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RESEARCH PAPER

Impacts of Anthropogenic Activities on the Benthic Macroinvertebrate Assemblages During the Wet Season in Kipsinende River, Kenya

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Abstract

Human activities have impacted negatively the benthic macroinvertebrate assemblage of River Kipsinende in Kenya consequently affecting the biodiversity of the area. The study assessed the impact of anthropogenic activities on benthic macroinvertebrates' assemblage in the river. Quantitative triplicate samples were collected from three different longitudinal sections along the river and four biotopes from six stations. Sample collection was done monthly from (November-December, 2019, January and March, 2020). 72 samples with 20,040 macroinvertebrate individuals belonging to 14 orders, 48 families, and 68 genera were identified. The relative abundance of Dipteran was greater than Ephemeroptera. Ephemeroptera abundance in percentage was also greater than Trichopteran and Bivalvia. The relative abundance of Dipteran and taxon group of % EPT had an inverse relation across study sites. The highest diversity and evenness were observed in station KB and the lowest in KA. Station KC had the highest number of individuals followed by station KA and the least was at station KE. The results of the canonical correspondence analysis (CCA) shown the physico-chemical parameters were affecting the macroinvertebrates communities in the river. This study provides baseline and scientific information for the appropriate water management of freshwater streams in Kenya.

Introduction

Currently, the human population growth in the world is increasing at an alarming rate, and development facilities have been centered on freshwater habitats, because of their vital role in ecological, economic, social, and cultural functions (Reddy, 2014; Lindborg, 2015). Human activities lead to habitat degradation, changes in land use, and water use that increasingly impact the structure of biodiversity and ecosystem service provisioning in rivers (Kibena et al., 2014). In East Africa, population growth is increasing, leading to accelerated deforestation, urbanization, industrial expansion, and commercial irrigation or agricultural activities that threatening freshwater bodies (GWP, 2015), and this is true in the study area. In the recent years, agricultural activities, deforestation, logging and human settlements in the Kipsinende River catchment area have increased. According to Ding et al. (2017), these human disturbances affect taxonomic distribution, abundance, composition, richness, diversity, and the functional feeding structure of benthic invertebrate assemblages. The benthic macroinvertebrates assemblages provide reliable and relevant signals about the environmental degradation and the health status of the river (Elias et al., 2014). The main reason is that they are normally found at the bottom of a stream and less mobile. Thus, these making

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them difficult to migrate away from environmental stress (Ghosh & Biswas, 2015). In addition, to that many recent studies suggested they have relatively short life cycles that enable quick reflection of environmental changes (Pellan & Piscart, 2018).

Studies have not been done in the Kipsinende River to assess the distribution, composition, and abundance of benthic macroinvertebrates before. Adequate management of riverine ecosystems therefore requires monitoring, assessing, and evaluating the health of streams and river conditions, by using surveys and other direct measures to determine the anthropogenic impacts on ecosystem structure and function (Parsons et al*.,* 2016). As stated by Lozupone et al. (2012), the diversity indices had two main assumptions. 1) stable communities have high diversity, while unstable communities have low diversity, and 2) community stability is an index of environmental quality. This idea is also supported by Lobera et al*.* (2017) and Sundstrom et al*.* (2017), the reduced diversity values are associated with environmental degradation and may result in community differences between sites over time, serving as a valuable indicator of stressors. The Shannon-Wiener Index (H') is currently one of the most widely used indices for the calculation and measurement of biological diversity. This study aimed to assess the impact of human activities on the Kipsinende River macrobenthic assemblage in, Kenya. The findings of this study would be a basis for further studies in the basin and would also be useful in the management of freshwater streams and other institutional stakeholders.

Materials and Methods

Study Site

The study was conducted in Kipsinende River and its two tributaries, Yatiene and Kipkwen. The River originates from Elgeyo Marakwet County and flows unidirectionally through the Kaptagat forest to Uasin Gishu County and lastly feeds into the Lake Victoria basin (Figure 1). With an average annual rainfall of 1200 mm to 1700 mm and an average annual temperature of 18°C (Mbaka *et al.,* 2017). The catchment of these rivers is under pressure due to various human activities (Aura et al., 2010). Six sampling stations were selected based on the level of human interference and land-use activities such as agricultural, forested, and mixed (agricultural + forested +Cattle grazing) (Table 1). The River is used for various domestic activities such as drinking, bathing, laundry, washing of vehicles, motorbikes, cattle drinking, and to some extent irrigation purposes (personal field observation).

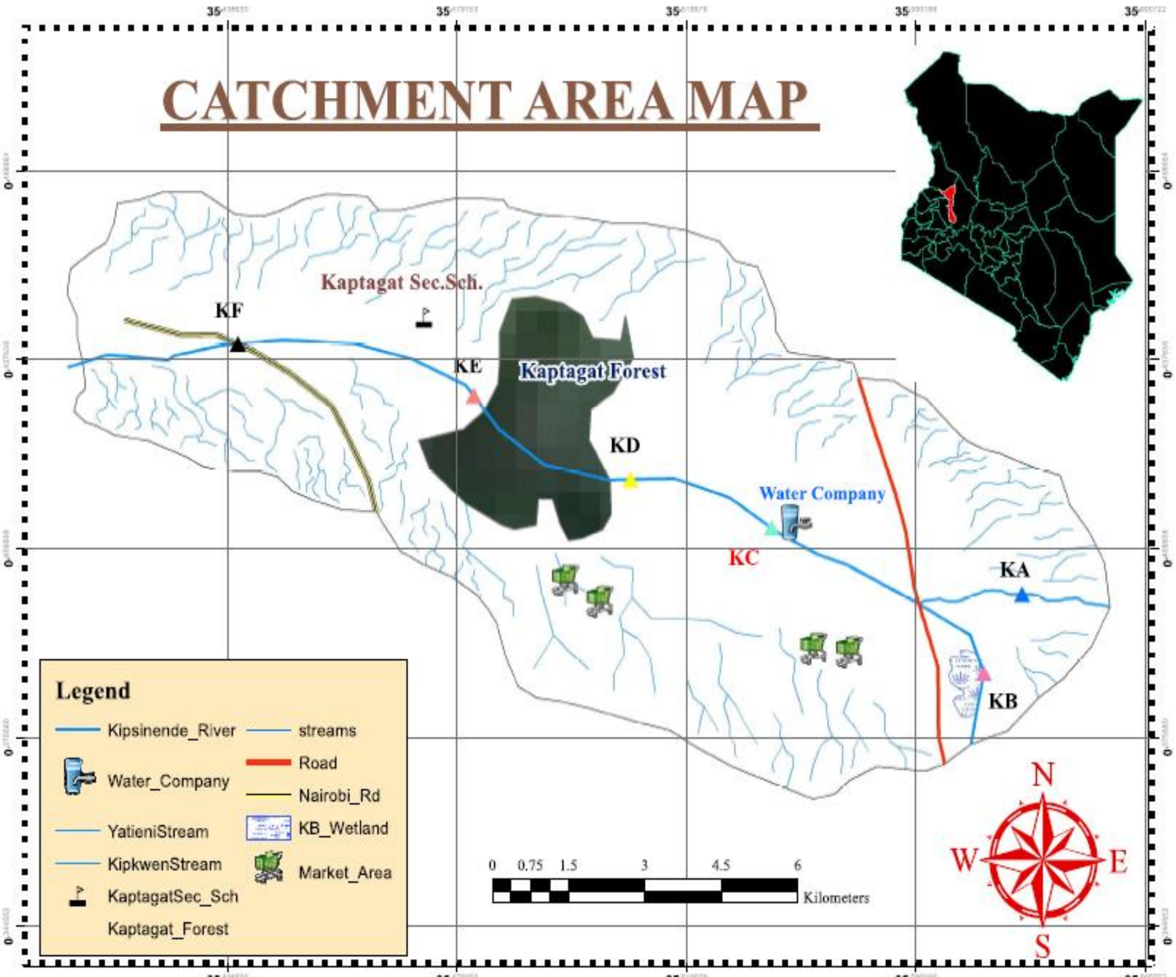

Figure 1. Map of the study area and the sampling stations (KA, KB, KC, KD, KE, and KF) during the study period in Kipsinende River

Sample Collection and Analysis

Samples were collected for a period of 4 months (November-December, 2019, January and March, 2020) during wet season. The sampling station was selected randomly to avoid bias and covering all catchments to determine the effect of land use and human disturbances on the river ecosystem based on the accessibility factor, physical proximity, habitat diversity, and riparian land use. The benthic macroinvertebrates sampling was carried out by using a kick net (1 m^2, 0.5 mm mesh size) against water current and dragged along the riverbank up to a distance of 1m for all sampling stations. However, benthic macroinvertebrates in the sediment were sampled by using Ekman grabs (Ziajahromi et al., 2018). Each sampling station was marked using a Geographical Positioning System (GPS) to be sure that samples were collected from the same place at each sampling time. To obtain representative data, quantitative triplicate samples were collected from three different longitudinal sections along the river (upstream, midstream, and downstream) and four biotopes (runs, riffles, pools, and marginal vegetation) from each station.

Visible organisms were removed with forceps from the substrate and put into the specimen bottles and preserved with 4% formalin in the field until laboratory analysis had been performed (Alonso & Camargo, 2010). The specimen bottles were well labeled twice for better and reliable information. In the laboratory, samples were washed through a 300 µm mesh size sieve, using tap water and sorted in a white plastic tray. After sorting and identification were done, the organisms were preserved in a vial containing 70% ethanol. The identification was done at the Genus level using a dissecting microscope and appropriate keys (Gerber & Gabriel, 2002; Merritt et al., 2008) in the laboratory of fisheries and aquatic science department, University of Eldoret.

Water quality parameters such as water ambient temperature, dissolved oxygen (DO), power of hydrogen (pH), total dissolved solids (TDS), conductivity, and salinity were measured in-situ using YSI 556 MPS portable multi-parameter. For laboratory analysis, 1 liter of water sample was collected for determining the concertation of nitrates, nitrites, ammonia, and soluble reactive phosphate and carried out according to APHA (1998).

Data Analysis

The benthic macroinvertebrate indices of abundance, composition, diversity, richness, evenness, equitability, and dominance were determined by enumeration, number of taxa, and the total number of individuals, by calculation and use various indices (Shannon-Weaver diversity index, Simpson's diversity index, and Margalef richness index). Composition measures like %EPT was calculated as: %EPT=[(E+P+T) *100]/N where, E=The number of Ephemeroptera, P =The number of Plecoptera, T=The number of Trichoptera and N=Total number of individuals in a station.

Water quality parameters were analyzed by using descriptive statistics and presented as mean, and Standard Error (mean±SE). Pearson correlation coefficient was carried out to determine the relationships between each water quality parameter. One-way analysis of variance (ANOVA) was used to evaluate the differences in the means of water quality parameters and abundance of macroinvertebrates at a 95% level of significance and followed by Post hoc Turkey's honest significance differences (HSD) tests. Canonical correspondence analysis (CCA) was also applied to evaluate the relationship between benthic macroinvertebrate community and Physico-chemical water parameters. Meanwhile, the abundance data of macroinvertebrates were transformed using log(x+1) before Canonical correspondence analysis was carried out to checked the statistical normality. Microsoft Excel® and PAST v4.02 (Hammer et al*.,* 2001) software were also used for the analysis.

Results and Discussion

Macroinvertebrates Distribution, Abundance, and Composition

From a total of 72 collected samples, 20,040 macroinvertebrate individuals belonging to 14 orders, 48 families, and 68 genera were identified and counted (Table 2). Hence, taxa abundances were much higher compared with benthic macroinvertebrates in other Kenyan rivers with similar sampling design and agroecology such as, 1499 individuals, (Aura et al., 2010) and 13 taxa, (Mbaka et al., 2014). The main taxonomic groups were Dipteran (11 families, 15 genera, 10187

Table 1. Geographical coordinates of the stations and main human activities during the study period in Kipsinende River

Characteristics	Upstream		Middle stream		Downstream	
	Station1	Station 2	Station 3	Station 4	Station 5	Station 6
Given code	KA	KB	KC	KD	KE	KF
Altitude(m)	2630	2613	2580	2563	2418	2392
Latitude(N)	00°23.005′	00°22.117′	00°23.184′	00°23.598′	0025°.589′	0025°.606′
Longitude(E)	035°34.144′	035°33.574′	035°33.023′	035°32.416′	035°27.865′	035°28.659′
Land-use type	agricultural	mixed	mixed	mixed	forested	mixed
Human activities	deforestation	grazing	grazing	logging	almost none	Washing
	agriculture	washing	agriculture	grazing	Or no visible impact	Grazing

Table 2. List of macroinvertebrate taxa found in River Kipsinende from November 2019 to March 2020 study period (x= indicates the presence of macroinvertebrate at each station).

			Sampling station					
Order	Family	Genus	KA	KB	KC	KD	KE	KF
Diptera	Simulidae	Simulium	x	x	x	x	x	x
	Tipulidae	Tipula	x	x	x	x	x	x
		Hexatoma		x				
		Limonia					x	x
		Antocha		x	x		x	x
	Chironomidae	Tanypodinae	x	x	x	x	x	x
		Chironomus	x	x	x	x	x	x
	Ceratopogonidae	Bezzia		x	x	x	x	x
	Tanyderidae	Tanyderus	x	x	x		x	x
	Dolichopodiae	Dolichopodid		x				
	Chaoboridae	Chaoborus	x	x	x	x		
	Syrphidae	Syrphinae			x			
	Ephydridae	Ephydrid	x					
	Dixidae	Dixa				x		
	Musidae	Mussa			x			
Ephemeroptera	Baetidae	Baetis	x	x	x	x	x	x
		Acanthiops	x	x	x	x	x	x
		Demoreptus			x			
		Rheoptilum						x
	Heptagenidae	Afronurus	x	x	x	x	x	x
	Caenidae	Caenis	x	x	x	x	x	x
		Afrocaenis	x	x				x
	Leptophlebiidae	Adenophlebia	x		x	x	x	x
	Ephemerellidae	Ephemerella	x	x		x		
	Tricorythidae	Disercomyzon					x	x
Trichopetra	Hydropsychidae	Hydropsyche	x	x	x	x	x	x
		Leptonema.sp			x			
		Cheumatosyche		x	x	x	x	
	Leptoceridae	Trianodes	x	x	x	x	x	x
		leptocerus	x	x				
		Adicella	x				x	x
	Lepidestomatidae	Lepidostoma		x	x		x	
	Pisulidae	Pisulia				x		
	Calamocetatidae	Anisocentropus					x	
	Philopotamidae	Chimarra		x			x	
Hemiptera	Gerridae	urimetra	x				x	
		Gerris	x		x	x	x	x
		Eurymetra	x					
	Hebridae	Hebrus		x				
	Nepidae	Ranatra	x	x				
		boborophilus			x	x	x	
	Naucoridae	Naucoris			x			
	Veelidae	Mesovelia	x				x	
	Mesorehidae	Mesorehia						x
	Corixidae	Corixa	x		x			x
	Notonectidae	Notonectha		x	x	x	x	x
	Hydrometridae	Hydrometra				x		
Coleoptera	Gyrinidae	Orechygrus	x	x		x	x	
		Orectogyrus	x	x				
		Orectochilini					x	
		Dineutus.sp	x	x	x	x		x
	Scirtidae	Elodes		x			x	x
	Elmidae	Elminae	x	x			x	x
	Dytiscidae	Hydaticus		x	x	x	x	
		Yola		x				
Decapoda	Potamonutidae	Potamonute	x	x	x	x	x	x
Bivalvia	Sphaeriidae	Pisidium	x	x	x	x	x	x
Gastropods	Thiaridae	Thiaridae	x					
Oligochaeta	Tubificidae	Tubifex	x	x	x	x	x	x
	Lumbriculidae	Lumbricus	x	x			x	x
Odonata	Gomphidae	Gomphus	x	x	x	x	x	x
	Lestidae	Lestes	x	x	x	x	x	x
	Aeshnidae	Ashena	x					
Arhynchobdellida	Hirudinae	Hirudo	x	x	x	x	x	x
Tricladida	Planariidae	Dugesia		x			x	
Lepidoptera	Crambidae	Paraponix				x		
		Syndita				x	x	
Araneae	Dictynidae	Argyroneta						x
Total	48	68	37	40	34	32	40	34

individuals ~ 51%), followed by the Ephemeroptera (6 families, 10 genera, 5457 individuals ~ 27%), Trichopteran (6 families, 10 genera, and 1123 individuals ~ 6%) and Bivalvia (1 family, 1 genus 1273, individuals ~ 6%) (Table 2 & 3). The remaining relative abundance consisted of Coleoptera, Hemiptera, Oligochaeta, Odonata, Decapoda, Arhynchobdellida, Tricladida, Lepidoptera, Gastropod and Araneae.

As mentioned above Diptera was the dominant taxonomic group during this study period. Spatially the highest relative abundance (79%) was found in station KA (agricultural land use pattern) and the lowest (7%) was in station KE (forested site) (Table 4 & Figure 2)**.** This might have been due to increased input of organic nutrients from agricultural activities, which could have possibly given the benthic macroinvertebrates communities to increase in number as well as their tolerance ability to high pollution. A similar study was done by Deborde et al. (2016), who observed that the highest abundance of benthic macroinvertebrates was found in agricultural and mixed land uses. Bartlett-Healy et al. (2012), were also reported that most of the Dipteran families such as Chironomidae, Dixidae, and Culicidae tolerate a wide range of water qualities, especially in polluted waters by using atmospheric oxygen. The four genera (Simulium, Tipula, Tanypodinae and Chironomus) under order Diptera were found in all stations.

Table 3. The abundances of orders with their significance level in each site during study period in Kipsinende River

Orders Name	No of individuals at each site						F-Value	p-value
	KA	KB	KC	KD	KE	KF		
Diptera	3584	310	3132	1225	102	1834	0.53	0.602
Ephemeroptera	527	1189	1148	1100	759	734	0.89	0.436
Trichopetra	40	310	393	273	60	47	1.88	0.195
Hemiptera	16	32	10	19	24	4	0.46	0.641
Coleoptera	16	31	10	42	8	9	1.36	0.294
Odonata	67	157	65	94	34	9	0.50	0.617
Decapoda	32	25	42	15	41	102	0.52	0.605
Oligochaeta	68	295	93	14	267	188	0.41	0.671
Bivaliva	177	500	127	75	183	211	1.05	0.379
Arhynchobdellida	6	104	5	5	3	4	0.45	0.647
Tricladida	0	6	0	0	1	0	0.40	0.681
Lepidoptera	0	0	0	23	8	0	1.53	0.256
Araneae	0	0	0	0	0	1	1.00	0.397

Table 4. Various metric categories based on benthic macroinvertebrates taxa that were selected from November 2019 to March 2020 during the investigation period in River Kipsinende

Category	Agricultural	Mixed		Forest		
	KA	KB	KC	KD	KF	KE
Richness measures						
Total No. of individuals	4538	2959	5025	2885	3143	1490
Total No. of taxa	37	40	34	32	34	40
No. of EPT Taxa	11	12	11	10	11	13
No. Ephemeroptera Taxa	7	6	6	6	8	6
No. Trichoptera Taxa	4	6	5	4	3	7
No. Hemiptera Taxa	6	3	5	4	4	5
No. Coleoptera Taxa	4	7	2	3	3	5
No. Diptera Taxa	7	10	10	7	8	8
No. Odonata Taxa	3	2	2	2	2	2
No. Oligochaeta Taxa	2	2	1	1	2	2
Composition measures						
% EPT	12	51	31	48	25	55
% EPT: % Diptera	0	5	0	1	0	8
% Ephemeroptera	12	40	23	38	23	51
% Trichoptera	1	10	8	9	2	4
% Hemiptera	0	1	0	1	0	2
% Coleoptera	0	1	0	1	0	1
% Diptera	79	10	62	42	58	7
% Odonata	1	5	1	3	0	2
% Oligochaeta	2	10	2	0	6	18
Dominance and diversity						
Dominance_D	0.61	0.16	0.31	0.27	0.35	0.17
Simpson_1-D	0.39	0.84	0.70	0.73	0.65	0.83
Shannon_H	1.05	2.39	1.73	1.75	1.64	2.28
Evenness_e^H/S	0.08	0.27	0.17	0.18	0.24	0.15
Margalef's index (S)	4.28	4.88	3.87	3.89	4.10	5.34
Equitability_J	0.29	0.65	0.49	0.51	0.46	0.62

Whereas, the highest relative abundance (55%) for taxon groups of EPT% (Ephemeroptera=51%, Plecoptera=0%, and Trichoptera=4%) were recorded in station KE and the lowest (12%) was in station KA. The probable reason could be due to the level of water quality, habitat quality, and the availability of food. This agrees with Patrick et al. (2014), who suggested that the presence of smaller number of EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera) and their individuals in most of the impacted stations indicated that there was poor water and habitat quality as well low food availability. During this study period, order Plecoptera was not found. It could have been because it belongs to groups of sensitive aquatic insects. The relative abundance of Diptera and group of %EPT had an inverse relation at each sampling station. A similar finding was reported by Raburu et al. (2009), who observed that when the abundance of Diptera increased, the group of EPT was reduced. Baetis, Acanthiops, Afronurus, and Caenis from Ephemeroptera as well as Hydropsyche and Trianodes from Trichoptera were frequently observed in all stations. While Anisocentropus was recorded only at stations KE.

On the other hand, the order (Odonata and Hemiptera) had a higher abundance in station KA (agricultural area). Whereas, Coleoptera and Oligochaeta, had a lower abundance at station (KC and KD). This might have the presence of relative higher pollution at each site with various human activities such as the washing of motorbikes, clothes, bathing laundry activities, grazing, animal wastes, and agricultural inputs (fertilizer, pesticides, and herbicides). Similar observations were carried out by Masese et al. (2014), Płociennik and Karaouzas (2014), Mariadoss and Ricardo (2015), who stated that the presence of a greater number of Hemipteran and Odonata might be an indication of water quality deterioration due to pollution. Based on ANOVA in (Table 3), there were significant differences among stations (P<0.05) for taxa Odonata, Ephemeroptera, Trichopetra, Coleoptera, Tricladida and Araneae. However, in other taxonomic groups, there were no significant differences among stations (P>0.05).

Diversity of Macroinvertebrates

The diversity of macroinvertebrates along with the sampling station in Kipsinende River during the study period is indicated in (Table 4). Thus, based on (Table 4) the value of the Shannon- Weiner diversity index (H) in the sampling stations varied from 1.05 to 2.39. The highest value (2.39) was observed at station KB followed by 2.28 at station KE. Whereas, the lowest (1.05) was found at station KA. This value is greater than what was reported by Mbaka et al. (2014). For their variation, the main reason could be the availability of quality and quantity of food sources, the trophic structure, and the level of environmental stress for each site. This result was agreed with Egler et al. (2012), and Lozupone et al. (2012), who stated that stable environments have high diversity, while unstable communities have low diversity. However, this idea was contrasted to Morphin-Kani & Murugesan (2014), who suggested that the high macroinvertebrate diversity could be an indication of a stress- environment and very low diversity showing the environment is under some lack of habitat availability.

Like, Shannon-Wiener index, diversity within the macroinvertebrate community was also described using Simpson's diversity index (1-D). According to Mandeville (2002), the Simpson Index (1-D), with values ranging from 0 to 1. The values 0, indicating a low level of

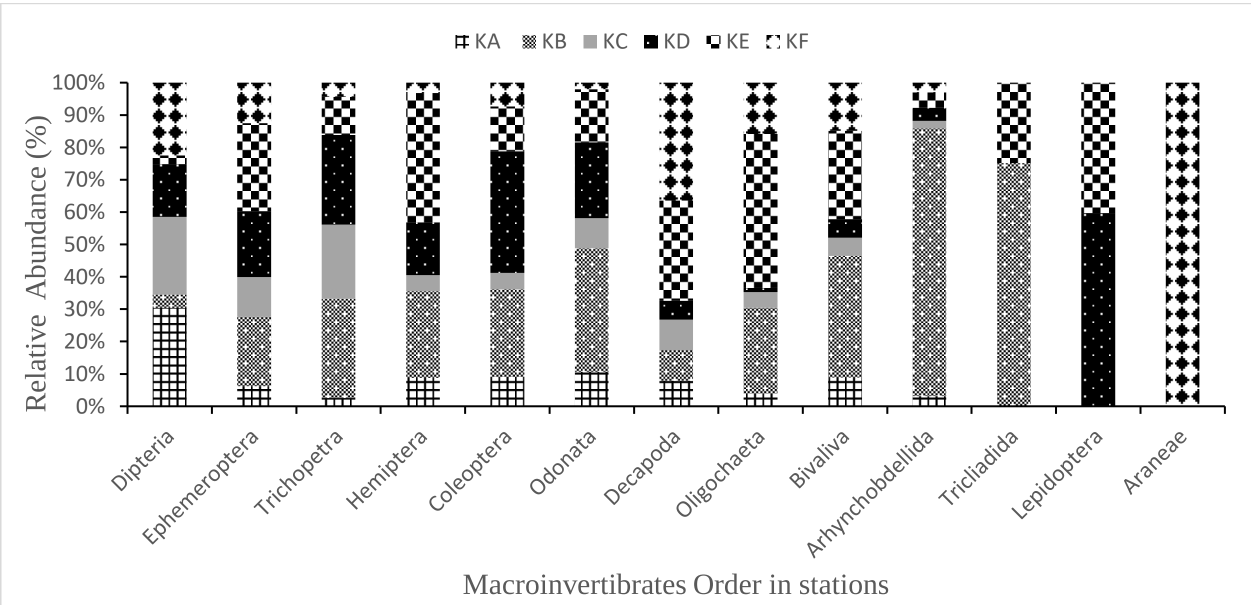

Figure 2. Overall percentage relative abundance of the macroinvertebrate order at each sampling station in River Kipsinende from November 2019 to march 2020 study period.

diversity and 1 for a high level of diversity. Simpson's diversity index in Kipsinende River varied from 0.39 (KA) to 0.84 (KB). The highest (0.84) was observed in station KB and the lowest (0.39) was in KA. This recorded value in Kipsinende river according to the given range indicated the presence of almost a high level of diversity. The Shannon-Wiener Index (H') and Simpson's diversity index (1-D) showing the same trend at each sampling station. However, they had an inverse relation to Dominance (D). This finding was also agreed with Magurran (2013), who stated that Shannon's diversity and Simpson's diversity indices differ in their theoretical foundation and interpretation, but they have strong correlations with each other.

Margalef richness index in Kipsinende River was observed in the range of 3.87 and 5.34. Relatively the highest Margalef richness index was 5.34 followed by 4.88 and 4.28 which were found at station KE, KB, and KA, respectively. Whereas, the lowest (3.87) was recorded at station KC. In the same way, the highest taxa richness was found in station KB (40) and station KE (40). While the lowest (32) was in station KD. The variation among sites might be due to the level of environmental stress in the area via increased human activities. This idea was verified by Andem et al. (2012), who suggested that low taxa richness may indicate the environment is seriously degraded with various anthropogenic activities. This also affected the benthic macroinvertebrate community.

The range of evenness was also varied from 0.08 to 0.27. The highest evenness (0.27) was located at station KB and the lowest (0.08) was at station KA. This might be due to the status of water quality. This result was agreed with Dipankar and Jayanta (2015), Upen and Sarada (2015), who observed high evenness were showing poor water quality and lack of available food. The recorded value indicating that the evenness index and richness index had the same trends from station KA to KD but, at station KE and KF contrast each other. This idea disagreed with Chrisoula *et al*. (2011), who suggested that the increasing value for species richness index was responsible for the reduced value of the evenness index. The equitability of benthic macroinvertebrates along sampling sites was found in the range of 0.29 and 0.65. The maximum value (0.65) was observed at station KB and the minimum at KA. It had similar trends with the Margalef richness index at each site.

Water Quality Parameters

The mean values of each physicochemical parameters at each sampling station have been presented in (Table 5). The mean surface water temperature in study stations varied between 16.54±0.23 and 19.17±0.43°C. The highest value was recorded in station KD (in mixed land use) and the lowest was in station KE (in forested site). Statistically significant differences were found among stations (ANOVA, P<0.05). This could be due to the presence and absence of vegetation cover/shading effect, anthropogenic activities in the watershed, and water depth. This result agreed with Dhinamala et al. (2015), who suggested that the surface water temperature is influenced by the intensity of solar radiation, evaporation, and river water influx. However, the maximum (8.78±0.75) mean concentration of dissolved oxygen was found in station KE (forested site) and the minimum (5.81±0.4) was in station KC (mixed land use) which indicated that temperature and dissolved oxygen had in direct relationship each other. Similar findings were reported by Vincy et al. (2012) and Deepa et al. (2016), who stated that dissolved oxygen is inversely proportional to the water temperature. Based on ANOVA there was a significant difference among stations (P<0.05).

The mean concertation of pH, total dissolved solids (TDS), total suspended solids (TSS), and conductivity were highest in station KF (downstream of the river). There were no significant differences among stations for pH, TSS, and TDS values. However, there were statistically significant differences in the value of conductivity in sampling stations. Likewise, mean concentrations of ammonia, nitrite, and soluble reactive phosphate (SRP), nitrate was higher at station KF and KB, respectively. This might have been due to agricultural fertilizer runoff, wastes from animals and humans as well as other anthropogenic activities such as washing clothes and cars which were prevalent near stations.

The Relationship Between the Water Quality Parameter and Macroinvertebrates

The relationship between the physicochemical parameter and macroinvertebrates communities illustrated in (Figure 3). The first and the second canonical axes explained 41.75% (eigenvalue of 0.066) and 30.18% (eigenvalue of 0.047) of the variation in the macroinvertebrates data respectively. The macroinvertebrates and physico-chemical correlation of the first axis were not statistically significant in a Monte Carlo permutation test (P>0.05). Based on (figure 3) the CCA ordination showed that variation benthic macroinvertebrates communities were related to temperature, conductivity, soluble reactive phosphate, nitrate, dissolved oxygen, ammonia, and other variables. In the first axis DO, TDS, pH, nitrite, ammonia and conductivity were positively correlated with Adenophlebia, Disercomyzon, Potamonute, Baetis, Afronurus, Caenis and Lumbricus. Benthic macroinvertebrates require the varied optimal temperature to survive (Singh & Sharma, 2014; Prommi & Payakka, 2015). In contrast, temperature, nitrate, salinity and soluble reactive phosphate (SRP) were negatively correlated with those macroinvertebrates. A similar result was observed in the study by Maneechan & Prommi (2015), who stated that Baetidae negatively correlated with the concentration of phosphate.

Table 5. Major water quality parameters with their (mean±SE) collected from six sampling stations from November 2019 to March 2020 study period in River Kipsinende (DO=dissolved oxygen, pH=power of hydrogen, TSS=total suspended solid, TDS=total dissolved solid)

	Agricultural		Mixed		Forested		F-value	P-value
Physico-chemical								
Temperature(c°)	16.87±0.23[bc]	17.06±0.29[b]	18.52±0.55[a]	19.17±0.43[a]	17.14±0.21[c]	16.54±0.21[b]	16.34	0.000
DO (mg/L)	7.35±0.89[ab]	6.71±0.62[ab]	5.81±0.4[b]	6.35±0.38[ab]	8.57±0.82[ab]	8.78±0.75[a]	3.23	0.014
pH	7.03±0.05	7.21±0.08	7.02±0.03	7.25±0.13	7.37±0.18	7.36±0.15	1.71	0.150
Conductivity (µS/cm)	28.89±3.1[b]	31.78±3.03[b]	32.22±1.8[b]	33.56±3.43[ab]	45±2.82[a]	39.4±2.19[ab]	4.26	0.003
TSS (mg/L)	0.06± 0.01	0.08± 0.01	0.04± 0.01	0.06± 0.01	0.08± 0.01	0.05± 0.01	2.49	0.053
TDS (mg/L)	21.27±0.65	22.47±1.4	22.78±1.54	22.91±1.04	23.41±1.22	23.04±0.99	1.11	0.367
Nutrients								
Salinity(mg/L)	0.11±0.003	0.12±0.01	0.13±0.01	0.14±0.005	0.13±0.01	0.11±0.008	1.95	0.104
Ammonia (mg/L)	0.78±0.27	0.41±0.16	0.39±0.13	0.53±0.18	1.05±0.40	0.58±0.15	1.14	0.363
Nitrate (mg/L)	2.09±0.14	2.40±0.14	1.91±0.31	2.03±0.26	2.16±0.07	1.87±0.15	0.98	0.448
Nitrite(mg/L)	0.42±0.12	0.39±0.12	0.43±0.09	0.50±0.13	0.56±0.04	0.45±0.06	0.41	0.841
Phosphate(mg/L)	0.20±0.02	0.74±0.28	0.23±0.05	0.55±0.32	0.49±0.13	0.19±0.04	1.57	0.198

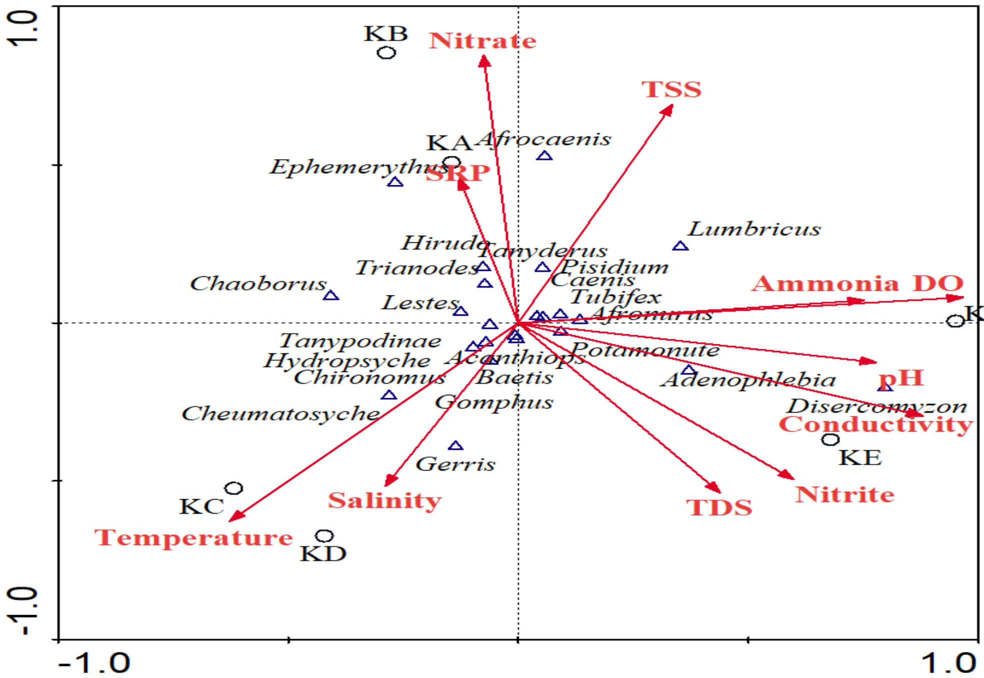

Figure 3. Canonical correspondence analysis (CCA) triplot of the macroinvertebrates with the Physico-chemical parameters in Kipsinende River.

Conclusion

Kipsinende River, just like other Kenyan rivers provide ecosystem services and livelihood for local communities that live in that place. The current study indicated that the abundance, composition, distribution, and diversity of benthic macroinvertebrates fauna of the study area was affected by deteriorating natural habitats and environmental stress. This attribute increased through human activities on the river and has negative consequences on the biotic strata of the aquatic system. This study can be used as a baseline for further studies in the area and provides information for the management and improvement of River Kipsinende and by extension to other stakeholders like ecologists, environmentalists in the Elgeyo Marakwet County, Kenya.

Ethical Statement

Not applicable.

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Author Contribution

Masresha Birara Fekadu, Simon Agembe and Clement Kiprotich Kiptum: conceptualization, designed the study, data collection and data analysis. Masresha Birara Fekadu, Simon Agembe and Minwyelet Mingist: drafting and revising of the manuscript. All authors commented on the manuscript and approved it for publication.

Conflict of Interest

The authors declare that they have no conflict of interest regarding the publication of this article.

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