



Analysis of Structure and Composition of Macro-Invertebrate Assemblages in Natural Lukaya River Stream

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Received: July 10, 2014; Accepted: August 2, 2014, Published: August 4, 2014.

ABSTRACT

Biological assessment of aquatic ecosystems is widely employed as an alternative or complement to chemical and toxicity testing due to numerous advantages of using biota to determine ecosystem condition. These advantages, especially to developing countries, include the relatively low cost and technical requirements. This study was carried out to establish relationship between water quality and macrozoobenthos assemblages along the Lukaya stream and to analyze fauna structure assemblages. Seven sites were selected along a 50-km stretch of the stream, which drained land under agricultural, residential and industrial uses. Water physico-chemical data was explored using multivariate analysis of Canonical Component Analysis to detect environmental trends. Water physico-chemical characteristics (temperature, pH, turbidity, conductivity, calcium, magnesium, nitrate, nitrite, sulphate and phosphate) and biodiversity indices (species richness, diversity, redundancy, evenness, abundance) did not show significant difference ($P = 1$) between sites along the stream but some correlation between variables and biodiversity indices were detected by spearman's correlation analysis. Sixty-two taxonomic groups identified are dominated by odonata, diptera, shelfish and molluscs but three taxa: *Lymnaeidae*, *Chironomyidae* and *Atyidae* presented the highest abundance in all assemblages. The model of DIMO made it possible to split the various sites in two groups in function of H' , H_{max} and J' . Moreover, rank-frequency diagrams of Frontier characterized stage 1 and middle between stages 1 and 2 structured curves.

Keywords: Macro-invertebrates, water quality, biodiversity indices, Lukaya stream, physico-chemical parameters.

INTRODUCTION

Water resources are fundamental to social and economic wellbeing [1]. All over the world the ecological integrity of river systems is being endangered by land-use changes. This widespread and ever-increasing phenomenon involving urbanization, agriculture, pasture conversion, deforestation, stream concentrations of many chemical constituents such as nitrate concentration and phosphorus compounds, channelization and realignment of rivers, and the replacement of native species by exotic ones with commercial value, represents a real and pervasive threat to the biodiversity and conservation of lotic ecosystems [2]. Particularly in Kinshasa, Democratic Republic of Congo (DRC), the freshwater system is became the real garbage of all types of waste, liquids or solids. Of this point of view, the relationship between land-use change and alteration of stream physical characteristics can be complex and influenced by many factors acting from different spatial scales ranging from local (e.g., adjacent to the stream) to basin level or to eco-regional scales [3]. However the units, resulting from the interaction between hydraulic and morphological processes, provide distinctive habitats for biota [4].

To restore good ecological status of watercourses, it is essential to recognize whether ecosystem degradation has resulted mostly from a decrease in water quality or rather from physical habitat degradation [4]. Conventional approaches for monitoring the status and recovery of aquatic systems include measures of biomass, abundance, species diversity and richness, or biotic indices based on combinations of these parameters [5]. Disturbance may affect each major level of organization, from the individual to ecosystem and landscape, and the consequences and mechanisms of disturbance are different at each hierarchal level [6]. Analyses of disturbance at each level of organization are vital to understand the importance of disturbance and the dynamics of the recovery process [7]. Among biological tools for assessing the stream ecological status benthic fauna is of major importance, because on the one hand it plays a vital role in nutrient cycling, detrital decomposition and as food source for higher trophic levels and on the other hand benthic species are sensitive indicators of changes in the freshwater environment. Effects of anthropogenic disturbances on the benthos include specifically changes in diversity, biomass, abundance of stress tolerant and sensitive benthic species, and the trophic or functional structure of the benthic community [8, 9]. However,

hydromorphological degradation can also be an important stressor influencing the composition of macro-invertebrate communities [10]. Although the cause-and-effect relationship between discharge and ecological impacts is not always obvious [11], it has been established that in many cases, aquatic biota provide the most reliable signals of the effects of pollutants or habitat alteration, providing the basis for direct biological assessment and monitoring [12]. Consequently, the existence of environmental gradients in large-scale community surveys provides a methodological challenge in quantifying the effects of human impact on native invertebrate richness.

Diversity indices are commonly used for assessing of biodiversity variation for good ecological status versus impacted ecosystems [13]. The majority of indices describe species richness and species “evenness” and are, as such, sensitive to sampling effort as a function of phenology and habitat type [14]. Moreover, [15] observed that the concept of biodiversity (species richness and evenness) is a central theme in community/ecosystem ecology and can be used to explain other ecosystem properties such as biological productivity, habitat heterogeneity, habitat complexity and disturbance. Consequently, species diversities are moderate in stable ecosystems, highest in intermediate and low in severely degraded ecosystems [16].

The use of biological indicators in applied limnological research is well established in north-temperate regions [17], but in DRC and to larger extent the whole of Africa the use of macro-invertebrates characteristics for assessment and monitoring of stream conditions is still uncommon. The biomonitoring and bioassessment of water quality are particularly useful for developing countries such as DRC because their low costs and their low technical requirements [18].

The present study analyses the diversity and composition of benthic invertebrate communities on the background of environmental conditions in seven sections of the Lukaya stream, which traverses through several land-use systems. The aim the study was to: (1) determine water physico-chemical characteristics, (2) describe macro-invertebrate composition and structure and (3) relate water quality to macro-invertebrate densities and biodiversity indices along the stream.

MATERIAL AND METHODS

Study area

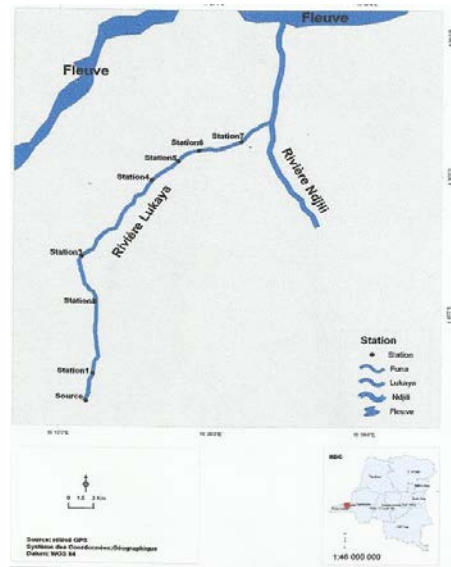


Fig. 1 Sampled locations. Map down the fig.1 represents Congo DR.

The Lukaya stream is one of tributaries of Congo River but its waters flock to N’djili stream before reaching the Congo River. The stream stretches around 50-km from the spring and it is situated between 04°44’S, 15°11’E and 04°27’S, 15°19’E. The climate of the area is of the wet tropical type (Aw_4) according to Köppen classification [19]. Rainfall is bimodal with long rains occurring during the months of September to December and the short rains from February to April. Dry seasons occur between May to August as well as January. The mean annual temperature ranges between 23 °C and 28 °C. Seven stations are located in water depth between 31 cm and 67 cm.

The majority substrate is compound by gravel, pebble, sand, paving stone of moss and aquatic macrophytes. The stream is affected by various human activities (removal gravel and sand, fishing, washing, crockery, market gardening, breeding, cleaning vegetables and swimming) along the channels.

Sampling processing

Seven sites (Selo, Sl; Kimpika, Kp; Kasangulu, Kg; Dokolo, Dk; Kimwenza-gare, Kw; Luzizila, Lz and Lemba-Imbu, Li) were selected holding account various human activities, presence of rapid and slow section on water wave, diversifying of habitat types. Water quality and macro-invertebrates samples were collected quarterly for a period of 12 months, which included wet and dry seasons. In overall 21 samples were carried out from October 2007 to September 2008. Temperature, pH, turbidity and conductivity was determined *in situ* using a portable Gombo multiparameter, Model N°H198129*N°198130, HANNA instruments. Water samples were taken and transported to the laboratory for quantitative analysis (e.g. total phosphorus, nitrate, nitrite, sulphate, calcium, magnesium) following standard methods. A detailed description of all variables can be found in [20].

Macro-invertebrates were sampled using a surber sampler (opening: 30 cm × 30 cm, mesh size 500 µm). In short, kick and sweep sampling technique was applied at the majority of running water sites during the sampling water period. Difficult access habitats (e.g. in dense aquatic vegetation) have been sampled using a hand net (opening: 30 cm × 30 cm, mesh size

500 μm). A single grab was taken at each of the seven stations. The samples were sieved over 63 μm mesh size and fixed in 4% buffered formaldehyde. After sorting in the white trays and determination of species abundance, the organisms were preserved in 70% alcohol. All sorted invertebrates were identified to the family level using a stereomicroscope at 20 \times magnification [21] and the following identification keys: [22]; [23]. For each sample, the following four characteristics were calculated: the number of organisms, the number of taxa (taxon richness), the redundancy and the diversity and evenness measures of Shannon–Wiener [24].

Statistical analysis

To detect changes and trends in water quality between sites, water physico-chemical data was explored using a multivariate technique of ordination, Canonical Correspondence Analysis (CCA) [25]. Water quality characteristics for suggested groups of sites were analyzed using ANOVA to establish whether they were significantly different. Macro-invertebrates data was used to calculate biodiversity indices and later summarized and presented as relative abundance. Indices were then compared between sites using ANOVA and significant levels accepted at $P < 0.05$. Significant effects of the ANOVA were further explored with post-hoc Tukey HSD tests [26]. Spearman's correlation analysis was performed to establish the association between biodiversity indices and water quality parameters.

Structural assemblage analysis of Lukaya stream includes several indices: McNaughton index known also by dominance index ID (= sum of species dominances occupying two first ranks in a sample), diversity index of Shannon-Wiener H' [24] and evenness index J' [27]. Three indices H' , J' and S are considered in DIMO model "DIversity MOdel" [28] thanks to synthetic graphic representation which allows simultaneously to display these indices. Following of structural assemblages of macro-invertebrate has been performed using rank-frequency diagrams [29] in order to compare and visualize spatial evolution of assemblages of each stream section. All calculations and statistical analyses were performed using PAST version 2.17c [30] and OriginPro 8 SR4 [31]. All data were log-transformed $\log_{10}(x + 1)$ prior to analysis to meet the statistical criteria of normality.

RESULTS

Characterization of sites using water physico-chemical parameters

Canonical Correspondence Analysis (CCA) ordered environmental variables and sites along axes (Fig.2). The analysis showed that the first axis had a variance of 56,84 %, was positively associated with turbidity and negatively with all remaining variables. It was positively associated with Kp and Kg sites and negatively with Sl, Dk, Kw, Lz and Li sites. Second axis explained a variance of 14,64 %, was positively associated with temperature, pH, turbidity, sulphate (SO_4^{2-}), nitrate (NO_3^-), calcium (Ca^{2+}) and magnesium (Mg^{2+}) and negatively with phosphate (PO_4^{2-}) and nitrite (NO_2^-). It was positively associated with Sl, Kp and Kg sites and negatively with remaining sites. Using the biplot scatter, sites were subjectively split into three groups: (1) site Sl; (2) sites Kp and Kg and (3) sites Dk, Kw, Lz and Li. Site Sl were influenced by Ca^{2+} , sites Kp and Kg were mainly characterized by high

turbidity level and sites Dk, Kw, Lz and Li were correlated with conductivity, PO_4^{2-} , SO_4^{2-} and NO_2^- .

Variation of environmental variables and biodiversity indices between sites

At the 0,05 level, the population means of sites are not significantly different ($F_{cal} = 0,57$; $F_{tab} = 2,18$; $P = 0,74$) along the stream as during the sampling period.

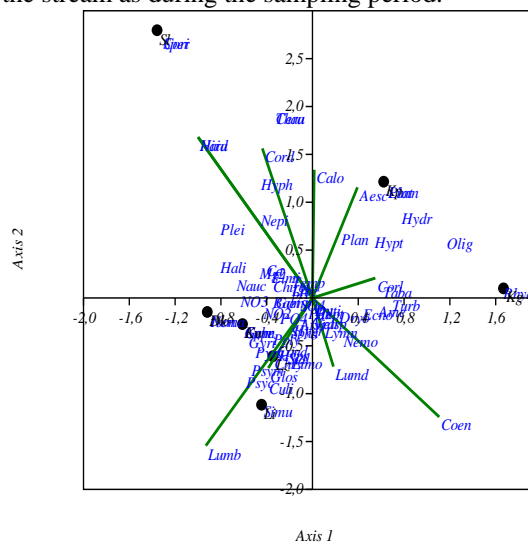


Fig 2 A CCA biplot showing the association between environmental variables and sites. Axes have total eigenvalues of 1.0 and variance explained by first and second axis was 56,84% and 14,68%, respectively. Two letters beside a point refer to the sites (Sl, Kp, Kg, Dk, Kw, Lz, Li) and the labels refer to invertebrates and environmental variables. For location of sites, see Fig. 1

Further analysis using Tukey HSD test showed that turbidity were significantly different between first and second sampling period. Increased values of this variable could be observed at sites Kp and Kg mainly. This particulate characteristic contributed to individualize these two sites, which were grouped together. The scenario was captured by CCA (Fig.2).

In contrast, the other parameters did not show important variation between sites. General evolution of all variables trended to increase from upstream to downstream sites.

Biodiversity indices (Table II) comparisons between sites of Lukaya stream did not show significantly different at 0,05 level ($F_{cal} = 0,007$; $F_{tab} = 2,55$; $P = 1$). Further, the Tukey HSD test showed no significant difference between means comparisons of sites.

Association between environmental variables and biodiversity indices

Spearman's rank correlation showed that redundancy R and temperature; R and richness S ; conductivity and abundance A ; turbidity and diversity H' ; turbidity and H_{max} ; PO_4^{3-} and S ; PO_4^{3-} and A ; SO_4^{2-} and S ; NO_2^- and pH; conductivity and PO_4^{3-} , Ca^{2+} and Mg^{2+} were significantly and positively correlated at 0,05 level (respectively with $r = 0,8$, $P = 0,007$; $r = 0,8$, $P = 0,027$; $r = 0,9$, $P = 0,003$; $r = 0,7$, $P = 0,03$; $r = 0,7$, $P = 0,03$; $r = 0,7$, $P = 0,03$; $r = 0,8$, $P = 0,027$; $r = 0,8$, $P = 0,009$; $r = 0,8$, $P = 0,014$; $r = 0,7$, $P = 0,041$ and $r = 0,8$, $P = 0,010$). However, evenness J' was negatively associated with temperature, redundancy and richness ($r = -0,8$, $P = 0,007$; $r = -0,8$, $P = 0,027$ and $r = -1,000$, $P = ,000$ respectively). Association between

environmental variables and biodiversity indices showed also that turbidity was negatively associated with Ca^{2+} and Mg^{2+} ($r = -0,8$, $P = 0,010$; $r = 0,8$, $P = 0,023$). Finally, H' was negatively correlated with Mg^{2+} ($r = -0,9$; $P = 0,001$).

Structural Macro-invertebrates assemblages analysis

Sixty-two taxa of benthic invertebrates have been collected and identified from 5521 individuals from 21 samples (Table I) performed in three sampling periods from October 2007 to September 2008. Macro-invertebrate populations increased from downstream to upstream with the highest densities recorded at sites Kw, Lz and Li (Table II). However, they were not significantly different between sites. Coleoptera, Diptera, Odonata, Trichoptera and Hemiptera dominated qualitatively biotic structure with nearly 66% of total species richness (respectively 17,74% ; 12,92% ; 12,92% ; 11,29% et 11,29%).

Qualitative dominance of Odonata also expressed quantitatively by totalizing almost 22% of the total workforce (Table I), followed successively by Diptera, Mollusc and Shellfish. Three taxa displayed dominances greater or equal to 10% compared with total dominance: *Lymnaeidae* (13,3%), *Chironomyidae* (12,5%) and *Atyidae* (9,7%). Composition of macrobenthic assemblage was dominated on the lower and middle watercourses by Odonata (*Coenagrionidae*, *Calopterygidae*) but replaced on the upper course by beetles (*Dytiscidae*, *Elmidae*, *Dryopidae*). Subsequently, proportion of organisms with high affinity for organic matter has increased considerably on Sl, Kg, Kw and Li stations in the same time that Molluscs and rheophile organisms: Lepidoptera (*Pyralidae*), Trichoptera (*Hydropsychidae*, *Polycentropodidae*) and Stoneflies (*Nemouroidae*).

Table I. Taxa found in Lukaya Stream with their total and relative abundance (percentage of the total number of individuals) per station. Marked '-' means absence.

Taxa	Sites and Frequency (%)									
	S	Ar	A	Sl	Kp	Kg	Dk	Kw	Lz	Li
Oligochaeta	5	0.0	58							
<i>Glossiphonidae</i>				-	-	-	-	0.4	0.2	-
<i>Hirudidae</i>				0.5	-	-	-	-	-	-
<i>Lumbricidae</i>				-	-	-	0.2	0.1	0.1	0.1
<i>Lumbriculidae</i>				0.3	-	0.7	-	1.1	0.6	0.1
<i>Naididae</i>				1.3	-	-	-	-	-	-
Odonata	8	21.7	1199							
<i>Aeschnidae</i>				0.3	3.2	-	-	-	-	-
<i>Calopterygidae</i>				4.3	8.8	1.2	3.3	0.2	0.4	0.3
<i>Cordulegasteridae</i>				5.9	1.2	0.2	-	-	-	0.2
<i>Coenagrionidae</i>				4.5	14.4	14.9	6.4	6.6	6.3	2.6
<i>Cordulidae</i>				5.6	8.4	12.1	23.5	0.9	1.4	0.6
<i>Gomphidae</i>				2.9	0.8	1.1	1.1	3.1	2.7	3.2
<i>Libellulidae</i>				8.8	3.2	5.3	0.2	7.5	8.6	4.6
<i>Platycnemidae</i>				-	0.4	-	-	-	-	-
Coleoptera	11	9.4	518							
<i>Chrysomelidae</i>				-	-	-	-	-	0.1	-
<i>Dryopidae</i>				-	4.8	4.0	1.1	0.1	0.2	2
<i>Dytiscidae</i>				1.1	5.2	5.4	-	0.5	12.7	7.4
<i>Elmidae</i>				8.3	0.8	1.2	3.1	0.4	0.3	3.1
<i>Gyrinidae</i>				-	-	-	0.2	0.4	0.2	-
<i>Halplidae</i>				0.3	-	-	0.2	0.4	-	-
<i>Hydraenidae</i>				0.3	-	0.7	-	-	-	-
<i>Hydrophilidae</i>				7.7	0.8	0.4	0.4	0.3	-	-
<i>Hygrobiidae</i>				0.3	-	0.4	-	0.1	0.9	0.4
<i>Limnebiidae</i>				-	0.3	-	-	-	-	-

<i>Spercheidae</i>				0.5	-	-	-	-	-	-
Hemiptera	7	4.2	231							
<i>Aphelocheiridae</i>				-	-	-	-	0.2	-	-
<i>Corixidae</i>				0.3	-	-	-	-	-	-
<i>Gerridae</i>				-	-	-	-	0.2	-	-
<i>Naucoridae</i>				3.7	-	-	-	1.1	1.1	0.7
<i>Nepidae</i>				3.5	-	0.4	-	0.1	-	0.3
<i>Pleidae</i>				4.3	-	-	-	0.4	0.3	0.1
<i>Veliidae</i>				-	3.6	4.4	6.9	0.8	3.3	0.7

Sl, Kp, Kg, Dk, Kw, Lz and Li represent different sites and S, A and Ar mean richness, abundance and relative abundance, respectively.

Taxa	Sites and Frequency (%)									
	S	Ar	A	Sl	Kp	Kg	Dk	Kw	Lz	Li
Molluscs	3	13.5	747							
<i>Lymnaeidae</i>				-	-	17.7	0.2	24.6	23.5	1.7
<i>Planorbidae</i>				-	1.2	-	-	0.1	-	-
<i>Sphaeriidae</i>				-	-	0.2	0.2	0.4	0.1	-
Lepidoptera	1	4.2	234							
<i>Pyralidae</i>				0.4	-	-	8.6	4.4	3.5	6.8
Megaloptera	1	0.0	42							
<i>Sialidae</i>				-	-	0.5	0.9	0.4	0.3	2.2
Diptera	8	14.1	779							
<i>Ceratopogonidae</i>				0.3	0.4	-	-	-	-	-
<i>Chironomidae</i>				30.1	7.6	1.9	9.1	11.2	7.3	19.1
<i>Culicidae</i>				-	-	-	-	-	0.1	0.1
<i>Limoniidae</i>				-	-	0.2	-	0.4	0.1	0.4
<i>Psychodidae</i>				-	-	-	0.9	-	-	1.7
<i>Simuliidae</i>				-	-	-	-	-	-	1.3
<i>Thaumaleidae</i>				0.3	0.4	-	-	-	-	-
<i>Tabanidae</i>				-	1.2	2.6	0.4	-	0.2	-
Ephemeroptera	5	9.4	519							
<i>Ametropodidae</i>				-	-	3.3	1.1	-	0.1	-
<i>Baetidae</i>				4.3	3.2	0.5	0.7	8	1.4	24.8
<i>Heptageniidae</i>				-	3.2	0.5	2.4	-	0.3	0.4
<i>Isonychiidae</i>				-	-	-	0.2	-	-	-
<i>Oligoneuriidae</i>				-	0.4	0.2	-	-	-	-
Crustacea	2	13.0	720							
<i>Atyidae</i>				-	20	2.3	9.8	7.2	19	4.6
<i>Graspidae</i>				-	3.6	6.1	5.3	5.6	2.6	1

Tricoptera	7	7.6	421						
<i>Ecnomidae</i>	-	0.4	4.2	-	1	0.5	-		
<i>Hydroptilidae</i>	-	2	0.2	0.2	-	-	-		
<i>Hydropsychidae</i>	-	-	0.5	1.8	2	-	4.6		
<i>Philopotamidae</i>	-	-	0.2	0.7	-	-	-		
<i>Polycentropodidae</i>	-	-	0.7	7.5	9.5	1.1	0.2		
<i>Psymchomyidae</i>	-	-	-	1.6	0.4	0.5	5.9		
<i>Rhyacophilidae</i>	-	-	0.7	-	-	-	-		
Plecoptera	2	0.0	52						
<i>Nemouroidea</i>	-	-	5.3	1.3	-	0.3	0.7		
<i>Capniidae</i>	-	-	-	-	0.3	-	-		
Nemathelminthe	1	0.0	1	-	-	-	0.2	-	-

Species richness S and density A showed an important relatively spatial variability between stations (Fig. 3), nevertheless their development displayed a synchronous character. These two characteristics of benthic assemblage were significantly correlated at the 95 % ($P < 0,05$; $r = 0,77$). Shannon-Wiener index H' ranged from 1,98 bits (station S1) and 2,29 bits (station Kp) (Table II). S1, Kw and Lz sites showed values of diversity below the average (2,13 bits) unlike the rest of stations whose values were broadly higher. Low values of H' noted here reflect the dominance of a small group of families, but strong workforce. In fact, over 57% of total abundance is due to six dominant families: *Coenagrionidae*, *Libellulidae*, *Lymnaeidae*, *Chironomidae*, *Baetidae* and *Atyidae*.

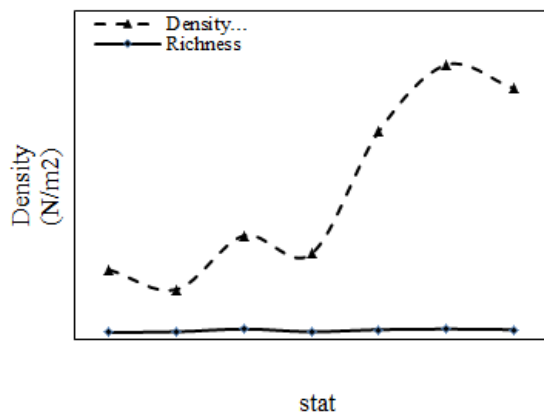


Fig.3 Spatial evolution of benthic invertebrate Richness and Density of Lukaya stream.

Evenness J' varies very little between different sites and set between 0,50 and 0,58 (Tab.II). However, highest values of this index were observed in Kp and Dk sites, thereby establishing a link with the low values of S and A . From the foregoing, evenness J' is highest in remote sites (S1, Kp and Dk) of high human pressure areas. It corresponds to 0,52; 0,55 and 0,58. However a low value (0, 50) of evenness was observed in Kg site.

Redundancy R is the estimate of the remaining path to an assemblage to reach its functional optimum [32]. All stations recorded redundancy R values less than 0,5 that is to say it varying between 0,41 and 0,49 values (table II).

With an average of 37,4% (values between 33,1% and 43,9%), McNaughton ID index (Table II) showed the dominance of a few species. However, no less representative number of taxa with moderately low abundances occupied the second rank. The spatial variation of evenness J' differs from H' [33]. The Kp and Dk sites, which are represented by the numbers 3 and 5 (Fig.4), are closest to the line of the maximum evenness than other stations. This is to be compared with the lowest values in S and A they recorded compared to other sites. The DIMO model (Fig. 4) split up stations in two groups. The first group gathers stations S1, Kp and Dk which are located upstream of the densely urbanized areas and which are characterized by a predominantly sandy substrate.

Table II Biodiversity indices (means±SD) and physico-chemical parameters (means±SD) recorded *in situ* among sites in Lukaya stream for period of 12 months. Full names for abbreviated biodiversity indices are given in site selection and laboratory procedures section

Sites	Indices					S	A	Physico-chemical parameters			
	H'	Hmax	J'	R'	ID (%)			T° (°C)	pH	Cond. (µs/cm)	Turb. (FTU)
Sl	1,98±0,16	3,78±0,28	0,52±0,08	0,47±0,08	39,5	14±2,64	126±37,24	23,8±0,8	4,6±0,6	3,8±1,04	5,6±4,5
Kp	2,29±0,28	3,89±0,24	0,58±0,04	0,41±0,04	34,4	15±1,7	91,66±16,5	22,1±1,4	6,2±0,7	9±4,3	58±57
Kg	2,19±0,31	4,31±0,19	0,50±0,05	0,49±0,05	32,6	20±2,64	189,33±79,82	24,6±0,8	5,9±0,4	12,3±4,1	222±218
Dk	2,10±0,27	3,65±0,45	0,55±0,07	0,44±0,07	33,2	14,6±4,16	157±97,54	23,4±3	7,05±0,7	18±8,8	21,6±14,5
Kw	2,03±0,34	4,11±0,82	0,50±0,05	0,49±0,05	35,8	19±8,88	383,33±251,81	25,7±2,8	7,4±0,9	23,6±11,5	34±26
Lz	2,16±0,16	4,28±0,41	0,51±0,09	0,48±0,09	42,4	20±5,19	497,66±436,86	23,9±2,2	6,6±0,5	29±25,1	55±45,9
Li	2,13±0,12	4,17±0,42	0,51±0,03	0,48±0,03	45,3	18,66±5,68	493,33±569,91	24,8±1,5	7,03±0,6	47,3±28,2	59±33

H', Hmax, J', R', ID, S, A, T°, Cond. And Turb, mean Shannon-Wiener diversity index, maximum diversity, evenness, redundancy, MacNaughton index, richness, abundance, temperature, conductivity and turbidity, respectively.

The average values of S and A are lower (respectively 14,6±0,6 and 125,6±32,6 ind./m²) with a richness not exceeding fifteen taxa in general. This decline is still marked in the Kp station with 15±1,7 and 93±24,6 ind./m². The second group includes stations further downstream (Kg, Kw, Lz and Li). Indices A and S are high (respectively 19,5±0,6 and 382,3±137,6 ind./m²) with maximum values at Lz site (20,3±3,7 species and 501,3±21 ind./m², respectively). The passage to the upstream sites is accompanied by a relative increase in both species richness and the Qinghong Q index (data no presented here).

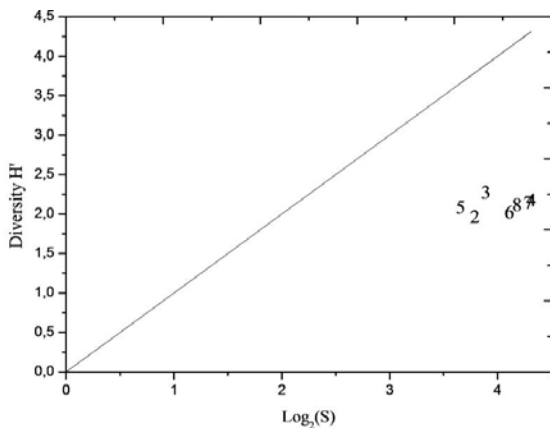


Figure 4. Positioning of different studied sites in function of specific richness (Log₂S) and diversity H'; the diagonal line represents maximum evenness J' (J'=1). Numbers 2, 3, 4, 5, 6, 7, and 8 represent Sl, Kp, Kg, Dk, Kw, Lz and Li sites, respectively.

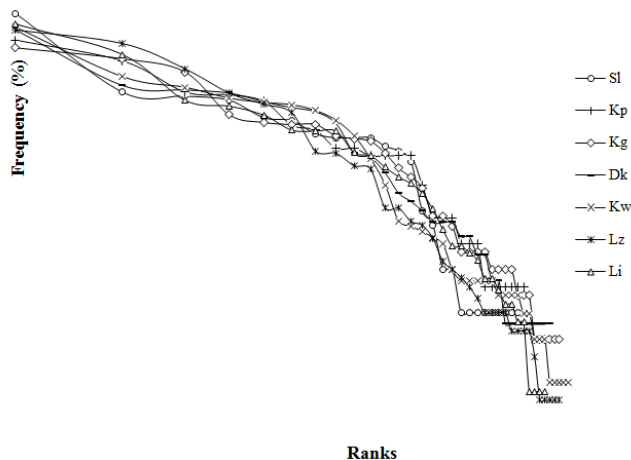


Fig 5: Rank-frequency diagrams of seven studied sites of Lukaya stream macrofauna.

The evolution of rank-frequency diagrams for the seven stations of Lukaya river allowed to characterize the demographic structure of benthic assemblage across space (Fig.5). The comparison between all stations can be placed in each one of the three stages of Frontier [34] based on the curve shape. Sl and Dk are the only stations that showed curves corresponding to characteristic diagrams of less structured communities (stage 1) with a largely dominant taxon, *Chironomidae* for Sl station and *Cordulidae* for Dk site with respectively 31 and 24% of total abundance. The other stations showed characteristic curves of an intermediate situation between stages 1 and 2. There are dominated by two taxa presenting high frequencies than 10%, which were accompanied by a group of taxa having frequencies between 5 and 10% (data not presented).

DISCUSSION

It was evident from our study that water quality worsened downstream in Lukaya stream mainly due to local land-use. Overall physico-chemical variables showed an increasing from upstream to downstream except turbidity values which showed the highest value at Kg site. This could be resulted probably of the proximity of called site at dredging material disposal (sand and pebble mainly) site. Improper land-use practices have been reported to contribute a considerable amount of allochthonous materials in lotic systems [35, 36]. Subsistence agriculture was evident in upper stream (sites Kp, Kg except site Sl) where low variables readings were recorded. However in the downer stream (Dk, Kw, Lz and Li) in addition of subsistence agriculture an industrial hen house (Baramoto) and a water treatment factory (REGIDESO) which discharge their effluents that were also suspected to contain high organic matter and other impaired components. These components contributed certainly to increase recorded variables at sites of this section. Turbidity significantly fluctuated between first and second sampling periods and between sites. It also showed associations with S, H' and specific richness Hmax. Although its strong effect in structuring macro-invertebrate communities has been documented [37], its influence during this study appeared to have been moderated by other environmental factors. Conductivity particularly showed association with abundance

A. In that case, conductivity was certainly one of the most important variables determining the presence or absence of macro-invertebrate taxa. This result is in agreement with what found by [38]. In addition, positive correlations between phosphate and A, S and conductivity and between sulphate and S also testified their influence in structuring macro-invertebrate communities particularly in disturbed areas. In contrast, [39] found no link between biodiversity indices and water P-concentrations in their study. However, temperature, conductivity, pH and remaining variables did not show significant difference between sites along the stream as during the sampling period. Nevertheless these results highlighted the importance of habitat characteristics in maintaining and assessing macro-invertebrates diversity and assemblages in running water [40, 41]. When catastrophic and unpredictable fluctuations of abiotic factors provoke perturbation in stream invertebrate communities, the response to such events varies between species [42]. This view was also supported by [43] who observed that physical disturbance could exert a major influence on the community structure of streams. In that case, the remaining species after fluctuations are not able to substitute the functions provided by extirpated species [44]. Death reported that habitat permanency or stability and biotic interactions could be a dominant force in structuring benthic invertebrate community in most streams [45]. Observed increase in invertebrate densities downstream could be translated into relatively high biodiversity indices except on site Kg. Our observations are in agreement with what showed by [2], which reported lower richness and higher densities in urban sites comparatively at other land-use practices (non-managed native forest, managed native forest, pine plantations and pasture). It is well known that heavily impacted zones have low number of species and high densities due to low interspecific competition [46]. Moreover in the absence of flow variability, biotic diversity would clearly be lower, with dominance by a single competitively superior taxon in the extreme case, as shown experimentally by [47] also by [41]. In all cases, invertebrate species diversity is favored by the presence of habitats with a complex three-dimensional structure, including wood debris or macrophytes, which are often, found growing in the shallow parts of the meanders [41]. When macrophytes are invasive they increase habitat complexity, hypoxia, allelopathic chemicals, facilitation of other exotic species, and inferior food quality leading to a decrease in abundance of native fish and macro-invertebrate species [48]. Nevertheless macro-invertebrate communities in stable sites are higher than those in unstable sites with communities in unstable streams being dominated by mobile collector/browsers [49].

Changes in macro-invertebrate assemblages were mostly observed in terms of species domination along the stream. Odonata (Coenagrionidae, Calopterygidae) dominated the turbid upper stream sites while Coleoptera (Dytiscidae, Elmidae, Dryopidae) were common in the lower sites with high conductivity levels. Three taxa (Lymnaeidae, Chironomyidae and Atyidae) which displayed higher abundances were captured in low flow waters which constitute high nutrient enrichment and sedimentation areas. Those areas are known to favour Chironomids and Oligochaeta at the expense of snails, algal piercing Trichoptera, Ephemeroptera and Plecoptera. However,

recolonization of previously impacted localities is faster with Chironomids than with other groups [50]. Sediment load hinders the growth of periphyton and reduces the availability of algae to grazers [51]. Consequently, sedimentation may lead to a decrease in the densities of certain groups, especially the scrapers, shredders and predators [52]. In addition sedimentation areas are characteristic of low energy and increase of muddy substrate in stream sections [53]. However, water quality degradation downstream the Lukaya River coincided with weak numbers of Ephemeroptera, Trichoptera and Plecoptera taxa (ETP taxa) and the EPT taxa can therefore be used for assessing water quality change.

Despite their synchronous evolution, species richness and density nevertheless allowed a categorization of the seven study sites into two groups. Sl, Kp and Dk stations formed the first group and showed low mean values of S and A, while the second group includes stations Kg, Kw, Li and Lz with higher mean values of S and A. However, H' and J' values of first group are roughly comparable to those of the second group. H' and J' Indices obtained are characteristic of rich-sites in organic matter, which are often colonized by tolerant organisms. In this study, Chironomyidae, Atyidae and Lymnaeidae were particularly abundant in these sites. Our results indicated a higher-than-expected diversity for the sites contaminated by organic matter, based on the expected relationship between these two indices. This implies that the observed high diversity values were most likely due to tolerant species. These results are in agreement with [54] for some streams in Ghana. Similar results have been found by [33], but in African north region.

The spatial evolution of structure assemblage of Lukaya river illustrated by using DIMO model resulted in changes of S and H' while J' remained relatively similar from one station to another. It is type 2 : "evenness-type" [28]. Moreover, separate analysis of the two groups formed by this model reflects a type 4 dynamic: "non-type" for Sl, Kp and Kw sites and a type 2 or evenness-type for Kg, Dk, Lz and Li sites. This suggests that the three parameters S, H' and J' either are changing or not from one station to the other within each group. Li and Lz stations, paving stone of moss and bryophytes, showed the highest of all the river species richness. In the opposite direction, Sl and Kp stations with the lowest species richness, were established on sand with some scattered plants.

Rank-frequency diagrams were used to monitor and visualize the spatial evolution of the demographic structure of assemblages [55], especially in disturbed areas where analysis by diversity indices proved to be insufficient [56]. Macro-benthic fauna of Lukaya river is situated between Frontier [56]'s stages 1 and 2, which characterizes immature state ecosystems but close to maturity as observed by [55]. This explains the presence, among the taxa collected, of a few species whose dominance is much higher number. However, the climax and subrectiligne stages corresponding to the end of a sequence or a maximum maturity of benthic assemblages have not been observed in Lukaya river.

In conclusion, this study revealed the capacity of macro-invertebrate communities to respond to changes when water quality is disturbed by human land-use practices. These changes were observed in variations in composition of species assemblages, and in biodiversity indices and densities. Improper land-use practices, such as intensive subsistence

agriculture on valley sides, industrial pollution from Baramoto hen house factory, removal dredge disposal, water treatment unit of REGIDESO and residential urban settlements around Lukaya stream basin, were suspected to negatively influence environmental conditions in Lukaya stream. Currently, there are no mitigation measures in place to reverse or contain this disturbing situation. There is a need for the Congolese government to strictly prohibit disposal of raw industrial or domestic effluent in rivers and streams by enforcing existing and new environmental legislation. Urban Councils together with other relevant government ministries should control unfriendly land-use and development plans on riparian land. Future development plans of residential and industrial areas should cater for proper sanitation and solid waste disposal systems. Cultivation of stream channels, riparian lands or all other activities on meander areas as well as reclamation of wetlands for human settlements should be properly planned and executed to minimize negative effects on water resources and biodiversity. Marshy and swampy areas along streams should be protected during implementation of development projects. In the meantime, more studies should be carried out to document macro-invertebrate assemblages and confirm their potential value for biological monitoring of water quality in lotic systems, especially in developing countries.

Acknowledgments

This study was supported by the Nile Basin Initiative (NBI). The authors are indebted to Mr. Lukanda who facilitates the access to financial aid. We greatly appreciate the support of hydro-biological laboratory, Department of Biology, Faculty of Science (University of Kinshasa).

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Citation: Koto-te-Nyiwa Ngbolua, et al (2014). Analysis of Structure and Composition of Macro-Invertebrate Assemblages in Natural Lukaya River Stream . *J. of Advanced Botany and Zoology*, V114. DOI: 10.15297/JABZ.V114.07.

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