae *(Cricotopus lebetis)* and aquatic earthworms (*Limnodrilus hoffmeister)*. They were more despite the high levels of pollution since they are highly tolerant of pollution. They can survive in areas with high levels of pollution [3]. Aquatic earthworms can survive in water with very low oxygen concentrations and even live without oxygen for weeks. They are capable of surviving in highly disturbed water bodies since they are in a position to regenerate the damaged or lost parts of their bodies naturally. Some of them have a long lifespan of up to several years. These characteristics make them capable of surviving in polluted and disturbed waters. During the rainy days, the most abundant macroinvertebrates were midge larvae and mosquito larvae as shown in table 4 below. Mosquito larvae *(Culicidae larvae)* are capable of surviving in varied levels of water pollution. They can survive in salt water, water polluted with organic and garbage material as well as in fresh water. Water polluted with garbage and organic material is the best for the multiplication of mosquito larvae *(Culicidae larvae)*. According to Tables 4 and 5 below, macroinvertebrates that were few both on wet and dry days were: crane fly *(Tupulidea latreille)*, water penny, gilled snail, fingernail clam, planaria, water bug nymph, rat-tailed maggots, and leech. Some of them are pollution sensitive while others are moderately sensitive and this resulted in their lower numbers.

According [10] monitoring of water quality parameters can be very expensive, instead monitoring the fluctuation of insect communities can be very insightful. Macroinvertebrates such as midges can be used to monitor the water quality of localized environments since they have limited mobility. Midges are tolerant to water pollution though this varies depending on the variety of midges. They tolerate high loads of pollution as well as low levels of oxygen. Aquatic midges manage to survive in areas with low oxygen levels and high organic matter due to some physiological and behavioural adaptations. In low-oxygen sediments, they construct burrows as well as fixed tubes made of sediments which are held together by silky secretions [27]. These organisms ventilate these tubes with fresh water by the dorsal-ventral undulations of their body. This facilitates gaseous exchange when the amount of oxygen is low. The larvae stage of the midges extends their tubes above the sediments to access enough oxygen when the level is low below the sediments. The physiological adaptation of midges (chironomids) is the possession of haemoglobin which increases respiratory efficiency. The haemoglobin has a very high affinity for oxygen. It serves as a temporary storage for oxygen which is absorbed through the cuticle. The oxygen is stored until the need arises. Haemoglobin also plays a vital role in the transportation of oxygen to various body tissues. This makes the midges alternate behavioral and physiological characteristics to survive even during the period of rest [22]

According to the results obtained, leech and gilled snails had the least tolerance to pollution, they were very few in the area under study and could not survive in the lower section of the river which had the highest levels of pollution. Leech adaptations to water quality vary depending on the species. Some can survive in extreme environmental conditions. The environmental extremes include extremes in salinity, light, temperature, pressure, moisture, and pollution. Leeches are capable of surviving in areas with insufficient water. They have mucus glands that produce mucus which is distributed in all parts of the body. The mucus has biological importance to leech among them being prevention against desiccation. They can tolerate some time out of water bodies.

Leeches also use various sensory structures to help them locate potential hosts, habitats, and prey. They sensillae as chemoreceptors to detect changes in chemical composition in water. Their eyes are used as photoreceptors to detect changes in light intensity inside the water. Sensillae are also used to detect sounds and vibrations in water. All these structural adaptations make some of the leeches survive in varied environmental conditions. Gilled snail undertakes gaseous exchange by use of their gills. They absorb dissolved oxygen from water through their gills. They rely on high oxygen concentration and thus cannot survive in water with low dissolved oxygen.

Abundance of macroinvertebrates in different sampling sites

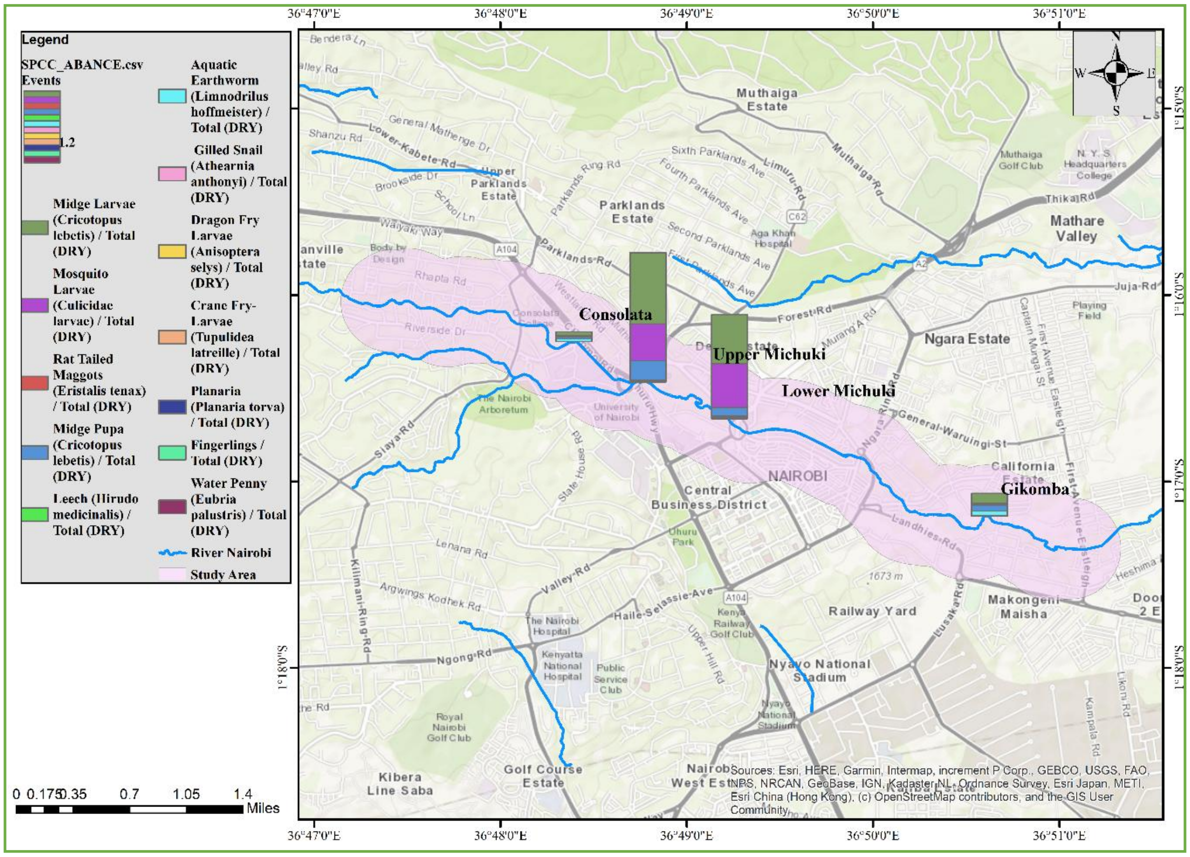

Figure 5: Spatial Distribution of macro-invertebrates abundance at the upper course (Consolata) – middle course (Michuki) – lower course (Gikomba) area

From map 5 above, it is evident that macro invertebrates' abundance was highest in the middle course with a mean value of (415 and 378) which was a rehabilitated section, and lowest in the upper course (92.28) which was a non-rehabilitated section. The rehabilitated section had fewer pollutants due to conservation measures put in place as compared to the non-rehabilitated section. The rehabilitated section also had the advantage of having higher dissolved oxygen as compared to other sections of the river. Some of the macroinvertebrates that were present in the water were midge larvae, aquatic larvae, water penny, crane fly, gilled snails, fingernail clams, and planaria during the dry days. During the rainy days, midge larvae, midge pupa, water bug pennies, rat-tailed maggots, leeches, gilled snails, aquatic earthworms, and water pennies were caught. This indicated a slightly higher diversity of macroinvertebrates during the rainy days as compared to dry days. This was due to higher concentration of dissolved oxygen in water and dilution of the polluted water during the rainy days as compared to dry days

Relationship between macroinvertebrates' diversity and water quality

Using Pearson correlation, the relationship between macro - invertebrate diversity and physical-chemical parameters along the lower course– upper course ecosystem of the study area in Nairobi River, Kenya was established. A significant negative relationship was found between macro- invertebrates diversity with nitrates and phosphate levels in the river water (r = -0.863 and -0.603, $P < 0.05$). A negative correlation value implied that, an increase in nitrates and phosphate levels in water lowered macro-invertebrates' diversity due to competition for oxygen and lower pH due to eutrophication. Conversely, diversity was high in the areas where the river had lower levels of nitrates and phosphate. Similarly, negative relationships, although not statistically significant at $P \leq 0.05$, were found between macro invertebrates' diversity with, water temperature, electrical conductivity, total dissolved solids and water turbidity.

Dissolved oxygen and pH had a positive correlation with macro invertebrates' diversity which indicates that pollution is higher in lower sections of the river. As shown in table 4 below.

Table 4: Relationship between macroinvertebrate diversity and water quality

		Diversity	Temp	pH	DO	EC	TDS	Turb	Nitrates	Phosp
Temp	r - value	-0.233	1							
	P- value	0.200								
Ph	r - value	0.217	.039	1						
	P- value	0.232	.831							
DO	r - value	0.016	-.665**	.047	1					
	P- value	0.931	.000	.799						
EC	r - value	-0.080	.393*	-.079	-.520**	1				

	P- value	0.665	.026	.667	.002					
TDS	r - value	-0.032	.434*	-.050	-.496**	.966**	1			
	P- value	0.864	.013	.785	.004	.000				
Turb	r - value	-0.072	-.419*	.136	.503**	-.661**	-.688**	1		
	P- value	0.697	.017	.460	.003	.000	.000			
Nitrates	r - value	-0.863**	.219	-.339	-.191	.254	.204	-.057	1	
	P- value	0.000	.229	.058	.295	.160	.263	.758		
Phosp	r - value	-0.603**	.210	-.128	-.176	.034	-.022	.067	.552**	1
	P- value	0.000	.248	.485	.335	.854	.906	.716	.001	
	N	32	32	32	32	32	32	32	32	32

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Using linear regression analysis to show how the number of macro-invertebrates is affected by the levels of nitrates and phosphates in river waters, the findings in this study showed that nitrates are more effective in determining the number of micro-invertebrates compared to phosphate levels. This is because nitrates dissolve in water more readily than phosphates, which have an attraction for soil particles. As a result, nitrates serve as a better indicator of the possibility of a source of sewage or manure pollution. The regression model was therefore established as; $Y = \text{constant} + \beta_1X_1 + \beta_2X_2 + \varepsilon$ (where Y is macroinvertebrates diversity, β is the beta coefficient, X_1 is nitrate level, X_2 is phosphorous level, . ε is error term. The model equation therefore is; $Y = 1.389 – 0.008X_1 + 0.0001X_2$

Conclusion

Nairobi River impacted in stream water quality differently. As a result, macroinvertebrates responded differently to water quality changes over wet and dry sampling seasons. This is because difference aquatic invertebrates have different tolerance and sensitivity levels to habitat changes as a result of disturbances. Areas with highly degraded water quality recorded a generally low diversity and abundance of sensitive species. Therefore, degraded rivers in the world need to be properly managed and conserved in order to improve the river's biological integrity as well as guarantee future ecosystem services to the river communities.

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Competing Interests

The authors have declared that no competing interests exist.

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Table 5. Macro Invertebrates Distribution – Wet Season

Macro Invertebrates	Sampling Site(s)							
	Upper Course (Consolata)		**Middle Course 1** (Upper Michuki Park)		**Middle Course 2** (Lower Michuki Park)		**Lower Course (**Gikomba)	
	1st Sampling	2nd Sampling	1st Sampling	2nd Sampling	1st Sampling	2nd Sampling	1st Sampling	2nd Sampling
Midge Larvae *(Cricotopus lebitis)*	101	40	107	98	131	117	6	35
Mosquito Larvae *(Culicidae larvae)*	44	21	18	88	65	159	5	0
Rat Tailed Maggots (*Eristalis tenax)*	1	0	2	0	0	0	1	0
Midge Pupa *(Cricotopus lebetis)*	55	33	19	37	11	30	4	21
Leech *(Hirudo medicinalis)*	0	1	0	0	2	0	0	0
Aquatic Earthworm *(Limnodrilus hoffmeister*)	0	**106**	0	0	0	3	20	0
Gilled Snail *(Athearnia anthonyi)*	**0**	**1**	3	0	0	4	0	0
Dragon Fry Larvae (*Anisoptera sel*ls)	**0**	**0**	0	0	0	1	0	0
Water Bug Nymph *(Lethocerus americanus)*	**0**	**0**	0	0	0	1	1	0
House Fry Larvae *(Musca domestica)*	**0**	**0**	0	0	0	0	0	1
Total	**201**	**202**	**149**	**223**	**209**	**209**	**37**	**57**

Table 6. Macro Invertrabraes Distribution Dry Season

Macro Invertebrates	**Sampling Site(s)**							
	Upper Course (Consolata)		**Middle Course 1** (Upper Michuki Park)		**Middle Course 2** (Lower Michuki Park)		**Lower Course (**Gikomba)	
	1st Sampling	2nd Sampling	1st Sampling	2nd Sampling	1st Sampling	2nd Sampling	1st Sampling	2nd Sampling
Midge Larvae *(Cricotopus phlebitis)*	55	359	46	316	99	103	6	178
Midge Pupa *(Cricotopus lebetis)*	13	74	1	108	0	53	3	41
Crane Fry-Larvae *(Tupulidea latreille)*	2	0	0	0	2	0	1	0
Planaria *(Planaria torva)*	1	0	0	0	0	0	0	0
Fingerlings	1	0	1	0	0	0	0	0
Rat Tailed Maggot Larvae (*Eristalis tenax)*	5	**0**	0	0	0	0	0	1
Aquatic Earthworm *(Limnodrilus hoffmeister*)	77	**0**	0	277	0	0	0	0
Dragon Fry Larvae *(Anisoptera selys*)	**0**	**0**	0	0	0	0	0	0
Mosquito Larvae (Culicidae larvae)	**0**	**1780**	0	413	34	0	2	12
Leech*(Hirudo medicinalis)m*	**0**	**0**	0	1	0	1	0	0
Gilled Snail *(Athearnia anthonyi)*	**0**	**0**	1	2	0	0	0	0
Water Penny *(Eubria palustris)*	**0**	**0**	0	0	1	0	1	0
Total	**154**	**2213**	**49**	**11117**	**135**	**157**	**13**	**232**

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