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Full Length Research Paper

Macroinvertebrate Diversity and Abundance in Rivers Kipkaren and Sosiani: A Comparative Analysis within the River Nzoia Basin, Kenya

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Benthic macroinvertebrates from Rivers Kipkaren and Sosiani in the upper reaches of River Nzoia basin, Kenya, were sampled semi- quantitatively monthly from December 2006 to May 2007 using a 0.5 mm mesh size scoop net in the riffles, pools and runs. Seven sampling sites were selected on the areas of the rivers along a longitudinal gradient in relation to anthropogenic impact. Physico-chemical parameters were measured *in situ,* while specific chemical parameters were determined calometrically in the laboratory using standard methods. Habitat and land use characteristics were also recorded. A total of 1499 macroinvertebrates belonging to 13 orders, 28 families and 31 genera were collected. The orders Ephemeroptera, Hemiptera and Coleoptera were taxonomically richest. Overall, a total of 31 genera for River Kipkaren dominated by the EPT and 19 macroinvertebrate genera for the lower River Sosiani dominated by dipterans were recorded. Conductivity, oxygen and total nitrogen varied significantly ($p < 0.05$) between sampled sites, but not temporally. The results of redundancy analysis using 9 dominant macroinvertebrate genera revealed a distinction between impacted and the less impacted sites and the physico-chemical parameters associated with this distinction.

Key words: Physico-chemical parameters, impacted sites, less impacted sites.

INTRODUCTION

Running water ecosystems encompass a wide spectrum of habitats spanning a continuum from small mountain springs to immense lowland rivers. The relative narrowness of lotic systems gives them an intimate contact with their surrounding catchments including the riparian terrestrial ecosystems (Hynes, 1975). The trophic dynamics of many low-order streams is driven primarily by inputs of terrestrial leaf litter and anthropogenic influence (Junk et al., 1989). Riparian vegetation has an important role in buffering potential impacts from the catchment (Osborne and Koviacic, 1993) and interactions between large rivers and their floodplains thus, serving to maintain the biodiversity and ecological importance of rivers (Ward, 1998).

In any aquatic ecosystem, physico-chemical parameters affect macroinvertebrates either positively or negatively depending on their source. Excessive physico-chemical parameters can cause long- or short-term shifts in invertebrate community richness, abundance and species composition. An increase in nutrient, organic matter or contaminant concentrations in surface waters, sediments or food sources for instance, has been shown to result in low diversity of macroinvertebrates, with an increase in the abundance of stress tolerant species (Sarkar et al., 2002).

Macroinvertebrate species composition is a function of the trophic and saprobic states. For example, tubificid oligochaetes increase in number of individuals with organic enrichment (Ndaruga et al., 2004). The number of species seems to reduce or increase in response to the amount of available nutrients. It is however, unclear

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whether this relation is positive or negative, but slight eutrophication seems to favour increased diversity (Herrmann, 1999; Lewis et al., 2001). However, excess amounts of nutrients resulting in increased primary production and quantities of organic matter consequently, oxygen depletion, probably affects diversity negatively (Paul et al., 2001). This could be because slight changes in metabolism can probably indicate slower response to nutrient enrichment due to low nitrogen and phosphorus levels or because of less efficiency in the uptake of such nutrients by organisms (Herrmann, 1999).

In Lake Victoria basin, eutrophication has been worsening since the 1960s and currently has reduced the lake volume by 25%. This makes a quarter of the lakes' volume not to be available to most biota due to low oxygen levels (Davies and Hirji, 2003). The extent of the eutrophication is controlled by the amount of phosphorus entering the lake that primarily comes from anthropogenic activities in the entire catchment and from the inlets such as Rivers Kipakaren and Sosiani that has attracted international attention (GEF, 2004).

Due to the crucial role of the Lake Victoria basin, such ecosystems must be well managed. In order to reach this objective and for the conservation of fresh water resources in such ecosystems, the understanding of the ecological structure and function of the various biological communities such as macroinvertebrates distribution is a prior step. A point to note is that, the distribution of organisms relative to their habitat is of central importance in ecology. The nature of this distribution provides information on the types of ecological processes that regulate settlements and assemblages (Tumwesigye et al., 2000).

Therefore, benthic communities are increasingly studied (Tumwesigye et al., 2000; Ndaruga et al., 2004) and commonly used as indicators of ecological disturbance (Lewis et al., 2001) because of their sensitivity to environmental changes and ease of sampling. Benthic macroinvertebrates consist of a diverse group of long-lived, sedentary species that react strongly and often, predictability to human influences on aquatic ecosystems (Paul et al., 2001). Therefore, the study focused on macroinvertebrates assemblage in Rivers Kipakaren and Sosiani in an effort to increase our knowledge on the structure and functioning of these environments. The aim of this study was to determine the assemblage structure and the spatial distribution of benthic macroinvertebrates in relation to physico-chemical parameters.

MATERIALS AND METHODS

This study was conducted on Rivers Sosiani and Kipkaren, tributaries of River Nzoia in the Lake Victoria basin that lies between latitudes 1°30'N and 0°05'S and longitudes 34°15'W and 35°45'E at an altitude of 2000 m to 2180 m above sea level (Figure 1) with a mean annual rainfall of 1200 mm and an average temperature of 18°C (Jaetzold and Schmidt, 1983). The catchment of these rivers is under pressure due to various human activities (Njiru et al., 2008), that lowers the ecological integrity of rivers in the upper reaches of Lake Victoria Basin (Table 1). Macroinvertebrate and selected water quality data were collected once per month from December 2006 to May 2007.

Land use characteristics and bank vegetation were recorded in each of the 3 microhabitats (sampling sites) that made up a station and summarized to give a description of each station. Each station had 3 sampling sites that included riffle, pool and run, that were randomly picked to avoid bias due to spatial variations at an approximate distance of 0.5 km from another that gave a total of 21 sampling sites.

A total of 7 sampling stations were established along Rivers Kipkaren and Sosiani and sampled for macroinvertebrates and physico-chemical parameters (Figure 1). Triplicate samples of macroinvertebrates per station were taken along with water samples from the riffles, pools and runs using a scoop-net of 0.5 mm mesh size at a 1 by 1 m breadth. The following water physical and chemical parameters were recorded *in situ* at each sampling site: temperature, hydrogen-ion concentration (pH), electric conductivity and dissolved oxygen (O2) using a multi-parameter analyser WTW 340i (Wetzel and Likens, 2000). Total nitrogen and total phosphorus were analyzed according to APHA (2000) and Wetzel and Likens (2000).

The values for the physico-chemical parameters from the 3 samples from each microhabitat that made up a station were averaged to get a representative water quality measure for each station. A total of 21 macroinvertebrate samples from all the (microhabitat) sampling sites were hand-sorted and preserved in 70% alcohol and identified using a stereoscope to the lowest taxonomic level as much as possible according to Merritt and Cummins (1997) and Mathooko (1998) in relation to the local conditions.

The macroinvertebrates structure was described through mean abundance, alpha diversity such as taxon richness R (number of taxa) and Shannon diversity index (H') to $\log_{10}$ (Dajoz, 2000). The beta diversity index was applied in order to evaluate the taxonomic similarity between stations communities. We considered pairs of stations on which we applied Whittaker index (w) (Whittaker, 1972), calculated as: w = (Sr/ mean) – 1, where Sr is the total richness in each station and mean, the mean richness of both stations. Significant differences in abiotic parameters and Shannon diversity index (H') between sites were determined using Kruskal-Wallis and Mann-Whitney tests. Analyses were conducted using the software package STATISTICA version 8.0.

In addition, redundancy analysis (RDA) was carried out with CANOCO 4.5 software (ter Braak and Smilauer, 2002) to elucidate the relationships between species composition and the environmental variables. The output was displayed as a triplot, in which the plotted points for species and sites could be related to physico-chemical parameters that were represented as rays. The strength of the correlation of a physico-chemical parameter was reflected in the length of the ray and its association was reflected in the acuteness of the angle with the axis.

RESULTS

Physico-chemical parameters

The mean (± SE) values of the physico-chemical parameters measured on the water surface during the survey are mentioned in Table 2. Conductivity, oxygen and total nitrogen was significantly different among the stations (Kruskal-Wallis test; $p < 0.05$). Mann-Whitney U test performed between stations showed that, the highest

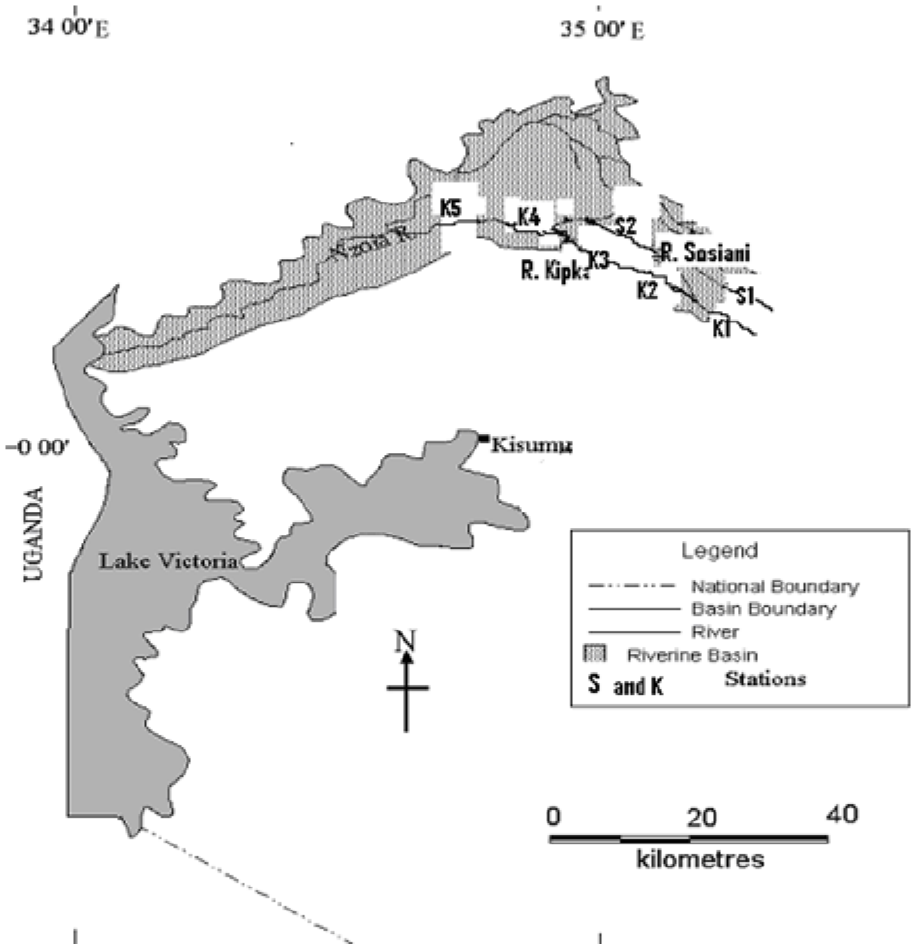

Figure 1. Sampling stations (each station was made up of a riffle, pool and a run) on Rivers Kipkaren and Sosiani during the study period.

Table 1. The altitude, physical characteristics and land use in the catchment of Nzoia River Basin, and at the stations (with riffles, pools and runs summarized from microhabitats into habitats = stations) in Kipkaren and Sosiani rivers during the study period.

Station	Altitude	GPS	Land use
K1	2180	0°35'N and 35°07'E	Swamp and grassland
K2	2160	0°35'N and 35°10´E	Forestry, agriculture and tarmac road
K3	2150	0°35'N and 35°12'E	Before confluence, dense bank vegetation.
S1	2120	0°35'N and 35°08´E	Eldoret-Huruma Sewage and urban centre
S2	2100	0°35'N and 35°14´E	Sewage and Turbo urban centre, agriculture
K4	2050	0°35'N and 35°16´E	Organic farming and bank vegetation
K5	2000	0°35'N and 35°18´E	Kipkaren Urban centre, agro-forestry and agriculture

mean conductivity and total nitrogen with the lowest dissolved oxygen was recorded at station S1.

Taxonomic composition

A total of 1499 macroinvertebrates belonging to 13 orders, 28 families and 31 genera were sampled. The analysis of taxonomic composition showed that, the orders Ephemeroptera, Hemiptera and Coleoptera were the most diverse taxa, consisting of four families each (Table 3). The highest taxonomic richness was recorded in River Kipkaren (31 taxons) when compared with those

Table 2. Mean (± SE) of Physico-chemical parameters at the seven study sites in Rivers Kipkaren and Sosiani.

	Stations							
Parameter	**K1**	**K2**	**K3**	**S1**	**S2**	**K4**	**K5**	**Kruska-Wallis test (p-values)**
Temperature (°C)	21.2± 0.0	22.2 ± 0.0	19.8 ± 0.0	22.2 ± 0.0	20.1± 0.0	22.0 ± 0.0	21.0 ± 0.0	0.64
pH	6.9 ± 0.3	6.9 ± 0.3	6.8 ± 0.5	7.1 ± 0.3	6.8 ± 0.1	6.8 ± 0.7	6.9± 0.9	0.34
Conductivity (µScm^{-1})	101.0 ± 4.0	109.0 ± 6.0	115.0± 5.0	121.8± 8.0	111.0 ± 3.0	114.0± 1.0	117.0 ± 4.0	0.04*
Oxygen (mgl^{-1})	6.4 ± 0.03	7.6 ± 0.02	5.0 ±0.03	4.0 ±0.01	5.8 ± 0.02	6.0 ± 0.07	3.9 ± 0.01	0.03*
TP (mgl^{-1})	0.05 ± 0.02	0.14± 0.02	0.34 ± 0.13	0.54 ± 0.23	0.26 ± 0.27	0.44 ± 0.31	0.49± 0.20	0.12
TN (mgl^{-1})	0.07± 0.04	0.20 ± 0.07	0.07± 0.04	0.72± 0.03	0.41± 0.14	0.17± 0.06	0.52± 0.14	0.02*

*: refers to significant p level ($p < 0.05$).

Table 3. Summarized taxanomic list of benthic macroinvertebrates found at the sampling stations in Rivers Kipkaren and Sosiani. X, means present.

Order	Family	Genus	R. Kipkaren	R. Sosiani
Ephemeroptera	Baetidae	*Baetis* sp.	x	x
	Caenidae	*Caenis* sp.	x	x
	Heptagenidae	*Heptagenia* sp.	x	x
	Ephemerellidae	*Ephemerella* sp.	x	
Hemiptera	Gerridae	*Gerris* sp.	x	
	Notonectidae	*Notonecta* sp.	x	
	Veliidae	*Velia* sp.	x	
	Corixidae	*Corixa* sp.	x	
	Nepididae	*Nepus* sp.	x	
	Belostomatidae	*Belostoma* sp.	x	
Coleoptera	Dysticidae	*Derenectes* sp.	x	
	Elmidae	*Elmis* sp.,	x	x
		Limnius sp.	x	x
	Gyrinidae	*Gyrinus* sp.	x	
	Hydraenidae	*Hydraena* sp.	x	x
Diptera	Chironomidae	*Chironomus* sp.	x	x
	Culicidae	*Culicida* sp.	x	x
Prosobranchiata	Valvatidae	*Valvata* sp.	x	
	Hydrobiidae	*Bithynia* sp.	x	
Odonata	Aeschenidae	*Aeschenia* sp.	x	
	Gomphidae	*Gomphus* sp.	x	x
	Agriidae	*Agrion* sp.	x	
Oligochaeta	Lumbriculidae	*Lumbricus* sp.	x	x
	Tubificidae	*Tubifex* sp.	x	x
Plecoptera	Nemouridae	*Nemoura* sp.	x	
	Leuctridae	*Leuctra* sp.	x	

Table 3. Contd.

Bivalvia	Unionidae	*Pisidium* sp.	x	x
		Sphaerium sp.	x	x
	Bithynidae	*Gabiella* sp.	x	x
Isopoda	Asellidae	*Asellus* sp.	x	x
Pulmonata	Lymnaidae	*Lymnaea* sp.	x	x
Trichoptera	Polycentropodidae	*Polycentropus* sp.	x	x
Hirudinea	Erpobdellidae	*Erpobdella* sp.	x	x
		Glossiphonia sp.	x	x

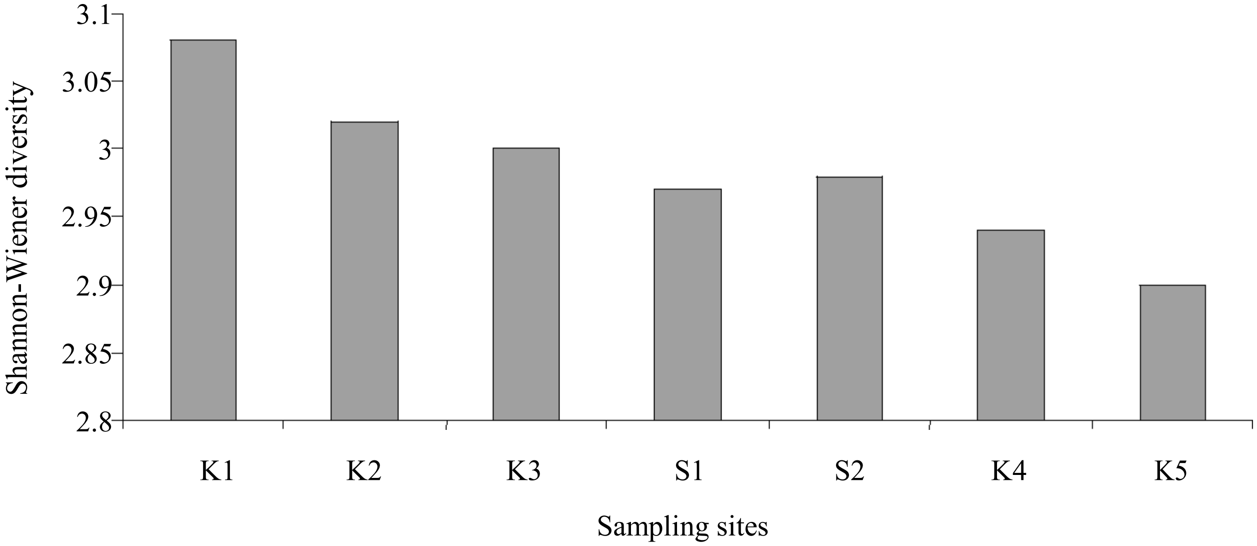

Figure 2. Shannon-Wiener diversity values based upon the sampling stations in Rivers Kipkaren and Sosiani.

of River Sosiani (19 taxons). The low values of W were observed for the K1-K3 pairs (0.36) and K2-K4 (0.40) while highest was obtained with S1-S2 (0.68), S1-K5 (0.72) and S2-K5 (0.81).

Baetis sp. was dominant in station K1 with a relative mean abundance of 29.10 ± 0.21, while *Chironomus* sp. had the lowest relative mean abundance of 0.33 ± 0.01. Station K3 experienced a high relative abundance of *Caenis* sp. (23. 12 ± 0.63) but with lowest mean relative abundance of *Pisidium* sp. (0.86 ± 0.02). *Lumbricus* sp. recorded the highest relative mean values of 19.34 ± 0.09 and 26.73 ± 0.96 in station S1 and S2, respectively. In the same stations, *Heptagenia* sp. and *Elmis* sp. were the least dominant with relative mean abundances of 0.56 ± 0.05 and 0.87 ± 0.03 in S1 and S2, respectively. *Baetis* sp. had the highest relative mean abundance of 27.78 ± 0.95, whereas, *Polycentropus* sp. had the lowest relative mean abundance value of 0.28 ± 0.06 in River Kipkaren at station K2. Station K5 was dominated by *Chironomus* sp. With a mean relative abundance of 26.1 ± 0.12, whereas, *Heptagenia* sp., had the lowest relative mean abundance of 0.74 ± 0.31. *Tubifex* sp., with a relative mean abundance of 27.56 ± 0.07 dominated stations K4 and *Elmis* sp. had the lowest relative mean abundance (0.74 ± 0.01).

The order diptera were the most abundant macroinvertebrates in River Sosiani (35 %) while the intolerant group of Ephemeroptera, Plecoptera and Trichoptera (EPT) constituted only 19%. More EPT were however, recorded in station K1 (44%), where dipterans recorded the lowest overall relative abundance of 10%. The test of Kruska-Wallis indicated significant variations of macroinvertebrates mean abundance ($p < 0.05$) among the stations.

Significant differences in Shannon-Wiener diversity index of macroinvertebrate genera was recorded among the stations (Kruskal-Wallis $p < 0.05$). Station K1 had the highest Shannon-Wiener diversity (3.08), followed by station K2 (3.02), whereas, stations K5 and K4 had the lowest diversity of 2.9 and 2.94, respectively (Figure 2).

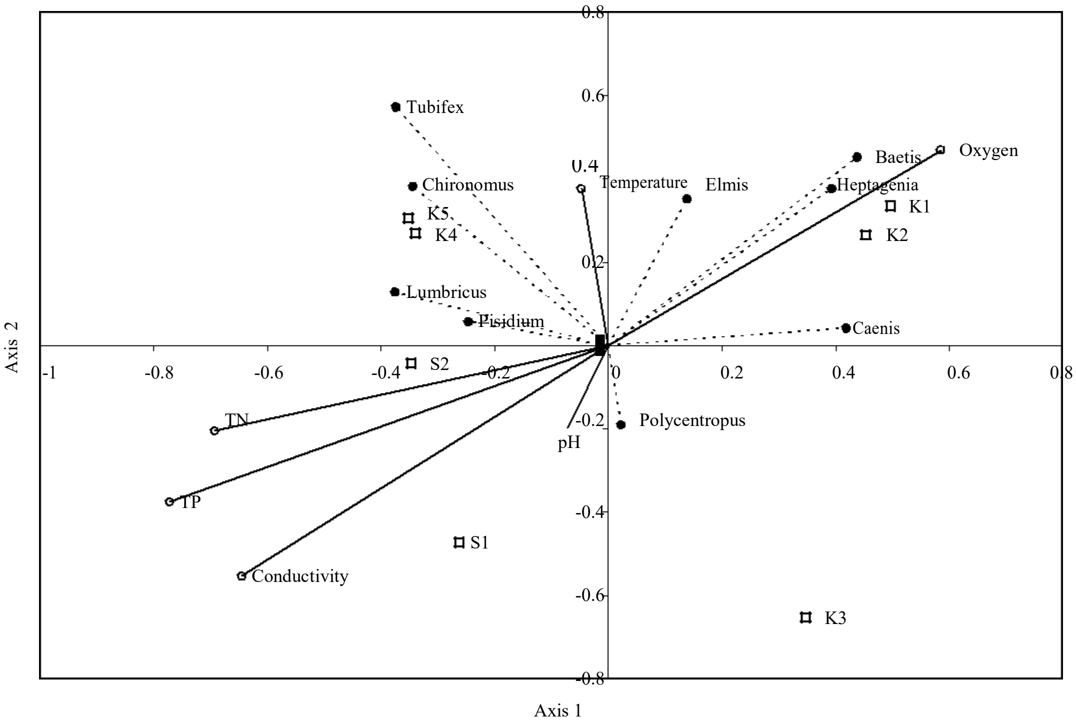

Figure 3. Redundancy analysis (RDA) diagram of sampled benthic macroinvertebrates in relation to environmental variables of Rivers Kipkaren and Sosiani.

Spatial distribution of species in relation to physico-chemical parameters

A redundancy analysis was carried out to connect principal taxons and the physico-chemical parameters. The analysis distinguished between impacted and less impacted sites and the physico-chemical parameters associated with this distinction. The result of the analysis is illustrated by Figure 3. The test of permutations of Monte-Carlo indicated the significance of all canonical axes ($p < 0.05$). Axes 1 and 2 expressed 95.4% of the information held by the biotic and abiotic factors. This axis opposed sites K1 and K2 with that of K3 characterized by high values of dissolved oxygen and the increased abundance of *Caenis* sp., *Heptagenia* sp. and *Baetis* sp. Axis 2 indicated a strong positive correlation to the total nitrogen, with moderate total phosphorus and a weak correlation with conductivity and pH. This axis characterized station S1 with the negative preferential abundance of taxons of *Tubifex* sp., *Chironomus* sp., *Lumbricus* sp. and *Pisidium* sp. The distribution of *Tubifex* sp. and *Chironomus* sp. is related to high temperatures, whereas, *Elmis* sp. prefers low temperatures.

DISCUSSION

Tolerant species like *Chironomus* sp., *Tubifex* sp. and *Lumbricus* sp. dominated stations S1, S2, S6 and K5 probably because these animals have got high glycogen content and reduced activity which allows them to withstand increased conductivity levels that were noted in the macrohabitats in such stations (Welch, 1992) that could have been caused by discharges due to urbanization in those areas. Chironomids were highly abundant in such areas probably because of high haemoglobin content in their blood (Welch, 1992). The intolerant group, mainly the EPT group, was common in stations K1, K2 and K3 because of probably less anthropogenic impact in the riparian zones in such areas. This seems to suggest the reasons for the insects like *Heptagenia* sp., *Baetis* sp., *Elmis* sp. and *Caenis* sp. being most abundant in stations of less human disturbance such as station K1 that showed high levels of dissolved oxygen (Figure 3).

Despite the differences in the number of sites sampled in both rivers, the significant differences among the mean abundance and high taxa richness of macroinvertebrates specifically in the sampled stations in River Kipkaren in comparison to River Sosiani could have been caused by changes in human activities of urbanization, agricultural inputs, sewage discharge and forested or wetland areas along both rivers. This is because, according to Matthaei et al. (2000), the micro-distribution of benthic macroinvertebrates in streams is in fact dynamic and is strongly influenced by anthropogenic impact that causes changes in conductivity, nutrients and dissolved oxygen levels. This is also in line with Margolis et al. (2001) who claim that, changes in the benthic macroinvertebrate assemblages are not determined by changes in the type and availability of food, but differences in the ability of resident genera to tolerate the environment around it (Figure 3) despite the environment determining the type of food available (Matthaei et al., 2000). For example, urbanization of a watershed may significantly alter stream water quality even in the absence of direct industrial or municipal discharges (Kari and Rauno, 1993). Despite the rainfall data being useful in interpreting seasonal differences especially with regard to urban sites, the short rains were experienced throughout the sampling period; implying that distinct variations in the rainfall pattern could be minimal. Station S1 had the highest mean value of macroinvertebrate occurrence probably due to the high abundances of tolerant taxa (of oligochaeta and some diptera genera like Chironomidae) to the discharges and sewage from the Eldoret (Huruma) municipality.

Variations in Shannon-Wiener and W values obtained could be due to variations in physico-chemical parameters related to sampling sites that could have been influenced by human activities. For example, although, modest values of conductivity were noted, high conductivity levels in S1, K4 and K5 could have influenced the osmoregulation of the aquatic invertebrates leading to sensitive freshwater organisms either to adopt or are phased out (Spiels and Mitch, 2000). Other than high conductivity levels, station K4 and K5 had a lower Shannon-Wierner diversity probably also due to the open access for livestock invasion that was evidenced in the stations. Herbivory of aquatic vegetation and nutrient input via urine and fecal deposition and trampling of sediments which was a common phenomenon in these areas, are associated to have direct impact on the river as observed by Griffith et al. (2005).

Variations were recorded in the nutrient concentrations among the stations, with an increase in concentrations downstream in both rivers. Sosiani River at station S1 had the highest levels of total phosphorus and total nitrogen possibly due to the high concentrations of nutrients discharged from Eldoret (Huruma) municipality. In addition, the presence of Kipkaren town that experiences an amalgamation of activities such as farming, agro-forestry and poor dumping of refuse could be the cause for increased levels of mainly organic matter, total nitrogen and total phosphorus in the river-water. River Kipkaren before and after the confluence, at the source and the station near the Eldoret Airport were dominated by tolerant species of the EPT group. This could be due to low pollution levels of organic matter or the dilution effect of water due to increased water volume in such areas. However, according to Barbour et al. (1999) , tolerant macroinvertebrates could be more of *Baetis* sp., which occurred in low abundances in such areas. Total nitrogen and total phosphorus concentrations at the source of Kipkaren river and at the station near the Eldoret Airport, had low nutrient levels than the rest of the stations probably due to absence of crop farming (Carpenter et al., 1998) and the cleansing effect of the swamps in their respective riparian zones. This implies that, a biological approach to ecosystem management in addition to the application of traditional monitoring to deal with point sources of contaminants should be the focus for river basin management since it was found to be sensitive to the habitat quality deterioration.

In conclusion, we may indicate that this study is a preliminary attempt to understand the spatial distribution of benthic macroinvertebrates of Rivers Kipkaren and Sosiani abundance and diversity. This study therefore, contributes to a better knowledge of such ecosystems. This study showed the tolerant species to be *Tubifex*, *Chironomus*, *Lumbricus* and *Pisidium* sp. that dominated impacted sites of both rivers. *Caenis*, *Heptagenia* and *Baetis* sp. dominated the less impacted sites of both rivers; an indication that they were intolerant. In addition, Our results allowed us to identify a total of 31 taxons for River Kipkaren dominated by the EPT and 19 macroinvertebrate taxons for the lower River Sosiani dominated by dipterans with major abiotic factors driving the taxonomic species spatial distribution.

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