Monitoring water and habitat quality in six rivers draining the Mt. Kenya and Aberdare Catchments using Macroinvertebrates and Qualitative Habitat Scoring

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Abstract

The study was conducted in June and September 2011 in six rivers that drain Mt. Kenya and the Aberdare catchments, i.e. Honi, Naro Moru, Liki, Sirimon, Mariara and Karigu. The main objective was to determine the ecological status of these rivers and identify macroinvertebrates with potential applicability as biomonitors. South African Scoring System version 5 (SASS-5), Multimetric Index (i.e. MI; values ranging from 0 = poor to natural = 1) and the Qualitative Habitat Assessment (QHA) methods were used in this study. Values more than 80% indicate largely unmodified systems (class B and A) whilst values below 40% indicate largely modified systems (classes, D, E and F). Class C (moderately modified systems fall within 60 – 79%). The highest number (16) of macroinvertebrate taxa were recorded at the Naro Moru and Mariara Rivers, while the lowest (3) was recorded at Karigu River. Macroinvertebrate abundance differed significantly among the rivers (One-way ANOVA, ($F_{(5,135)} = 3.533$, $p < 0.01$). Based on QHA, Naro Moru River could be categorized as management class B, while the rest of the studied rivers fall under management class C. On MI basis, Naro Moru, Liki and Sirimon Rivers were of good water quality (MI = > 0.6) while Honi and Mariara Rivers were of moderate water quality (MI = 0.4-0.6). Monitoring with macroinvertebrates enabled identification of anthropogenically affected rivers and placement of the study sites in their respective management classes for future interventions.

Key words: Assessment, habitat, anthropogenic, freshwater ecosystems, water quality

Introduction

Fresh water on earth constitute only 2.5 % of the total water mass and about 68.7 % of this is locked in icecaps, 29.9 % in groundwater and only 0.26 % occur in lakes, rivers and reservoirs, while the remaining occur as soil and atmospheric moisture (Carpenter *et al.*, 2011). Distribution of fresh water resource in Kenya is limited both spatially and temporally thus creating immense pressure in many parts of the country (GOK, 2002).

Water quality characteristics are an outcome of both natural processes and anthropogenic activities. Rapid expansion of farm lands has led to degradation of natural forests and wetlands. This in turn has affected the hydrological cycle since these are perceived to be the main water catchment areas. Anthropogenic activities in riparian areas are known to reduce canopy cover (Mbaka, 2010), increase sun's radiation, soil erosion and siltation in rivers (Booth and Jackson, 1997). A change in hydrological cycle is a good indicator of climate change characterized by unpredictable rain patterns, frequent droughts that threaten food security and reduction in stream flows.

Mathooko (2001) noted that small-scale anthropogenic activities along the banks and on the sediment surface of the Njoro River led to sediment compaction due to trampling by domestic animals. This in turn led to reduction of refugia for macroinvertebrates and retention of coarse particulate organic matter on the banks of this river (M'Erimba *et al.,* 2006). Streams and rivers that have been degraded are regarded as unhealthy (Meyer, 1997). "River health" is usually defined in terms of ecological integrity and is used to give a measure of the overall condition of a river ecosystem. The working definition of "river health" is: 'the ability of the aquatic ecosystem to support and maintain key ecological processes and a community of organisms with a species composition, diversity, and functional organization as comparable as possible to that of undisturbed habitats within the region' (Karr, 1999).

The need to monitor water and habitat quality changes in rivers and streams led to the development of different bioassessment protocols. For example, the Rapid Bioassessment Protocols (RBPs) have been widely used to assess ecological conditions of aquatic ecosystems (Buss & Vitorino, 2010). The specific aim of RBPs is to indicate ecological condition of an aquatic ecosystem using low-cost protocols to enable long-term and routine monitoring (Buss & Vitorino, 2010). For example, the South African Scoring System (SASS) is a RBP based on the resident macroinvertebrate community, where each taxon is allocated a score according to its level of tolerance to river health degradation (Chutter, 1994). The Multimetric Index (MI) uses a number of single metrics to assess environmental conditions. Each metric provides different ecological information about the observed community and acts as an overall indicator of the ecological condition of an aquatic ecosystem. The final MI provides a score that represents the overall relationship between the combined values of the biological parameters observed for a given site and the expected value under reference conditions (Karr & Chu, 1997). The Qualitative Habitat Assessment (QHA) is based on a qualitative rating of the major anthropogenic factors affecting river condition, such as water abstraction, flow regulation, bank erosion and channel modification (Kleynhans, 1996).

Biomonitoring of rivers can be carried out using different organisms (Li *et al.,* 2010). Among them, the most frequently used biomonitor is macroinvertebrate communities (Walsh, 2006). In comparison to other biomonitors, macroinvertebrates are advantageous because they spend most of their life cycle in water bodies, giving them the unique ability to indicate anthropogenic impacts over a long period of time. They migrate over short distances, enabling site specific assessment of ecological conditions. Being ubiquitous and diverse in nature, they can be found in most freshwater ecosystems over a wide environmental spectrum. The sizes of macroinvertebrates are visible to the human eye enabling easy identification up to family level, although species identification requires more training (Bonada *et al.,* 2006). The specific objective of the current study was to infer the quality of water and habitat , using macroinvertebrates and qualitative habitat scores, of rivers draining the Mt. Kenya and Aberdare catchments, Kenya.

Materials and Methods

Study Rivers and Sites

Six rivers located within Mt. Kenya drainage basin were studied (Figure 1). They were Honi, Naro Moru, Liki, Sirimon, Mariara and Karigu. Details of the geographic position, altitude, and physical characteristics of the biotopes are presented in Table 1. A river reach measuring 5.5 m in width and 50 m in length was chosen in the Honi River. Within this reach, runs and riffles formed 50:50 ratio and the average water depth was 0.34 m. Buffer strip of riparian vegetation close to 10 m in width was located between a farm and the river on the left bank. On the right bank there was a strip of riparian vegetation at some parts. Small scale water abstraction for domestic use by the local people was observed. The site was frequented by few domestic animals.

Figure 1: Map of Kenya showing Mt. Kenya and the Aberdare National Parks

The Naro Moru River originated from the Mt. Kenya National Park. The study site was largely a riffle that measured 55 m in length, 6.5 m in width and an average water depth of 0.38 (± 0.08) m SE, respectively. The site was less frequented by wild animals (e.g. elephants) and people. Finally, there was evidence of fire wood collection and watering of domestic animals at the downstream side.

Table 1: The geographic position, canopy cover and biotopes of each river’s study site

River	Latitude	Longitude	Elevation	Canopy cover	Biotopes
Honi	S 00°19′04.8″	E 36°54′03.5″	1880 m.a.s.l	30%	Boulders 10%,Stones 30%, Cobbles 45%, Sand 15%
Naro Moru	S 00°10′45.2″	E 7°06′43.6″	2223 m.a.s.l	90%	Boulders 40%, Stones 30%’ Cobbles 20% Gravel 5% Sand 5%
Liki	N 00°01′12.6″	E 37°05′17.6″	1939 m.a.s.l	55%	Boulders 25%, stones 50%, cobbles 10%, gravel 5%, sand and mud 10%.
Sirimon	N 00°03′18.3″	E 37°12′25.2″	2163 m.a.s.l	10%	Boulders 5%, stones 65%, cobbles 15%, gravel 10%, sand and mud 5%.
Mariara	N 00°01′27.8″	E 37°39′39.6″	1520 m.a.s.l	40%	Bedrock 85%, boulders 10%, Pebbles, gravel, sand and mud 5%.
Karigu	N 00°01′36.2″	E 37°39′50.2″	2181 m.a.s.l.	90%	Mud 95% 5% pebbles

The study site at the Liki River measured 45 m in length, 5 m width and had an average water depth of 0.21 (± 0.05SE) m. The site was frequently used as a watering point for livestock and source of water for domestic and construction purposes. A tree nursery was located next to this site and some residential houses were nearby. The Sirimon River study site was located along the Meru – Nanyuki road and measured 55 m in length, 4.5 m in width, and with average water depth of 0.32 (± 0.00SE) m. Small-scale water abstraction for domestic use was common. The site was frequented by livestock that grazed on the left bank. Small scale maize farming was observed on the right bank.

The Mariara River study site was located along the Meru – Nairobi highway and measured 50 m in length, 5.5 m in width, and had an average water depth of 0.37 (± 0.07SE) m. The banks were largely dominated by planted Napier grass and bedrock formed 85 % of the bottom substrate. The Karigu River drained a banana plantation (~ 0.5 ha) with dense planted Napier grass stands. The right bank had blue gum (*Eucalyptus* spp.) trees that provided 90% of the total canopy cover. The length of the study site was 45 m and the width was 1.5 m with an average water depth of 0.29 (± 0.00SE) m.

Chemical and Physical variables

Water electrical conductivity was measured with a WTW-LF 90 conductivity meter. Dissolved oxygen concentration was determined using a WTW-OX 192 oxygen meter, whereas pH and water temperature were determined using a combined WTW - pH 91 meter. Canopy cover was determined visually (Jesus *et al.,* 2004). Current velocity was measured at 60 % of the total water depth with a General Oceanics flow meter model 2030R. Water discharge was calculated from velocity, width and depth data following Platts *et al.* (1983) and Gordon *et al.,* (1993).

Macroinvertebrates Sampling

Macroinvertebrates were collected using both qualitative and quantitative methods. For qualitative sampling, a Kick net sampler (net size = 1mm) was used for collection of macroinvertebrates from in-stream vegetation, stones, sand and mud biotopes following Dickens and Graham (2002). The biotopes were identified from the stream banks following Wadeson & Rowntree (2001). Stones in current were sampled for 2 minutes and stones out of current, gravel, sand and mud biotopes for 1 minute. The marginal vegetation in and out of current was sampled up to 2 m stretch. Submerged vegetation was sampled over a $1m^2$ area if present. Hand-picking and visual identification was conducted for 1 minute. The samples from biotopes were placed on a white tray and identified up to the family level in the field following Gerber & Gabriel (2002).

With regard to quantitative sampling, a modified Hess sampler (effective sampling area = 0.029 m^2 and mess size 100 µm) was used for collection of benthic macroinvertebrates samples, for quantification of abundance and diversity. Sampling always started from downstream moving upstream, to minimize drift induction. The sampler was placed at the first sampling point with the front opening facing upstream and sediments enclosed within the working area (0.029 m^2) were disturbed by hand for about 30 seconds to a depth of about 10 cm. The materials that drifted into the net were removed by hand and put in well-labeled polythene bags, fixed with 4 % formalin and transported to the laboratory for further processing. In total, five samples were collected per site during each sampling occasion. In the laboratory, the samples were washed through a series of 1mm, 500 and 100 µm mesh sieves to separate invertebrates from stones, sediment and organic materials. Macroinvertebrates were picked by hand under a dissecting microscope, counted, enumerated and identified to the family level following Gerber and Gabriel (2002). Macroinvertebrates were allocated to functional feeding guilds following Meritt & Cummins (1996).

Qualitative Habitat Assessment

Qualitative Habitat Assessment was used for evaluation of in-stream and riparian modifications as described by Kleynhans (1996) and King *et al.* (2000). Two assessment criteria are involved; in-stream habitat integrity and riparian habitat integrity based on a number of key modifiers which are water abstraction, flow modification, bed modification, channel modification, water quality, indigenous vegetation removal, exotic macrophytes/fauna, and inundation among others. Impact categories ranging from 0 (no observable impact) to 25 (critically impacted) are assigned to each modifiers and multiplied by the weight provided for each modifier. The results are summed up and divided by the critical value of 25 as indicated in the formula below. The final score is used to classify the river reach as excellent, good, fair or poor management classes (Table 2).

$$100 - \left(\frac{\sum \left(Eachscore \times Eachweight \right)}{25} \right)$$

Table 2: Classes for assessment of river habitat (Adapted from King *et al.* 2000)

Class	Description	Score (%)
A	Unmodified, natural	100
B	Largely natural with few modifications. A small change from natural in habitats and biotas may have taken place, but the ecosystem functions are essentially unchanged	80 - 99
C	Moderately modified. A loss of and change from natural habitats and biotas has occurred, but the basic ecosystem functions are still predominantly unchanged	60 - 79
D	Largely modified. A large loss of natural habitats, biotas and basic ecosystem functions has occurred	40 - 59
E	The losses of natural habitats, biotas and basic ecosystem functions are extensive	20 - 39
F	Modifications have reached a critical level and the lotic system has been completely modified, with an almost complete loss of natural habitats and biotas. In the worst instances, basic ecosystem functions have been destroyed and changes are irreversible	0 - 19

South African Scoring System

The South African Scoring System (SASS-5) which is a rapid bio-assessment method for rivers was adapted in this study (Chutter 1994, 1998). This technique is the standard for the rapid bioassessment of rivers in South Africa and now forms the backbone of its National River Health Programme (Uys *et al.,* 1996). Macroinvertebrate data collected using the Kick net sampler was used for calculation of three SASS-5 indices namely; the SASS scores, Total Number of Taxa, and Average Score Per Taxon (ASPT). This was achieved by assigning each family (taxon) to a quality value (QV) according to Dickens and Graham (2002). Quality values ranged from 1-5 (highly tolerant to pollution), 6 – 10 (moderate tolerance to pollution) and 11-15 (very low tolerance to pollution. High SASS scores are indicative of good water quality. Further, the sites were assigned to ecological management classes (EMCs) by calculating the Average Score Per Taxon (ASPT) by dividing the SASS Scores by the number of taxa obtained at each site (Dickens & Graham 2002). The ASPT values were compared against assigned water quality values: < 5 = Poor (population dynamics disrupted), 5 – 6 = Fair (sensitive species lost or less abundant); 6 – 7 = Good (biodiversity largely unmodified) and > 7 = Natural (no measurable modification).

Abundance, Diversity and Multimetric Index

Macroinvertebrate data collected using the Hess sampler was used for calculation of abundance (ind. m^{-2}), Shannon-Wiener diversity index (H') (Shannon & Wiener, 1949) and the Multimetric Index (MI). The MI was calculated by combining a number of single metrics such as richness, composition, abundance, among others (Dahl, 2004). The single metrics are assumed to increase or decrease with increase in ecological degradation of river conditions. The final MI index provides a score that represents the overall relationship between the combined values of the biological parameters observed for a given site and the expected value under reference conditions. This score is expressed as a numerical value between 0 and 1. Values < 0.4 indicate poor water quality, 0.4 – 0.6; moderate water quality, 0.6 – 0.8; good water quality and > 0.8 is indicative of reference condition.

Data Analysis

Comparison of the mean macroinvertebrates abundance among the rivers was done using analysis of variance (ANOVA) (Statistical Package for Social Sciences, SPSS® version 8.0 for windows). Abundance data was log (x+1) transformed to improve normality before parametric tests (Zar, 1996) at 5% level of significance. Least Significant Difference (LSD) test was applied in multiple comparisons.

Results

Water chemistry and physical characteristics

Stream water variables determined during sampling are presented in Table 3. The highest temperature (19.7 ± 2.7°C) was recorded in the Mariara River and the lowest at Liki River. In terms of pH, the highest value was measured in the Honi River. Conductivity values ranged between 68.2 ± 9.0 µs cm^{-1} and 119.2 ± 18.5 µs cm^{-1}.

Table 3: Average chemical and physical variables recorded in Study Rivers. Un bolded values are standard errors, ±SE

	Honi	Naro Moru	Liki	Sirimon	Mariara	Karigu
Temperature (^{o}C)	**19.1** 0.9	**17.3** 1.3	**16.8** 0.3	**17.5** 0.3	**19.7** 2.7	**17.5** 1.0
Dissolved oxygen (mg/L)	**7.7** 0.1	**7.6** 0.1	**7.5** 0.0	**7.4** 0.0	**7.7** 0.3	**7.2** 0.1
Conductivity (µS/cm)	**119.2** 18.5	**68.2** 9.0	**79.6** 3.5	**83.1** 1.4	**101.1** 12.5	**68.5** 10.0
Velocity (m/s)	**0.2** 0.0	**0.4** 0.1	**0.1** 0.0	**0.2** 0.0	**0.5** 0.0	**0.9** 0.0
Discharge (m^3/s)	**0.4** 0.1	**0.8** 0.2	**0.1** 0.0	**0.3** 0.0	**1.1** 0.0	**0.4** 0.0
pH	**8.1** 0.1	**7.6** 0.2	**7.5** 0.1	**7.8** 0.1	**7.3** 0.5	**6.1** 0.4

Macroinvertebrate taxonomic groups

20 taxonomic groups of macroinvertebrates were collected in the six study rivers (Table 4). Ephemeroptera was represented by three families; Baetidae, Caenidae and Heptageniidae. The latter two families were absent in Karigu River. Chironomidae was present in all rivers, but Collembola and Culicidae were only found in Sirimon River. The Naro Moru and Mariara Rivers had the highest number of macroinvertebrate taxa, while while the Karigu River had the lowest number of macroinvertebrate taxa (Table 4). Ephemeroptera, Plecoptera and Trichoptera (% EPT) was highest at the Sirimon (70 ± 3) and Liki (57 ± 5) Rivers and lowest (39 ± 9) at the Mariara River (Figure 3).

Table 4: List of macroinvertebrates collected from the six rivers and their associated quality values (QV). Occurrence of a taxon/family is indicated with a + sign. Question mark (?) means QV assignment was not possible.

Taxa	Honi	Naro Moru	Liki	Sirimon	Mariara	Karigu	QV
EPHEMEROPTERA							
Baetidae	+	+	+	+	+	+	**4**
Caenidae	+	+	+	+	+		**6**
Heptageniidae	+	+	+	+	+		**13**
DIPTERA							
Ceratopogonidae	+	+	+	+	+		**5**
Chironomidae	+	+	+	+	+	+	**2**
Simuliidae	+	+	+	+	+		**5**
Culicidae				+			**1**
TRICHOPTERA							
Hydropsychidae	+	+	+	+	+		**6**
COLEOPTERA							
Elmidae	+	+	+	+	+		**8**
Helodidae		+	+		+		**12**
PLECOPTERA							
Perlidae	+	+	+	+	+		**12**
PELECYPODA (Bivalvies)							
Sphaeridae	+	+	+				**3**
ANNELIDA							
Oligochaetes	+	+	+	+	+	+	**1**
HEMIPTERA (AQ. BUGS)							
Gerridae (water striders)		+			+		**5**
HYDRACARINA (Mites)							
Water mites	+	+	+		+		**8**
ODONATA							
Coenagrionidae	+			+	+		**4**
CRUSTACEA							
Ostracoda	+	+	+	+	+		**?**
Copepoda				+	+		**?**
Potamoneutidae		+					**3**

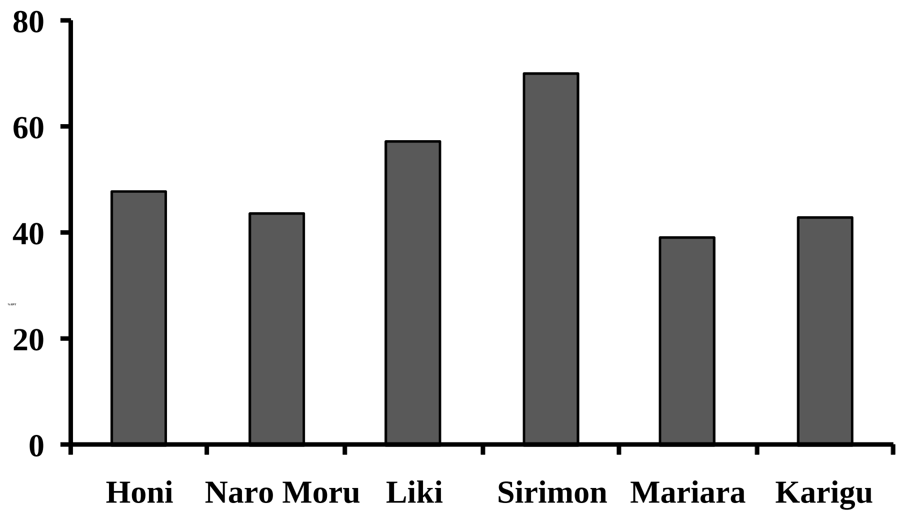

Figure 3: Percent EPT taxa in the study rivers.

Macroinvertebrate abundance, diversity and feeding groups

Macroinvertebrate mean abundances ranged from 70.4 (± 14.37) to 1176.72 (± 240.2) ind. m^{-2} (Figure 4). The Liki (1176.72 ± 240.2 ind. m^{-2}) and the Sirimon (1041.67 ± 212.63 ind. m^{-2}) Rivers had the highest mean abundances while the Karigu River (70.4 ± 14.37 ind. m^{-2}) had the lowest mean macroinvertebrate abundance. One way Analysis of Variance (ANOVA) indicated statistically significant difference in the macroinvertebrate mean abundance among the study rivers ($F_{(5,135)} = 3.53$, $p < 0.01$) with the Karigu River having the least densities (LSD, $p = 0.001$).

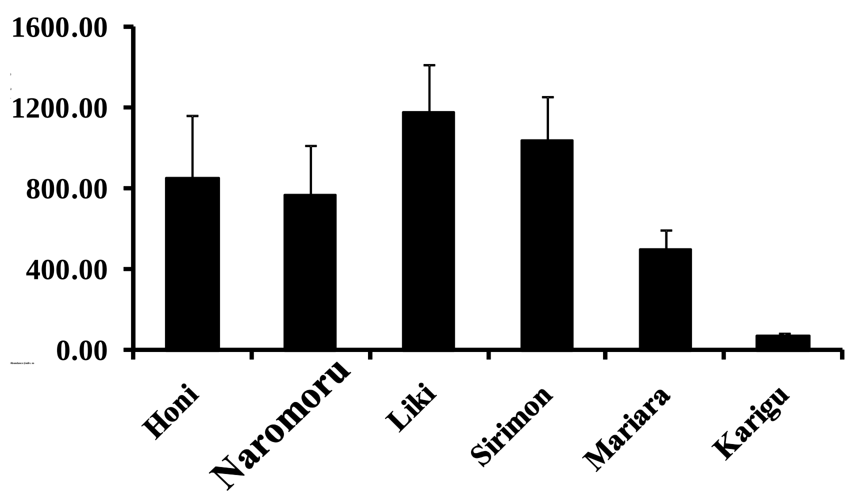

Figure 4: Mean macroinvertebrate abundance for the six study Rivers. Vertical bars are ± SE.

Baetidae mean densities among the study rivers differed significantly (One-Way ANOVA; $F_{(5, 44)} = 12.517$, $p < 0.001$) (Table 5). Post hoc analysis (LSD = 0.001) indicated that the Karigu River had the lowest mean Baetidae abundance. Similarly, the Karigu River had statistically significant lower abundances of Chironomidae and Plecoptera than the other rivers.

With regard to macroinvertebrate diversity, the highest diversity (*H´*) was recorded at the Mariara River (1.72) while the lowest macroinvertebrate diversity value was recorded at the Karigu River (0.38) followed by the Honi River (1.12) (Figure 5).

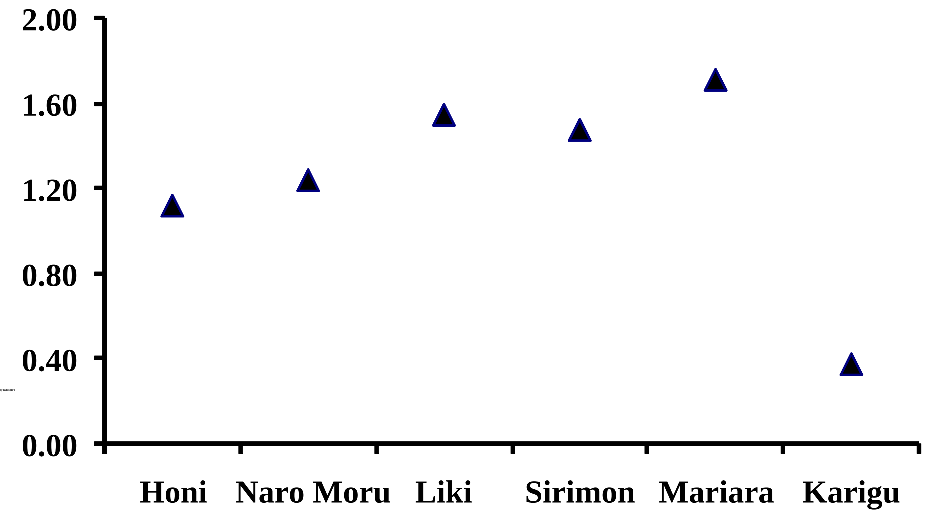

Figure 5: Shannon-wiener diversity index (H´) values for the study rivers.

Table 5: Mean abundance values of the major macroinverterbrate taxa. Bolded values are means, ± SE, n = 15. Values are n.s. = not significant, * = p < 0.1, ** = p < 0.01 and *** = p < 0.001.

Taxa	Honi	Naro Moru	Liki	Sirimon	Mariara	Karigu	Anova
Chironomidae	**1871.3**	**1551.7**	**1724.1**	**1172.4**	**558.6**	**137.9**	**12.517*** **
	473.7	285.6	396.9	183.4	145.2	65.4	
Baetidae	**1282.8**	**855.2**	**1951.7**	**965.5**	**565.5**	**165.5**	**7.858*** **
	246.7	93.8	493.2	214.8	117.7	139.8	
Oligochaetes	**223.0**	**632.2**	**96.6**	**48.3**	**503.4**	**34.5**	**1.746**$^{n.s}$
	88.0	224.6	96.6	48.3	317.8	26.7	
Plecoptera	**356.3**	**446.0**	**1951.7**	**2241.4**	**213.8**	**0.0**	**6.529*** **
	154.0	101.0	493.2	512.2	84.7	0.0	

Gatherer-collectors (GCOL) dominated all the six rivers, forming more than 50% of the total macroinvertebrates (Figure 6). Predators (PRED) dominated Sirimon River, forming 44% of the total macroinvertebrates, whereas none were found in Karigu River. GCOL formed 100% of the macroinvertebrates found at the Karigu River. Shredders (SHR) and scrapers (SCR) were absent in all the study rivers but there were few filtering-collectors (FLT).

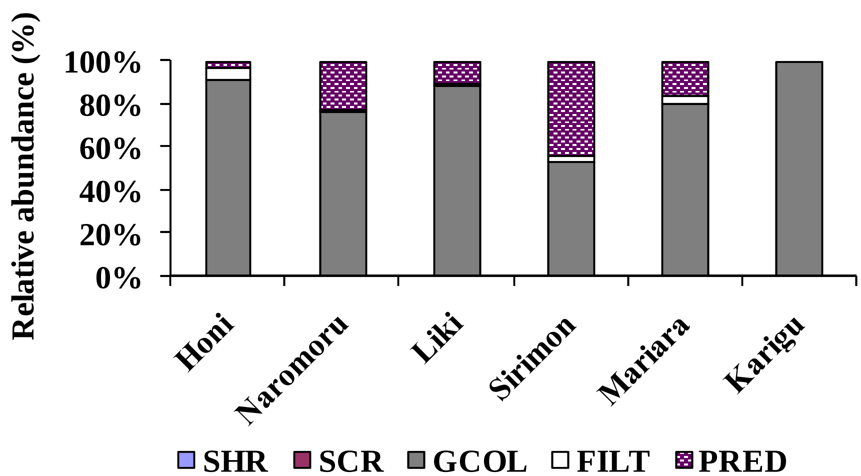

Figure 6: % abundance of macroinvertebrate feeding groups in the six rivers (SHR-Shredders, SCR-Scrappers, GCOL-Collector-Gatherers, FLT-Filterers, PRED-Predators).

Qualitative Habitat Assessment

QHA scores ranged from 59.7 to 82.5 % (mean = 70%). The highest QHA score was recorded at Naro Moru River (82.5%) while the lowest QHA scores were recorded at Honi (60.1%) and Liki (59.7%) Rivers (Figure 7). QHA scores for all rivers were generally > 50% (Figure 7).

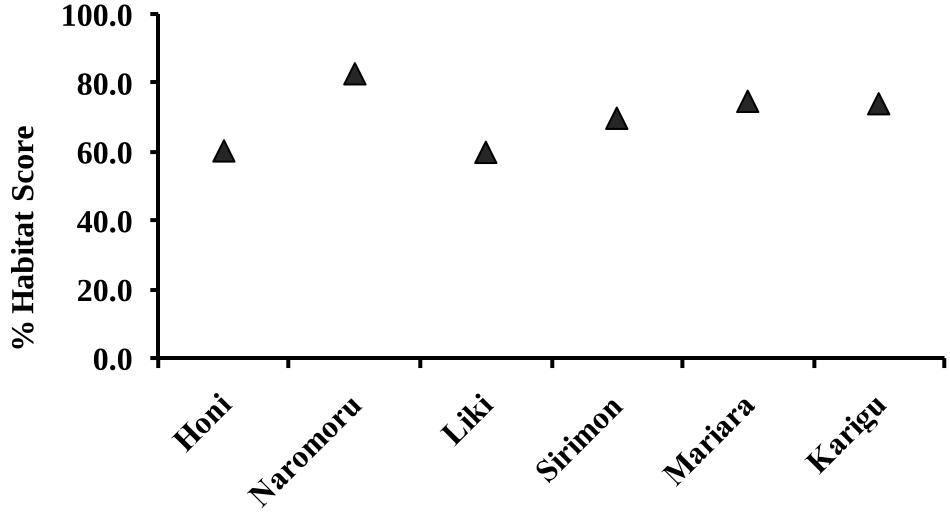

Figure 7: Qualitative habitat assessment (QHA) scores determined for the six rivers

South African Scoring System

SASS scores ranged from 57 to 165 (mean = 106.7). The highest SASS scores were recorded at the Honi (165), the Liki (140) and the Sirimon (119) Rivers, while the lowest (57) SASS score was recorded at the Karigu River (Figure 8). The ASPT obtained ranged from values of 6 at the Karigu River to 9 at the Sirmoni River. The Naro Moru and the Liki Rivers had an ASPT score of 8 whilst the Mariara and the Honi had a score of 7 per site.

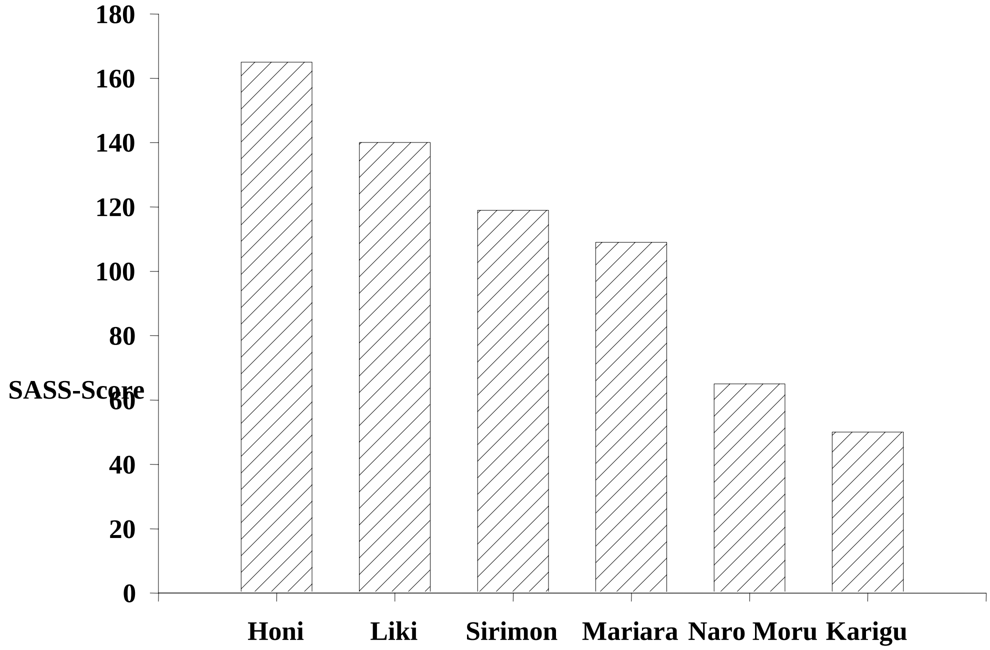

Figure 8: SASS scores determined in the six study rivers

With regard to macroinvertebrates tolerance to pollution, dipterans had the lowest QV values (1-5). Also Oligochaetes, Sphaeridae, Gerridae and Potamoneutidae had similar QV values. Plecoptera (e.g., Perlidae), coleopterans (e.g., Helodidae) and ephemeropterans (e.g., Heptageniidae) had the highest QV values (12-13) (Table 6).

Multimetric Index (MI)

The MI values obtained from the six rivers ranged from 0.33 to 0.68. The Karigu River had a mean value of 0.33, the Mariara and the Honi Rivers had 0.53 and 0.58, respectively (Figure 9).

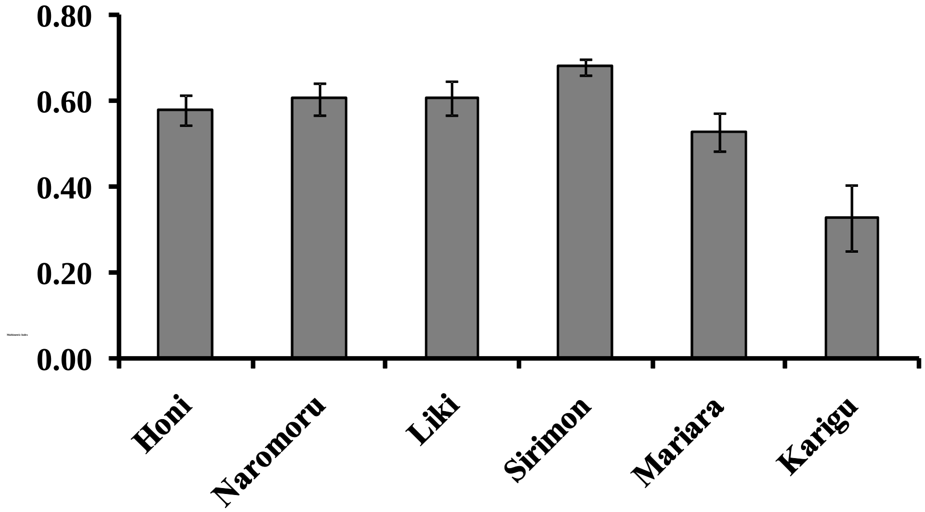

Figure 9: Multimetric Index values for the six rivers

Discussion

The mean physical and chemical variables measured in this study were similar to those measured by other studies conducted in the same catchments (e.g., Dobson *et al.,* 2007). The Karigu River had the lowest number of macroinvertebrate taxa, % EPT, diversity (*H′*) and mean macroinvertebrate abundance. The surrounding land at the Karigu River study site was a banana plantation and most of the native vegetation had been cleared. Furthermore, the Karigu River bottom substrates were dominated by mud and this could have affected some macroinvertebrate negatively. The distribution, diversity and abundance of macroinvertebrates in aquatic systems are influenced by substratum particle size and substratum heterogeneity promotes different macroinvertebrate taxa (Brooks, 2003). For example, while Chironomidae are adapted to living in aquatic systems dominated by mud substrates, EPT taxa are influenced negatively (Demars *et al.,* 2012). Gatherer-collectors dominated the macroinvertebrates collected from the study rivers, while no shredders were recorded. This finding is in line with previous studies, which documented paucity of shredders in tropical streams (e.g., Tumwesigye, 2000; Dobson *et al.,* 2002). This finding remains unexplained and is worthy of further investigation to determine whether it was as a result of trophic flexibility by some taxa or unpalatability of coarse plant organic materials by shredders.

The highest Quality Habitat Score (QHA) scores were recorded at the Naro Moru River, while the lowest QHA scores were recorded at the Liki and the Honi Rivers. This may be attributed to the fact that there were less anthropogenic activities at the Naro Moru River. Anthropogenic influences (e.g., cattle grazing, watering of plants and farming) were evident at the Liki and the Honi Rivers. Anthropogenic activities affect habitat quality both at the riparian zones and in rivers (Mathooko & Kariuki, 2000; Mathooko, 2001). According to the classification of Kleynhans (1996), on the basis of QHA scores, the Naro Moru River study site could be placed in the category B (80-99%: slightly modified site) where a slight change in natural habitats and biota could have taken place. The rest of the rivers were in class C (60-79%: moderately modified), where a loss and change from natural habitat and biota could have occurred.

The SASS scores were highest at the Honi, the Liki and the Sirimon Rivers, while lower SASS scores were recorded at the Naro Moru, the Mariara and the Karigu Rivers. This was contrary to our expectations because more preserved sites (e.g. Naro Moru River) had lower SASS scores. Unlike QHA which integrates both riparian and in-stream habitat conditions, SASS scores rely on the diversity of in-stream habitat areas (e.g. mix of mud, cobbles, bedrock). Therefore, it is plausible that the diversity of river habitats recorded at the study sites had an influence on SASS scores (Table 1). For example, the Mariara and the Karigu Rivers were largely dominated by bedrock and mud biotopes (Table 1) and this could have influenced SASS scores, based on availability of habitats for specific taxonomic groups of macroinvertebrates (Dickens & Graham, 2002). Based on Average Score Per Taxon (ASPT), the Karigu River (ASPT = 6) could be placed in Fair (heavy impact) Ecological Management Class (EMC) whilst the Mariara (ASPT = 7) and the Honi (ASPT = 7) Rivers could be placed in Good (slight impact) EMC category. The other study sites in the Naro Moru, the Sirmoni and the Liki Rivers (ASPT = > 7) were categorized as Natural (minimal impact) (Table 7).

Table 7: SASS 5 Ecological (health) Categories and their attendant Ecological and Management perspective (Dickens & Graham 2002)

Ecological Categories	Ecological perspective	Management perspective
Natural	No or negligible modification of instream and riparian habitats and biota	Protected rivers; relatively untouched by human hands; no discharges or impoundments allowed
Good	Ecosystem essentially in good state; biodiversity largely intact	Some human-related disturbance but mostly of low impact potential
Fair	A few sensitive species may be lost; lower abundances of biological populations may occur	Zones of competing users; developmental pressures are dominant feature
Poor	Habitat diversity and availability have declined; mostly only tolerant species present; species present are often diseased; population dynamics have been disrupted (e.g. biota can no longer breed or alien species have invaded the ecosystem)	Often characterized by high Human densities or extensive resource exploitation. Management intervention is needed to improve river health- e.g. to restore flow patterns, river habitats or water quality.
Seriously Modified	Loss of habitat availability and high levels of pollution, result in few families being present due to the loss on most intolerant forms.	Often characterized by high human densities, pollution or extensive resource exploitation and modification. Management intervention is needed for improvement to occur.

Macroinvertebrates such as Diptera, Oligochaeta and Spaeridae were assigned low Quality Values (QV), while Coleoptera (Helodidae), Plecopterans (Perlidae) and Ephemeropterans (Heptageniidae) had the highest QV. It was not possible to assign pstracods and copepods to any QV because they are normally smaller than 1 mm and are t difficult to identify with a naked eye in the field and thus are given less attention (Graham pers. Coms). Macroinvertebrates such as Trichoptera and Coleoptera are sensitive to pollution and their lack in some sites (e.g. Karigu) is indicative of degraded habitat (Olomukoro & Dirisu, 2014).

The highest MI values were recorded in the Sirimon River, followed by the Liki and the Naro Moru Rivers. Based on MI approach, three rivers could be regarded as of good water quality (Liki, Sirimon and Naro Moru), while the Honi and the Mariara Rivers had moderate water quality with the Karigu River being of poor water quality. It is surprising to note that just as in SASS 5 ASPT classification, three rivers (Liki, Sirimon and Naro Moru) could be placed in a similar water quality class whilst two (Honi and Mariara) were had similar water quality. Consistently, the Karigu River differed with the rest in terms of water quality. MI was also able to distinguish rivers with degraded habitats in other studies (e.g. Emery *et al.,* 2003).

Conclusions and Recommendations

The six rivers studied were well oxygenated (O_2 >7 mg/L) with temperatures well above 16°C. The Karigu River had the lowest mean macroinvertebrate abundance and diversity. Collector-Gatherers (GCOL) dominated in the studied rivers but no shredders and scrapers were recorded. Macroinvertebrates can be applied in biomonitoring of ecological conditions of Kenyan rivers. It is recommended that further investigations should be carried out to establish the utility of macroinvertebrates as biomonitoring tools at larger spatial scales and that a national biomonitoring programme should be established. The role of disturbance in maintaining macroinvertebrate diversity should be considered when interpreting SASS scores in future to avoid misrepresentation of facts since study sites in rivers that experience moderate disturbances (midstream sites) had the highest SASS scores, unlike sites in more forested areas like upstream of the Naromoru River. There is a need to employ other indices like MBI (Macroinvertebrate Biotic Indices), including the QHA and MI, during biomonitoring in order to get an integrated view of river habitat based on different indices. Finally, it is recommended that detailed documentation (inventory) of the invertebrates in Kenyan rivers be made for the purposes of management of these ecosystems in future.

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