Biological Assessment of the Mayo Kaliao River, an Ephemeral Stream in Sudano-Sahelian Zone (Far North, Cameroon)

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Abstract: The biological assessment of the Mayo Kaliao River was carried out from 2013 to 2014 using macroinvertebrates. The bioevaluation attributes were FFGs, P/R index, Channel Stability, Temperature, HBI, percentage of tolerant taxa and percentage of intolerant taxa to organic pollution. Channel stability revealed that, from the beginning of water flow until its drying up, the substrates are unstable. This instability is marginal and sub-adequate. The permanently high temperature promoted rapid degradation of organic matter and the hydrology enable a constant resuspension. The watercourse is strongly heterotrophic (P/R index varied from 0.33 to 0.43). This heterotrophy favored the domination of tolerant taxa to organic pollution and collectors-gatherers which feed on FPOM in suspension. The contrast observed during this study showed the necessity to reevaluate the degree of tolerance to organic matter in sudano-sahelian zone, their trophic levels, their food resource and their mode of food acquisition.
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Key words: macroinvertebrates, functional feeding group, Mayo Kaliao River, sudano-sahelian zone, biological assessment.

1. Introduction

Macroinvertebrates are the most commonly used for biological monitoring of freshwater worldwide. They show predictable responses as the quality of water and riparian habitats degrades (Weigel et *al*., 2000; Sponseller et *al*., 2001; Rios and Bailey, 2006; Zhang et *al*., 2013). This is because they are found in most habitats, have generally limited mobility, are quite easy to collect by way of well established sampling techniques, and there is a diversity of forms that ensures a wide range of sensitivities to changes in both water quality habitats (Hellawell, 1986; Abel, 1989).

Biological assessments of running water usually involved two general approaches: taxonomic approach and functional approach (Cumming et *al*., 2005). The taxonomic approach is on determining biological indices (Shannon-Weaver index, EPT/Chironomidae ratio, Hilsenhoff's Biotic Index, taxa richness…) while functional approach is based on easily recognizable morphological and behavioral characteristics of the macroinvertebrates which are directly related to their modes of food acquisition (Cummins et *al*., 2005). Madomguia et *al.* (2016) showed that, the taxonomic approach alone is not appropriate to characterize temporary watercourses in the Sudano-Sahelian zone. This approach must be used in synergy with the functional approach which is faster. These authors recommend the use of functional feeding groups, Hilsenhoff's Biotic Index, Percentage of Tolerant Taxa and Percentage of Intolerant Taxa of organic matter to bioassess an ephemeral stream in Sudano-Sahelian zone in Cameroon. Otherwise, these authors showed that, the principal parameters which govern the distribution of benthic macroinvertebrates are riparian vegetation, temperature of water and hydrology.

Functional approach which the goal is to characterize ecosystem condition uses Functional Feeding Groups (FFGs) to describe ecosystem attributes in rivers and streams (Cumming et *al*., 2005). These authors use the mechanisms for obtaining food and the particle size of food eaten to distinguish five types of macroinvertebrates FFGs. Those are (1) shredders which chew Coarse Particulate Organic Matter (CPOM) composed mainly of leaves falling down from riparian vegetation (litter or live vascular plant tissue); (2) scrapers that harvest attached algae from surface of substrates; (3) collectors-filterers which collect Fine Particulate Organic Matter (FPOM) from the water column using a variety of filters, (4) collectors-gatherers remove FPOM from the stream bottom (in suspension) and (5) predators are those macroinvertebrates that capture and consume live animals.

Cummings et *al.* (2005) also use FFGs ratio as surrogates for ecosystem attributes, because any change in ecosystem condition that impact the nutritional resource base of the invertebrate FFGs will be captured by measurements of the relative proportions of those groups. Among them, Autotrophic to Heterotrophic index and the stability of the stream channel are used. The balance between autotrophic (in which the dominant base chains is algae or rooted vascular aquatic plants) and heterotrophic (in which the major base of the food chain is leaf litter derived from riparian zone) allows the origin of organic matter on the water column (photosynthesis or decomposition of organic matter). The stability channel of the stream ecosystems are reflected in the relative permanence (stability) of various bottom materials, such as large cobbles or boulders, large woody debris, and firmly rooted plants. If the bottom is stable, invertebrates that cling to surface of stones or large wood or climb on vegetation while feeding on attached algae would be more abundant.

This work aimed at study the Mayo Kaliao River biologically with the use of FFGs, Autotrophic to Heterotrophic ratio, stream channel ecosystems, Hilsenhoff's Biotic Index, Percentage of Tolerant Taxa and Percentage of Intolerant Taxa on organic matter.

2. Material and Methods.

2.1. Description of study area

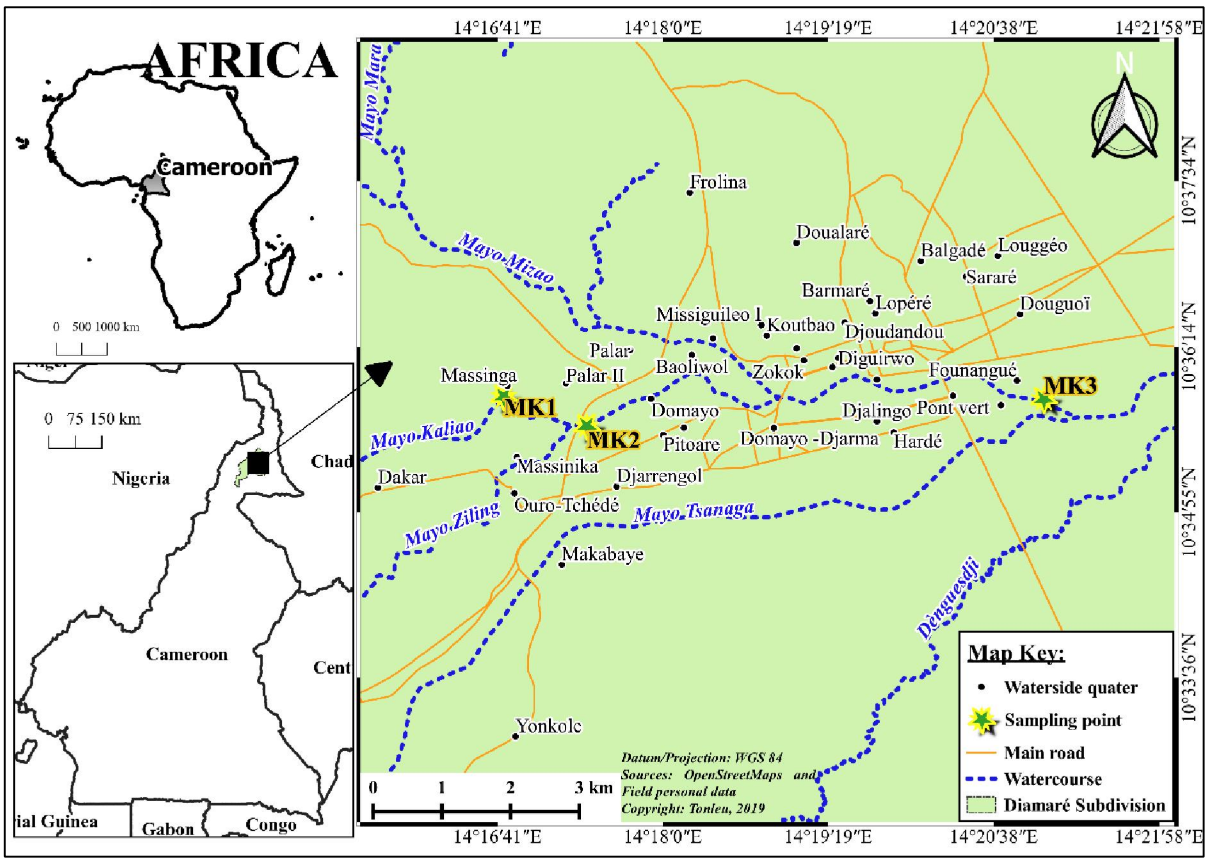

Figure 1: Map of the study site showing the sampling stations.

Mayo Kaliao River is an ephemeral stream flowing across the main settlement of Maroua town situated at Sudano-Sahelian zone of Cameroon (fig. 1). Maroua is a town with more than 500.000 habitants situated between latitudes 10°26'41'–11 °00'13''N and longitudes 14°8'40''–14°38'44''E. This town experiences two seasons of unequal length. In the course of study realized in 2013 and 2014, the dry season prolong for about 9-10 months, from mid-October to the end of July. The short rainy season was only for about 2-3 months, from the end of July to the first half of October. Annual rainfall ranges from 400 to 1000 mm and the atmospheric temperature is situated between 15-43°C (L'Hôte, 1999). The studied river is composed of sandy sediments covered by a small layer of leaf litter near the vegetation of the bank. Riparian vegetation is scarce and consists mainly of grasses (*Ipomea aquatica, Echinochloa* *stagnina, Ipomoea carnea* ssp. *fistulosa* (Convolvulaceae) is the major grass on this vegetation). No impediment blocks the flow. The predominant microhabitats are sand, litter and vegetation. Shading canopy are absent around the rivers.

The river is ephemeral and the stream duration varies between the years. Intense sand mining takes place there throughout the year. The width of the river is between 40 and 80 m or more. When the water colomn is permanent, this activity regularly–changes the slope of the stream bed and wet areas from one week to another; this is especially when they remains only very few water in the streambed. The tides, the flow duration and the depth of water column varied closely with rainfall. Sedimentation and alteration of the banks are noticeable between the rain, and the depth of the banks rarely exceeds 50 cm.

At the level of Maroua town, River Mayo Kaliao drains many dense quarters like Ouro-Tchede, Palar, Domayo, Pitoare, Pont vert, Baouliol (fig. 1) and collects the wastewaters from Regional Hospital of Maroua, social housing and from Mizao Hotel. Agriculture and breeding are the other major human activities that occur along the stream.

The Mayo Kaliao River originates in the south of the Méri massif and flows into the Mayo Tsanaga River after 40 km. It flows into Maroua, at the level of the Palar bridge the Mayo Ziling and at the level of the "Pont rouge" on the left bank the Mayo Mizao. Its slope is close to 0.3%.

2.2. Measurement of environmental variables

At the level of each sampling stations, two (02) hydrological variables were taken into account: maximum depth of water column during the sampling (Hwt) and water velocity – were measured every week of flow duration. Hwt (cm) was estimated using a graduated stick. In fact, the maximum depth of water at the time of sampling (Hwt) permits to differentiate three periods of flow duration. The first period, named "beginning-flow permanence" corresponds to Hwt ≤ 50 cm; the second period called "mid-flow permanence" refers to the period of floods with Hwt >50 cm, and the third period called "end-flow permanence" refers to Hwt ≤ 50 cm. Current velocity (m/s) was evaluated by timing 3 times the front of a light object (polystyrene) over a known distance along the station.

The temperature of waters (°C) was measured on water column using EXTECH EC500 multiparameter between 7 a.m. and 1 p.m. during each sampling period.

2.3. Sampling and identification of macroinvertebrates

Sampling of macroinvertebrates was conducted between 7 am to 1 pm and every week during flow duration. Invertebrates were collected using a kick-net (30 x 30 cm side, 300 µm mesh size, 30 cm depth) from any identified microhabitat (sand, plant, litter, dead wood, roots of plants). Macroinvertebrates are thus dislodged from the targeted habitat by dredging with the net. Some organisms with considerable size are caught by hand using pliers.

The samples were later transferred into into a 15 L plastic bucket containing the water to a primary sort in order to eliminated coarse particles (plants, leaves, dead wood). Then, the samples are filtered through a plankton net (64 µm porosity), taking care to leave the sand at the bottom of the bucket. When necessary, the sand was stirred repeatedly to let the residual float benthic organisms. Thereafter, the filter contents are transferred to glass bottles of 250 mL and organisms were fixed in 5% formalin. In the laboratory, after rinsing the samples with tap water to get rid of formalin, a secondary sort is performed on the residual substrate in order to extract the remaining invertebrates. This sorting is done, firstly naked eyes for the largest specimens, and secondly under a magnifying glass MOTIC stereomicroscope brand for smaller specimens. Organisms were manipulated in Petri dishes of 90 cm diameter using tongs to handle them. The fauna so concentrated were preserved in 70°ethanol for further identification and enumeration.

The identification and counting of organisms were made under the MOTIC stereomicroscope. The identification keys used were those of Durand and Levêque (1981), De Moor et *al.* (2002, 2003a, 2003b, 2007), Tachet et *al.* (2006), Szpila (2010) and Moisan (2010).

2.4. Data analyses

The FFGs, Hilsenhoff's Biotic Index (HBI), percentage of intolerant taxa (%IT) and percentage of tolerant taxa (%TT) to organic matter were calculated to estimate the degree of perturbation doing by the presence of organic matter on the site of study. The formulas were followed:

$$HBI = \sum \frac{x_i t_i}{n}$$

$$\% IT = \frac{Abondunce\ of\ taxa\ with\ FTV < 4}{Total\ abondunce} * 100$$

$$\% TT = \frac{Abondunce\ of\ taxa\ with\ FTV > 6}{Total\ abondunce} * 100$$

x_i = total number of individuals belonging to taxon i ; t_i = tolerance of taxon i ; n = total individuals.

FFGs were calculated using Mandavile (2002). Autotrophic to Heterotrophic index (P/R) and the channel stability of the stream ecosystems was calculated by the following:

$$\mathbf{P/R} = \frac{\boldsymbol{Scrapers}}{\boldsymbol{Shredders} + \boldsymbol{collectors}}$$

If P/R > 0.75, then the organic matter present in the river mainly come from photosynthesis; otherwise, heterotrophy dominates (Cummings et *al.* 2005).

$$\boldsymbol{Channel\ stability} = \frac{\boldsymbol{Scrapers} + \boldsymbol{Collectors} - \boldsymbol{filterers}}{\boldsymbol{Shredders} + \boldsymbol{Collectors} - \boldsymbol{gatherers}}$$

When channel stability > 0.50, substrates are stable; if it is < 0.50, substrates are not stable.

3. Results

3.1. Hydrological variables

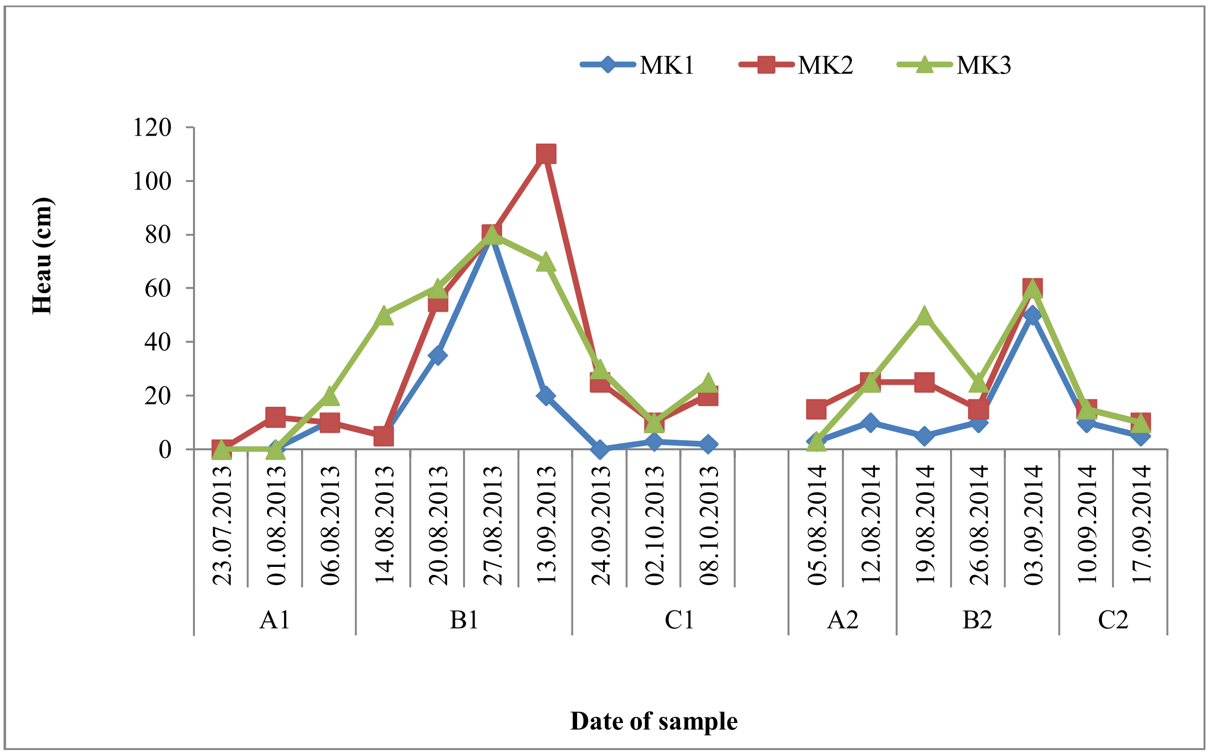

Figure 2: Variation of the maximum depth of water and current velocity at the moment of sampling during flow permanence.

The maximum depth of water at the moment of sampling (Hwt) varied from 0 to 110 cm in 2013 and from 0 to 60 cm in 2014 (fig. 2). It should be noted that, the day of beginning of the permanence water flow varies from one year to another. It's not possible to predict it; it depends on both the quantity of rain fall and the duration of the dry season. The stream duration was 11 weeks in 2013 (from August 1st to October 8) and 6 weeks in 2014 (from August 5 to September 17 (fig. 2). The beginning-flow permanence (A1, A2) and end-flow permanence (C1, C2) spread on 2-3 weeks and Hwt is less than 50 cm (Hwt < 50 cm). As to mid-flow permanence (B1, B2), it spreads on 3-4 weeks and Hwt is greater than 50 cm (Hwt ≥ 50 cm).

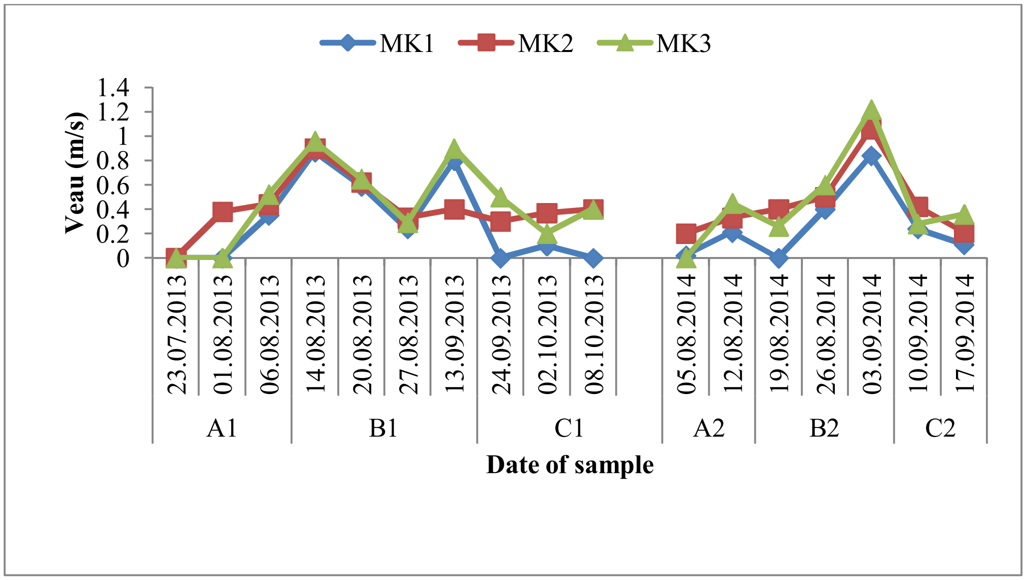

Figure 3: Variation of current velocity at the moment of sampling during flow permanence in Mayo Kaliao River.

The current velocity at the moment of sampling varies highly from one week to another. It fluctuated between 0 and 0.96 m/s in 2013 and between 0 and 1.22 m/s in 2014 (fig. 3). Current velocity not depends on Hwt. Globally, water are fast to very during mid-permanence which corresponding to high flow period.

Water temperature varies between 23.5°C and 35.5°C in 2013 and between 25.8°C and 38.0°C in 2014 during water permanence (fig.4). The thermal amplitudes are 12.0°C in 2013 and 12.2°C in 2014. The periodical means of temperature of waters globally show that, temperature increases from the beginning of permanence to the end of permanence. They was no significance difference between the 3 sampling periods concerning this parameter in the studied river (Kruskall-Wallis test: $p = 0.054$; $\alpha = 0.05$).

3.2. HBI, %TT, %IT, FFGs and degree of pollution by organic matter

A total of 5954 individuals (3860 individuals in 2013 and 2094 individuals in 2014) were recorded during flow permanence in the Mayo Kaliao River**.** They all belong to 49 taxa (1 Oligochaeta, 1 Crustacean, 1 Mollusc and 46 Insects). Taxonomic richness decreased from 41 taxa at "beginning-flow duration" to 37 taxa at "mid-flow duration" and to 35 taxa at "end-flow duration". Concerning taxonomic abundance, the "end-flow permanence" was more abundant (2690 individuals) than "mid-flow permanence" (2616 individuals) and then "beginning-flow permanence" (648 individuals). Seven (7) taxa concentrated 78.21% of total abundance (Ephemeroptera Baetidae: 35.56 %; Heteroptera Corixidae: 13.72 %; Diptera Chironomidae: 7.21%; Heteroptera Gerridae: 6.60%; Diptera Culicidae: 6.24%; Ephemeroptera Leptophlebiidae: 4.60% and Odonata Coenagrionidae: 4.28% %). They are not significative sdifference between the 3 sampling periods concerning taxonomic richness (Kruskall-Wallis test: $p = 0.860$; $\alpha = 0.05$) and concerning taxonomic abundance (Kruskall-Wallis test: $p = 0.550$; $\alpha = 0.05$).

HBI decreased from 4.629 at "beginning-flow permanence" to 0.655 at "mid-flow permanence" and to 0.154 at "end-flow permanence". This variation of HBI reveals some organic pollution on "beginning flow permanence" which is no apparent on "mid flow permanence" and on "end flow permanence" (Tab. I). The percentage of tolerant taxa (%TT) was higher than the percentage of intolerant taxa (%IT) on each sampling period (fig.5).

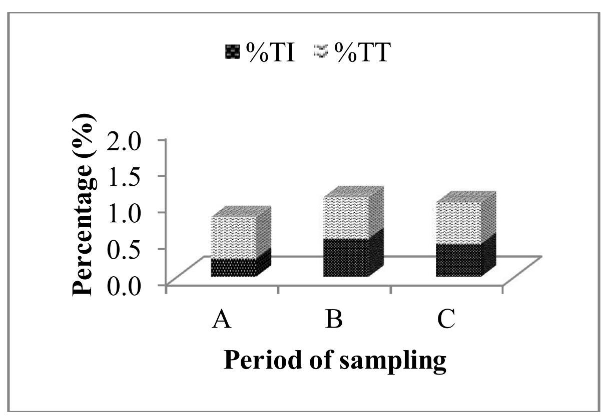

Figure 5: Percentage of tolerant taxa (%TT) and intolerant taxa (%IT) to organic matter during study period.

Table I: Values of HBI obtained during sampling 3 periods in Mayo Kaliao River

Mayo Kaliao			
	HBI	**N**	**Signification**
A	4,629	604	Some organic pollution
B	0,655	2616	No apparent organic pollution
C	0,154	2691	No apparent organic pollution

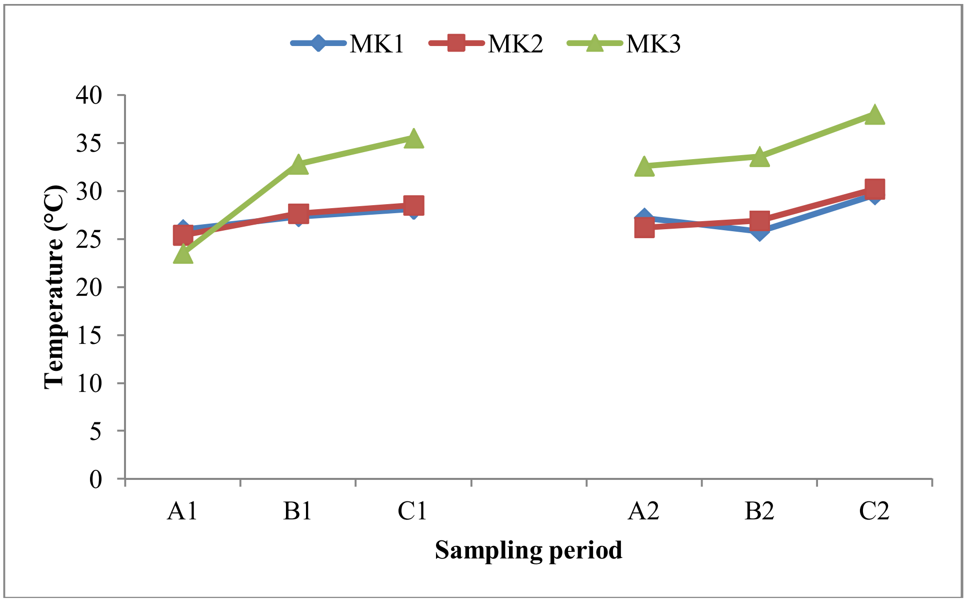

Figure 4: Variation of temperature of water during flow permanence in Mayo Kaliao River.

P/R index decreased from 0.40 at "beginning-flow permanence" to 0.33 at "mid-flow permanence" and increased at 0.34 at "end-flow permanence" (tab. II). These values of P/R index reveal that the organic matter present in the studied river does not come mainly from photosynthesis and that, the Mayo Kaliao River is strongly heterotrophic, from "beginning-flow permanence" to "end-flow permanence".

3.3. Functional feeding Groups, P/R index and Stable Channel

Five functional feeding groups (FFGs) were recognized in the Mayo Kaliao River. These include collectors-gatherers (c-g), predators (prd), collectors-filterers (c-f), scrapers (scr) and shredders (shr). Collectors-gatherers were the most abundant FFGs during each sampling period, followed by predators and scrapers (fig. 5). The high densities of collectors-gatherers (1423 individuals) were recorded at the "mid-flow duration" while the high densities of predators (827 individuals) were recorded at "end-flow duration". These results showed, on one hand that the major foods resources in the Mayo Kaliao River are the Fine Particulate of Organic Matter (FPOM) and algae attached on substrates and on the other hand that these FPOM and algae are more abundant during "mid-flow permanence".

Table II: Values of HBI P/R ratio obtaining during study in Mayo Kaliao River

Mayo Kaliao		
	P/R	**Signification**
A	0.40	Strongly heterotrophic
B	0.31	Strongly heterotrophic
C	0.32	Strongly heterotrophic

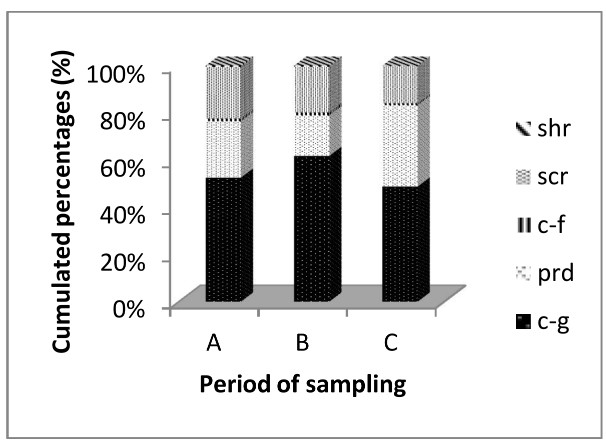

Figure 6: Functional feeding groups identified during study period.

The channel stability of Mayo Kaliao River which was 0.43 at the beginning of the permanence of the waters, dropped to 0.33 at mid-permanence, before increasing to 0.34 at the end of the permanence of the waters. These values of channel stability show that during the “beginning-flow permanence”, the channel stability is marginal and it becomes sub-adequate during “mid-flow permanence” and “end-flow permanence”.

Table III: Values of stable Channel during flow permanence in Mayo Kaliao River

Mayo Kaliao		
	Stable Channel	**Signification**
A	0.43	Stable substrates sub-adequate
B	0.3	Stable substrates marginal
C	0.34	Stable substrates marginal

4. Discussions.

Permanent hydrological changes were mentioned in the Mayo Kaliao River which is an ephemeral stream. These hydrological changes, are due to the rainfall which create instability (hydraulic stress) on the stream. The macroinvertebrates inhabiting this environment should have the specific energy-saving adaptations (behavioral, morphological, etc.) that increase their probability of survival and reproduction (Townsend and Hildrew, 1994). The instability of Mayo Kaliao was confirmed by the "channel stability" parameter which showed that, from the beginning of the flow of water until its drying up, the substrates were unstable, the instability being marginal and sub-adequate (Cummings et al., 2005). The instability of the substrates would promote the resuspension of food resources, hence the predominance of collectors-gatherers which are invertebrates able to remove suspended FPOM on the stream bottom (Cummings et al., 2005). FPOM come from the degradation of organic matter of various human activities which are carried by runoff into the Mayo Kaliao. Rapid degradation of organic matter is favored by the temperature of water which is permanently elevated. this stream remain warm throughout the year, this is partly due to the absence of canopy along the stream and partly by the shallow nature of the waters and also by the reflection effect of light rays by the sand which constitutes the bottom substrate of the Mayo Kaliao. Madomguia et al. (2016) have already reported the instability and dominance of collectors-gatherers in the Mayo Tsanaga, the other ephemeral stream running in Maroua town whose Mayo Kaliao is a tributary. This suggests that the ephemeral streams of the Sudano-Sahelian zone would be characterized by the instability of their waters, their richness in FPOM and the dominance of the collectors-gatherers. Palmer et al. (1993a), Tomanova et al. (2006), Uwadiae (2010) and Adandedjan (2012) reported the importance of FPOM and the collector-gatherer, activity of organisms in neotropical freshwater ecosystems. These authors related that the omnipresence and the abundance of fine detritus in tropical freshwater are due to the rapidity with which the leaves are decomposed, since the waters stay warm throughout the year (Dudgeon, 1982 in Covich, 1988; Mathuriau and Chauvet, 2002; Dobson et al., 2003). The feeding strategies of scrapers, predators and shredders involve a higher mobility (active searching for food) or visiting unstable substrates (shredders in settled leaf litter), and thus higher exposure to the flow and finally higher risk of drift. The present study shows that scrapers are more numerous during “mid-permanence” of waters where the stream is more turbulent. This showed that the organisms known as scrapers in ephemeral stream in sudano-sahelian zone would be adopting another strategy of food acquisition. Lamouroux et al. (2004) and Tomanova et al. (2006) revealed that organisms of neotropical streams may adopted a collector-gatherer feeding strategy in order to avoid the constraints of fast currents. This reveals an urgency to study gut and mouthpart of macroinvertebrates identified in Mayo Kaliao. The dynamic of predators appears to be link to the availability of their prey like chironomid. Diomandé (2001) related that the high abundance of predators is primarily related to the great diversity of Diptera such as chironomid on which they feed. In addition, Wallace et al. (1999) have demonstrated that fauna of bedrock streams with storm discharge shows a stronger relation to fine benthic organic matter than to leaf litter.

HBI revealed some organic pollution at the “beginning-flow permanence” with no apparent organic pollution during the other two periods of permanence of water. However, tolerant taxa to organic pollution have been more abundant from the beginning to the end of the water flow in Mayo Kaliao. Moreover, P/R index showed that the Mayo Kaliao River is strongly heterotrophic during flow duration. These results shows that, the degree of tolerance of benthic macroinvertebrates of ephemeral streams in the Sudano-Sahelian zone must be re-evaluated in order to obtain results that reflect actual conditions on the streams. Tomanova et al. (2006) had previously pointed the need to re-evaluate trophic levels and functional feeding groups of macroinvertebrates inhabiting the tropical waters. This is because, the highly flexible life history and mobility that seem to characterize many neotropical stream taxa may as well influence their flexibility in obtaining food resources (Covich, 1988). This can produce significant differences in FFG classification because some neotropical taxa may not feed like the majority of their congeners inhabiting the temperate zone, and therefore should not be placed in the same FFG (Tomanova et al., 2006). For example, Limnophila (Dipterian Tipulidae), previously assigned as predators in temperate zone, was cited like a consumer of CPOM (48.9%) and FPOM (33.1%). Tomanova et al. (2006) reported that sediment particles, fine detritus and microphytes were the most frequently ingested items for practically all taxa examined; macroinvertebrates and coarse detritus (>1 mm) were less ingested, and finally, macrophytes, dead animals or microinvertebrates were the food items rarely found.

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