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Preliminary study of the structure of the aquatic macroinvertebrate stands in lake Mai Ndombe in the province of Mai Ndombe in the RDC

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Abstract

The preliminary study of the structure of the macroinvertebrate stands of Lake Mai Ndombe in the DRC was carried out in February 2020. Six hundred and ten (610) aquatic macroinvertebrates were captured, divided into 7 orders and 28 families. The family of Corduliidae was the most abundant with 17.7% of the total specimens, it was followed by the Dystiscidae (14.1%), Naucoridae (12.7%), Limnebiidae (11.3%), Atyidae (7.7%), Coenagrionidae (6.5%) and Libellulidae (6.4%). The other families were poorly represented. The diversity indices calculated for the different stations varied between 1.67 (Ndom IV) and 2.8 (Ndom I) and the fairness between 0.93 (Ndom III and Ndom IV) and 0.96 (Ndom II) . The IBGN calculation revealed that the biological and ecological quality of the waters of this lake ranges from fair quality with Polycentropodidae as the indicator group to poor quality with the oligochaetes as the indicator group.

Keywords: Lake Mai Ndombe; Preliminary study; Aquatic Macroinvertebrate; Stand Structure

1. Introduction

The preservation of biodiversity and the sustainable management of aquatic ecosystems require the basic tools necessary for an in-depth knowledge of the species that inhabit the environments that we want to manage or preserve [1].

An ecosystem, whether aquatic or terrestrial, is characterized by a set of ecological factors. These are either abiotic or biotic. Abiotic factors include all the physico-chemical characteristics of the environment and biotic factors are all the interactions that take place between individuals of the same species or different species [2].

Faunistic and ecological studies are of primary importance in understanding the functioning and management of natural systems on the one hand, and on the other hand, in assessing the ecological health of hydrosystems. Benthic macroinvertebrates are considered as very good biological indicators. Indeed, they are relatively sedentary, abundant and relatively easy to collect. Their communities are able to present a characteristic gradient of responses according to the intensity and nature of the stress [3].

The Democratic Republic of Congo (DRC) has a very dense hydrographic network that includes huge wetlands (lacustrine, fluvial and even maritime) with a total surface area estimated at 86,080 km2 [4]. However, the characterization of the benthic macroinvertebrate populations of this hydrographic network is still embryonic. Thus,

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this study is a contribution to the deepening of knowledge on the benthic macroinvertebrate fauna of Lake Mai-Ndombe in Mai-Ndombe province.

Its objective is to characterize the structure of the biocenoses of the benthic macroinvertebrates of this lentic system (Lake Mai-Ndombe) and to understand the mode of distribution of the latter in order to explain the elements at the base of their distribution.

It is a question of:

- to characterize the habitat of the benthic macroinvertebrates from the characteristic environmental parameters of each station;
- to inventory the benthic macrofauna of the latté;
- to evaluate the biological and ecological quality of this hydrosystem.

1.1. Study Environment

Lake Mai Ndombe (1° 53' South, 18° 14' East) and its tributaries belong to the hydrographic system of the central Congolese basin (Figure 1). The latter is a vast depression of floodable tropical forest of 7,500 km². It is located in the province of Maï-Ndombe. The climate is equatorial: rainfall greater than 1900 mm, average daytime temperature of about 25°C. It has a climate with two rainy seasons with two dry seasons interspersed with rain.

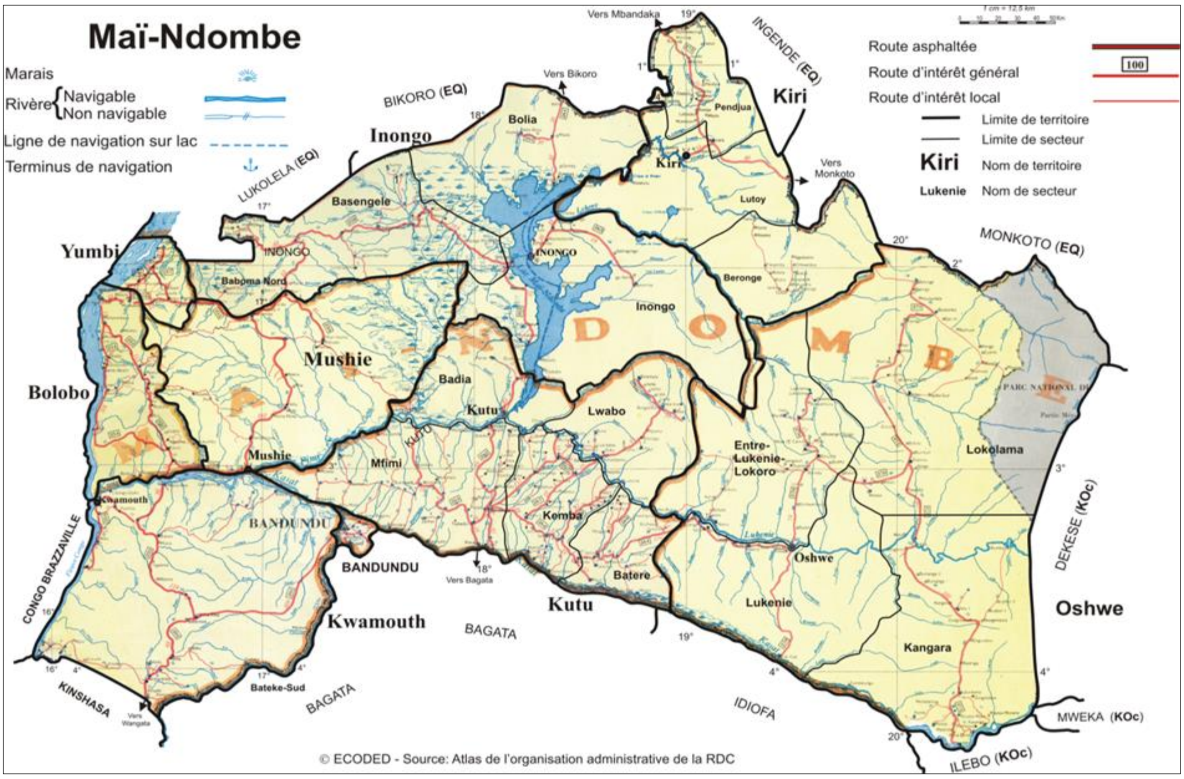

Figure 1 Location of Lake Maï Ndombe in the province of Maï Ndombe

The lake is supplied by its many tributaries (Figure 1), the most important of which are: Lobeke, Lokoro, Mbalenzala, Mpata-mbalu, Bolongoonsongo, Bolongoolule, Bolongomboo, Bowola, Botswana, Podote, Monopoli, Nkolé and Nzalenkanda. Its average area is 2,300 km2. It can double or triple depending on the rains. Its length is about 130 km and its average width is 14 km (4 to 30 km). It is shallow (maximum 10 m, average 5 m). It is located at an altitude of 320 m and flows south into the Congo River via the Fimi, Kasai and Kwa rivers.

The climatic characteristics are more equatorial: rainfall greater than 1900 mm, dry seasons interspersed with rains, average daytime temperature of about 30 ° [5].

Given the size of Lake Mai Ndombe, four stations were selected from the south to the north. These are:

- one station in the south towards the village of Mposo
- two stations located in the town of Inongo (one station in the south and another in the north of the town);
- a fourth station located to the north of the lake in the village of Isengi-angamba.

The selected stations are all in the littoral of Lake Mai Ndombe. Their geographical coordinates are shown in Table 1.

Table 1 Geographical coordinates and environmental characteristics

Stations	Latitude	Longitude	Altitude (m)	Végétation
Ndom I	02°41'50.4''	018°11'30.2''	292	Wild
Ndom II	01°45'43.0''	018°18'09.5''	293	Wild
Ndom III	01°55’14.5’’	018°16’55.2’’	292	Wild and anthropized
Ndom IV	01°56’23.7’’	018°16’22.2’’	292	Wild and anthropized

2. Methods

2.1. Measurements of physical and chemical parameters

Five parameters were sampled in-situ, because of their sensitivity to environmental conditions and their susceptibility to vary in significant proportions that could influence the interpretation. They are: temperature (°C), conductivity at 20°C (µs/cm), turbidity (NTU: Nephelometric Turbidity Unit), dissolved oxygen and pH. These parameters were measured at each station studied using two multiparameters, one brand Ysi 10E100340 for sampling at depth and the other brand Combo Hanna HI 98130 for surface water.

2.2. Sampling of the specimens of benthic macroinvertebrates

Six hundred and ten (610) specimens of benthic macroinvertebrates, divided into 7 orders and 28 families were captured in Lake Mai Ndombe using a haze bucket. The latter consists of a vertical metal frame of 20 cm on each side to which a conical net with a mesh size of 500 µm is attached.

The net was placed vertically with the opening facing the roots. The water was then stirred to draw organisms into the net. The sampled specimens were sorted and stored in 2-liter jars containing site water. In the laboratory, after careful sorting, the specimens were fixed in 5% formalin in 20 ml vials before identification.

On each jar and vial, the date and time of collection, the number of the station and the type of substrate were mentioned.

The identification was done mainly with the help of the determination keys proposed by [6], [7], [8], [9], [10], [11]; under binocular stereo-loupe. The microscope was also used for some precise details.

2.3. Index analysis of macroinvertebrates stands

The different indices and analyses were calculated using a statistical software Past (Paleontogy statistica) version 6.1. These are:

2.3.1. Taxonomic diversity

It is represented by two components: taxonomic richness and relative abundance [12].

2.3.2. Taxonomic richness

This represents the number of taxa present in a community sampled in each station of each of the hydrosystems studied.

2.3.3. Taxonomic composition

The taxonomic composition or relative abundance of taxa is the proportion of each MIB family in relation to the total number of individuals in a community. It provides a picture of the organization and relative contribution of a population to the faunal assemblage in the sample [13].

2.3.4. The Shannon and Weaver H' index

Used in ecology to measure specific diversity [14]. It is calculated by the following formula:

$$H' = -\sum_{i=1}^{S} Pi \log Pi$$

With: H': Shannon and Weaver diversity index.
S: number of taxa (species),
Pi: relative abundance of each taxon ((Pi= $\frac{ni}{N}$),
i: varying from 1 to S,
ni: number of taxa i;
N: total number of taxa in the station.
H' varies between 0 and 4.5. Its value is null (0) if the population consists of only one species; and maximum in the case where the species represent equivalent abundances.

2.3.5. Piélou's Equitability J'

This measures the balance of taxa within a stand [14]. This index is obtained by the ratio between the Shannon-Weaver diversity index (H') and a fictitious equitable distribution of these taxa [15], [14]. This index varies from 0 to 1, and is obtained by the formula: J'= H'/Hmax

The value of J' varies between 0 (a single species dominates) and 1 (all species have the same abundance);

2.3.6. Simpson's index (1-D)

This corresponds to the probability that two individuals drawn at random belong to the same category (species). When diversity is maximal, its value is 0, when diversity is minimal it is 1, which sometimes hinders its interpretation. It is an index independent of a distribution. To obtain more intuitive values, we use the diversity index represented by 1-D, with the maximum diversity represented by the value 1 and the minimum by zero [16]. The index gives more weight to abundant species than to rare species. It is given by the expression: : $\boldsymbol{D = \sum_{i=1}^{k} \frac{1}{pi^2}}$

The parameter Pi is the proportion of the total number of individuals. This expression poses a problem for the weight of abundant species which can be difficult to collect. Hence the use of the formula of [17] : $\boldsymbol{D = 1 - \sum_{i=1}^{s} Pi^2}$;

2.3.7. Jaccard's similarity index

Measures the degree of similarity between the populations of different stations within a hydrosystem. It is calculated using the formula [18], [19]: $I = \frac{Nc}{Nx + Ny - Nc}$

Where: Nc: number of taxa common to stations x and y

Nx and Ny: number of taxa present at stations x and y respectively. Jaccard's similarity index varies from 0 to 1.

Global Biotic Index (GBI):

The evaluation of the biological and ecological quality of the three rivers studied was done using the GBI in accordance with the requirements of the NFT 90-350 standard of March 2004 according to the French Agency for Standardization [20]. The purpose of this index is to evaluate the evolutionary trend of the water quality of lotic ecosystems from the study of negative (pure water) or positive (polluted water) biological indicators existing in the benthic macrofauna [21].

The GBI makes it possible to assign a biological quality score to the environment, which integrates both the influence of the physical and chemical quality of the water and the influence of the morphological and hydraulic characteristics of the watercourse. This method evaluates the overall ability of an environment to host living beings by taking into account both the variety of BIMs and the representativeness of the habitats present on the station [20].

The range of values of the NBI varies from 20 (for very pure waters) to 1 (for waters highly polluted by fermentable organic matter) [21].

The calculation of the NGSI is done in 3 steps:

- determination of the taxonomic variety class (st) ;
- the indicator faunal group (IFG), taking into account only the indicator taxa represented in the samples by at least 3 individuals or 10 depending on the taxon;
- reading the index at the intersection of the taxonomic variety (st) column and the indicator faunal group (IG) row.

Table 2 Interpretation of biological and ecological water quality [20]

Color Class	Biological quality	Note from I.B.G.N
Blue	Very good	Note ≥ 17
Green	Good	16 ≥ Note ≥ 13
Yello	Fair	12 ≥ Note ≥ 9
Orange	Bad	8 ≥ Note ≥ 5
Red	Very bad	Note < 5

The biological and ecological quality of the waters of the rivers studied is based on the taxonomic richness of each station and the sensitivity to pollution of the indicator faunal groups [22].

2.4. Statistical analyses of the data

Several multivariate analysis methods have been developed for the processing of ecological data [23], [24], [25]. Principal Component Analysis (PCA) is one of the most classical techniques of multivariate statistics [26], [14].

In this study, Principal Component Analysis (PCA) was used to investigate the influence of environmental variables on the distribution of MIB families in Lake Mai Ndombe.

PCA allows for an arrangement of ecological entities (sites, families or other variables) along bi- or multidimensional axes based on data on taxonomic composition or environmental variables.

According to [14], using PCA involves the following steps:

- Construct a two-dimensional data matrix, species-station abundance or environmental-station variables ;
- Transform the raw quantifiable data (abundance into log (x+1)), environmental variables into ln (x+1) ;
- Submit the data to the actual analysis.

Principal Component Analysis (PCA) was used to determine the relationships between macroinvertebrates and environmental variables. PCA was also used to process data on macroinvertebrate population changes in Lake Mai Ndombe.

3. Results

3.1. Physical and chemical characteristics of the waters of Lake Mai Ndombe

The average values of different environmental variables are shown in Table 2.

Table 2 shows that the water temperature in Lake Mai Ndombe varied between 28.8°C (Ndom III) and 32.3°C (Ndom IV). The peak (32.3°C) was reached by the Ndom IV station. The Ndom III station recorded the lowest temperature (28.8°C).

The pH values of the waters of Lake Mai Ndombe varied between 5.1 and 5.6. The highest value was reached by the Ndom I station and the lowest pH value was recorded at the Ndom IV station (i.e. 5.1).

Table 3 Variations of physico-chemical parameters of Lake Mai Ndombe in February 2020

Physical and chemical parameters	Sampling stations				Average	Sd
	Ndom I	Ndom II	Ndom III	Ndom IV		
Temperature (°C)	29.5	29.1	28.8	32.3	29.9	1.61
pH	5.6	5.4	5.3	5.1	5.3	0.21
Turbidity (NTU)	22	22	20	23	21.8	1.26
Conductivity (µs/cm)	39	41	37	42	39.8	2.22
Dissolved oxygen (mg/l)	7.95	7.45	5.4	3.8	6.15	1.92
Saturation (%)	105	85	73	63.4	1.92	17.8

The variations in turbidity observed during this study, were around 20 NTU and 23 NTU. The highest value (23 NTU) was observed at the Ndom IV station and the minimum value at the Ndom II station (20 NTU).

Regarding the values of conductivity, they oscillated between 37 (µs/cm and 42 (µs/cm. The station Ndom IV recorded the highest value (42 (µs/cm) and the lowest value was observed at the station Ndom III (56 (µs/cm).

As for the dissolved oxygen levels, they varied between 3.8 mg/l and 7.95 mg/l. The highest content was observed at the Ndom I station (7.95 mg/l) and the Ndom IV station presented a low content (3.8 mg/l).

Saturation values ranged from 63.4% to 104%. The highest value was recorded at the Ndom I station. The station Ndom IV recorded low concentration.

3.2. Structure of Macroinvertebrate populations in Lake Mai Ndombe

The station distribution of Macroinvertebrates, their gross and relative abudances in Lake Mai Ndombe are recorded in the table 4.

Table 4 Taxonomic distribution of macroinvertebrates in Lake Mai Ndombe in February 2020

Order	Family	Sampling stations								N'
		Ndom I		Ndom II		Ndom III		Ndom IV		
		ni	ni/N	ni	ni/N	ni	ni/N	ni	ni/N	
Coleopteran	Dystiscidae	18	0.071	31	0.21	37	0.21	0	0	86
	Hydrophilidae	5	0.02	1	0.01	0	0	1	0.03	7
	Limnebiidae	7	0.028	12	0.08	50	0.29	0	0	69
	Spercheidae	2	0.008	0	0	1	0.01	0	0	3
	Hygrobiidae	0	0	15	0.1	4	0.02	0	0	19
	Nepidae	5	0.02	0	0	3	0.02	0	0	8
Decapods	Atyidae	30	0.119	17	0.12	0	0	0	0	47
	Palemonidae	3	0.012	0	0	0	0	0	0	3
Odonata	Aechnidae	2	0.008	0	0	0	0	0	0	2
	Gomphidae	3	0.012	4	0.03	0	0	0	0	7

	Libellulidae	11	0.044	6	0.04	22	0.13	0	0	39
	Corduliidae	97	0.385	3	0.02	8	0.05	0	0	108
	Calopterigidae	0	0	7	0.05	0	0	0	0	7
	Coenagrionidae	9	0.036	27	0.19	4	0.02	0	0	40
	Lestidae	4	0.016	9	0.06	0	0	0	0	13
Hémiptera	Naucoridae	45	0.179	3	0.02	30	0.17	0	0	78
	Aphelocheiridae	3	0.012	0	0	0	0	0	0	3
	Syrphidae	0	0	0	0	1	0.01	0	0	1
	Dolichopodidae	1	0.004	0	0	0	0	0	0	1
Trichoptera	Philipotamidae	0	0	1	0.01	1	0.01	0	0	2
	Potamanthidae	0	0	0	0	1	0.01	0	0	1
	Polycentropodidae	5	0.02	9	0.06	2	0.01	0	0	16
Basometaphora	Ancylidae	1	0.004	0	0	0	0	0	0	1
	Lymnaeidae	1	0.004	0	0	3	0.02	8	0.2	12
	Physidae	0	0	0	0	1	0.01	1	0.03	2
Oligocheta	Tubificidae	0	0	0	0	5	0.03	5	0.13	10
	Lumbriculidae	0	0	0	0	0	0	12	0.3	12
	Lumbricidae	0	0	0	0	0	0	13	0.33	13
N		252	1	145	1	173	1	40	1	610
S		19		14		16		6		

Legend: ni : Number of individuals per family; N' : Sum of ni within a family in the 4 stations; N : Number of individuals per station; ni/N : Relative abundance per station; S : Number of taxa per station

3.2.1. Taxonomic richness

The taxonomic richness of the MIB populations surveyed in Lake Mai Ndombe indicates that 28 families divided into 7 orders and 4 classes were collected.

The St I station had the highest number of families (S=14), followed by the St III (S=16), St II (S=14) and St IV (S=6) stations.

3.2.2. Gross abundance and relative abundance

Table 3 shows that six hundred and ten (610) individuals were caught in Lake Mai Ndombe.

The St I station showed a higher gross abundance than the others, with 41.3%. The St III, St II and St IV stations showed respectively 28.3%, 23.7% and 6.5% of the total MIB harvested in Lake Mai Ndombe.

At the St I station, the family Corduliidae is the most abundant with 38.5% of individuals collected, followed by Naucoridae (17.9%), Atyidae (11.9%), Dysticidae (7.1%), Libellulidae (4.4%), Coenagrionidae (3,6%), Limnebiidae (2.8%), Hydrophilidae, Polycentropodidae and Nepidae (2% each), Lestidae (1.6%), Palemonidae, Gomphidae and Aphelochiridae (1.2% each), Spercheidae and Aechnidae (0.8% each). Each of the families Dolichopodidae, Ancylidae, and Lymnaeidae Hydrochidae presented 0.6%.

The St II station was characterized by a high relative abundance of the family Dystiscidae with 21.4% of individuals caught, followed by the families Coenagrionidae (18.6%), Atyidae (11.7%), Hygribiidae (10.3%), Limnebiidae (8.3%), Lestidae and Polycentropodidae (6.2%), Calopterigidae (4.8%) Libellulidae (4.1%), Gomphidae (2.8%), Cordulidae and Naucoridae (2.1%) and Hydrophilidae and Philopotamidae (0.7%).

The family Limnebiidae recorded a large number of individuals collected at the St III station, representing 28.9% of the total specimens collected there. This family is followed by Dystiscidae (21.4%), Naucoridae (17.3%), Libellulidae (12.7%), Corduliidae (4.6%), Tubificidae (2.9%) Hygrobiidae and Coenagrionidae (2.3%), Nepidae and Lymnaeidae (1.7%), Polycentropodidae (1.2%), and Spercheidae, Syrphidae, Philopotamidae, Potamqnthidae and Physidae (0.06%).

At the St IV station, the peak of individuals collected was observed in the family Lumbricidae with 32.5% of the sum of specimens collected there. This was followed by the families Lumbriculidae (30%), Lymnaeidae (20%), Tubificidae (12.5%), Hydrophilidae and Physidae (2.5%).

The enumeration of individuals collected in all the study stations of Mai Ndombe the family Corduliidae was the most abundant with 17.7% of the total specimens collected. It is followed by the families Dystiscidae (14.1%), Naucoridae (12.7%), Limnebiidae (11.3%), Atyidae (7.7%), Coenagrionidae (6.5%) Libellulidae (6.4%), Hygrobiidae (3.1%), Polycentropodidae (2.6%), Lestidae and Lumbricidae (2.1%), Lymnaeidae and Lumbriculidae (1,9%) and Tubificidae (1.6%), Nepidae (1.3%), Hydrophilidae, Gomphidae, and Calopterigidae (1.1%), Spercheidae, Palemonidae, and Aphelocheiridae (0.5%), and Aechnidae, Philopotamidae, and Physidae (0.3%), and Syrphidae, Dolichopodidae, Potamanthidae, and Ancylidae (0.2%).

3.3. Index analysis of macroinvertebrates populations in the Mai Ndombe by station

Figure 2 illustrates the station variation in Shannon-Weaver index, Piélou equitability, Simpson index and dominance within the MIB populations in the 4 stations studied in Lake Mai Ndombe.

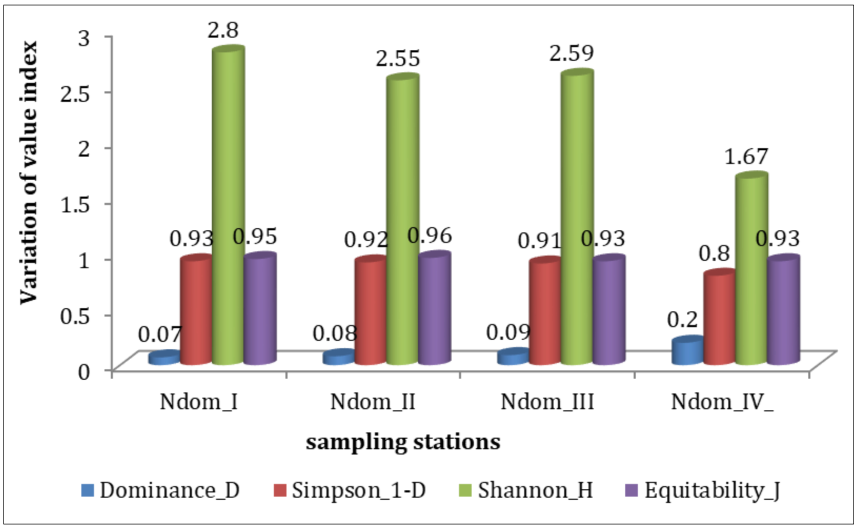

Figure 2 Station variation in stand indices of MIBs in Lac Mai Ndombe in February 2020

Figure 2 indicates that the MIB stand harvested at Ndom I station (H'=2.8) is more diverse than that of the other stations. The MIB diversity index at Ndom III (H'=2.59) is higher than at Ndom II (H'=2.55) and Ndom IV (H'=1.67).

With respect to the balance of taxa within the MIB stands collected at the different study stations in Lake Mai Ndombe, Piélou's equitability index (Figure 2) indicates that taxa are better distributed at the Ndom II station (J'=0.96) than at the Ndom I (J'=0.95), Ndom III and Ndom IV stations (J'=0.93).

The calculation of the dominance and Simpson's indices allowed the evaluation of the dominance within each station stand in Lake Mai Ndombe. The highest dominance was recorded at the Ndom IV station (D=0.2), while the lowest was obtained at the Ndom I station (D=0.07). Dominance at Ndom II and Ndom III stations was 0.09 and 0.08 respectively (Figure 2).

Simpson's index showed the highest value at Ndom I, Ndom III and Ndom IV stations (1-D=0.93). The Ndom II station had a low Simpson index value (1-D=0.92).

The similarity matrices (Table 3), derived from the Jaccard similarity index calculated for the five stations studied, show that the stands exhibit some relative variability in similarity in their specific compositions.

Table 5 Similarity matrix between the stands of the four study stations in Lake Mai Ndombe in February 2020

	Ndom I	Ndom II	Ndom III	Ndom IV
Ndom I	1			
Ndom II	0.50	1		
Ndom III	0.34	0.36	1	
Ndom IV	0.08	0.05	0.15	1

The calculation of Jaccard's index showed a close relationship between the stations of Lake Mai Ndombe with respect to the taxonomic composition of the MIB assemblages. It was found that the St I and St II stations showed a very high affinity (I=0.5). Taken 2 to 2, the remaining stations showed the following similarity indices: St II and St III (I=0.36); St I and St III (I=0.34); St III and St IV (I=0.15) St II and St IV (I=0.05).

3.4. Global Normalized Biotic Index (GNBI)

The biological and ecological quality of the water at the stations studied in Lake Mai-Ndombe is shown in Table 4.

Table 6 Evaluation of the biological and ecological quality of the water of the stations studied in Lake Mai-Ndombe

Stations	Ndom I	Ndom II	Ndom III	Ndom IV
Sum of taxa Σt	19	14	16	6
Variety class	6	5	5	2
Indicator faunal group	Polycentropodidae	Polycentropodidae	Oligocheta	Oligocheta
GNBI	9	9	5	2
Environmental quality	Fair	Fair	Poor	Very poor

Table 4 above indicates that the stations Ndom I and Ndom II presented the family Polycentropodidae as an indicator faunal group, while the stations Ndom III and Ndom IV had as an indicator group the oligochaetes (Tubificidae).

Regarding the biological and ecological value of the waters of this lake, the calculation of the IBGN revealed that the stations Ndom I and Ndom II are of fair quality, while the station Ndom III is of poor quality and the station Ndom IV is of very poor quality.

3.5. Principal Component Analyses

3.5.1. Correlations between MIBs and physical and chemical parameter

Figure 3 shows that two main axes (axis 1 and axis 2) were selected since they are responsible for 84.3% of the dispersion of the variables; axis 1 presented 64.7% of the total variance and axis 2 19.6%.

The Principal Component Analysis of the ecological factors in Lake Mai Ndombe revealed a positive correlation between axis 1 and all the stations studied in the lake.

In relation to biotic factors, axis 1 is strongly correlated with the families of Dystiscidae (r=1.9064), Naucoridae (r=1.3734), Limnebiidae (r=1,3585), Corduliidae (r=1.1752), Libellulidae (r=0.9672), Coenagrionidae (r=0.82922), Atyidae (r=0.45977) and Polycentropodidae (r=0.05223).

This axis is highly negatively correlated with the following MIB families: Lumbricidae (r=-1.1952), Lumbriculidae (r=-1.2153), Lymnaeidae (r=-0.51816), Tubificidae (r=-0.72918), Physidae (r=-1.4536), Aphelocheiridae (r=-13935), Syrphidae (-1.6415), Dolichopodidae, and Ancylidae (r=-1.6521).

In relation to physicochemical parameters, axis 1 correlated positively with pH (r=0.69784), temperature (r=2.9158), turbidity (r=2.4845), O-conductivity (r=3.3062), dissolved oxygen (r=0.85733) and saturation (r=4.3082).

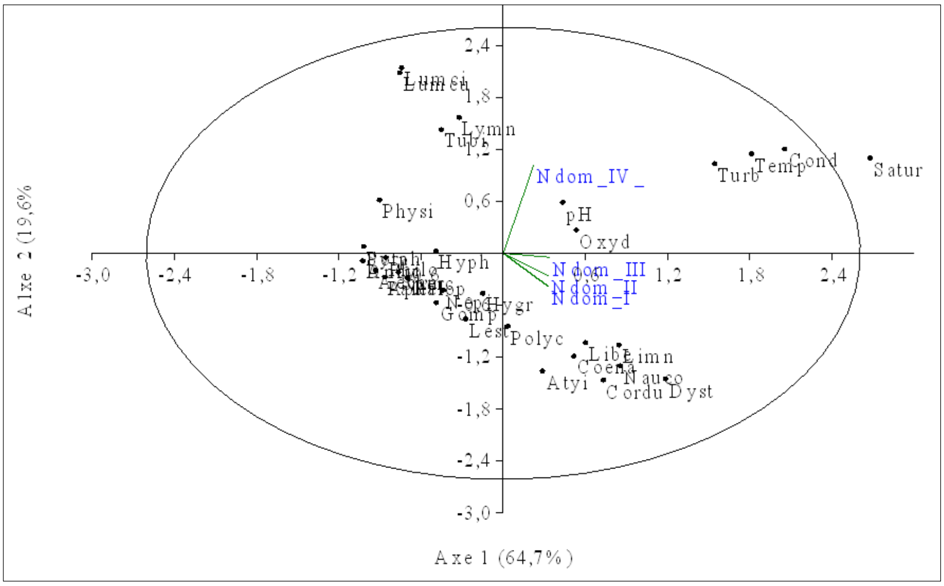

Figure 3 Correlations between MIB and physical and chemical parameters in Lake Mai Ndombe in February 2020

4. Discussion

In shallow lakes, water temperature is generally little different from air temperature [27]. Throughout intertropical Africa, average temperatures are high, most often above 20°C, which favors the speed of chemical and biological reactions in the different trophic levels such as bacterial decomposition but also photosynthesis or metabolic reactions [18].

The water temperature of Lake Mai-Ndombe showed less sensitive variations in all sampling stations and at different depths; the lowest average value was recorded at the Ndom III station (28.8°C) and the highest at the Ndom IV station with 32.3°C. The fluctuations of this abiotic parameter have always been related to the local and regional climatic conditions and more particularly to the air temperature, as well as the phenomena of water evaporation and precipitation that result when the latter increases [14], and by the thermal stratification that is a major effect of temperature on the functioning of the lake [19]. This means that in the warm season, the thermal zone known as the epilimnion (surface layer) is warmed and wind movements allow for a homogenization of the water temperature.

The pH values are most often related to the nature of the land through which the water flows [20].

The pH values recorded at the four stations surveyed range from 5.1 at Ndom IV to 5.6 at Ndom I. At all stations, the pH was acidic. This acidity would be due to the fact that this limnic hydrosystem rests on a substratum of naturally acidic rock [21] and by the decomposition of organic matter which releases carbon dioxide tending to acidify the waters [14].

The average turbidity values recorded in Lake Mai Ndombe ranged from 37 µS.cm-1 to 42 µS.cm-1. This is justified by the speed of the currents caused by the winds, which leads to the daily displacement of 3 to 4 km of the water masses [29], which prevents the stagnation of the necromass; this disrupts the process of mineralization and induces low values of conductivity, the average of which is 39.8 µS.cm-1.

The amount of dissolved oxygen recorded in Mai Ndombe is higher. The average value is 6.5 mg/l. The important presence of vegetation in the littoral, the important movements of water masses caused by waves and the low activity of decomposition of organic matter, justify the permanent renewal of oxygen in this hydrosystem [31], [32].

In Lake Mai Ndombe, the relative frequency of Odonata (34.8%), Dystiscidae (17.7%), Limnebiidae (11.3%), Atyidae (7.7%) and Hygrobiidae (3.1%); reveals the favorable conditions of their environment: good dissolved oxygen content, acid pH and nutrients.

The presence of Trichoptera (Polycentropodidae, Philopotamidae and Potamanthidae) in the stations Ndom I, Ndom II and Ndom III proves sufficiently that the physical and chemical properties encountered in these stations are favorable to them. These organisms require less dissolved oxygen as explained by Principal Component Analysis (Figure 3).

This is confirmed by [33] who link the biological potential of a community of macroinvertebrates to the quality of the physical habitat in which it develops. In addition, an abundance of insects has been observed in the lake, including Odonata, Coleoptera, Heteroptera and Diptera with a character of predatory detritus [33] proving a good ecological approach to their development previously because of abundance of periphytoplankton. Hence a diversity of these faunal groups in three first stations.

The research of [34]; [35]; [36] and [37] tested several sites in the Lake Kivu basin region and showed that the abundance and diversity of aquatic macroinvertebrates are a function of their eco-physiological requirements and tolerances. Our results correlate with those of [38], [39], [40], [41] and [42] who described the habitat of aquatic macroinvertebrates and its main influences. For this first preliminary inventory study of macroinvertebrates in Lake Mai Ndombe, the observations of groups present in the samples coupled with their frequency of occurrence allow us to identify macroinvertebrate taxa that can be qualified as pollutant-sensitive in non-anthropized stations. Indeed, these taxa are only present at the level of stations Ndom I and Ndom II, they are: Polycentropodidae, Potamanthidae and Philopotamidae.

The families (Tubificidae, Lumbriculidae and Lumbricidae) that were only found in the anthropized stations (Ndom III and Ndom IV) can be considered as pollutant resistant and could be of another type of interest for the bioindication of this hydrosystem. The values of the Shannon-Weaver index obtained in the four stations studied in Lake Mai Ndombe are respectively 1.67; 2.55; 2.59 and 2.8. These values between 0.5 and 4.5 indicate that the Ndom IV station is weakly diversified while Ndom I, Ndom II and NDom III are strongly diversified [19].

The values of the Piélou equitability index calculated for the same stations are as follows: 0.93 in Ndom III and Ndom IV stations; 0.95 and 0.96 in Ndom II and Ndom I stations respectively. The low equitability indices observed in Ndom III and Ndom IV stations justify the dominance of some taxa. The Ndom I and Ndom II stations, on the other hand, have an equitability close to 1, justifying a balance between the taxa [15].

Calculation of Jaccard's similarity index based on taxa collected at the four stations revealed the following similarity values: Ndom I and Ndom II stations are 50% similar; Ndom I and Ndom III 34% similar; Ndom II and Ndom III 36% similar. The difference in similarity between these stations is explained by the degree of occupation and use of the shoreline.

Considering the lake as a continuum, the taxa collected in the four stations led to the calculation of the NBI. The index values obtained revealed that the waters of stations Ndom III and Ndom IV are of poor biological quality (indicator taxon: oligochaetes). While the calculation of the IBGN from taxa collected in stations Ndom I and Ndom II revealed that the waters at this level are of fair biological quality (indicator taxon: Polycentropodidae).The riparian populations put pressure on the hydrosystems especially in large African cities by their discharge of effluents of various kinds. This observation was also made by [43] and [44] in Burkina Faso. These discharges pollute these aquatic ecosystems and have harmful effects on the life of benthic macroinvertebrate communities [45]; [44]; [46].

5. Conclusion

This study focused on the preliminary inventory of aquatic macroinvertebrates from Lake Mai Ndombe in the Mai Ndombe Province of northwestern D.R. Congo. In this ecosystem located in the central basin region showed an abundance of 610 individuals collected in the 4 stations selected in relation to anthropic activities and accessibility. An abundance of Odonata, Coleoptera and Hemiptera was found brought together by an important floristic richness case of macrophytes and phytoplankton. Anthropogenic activities are the main factors influencing the diversity of aquatic macroinvertebrates.

The values of the Shannon-Weaver index obtained in the four stations studied are between 1.67 and 2.8. These values indicate that the Ndom IV station is low in diversity while Ndom I, Ndom II and Ndom III are high in diversity.

The NBI revealed that the waters of stations Ndom III and Ndom IV are of poor biological quality, while stations Ndom I and Ndom II showed a fair biological quality.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

References

[1] Mbega J.D & Teugels G.G. Ogooué Fish Determination Guide. SLACK incorporated, 165p. 2003.

[2] Dajoz. R. Precis of ecology. 2nd and 3rd university cycle. 6th edition, Dunod, Paris, 542 p. 1996..

[3] Sanogo S. and Kabre. T.J-A. Dynamics of spatio-temporal structuring of populations of macro-invertebrate families in a continuum of a dam lake-effluent-river from an irrigated perimeter. Volta Basin (Burkina Faso).Journ. of Applied Biosciences 78: 2014, 6630-6645.

[4] Tusanga. M.S. Support project for improving the management of shrimp fisheries in the Democratic Republic of Congo (Case of the Atlantic coast and the Congo River estuary. EAF-Nassen project (GCP/INT/003/NOR), FAO , Reference Report, 60 pp. 2015.

[5] Micha J-C., Nabwenge, B-L.B., Ibofa R., Mumba, F., Mutambwe, S., Zanga, N., Willem, E., Svennson J-E. and A. Wilander. An overexploited resource, Nannothrisa stewarti, an endemic sardine from Lake Maï-Ndombe (DR Congo), an unforeseen result of the National Malaria Control Programme. 24p. 2018.

[6] Macan. T. A guide to fresh water invertebrate animals, éd. M.A, PHD, Paris, 249 p. 1959.

[7] Evrard. M. Macroinvetebrates infested with Belgian fresh waters, Freshwater invertebrates, (Freshwater ecology units), FUNDP, 19 p. 2001.

[8] Mary. N. Physical and chemical characterizetion of new caledonian revers. Proposal of a biotic index based on the study of macroivertebrates. 90p. 2010.

[9] Tachet, H., Richoux, P. Bournaud M. and Usseglio-Polater, P. Freshwater invertebrates: systematics, biology and ecology. CNRS éditions, Paris, France, 588 p. 2006.

[10] Doucet. G. Key for determining the exuviae of the Odonates of France. 3rd edition, revised, corrected and argued. French Society of Odonatology. Nature and Discoveries Foundation. 64 pp. 2012.

[11] Frank, S., Müller O. and Martens A. The dragonfly larvae of Namibia (Odonata), Druckerei Koch, Reutlingen 2014.

[12] Campbell N. and Reece J. Biologie. 7ème édition. Pearson Education, Quebec, 1334p. 2007.

[13] Goaziou Y. Methods for assessing the biotic integrity of the aquatic environment based on benthic macro-invertebrates - Internship report, Quebec, Ministry of the environment, Department of monitoring the state of the environment, envirodoq no ENV/2004/ 0158, Collection No. QE/146. 37 p. 2004.

[14] Kamb T.J-C. Structure of benthic macro-invertebrate populations and assessment of the biological and ecological quality of the Gombe, Kinkusa and Mangengenge rivers in Kinshasa/ DR Congo, Doctoral Thesis, UPN, 230 p, 2018.

[15] Moisan J. and Pelletier. L. Sampling protocol for benthic macroinvertebrates in freshwater in Quebec - shallow watercourses with soft substrate. State of the Environment and Parks Monitoring Department, 39 p. 2011.

[16] Schaepfer R. and Butler R. Analysis of landscape dynamics, Teaching sheet 4.2, polytechnic school of Lausanne, 1 p. 2002.

[17] Hayek L. C. and Buzas M. A. Surveying natural populations: Columbia University Press, New York, 563p. 1997.

[18] Kapoor V. and White J. Conservation biology a training manual for biological diversity and genetic resources c.s.c., U.K, pp. 71- 85. Action satellitaire à haute resolution, in Revue Belge de Géographie (Belgo.) 339-456. 1992.

[19] Evrard M. Use of pupal exuviae of Chironomidae (Diptera) as biological indicators of the quality of Walloon surface waters. Doctoral thesis, Notre Dame de la paix University Faculties (Belgium), 204 p. 1996.

[20] French Agency for NORmalisation (FANOR), Water testing. Determination of the normalized global biological index (IBGN). Approved standard. T.90-350, 9 p. 2004.

[21] Ramade F. Ecology elements. Applied Ecology, 6th ed. Dunod, Paris, 864p. 2005.

[22] Rodier J. Water analysis. 9th ed.; Dunod, Paris. 1526p. 2009.

[23] Legendre L. and Legendre P. Digital Ecology. Volume 1: multiple processing of ecological data. 2nd edition, Masson, Paris of the University of Quebec. 260 p. 1984.

[24] Ter Braak C.J.F. and Smilauer P. CANOCO Reference manual and user's guide to Canoco for Windows (version 4). Centre for Biometry, ageningen, Netherlands, 351 p. 1998.

[25] P. Legendre and L. Legendre. *Numerical Ecology*, *2nd edition, Elsevier*, 853 p. 1998.

[26] Lebart L., Morineau A. & Fenelon J.P. Statistical data processing methods and programs. Dunod edition. Paris. 518 p. 1997.

[27] Lemoalle J. Elements of hydrology of Lake Chad during a drought period 1973-1989. Rome, FAO, Fisheries Report, No. 445: 1991, 54-61..

[28] Lemoalle. J. Photosynthetic production and phytoplankton in the euphotic zone of some African and temperate lakes. *Rev. Hydrobiol. trop*., 14 : 31-37. 1981.

[29] Dussart, B. Limnology. The study of continental waters. 2nd edition. Collection "Current Faunas and Flora", 680 p, 1992.

[30] Rodier J. Water analysis, natural waters, waste water, sea water, Bordas, Paris, 1365 p. 1984

[31] Dajoz. R. Summary of ecology: Fundamental and applied ecology, third edition, Bordas, Paris, 549 p. 1975.

[32] B.C. Genin, Chauvin S., Menard. Rivers and biological indices - pollution - Methods, IBGN. ENSESAD-CNERTA (ed), ISBN 2-11-090285-x, 202 p. 1997.

[33] Tâcher H., Bourneaud, M., Richoux P., Dessaix and Pattes. Introduction to freshwater invertebrates. French Association of Limnology, University of Lyon. Ecology of River Hydrosystems, Geolab, 199p. 2009.

[34] Ngera M.F., Baluku B., Cammaerts D., & Bisimwa M.A. Biological evaluation of the population of the Kalengo river by aquatic invertebrates, Cahier du CERUKI, Special Issue CRSN-Lwiro, 2009, p89-94.

[35] Zirirane D., Bagalwa J.J., Isumbisho M., Mulengezi M., Mukumba I., Bora M., Mucheso J.M,, Lukamba A., Iragi, G. Irenge, Kibangu B.F. and Kamangala R. Comparative assessment of pollution of Kahuwa and Mpungwe rivers by the use of benthic macro-invertebrates, International Journal of Innovation and Scientific Research, ISSN 2351-8014 Vol.14: Number 3. 2014,

[36] Ndakala P.M., Bisimwa A.M., Masilya P.M. and Ngera F.M. Study of the aquatic macrofauna of the Kalengo River, South Kivu, Democratic Republic of Congo, International Journal of Innovation and Scientific Research, ISSN 2351-8014 Vol. 13 No. 388-397 pp. 2015.

[37] Irenge E. Evaluation of the physical, chemical and biological qualities of the waters of the Nyamuhinga river (Bukavu/ DR-Congo); Unpublished master's thesis UEA. 2012.

[38] Samba F.B. Water and Aquatic Ecosystem, integrating indicators, Journal Officiel, Paris, 15p. 2008.

[39] Ministry of Sustainable Development, Environment, and Parks (MSDEP). Guide to biological monitoring based on freshwater benthic macro-invertebrates in QUEBEC, Quebec, ISBN 978-2-550-66035-4, 86p. 2008.

[40] United States Environmental Protection Agency (U.S. EPA).Biological Assessments and Criteria: Crucial Components of Water Quality Programs, EPA 822-F-02-006. 2002.

[41] Banaru D. and Perez. T. Bioindicators, Biomarkers, Course Notes. University of Marseilles, Paris, 24p. 2010.

[42] Leclercq L. and Solite M. Simple key for determining freshwater macro-invertebrates for the use of small "river guardians", Hautes-Fagnes Scientific Station; University of Liege; 62p. 2010.

[43] Gire. State of water resources in Burkina Faso and their management framework. Final version, May 2001. General Directorate of Water Resources. Ouagadougou, Burkina Faso. 2001.

[44] Davis A.M., Thorburn P.J., Lewis S.E., Bainbridge Z.T., Attard S.J., Milla R. and Brodie J.E. Environnemental impacts of irrigated sugarcaneproduction: Herbicide run-off dynamics fromfarms and associated drainage systems. *Agric.Ecosyst. Environ*, doi : 10.1016. 2011.

[45] Alhou B. Impact of discharges from the city of Niamey (Niger) on the water quality of the Niger River. Dissertation presented for obtaining the degree of Doctor of Science. Namur University Press, 230 p. 2007.

[46] Kamb T.J-C., Ifuta N.S., Mbaya N.A and Pwema V.K. Influence of the substrate on the distribution of benthic macro-invertebrates in a logical system: case of the Gombe, Kinkusa and Mangengenge rivers, Int.J. Biol. Way. Sci 9(2): 2015, 970-985.