Macroinvertebrate Functional Feeding Groups in a High-Altitudetropical Stream (A Case Study of Gura River in Central Kenya)

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Abstract

Functional feeding groups (FFGs) classification of aquatic macroinvertebrates is an important tool that enhances the knowledge of trophic dynamics in tropical streams by assigning the benthic community into trophic guilds. The current study aimed at determining the relative abundance, distribution and the factors influencing macroinvertebrate functional feeding groups along Gura River. Macroinvertebrates were collected between November and December 2018 in seven sites along the Gura River from an altitude of 2977 to 1547 metres above sea level (m. a.s.l). At the same time, selected physical chemical variable were measured *insitu* at every site. Dissolved oxygen concentration, water temperature, electrical conductivity pH and turbidity had a significant difference among the sites ($p < 0.05$). Nitrates and phosphate had a significant difference among sampled sites($p < 0.05$) except NO_2-N (one-way ANOVA, $F_{(6,14)} = 2$, $p=0.085$). A total of 4016 macroinvertebrates specimen were collected belonging to 9 orders and 28 families and assigned into 5 respective FFGs. Overall, scrapers, dominated by Heptageniidae (*Afronurus*) had the highest relative proportion (42%) of FFGs in all the sites. Collector-filters percentage proportion was second highest with a relative proportion of (27%). Collector-gatherers FFG had a percentage proportion of (22%) from all the study sites. Shredders and predators were the least represented functional feeding groups with proportions of 6% and 3% respectively.

Keywords: Functional feeding groups (FFGs), Gura, Scrapers, Shredders, Predators

Introduction

Benthic macroinvertebrates are among the dominant groups of stream and river habitats aquatic ecosystem (Rosenberg and Resh 1993). Functional feeding groups (FFGs) classification of aquatic macroinvertebrates is important tool that enhance the knowledge of trophic dynamics in tropical streams by assigning the benthic community into trophic guilds (Cummins, 1993). Macroinvertebrates feeding strategies are traits that reflect the adaptation of species and they could form part of a unified communities differing in taxonomic composition (Statzner *et al.,* 2004). An imbalance in functional feeding groups can result in case of unstable food dynamic, therefore, reflecting a stressed condition. Aquatic benthos plays a vital role in aquatic systems serving as a linkage to the bottom -up and top-down flow of materials and energy in the aquatic food web(Wallace and Webster,1996). Macroinvertebrates for a long time have been used as surrogate of ecosystem attributes, and the relative abundance of functional groups can reflect anthropogenic impact in aquatic systems (Masese *et al*., 2014; Merrit *et al*., 2002; Merrit and Cummins, 2006).

Naturally, macroinvertebrate occurrence, abundance and distribution in rivers and streams is determined by several factors such as, flow velocity, width of the river, pH, temperature, and dissolved oxygen (Vannote *et al*., 1980). River morphology, hydrologic aspects, and the importance of riparian vegetation change along the upstream-downstream gradient and shape the biological communities. The upstream reaches of the river are dominated by the shredders which break large leaves from coarse particulate organic matter (CPOM) to fine particulate organic matter (Vannote *et al*., 1980). The functional feeding guild changes from shredders to collectors as the energy input changes downstream. The collectors are further categorized into collector-filters and collector -gatherers. In the middle reaches of a river the functional feeding group is predominated by the grazers or scrapers which tend to feed on the available diatom. The downstream river reach is dominated by the collectors and predators (Vannote *et al*., 1980).

Freshwater ecosystems are among the most threatened habitat types. The world's greatest challenges to freshwater ecosystems in the coming decades will be biodiversity loss, water shortages and climate change (Dudgeon, 2010). Globally, land use change has led to loss of diversity and major shifts in the structural and functional organization of macroinvertebrates in streams (Allan, 2007). In Kenya and other East Africa countries, land cover changes and unsustainable land use being witnessed present other set of environmental challenges (FAO 2010). The loss of riparian forest has been found to increase the river temperatures through loss of shade and can affect the macroinvertebrates community (Baxter *et al*., 2005). Riparian deforestation is a major threat to the shredder taxa because it can result to elimination of their food sources.

Most of the shredder taxa are adapted to cold water conditions and might be susceptible to increased water temperatures in the tropics (Masese *et al*., 2014; Iron and Cathy, 1994). Other anthropogenic activities, such as agriculture and urbanization are known to impair aquatic ecosystem functioning worldwide (Li *et al*., 2018; Fernandes *et al*., 2019). The freshwater ecosystems in the world also face threat from several stressors such as pollution which can shape the macroinvertebrates community in local and catchment scale (Ormerod *et al*., 2010).Therefore, the main objective of this study was to determine relative abundance, distribution and the factors influencing macroinvertebrate functional feeding groups along Gura River.

Materials and Methods

Study Area

The Gura River is a fast-flowing river in Nyeri County running from an altitude of 2977 to 1547 m a.s.l. Its source is the Aberdare ranges, one of the major water catchment areas in Kenya. Gura River changes from 1st to 2nd and finally to 3rd order stream from upstream to downstream sites. The river has several tributaries from the source to the mouth amongst them is Mumwe, Maragoya, Thuti, Chinga, Gikira and Kiro (Figure 1). The Gura River lies between latitude (0°29′S, 0°31′S) and longitude (36°45′ E - 37° 12′E). Intensive small-scale agriculture is the main human activity along the Gura watershed catchment.

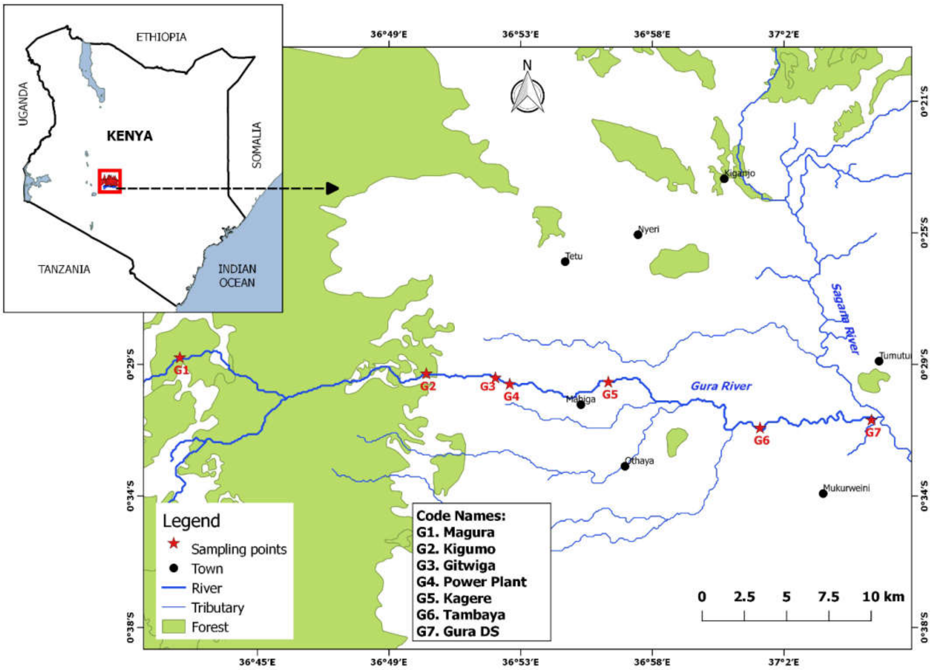

Figure 1: Location of study area in Kenya and sampling sites along Gura River

The Sampling sites along Gura River were selected based on accessibility and availability of suitable biotopes (Table1). The most upstream site (G1) and G2 are within Aberdare National Park, an area without human activity. The other five sites are outside the forest and the main human activity is subsistence agriculture.

Table1: Characteristics of sampling sites along Gura River with code, distance from source, geographical coordinates, and altitude

Site code	Site name	Distance from source (km)	Coordinates		Altitude (m)
			Latitude	Longitude	
G1	Magura	6.58	0°29′ 11″S	36°42′ 28″E	2977
G2	Kigumo	21.64	0°29′ 42″S	36°50′ 20″E	2046
G3	Gitwiga	26.56	0°29′ 42″S	36°52′ 32″E	1911
G4	Powerplant	26.68	0°29′ 57″S	36°52′ 59″E	1879
G5	Kagere	32.72	0°30′ 01″S	36°56′ 08″E	1746
G6	Tambaya	43.04	0°31′ 25″ S	37°00′ 58″E	1562
G7	Gura downstream	50.30	0°31′ 10″S	37°04′ 32″E	1547

Water Quality Parameters

Dissolved oxygen concentration (mgL^{-1}), water temperature (^oC), electrical conductivity (μScm^{-1}) and pH were measured *in-situ* using the universal multimeter (Model: HACH HQ40d, USA) prior to macroinvertebrates sampling. Turbidity was measured *in-situ* using the HACH 2100Q Portable Turbidity Meter. The measurement of physico-chemical parameters was done in triplicates and the mean value calculated for each site.

Triplicate water samples were collected from all the sampling sites using 1 litre acid -washed sample bottles for nutrient analysis, which included nitrite-nitrogen (NO_2-N), ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), Soluble Reactive Phosphorus (SRP), and Total Phosphorus (TP).Water sample filtration was done *insitu* using a filtration unit that used a 47mm diameter Whatman GF/F Glass microfiber filters with 0.42mm thickness and 0.7 µm pore size. The water samples were well labelled and stored immediately in a cooling box for further analysis of nitrates and phosphates at Egerton University Limnological laboratory. Analyses of nitrates and phosphates concentrations were determined calorimetrically following sodium-salicylate method (APHA, 2004).

Field Sampling of Macroinvertebrates

A river stretch of 100 m was selected within each sampling station based on accessibility and availability of suitable biotopes. Multi habitat sampling design was employed in this case according to Aquem Consortium 2002. Macroinvertebrates samples were collected using a hand net of mesh size 500 µm with a frame size measuring 25cm x 25cm from pools, runs and riffle within 100mriver reach. Macroinvertebrate sampling within a site started from downstream moving towards upstream to minimize drift induction. Macroinvertebrates samples were collected for 12 days during the month of November and December 2018. The samples were put in well labelled sampling containers containing 4% formaldehyde for preservation and transportation to Egerton University for sorting, identification, and enumeration.

Laboratory Sorting and Identification

Macroinvertebrates samples were sorted by passing the samples through a set of sieves to remove debris and separate benthic macroinvertebrates size classes. Benthic macroinvertebrates trapped in the big fraction of the sieve were sorted by naked eyes. Other trapped organisms in the smaller sieve fraction were sorted with an aid of a dissecting microscope at 400X Magnification. Macroinvertebrates were identified and finally enumerated up to family and genus level where possible using several identification guides (Gerber and Gabriel 2002; Merritt *et al*. 2008). The identified macroinvertebrates were assigned to their respective functional feeding groups based on the existing literature by (Merritt and Cummins 2008) as shown in Table 2.

Table 2: Functional feeding groups (FFG)-Scrapers (Sc), Collector-gatherers (Cg), Collector-filterers (Cf), Shredders (Sh)-assigned to the genera of aquatic macroinvertebrates.

Order/family	FGGs	References
ANNELIDA	Cg	Merritt *et al*., 2008
Oligochaeta		
CRUSTACEA	Sh	Merritt *et al*., 2008
Potamonautidae*(Crabs)		
COLEOPTERA		
Scirtidae	Sc	Merritt *et al*., 2008
Psephenidae	Sc	Merritt *et al*., 2008
Elmidae (*Potamodytes*)	Sc	Merritt *et al*., 2008
DIPTERA		
Tipulidae	Sh	Merritt *et al*., 2008
Simuliidae	Cf	Merritt *et al*., 2008
Chironomidae	Cg	Merritt *et al*., 2008
Athericidae	Pr	Merritt *et al*., 2008
Muscidae	Pr	Merritt *et al*., 2008
Tabanidae	Pr	Merritt *et al*., 2008
EPHEMEROPTERA		
Baetidae (*Baetis*)	Cg	Merritt *et al*., 2008
Baetidae (*Afrobaetodes*)	Cg	Merritt *et al*., 2008

Baetidae (*Rheoptilum*)	Cg	Merritt *et al*., 2008
Heptageniidae (*Afronurus*)	Sc	Merritt *et al*., 2008
Caenidae (*Caenis*)	Cg	Merritt *et al*., 2008
Leptophlebiidae	Cg	Merritt *et al*., 2008
Prosopistomatidae	Sc	Merritt *et al*., 2008
Oligoneuridae	Cf	Merritt *et al*., 2008
Dicercomyzidae	Sc	Merritt *et al*., 2008
Polymitarcyidae	Cg	Merritt *et al*., 2008
Tricorythidae	Cg	Merritt *et al*., 2008
Ephemerythidae	Sc	Merritt *et al*., 2008
ODONATA		
Aeshnidae	Pr	Merritt *et al*., 2008
Libellulidae	Pr	
PLECOPTERA		
Perlidae (*Neoperla*)	Pr	Merritt *et al*., 2008
TRICHOPTERA		
Hydropsychidae	Cf	Merritt *et al*., 2008
Philopotamidae	Cf	Merritt *et al*., 2008
Lepidostomatidae	Sh	Merritt *et al*., 2008
Leptoceridae	Cg	Merritt *et al*., 2008

Data Analysis

Descriptive statistics (mean and standard deviation) were applied for the physico-chemical water parameters and nutrients and presented using a table. We used one-way analysis of variance (ANOVA) to test the differences in physico-chemical water parameters and nutrients. For macroinvertebrates analyses, different taxonomic levels (i.e. family) were used to produce bar graphs of percentage proportion of functional feeding groups. PCORD version 5 was used to perform principal component analysis between the water quality parameters and the functional feeding groups.

Results

Water Quality Parameters

All the physico-chemical parameters had a significant difference between the sampled sites ($p < 0.05$) Table 3b. The mean ± standard deviation of water quality parameters in Gura River are presented in Table 3: Temperature showed an increase in trend from upstream sites to downstream sites with the highest value at G5 (19.60±0.26°C) and the lowest G1 (13.77±0.47°C). DO range at each sampled site was above 7mgL^{-1}with the highest measurement at G3 (8.35±0.08 mgL^{-1}) and lowest at G1 (7.34±0.12 mgL^{-1}). pH range increased from upstream to downstream with highest measurement at G6 (7.51-7.55) and lowest at G16 (70-7.20). Turbidity showed similar trend in increase from upstream to downstream with highest measurement at G7 (61.73±3.09 NTU) and lowest at G4 (9.43±0.66 NTU). Electrical conductivity increased from upstream to downstream with the highest measurement at G7 (40.17±0.21µScm^{-1}) and lowest at G1 (12.77±0.03µScm^{1}). Total phosphorus concentration was highest at G7 14.02±1.79µgL^{-1} and lowest at G1 2.39±0.07µgL^{-1}.while SRP was highest at site G7 (6.74±1.17µgL^{-1}) and lowest at G1 (3.20±0.57µgL^{-1}). Most of the nitrates and phosphate nutrients had a significant difference between sampled sites except NO_2-N as demonstrated by analysis of one -way variance ANOVA ($F(6,14) = 2$, $p=0.085$).

Table 3a: Mean values and Standard deviation for Water Quality Parameters of Gura River in November 2018

Parameter	G1	G2	G3	G4	G5	G6	G7
Temperature (^oC)	13.77±0.47	15.10±0.26	15.60±0.26	18.53±0.25	19.60±0.26	17.43±0.25	18.87±0.57
DO (mgL^{-1})	7.34±0.12	8.24±0.60	8.35±0.08	7.97±0.06	7.76±0.04	8.29±0.72	8.04±0.15
Electrical Conductivity (μScm^{-1})	12.77±0.03	21.55±0.13	23.87±0.15	23.30±0.10	26.10±0.10	34.83±0.21	40.17±0.21
pH	6.70-7.20	7.30-7.76	7.43-7.79	7.50-7.64	7.51-7.55	7.45-7.95	7.46-8.41
Turbidity (NTU)	11.17±0.12	31.43±2.60	13.37±1.91	9.43±0.66	13.33±1.43	43.63±3.76	61.73±3.09
NH_4-N (μgL^{-1})	6.58±0.64	7.94±0.00	5.12±1.60	7.26±1.62	6.83±0.39	5.21±2.24	5.38±1.42
NO_2-N(μgL^{-1})	1.79±0.65	0.99±0.37	1.09±0.62	0.99±0.31	0.89±0.25	1.74±0.43	1.64±0.29
NO_3-N(mgL^{-1})	0.36±0.04	0.78±0.08	0.58±0.06	0.55±0.01	0.56±0.05	0.37±0.34	0.51±0.06
SRP (μgL^{-1})	3.20±0.57	4.08±0.73	4.89±0.44	4.13±0.59	3.87±0.19	6.57±0.87	6.74±1.17
TP (μgL^{-1})	2.39±0.07	6.42±0.37	4.46±0.67	5.11±0.32	4.64±0.12	14.02±1.79	10.97±1.28

Table 3b: ANOVA

Parameter	df	F	p
NO2 (μgL^{-1})	6	2.000	.085
Temperature(°C)	6	114.000	.000
NO_3(mgL^{-1})	6	2.000	.045
NH_4 (μgL^{-1})	6	2.016	.000
SRP (μgL^{-1})	6	10.000	.000
TP (μgL^{-1})	6	7.000	.001
DO (mgL^{-1})	6	44.000	.000
pH	6	134.000	.000
Turbidity (NTU)	6	229.000	.000
EC(μScm^{-1})	6	11483.000	.000

Macroinvertebrates Functional Feeding Groups

A total of 4016 macroinvertebrates specimen were collected belonging to 9 orders and 28 families (Table 4).

Table 4: Macroinvertebrate occurrence and FFGs in Gura River. (+) indicate presence of taxa, (-) indicate absence of taxa

Taxa FFGs	Sites						
	G1	G2	G3	G4	G5	G6	G7
ANNELIDA							
Oligochaeta Cg	+	-	-	-	+	-	-
TURBELLARIA							
Planaria Pr	+	+	-	-	-	-	-
CRUSTACEA							
Potamonautidae Sh	+	+	+	+	+	-	-
COLEOPTERA							
Scirtidae Sc	+	+	+	+	+	-	-
Psephenidae Sc	-	+	+	+	+	+	+
Elmidae Sc	-	+	+	-	+	+	+
DIPTERA							
TipulidaeSh	+	+	+	+	+	+	+
SimuliidaeCf	+	+	+	+	+	-	+
ChironomidaeCg	+	+	-	+	+	+	+
AthericidaePr	-	-	-	-	-	-	-
MuscidaePr	+	+	-	+	-	+	+
TabanidaePr	+	-	-	-	-	-	-
EPHEMEROPTERA							
Baetidae A (*Baetis*) Cg	+	+	+	+	+	+	+
Baetidae B (two tailed) Cg	-	+	+	+	-	-	-
Heptageniidae Sc	+	+	+	+	+	+	+
Caenidae (*Caenis*) Cg	+	-	+	-	-	-	-
Leptophlebiidae Cg	+	+	+	-	+	-	+
Prosopistomatidae Sc	-	-	+	+	-	-	-
Oligoneuridae Cf	-	-	+	+	-	-	-
Dicercomyzidae Sc	-	-	+	-	-	+	+
Tricorythidae Cg	-	+	+	+	+	+	+
ODONATA							
Aeshnidae Pr	-	+	+	+	+	+	-
Libellulidae Pr	-	-	+	-	-	+	-
PLECOPTERA							
Perlidae (*Neoperla*) Pr	-	+	+	+	+	+	+
TRICHOPTERA							
Hydropsychidae Cf	+	+	+	+	+	+	+
Philopotamidae Cf	+	+	+	+	+	+	+
Lepidostomatidae Sh	+	+	+	+	+	+	+
Leptoceridae (OecetisCg	+	-	-	+	+	-	-

Shredders were represented by Potamonautidae, Tipulidae and Lepidostomatidae family. Scrapers/Grazers were represented by the following families: Heptageniidae, Scirtidae, Psephenidae, Elmidae, Dicercomyzidae and Prosopistomatidae. Collector-filters were dominated by Hydropsychidae, Philopotamidae, Oligoneuridae and Simuliidae families. The dominant collector-gatherer family was Baetidae, other collector-gatherer families included Leptoceridae, Tricorythidae, Leptophlebiidae, Caenidae, Chironomidae and Oligochaeta.

Overall, scrapers were the most dominant FFGs at spatial scale (sampled sites) with a proportion of 42 %. Collector-filters were second in percentage with a proportion of 27% from upstream to downstream sites. Collector-gatherers group was third highest in percentage with a proportion of 22%. Shredders and predators were the least represented functional group in all the sites with proportions of 6 % and 3 % respectively (Figure 2).

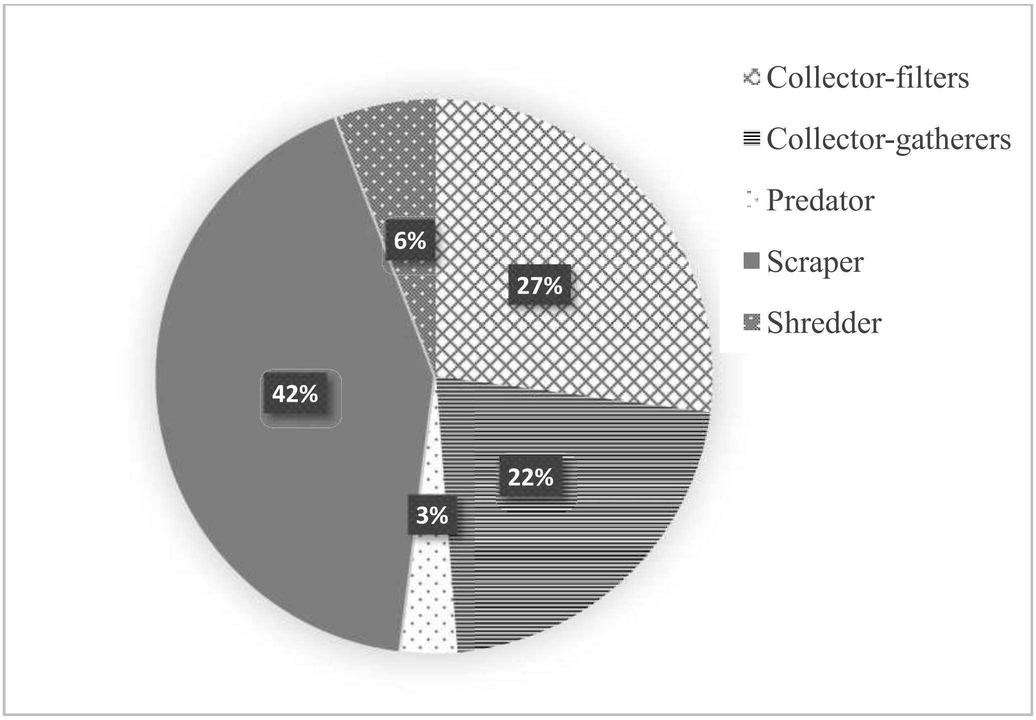

Figure 2: Overall FFGs proportions in Gura River

Scrapers had the highest percentage relative proportion in Gura River with site G3 and G4 recording the highest relative proportion. Site G7 and G6 recorded the least relative abundance of scrapers in Gura River (Figure 3). Shredders had a nearly constant relative abundance in all the sites. Collector-filters had the second highest relative proportion after the scrapers with site G7 and G6 recording the highest percentage proportion in Gura River, respectively. Collector-gatherers were also abundant in Gura River with their proportion decreasing downstream. Predators were the least represented FFGs in Gura River with their percentage proportion decreasing downstream.

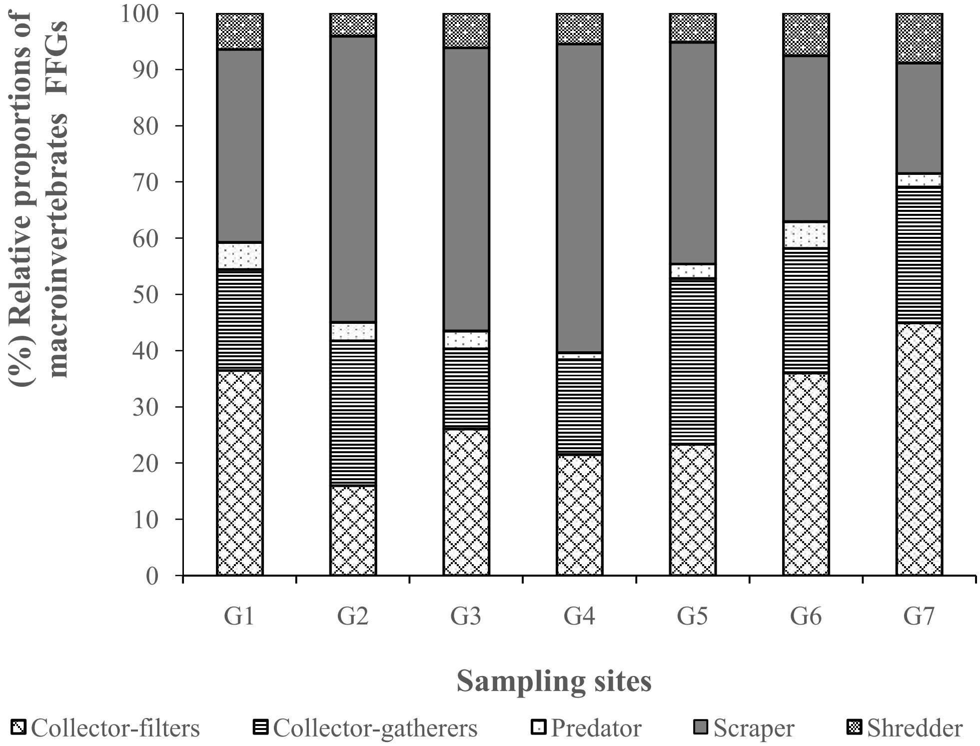

Figure 3: Relative abundance of the functional feeding groups in Gura River

Influence of Water Quality Parameters on the FFGs

The macroinvertebrates functional feeding groups (scrapers, shredders, collector-filters, collector-gatherers, and predators) had a strong positive correlation with altitude, physico-chemical parameters, and nutrients(Figure 4). The FFGs were abundant in sites with the least nutrients' concentration and low physico-chemical measurement. Upstream sites recorded low temperature, pH, EC, turbidity, ammonia, nitrite, nitrate, total phosphorus and soluble reactive phosphorus, therefore high abundance of FFGs recorded at upstream site (G1, G2 and G3).

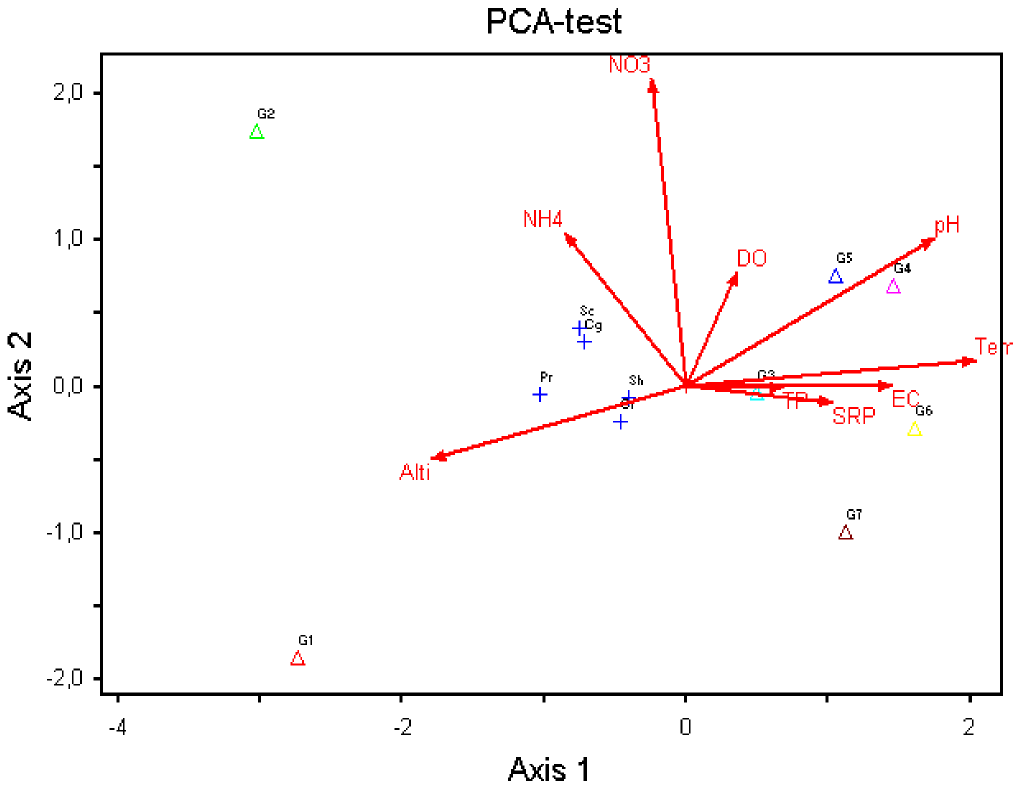

Figure 4: Principal Components Analysis showing influence of the water quality parameters to functional feeding groups in Gura River

Discussion

The present study is one of the main studies in Aberdare water catchment area focusing on functional feeding groups as bioassessment tool in Gura River. This study recorded low diversity and abundance of shredders in all sites which is in agreement with earlier studies in some tropical regions which reported similar diversity and abundance of shredders (e.g. Costa Rica: Irons *et al*., 1994; Brazil: Gonçalves *et al*., 2006; East Africa: Dobson *et al*., 2002, Masese *et al*., 2009b).

This low diversity and abundance of shredders might be attributed to use of temperate - stream keys to assign the tropical macroinvertebrates FFGs. Dobson *et al.,* 2002, noted that they might have allocated taxa to FFGs incorrectly after they found out that the tropical baetid, *Acanthiops sp*., was a shredder (baetids in northern temperate streams are usually scrapers or collector– gatherers; Merritt *et al*., 2008). Additionally, the low taxonomic resolution (most to family) used in tropical streams could also attribute to incorrect allocation of taxa to FFGs hence resulting to low diversity.

On the other hand, the low abundance of shredders in Gura River might not be attributed to shortage of Coarse particulate organic material (CPOM) since Gura River supported high biomass of detritus. Dobson *et al.,* (2002), obtained similar findings were obtained from Njoro and Naromoru Rivers.

Therefore, shredders in Kenyan rivers have been reported to be rare despite high CPOM levels. Low variation in shredder abundance in Gura River might also be attributed to eucalyptus plantations along the river banks in some sites. Earlier studies have shown that litter decomposition in tropical streams is inhibited by eucalyptus plantations in some rivers (Ferreira *et al*., 2018).

Furthermore, diverse shredder guild has been reported in tropical rivers where low abundance and few taxa were expected (Cheshire et al 2005; Masese *et al*., 2014; Yule *et al*., 2009). This kind of discrepancy shows that tropical shredders may be misclassified when using temperate-stream keys (Camacho *et al*., 2009).

Scraper abundance was high in all sampled sites which could be attributed to availability of algal food sources in these sites. Gura River was dominated by different substrate types (megalithal, mesolithal, macrolithal, microlithal and psammal) which provided attachment of algae and fungi hence providing food to the high abundance of scrapers. Wright and Li (2002), noted that the proportion of collectors–filters and scrapers is considered to represent the balance between food sources. High abundance of collector-filters in Gura River indicate the importance of seston transport in the water column (Minshall *et al.,* 1992*;* Palmer *et al.*1993b). All sites had a low Plecoptera abundance represented by only one family (Perlidae). The low diversity of Odonata and other predator taxa was a clear evidence of the weak top-down food web dynamics (e.g. Wallace and Webster, 1996).

The dominant macroinvertebrates functional feeding group in Gura River were the scrapers, followed by collector-filterers. Shredders and predators were the least represented FFGs in Gura River. The FFGs in Gura River were not in correspondence with the RCC concept by Vannote *et al.,* (1980) which dictate that the shredder FFG is the dominant group upstream of a river due to the availability of CPOM for the macroinvertebrate communities.

Water quality parameters play a crucial role to the survival of macroinvertebrates communities. The head waters of Gura River recorded the highest abundance of macroinvertebrates and had the least temperature, pH, turbidity, and electron conductivity because it is in a well-protected riparian zone with limited human activities. The increase in nutrients from upstream to downstream sites in Gura River could be attributed to the increase in agricultural activities in Gura catchment.

Conclusion

This study has demonstrated that tropical streams can use FFGs as an indicator of aquatic ecosystem changes in case there is alteration of ecosystem function due to changes in environmental variables. Macroinvertebrates Functional Feeding Groups is an important tool especially when studying the role of aquatic macroinvertebrates in tropical streams, because they provide crucial information of a macroinvertebrate and its role within aquatic ecosystems processes.

Accordingly, the high abundance (4016 individuals) of FFGs recorded in this study underscores their ecological importance hence the need for their enhanced conservation particularly in plight of increasing anthropogenic impacts on river and stream ecosystems.

Recommendation

Based on the results of this baseline study, future detailed studies covering an all year round sampling during both wet and dry season months in river Gura and other rivers draining Aberdare range are recommended to understand the seasonal distribution patterns of FFGs in rivers for informed conservation.

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