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Impact of the Anthropogenic Activities on the Diversity and Structure of Benthic Macroinvertebrates in Tropical Forest Stream

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***Abstract*— The diversity and structure of benthic macroinvertebrates related to some physico-chemical parameters were studied in the Konglo stream, an affluent of the Nyong river in Cameroon. The benthic macroinvertebrates were collected at three stations according to multihabitat the approach and physic-chemical parameters were sampled and analyzed using classic methods between February 2014 and August 2014. During this study, 1969 individuals belonging to 3 phyla, 7 classes, 16 orders, 63 families and more than 90 genera were sampled. The class of Insects, including 9 orders, 54 families and more than 79 genera, predominates with 74.81 % of the relative abundance, followed by the class of Decapods regrouping 21.94 % of the individuals distributed in 1 order, 2 families and 2 genera, however less varied. The other classes (Achaeta, Oligochaeta, Bivalvia, Gastropoda and Arachnida) represent only 3.25 % of relative abundance. The spatial variation of taxonomical richness shows a decrease of the diversity from upstream to downstream as well as the Ephemeroptera-Plecoptera-Trichoptera (EPT) index. Moreover, the Sörensen similarity index indicates dissimilarity between the station K3 and the two others stations. Otherwise, the rank-frequency diagram of Frontier and the Shannon and Weaver index show that the structure of benthic macroinvertebrates is in ecological starting succession in upstream and middle while it is closed to ageing in downstream.**

Keywords— Anthropogenic Activities, Benthic Macroinvertebrates, Biodiversity, Forest Stream, Phyisico-Chemical Parameters.

I. Introduction

Since the Rio Summit in 1992, the preservation of biodiversity has been considered as one of the key issues of sustainable development. This biodiversity faces even greater problems linked to urban development, agriculture and intensive exploitation. These various factors are among other things responsible for the degradation of aquatic environments [1]. Measurement methods based on biological assessment use living organisms to provide insights into their responses to the many environmental pressures imposed by different environments [2]. Several groups of organisms have been used for aquatic assessments, including benthic macroinvertebrates. The choice of benthic macroinvertebrates as better bioindicators is necessary for several reasons. They form an important link in the food chain and they incorporate the cumulative and synergistic effects of multiple disturbances in aquatic environments [3]. Biological monitoring is therefore needed to assess the biological health of aquatic environments [4], [5]. The monitoring of this biodiversity is useful not only for documenting the diversity of benthic macroinvertebrates but also for assessing the ecological health status of streams, the evolution and the effect of a source of pollution on the integrity of benthic macroinvertebrates in the hydrosystem [6], [7].

In Cameroon, benthic macroinvertebrates in forested areas are poorly known although some work has been done in this direction [8], [9], [10], [11], [12], [13]. These studies have shown that the waters are of good quality and the population of benthic macroinvertebrates is more diversified in the forest zone when advancing into the non-anthropized zone. However, several streams are still unexplored. With the urbanization and the rapid growth of the population, it become a priority and very urgent to build a database that can serve as a reference for future work and guideline for decision-making by public authorities and stakeholders. It is for this purpose that our study has focused on the influence of anthropization on the dynamics and structure of the benthic macroinvertebrates of Konglo stream, a tributary of Nyong river at Mbalmayo. More specifically, it focused on (i) studying the spatio-temporal evolution of some physicochemical parameters of water in Konglo stream; (ii) identify and enumerate the benthic macroinvertebrates present in this stream; and (iii) evaluate the ecological quality of this stream using bioindicators and biocenotic index.

II. Material And Methods

A. *Study zone*

The study area is located in the ecological Centre-South Forestry region of Cameroon, between 3°30'-3°58' N and 11°20'-11°40' E. The climate is an equatorial type with four seasons unequally distributed as follows: a long dry season from mid-november to mid-march, a small rainy season from mid-march to the end of June, a small dry season from july to august and a long rainy season September to mid-november [14]. Precipitation varies from 1500 to 2000 mm and the annual temperature average is around of 25°C with amplitude of 2.4°C [15], [14]. The hydrographic network is dense. Soils include, ferralitic soils located at the top of the interfluves and at the bottom of slopes, hydromorphic soils and poorly developed soils, respectively in marshy valleys and steep slope mountainous terrain [15], [16]. The vegetation is of secondary dense forest type. There is a dense humid evergreen forest at low and medium altitudes, and a semi-deciduous forest [15].

The Konglo watershed is located in the Nyong and So'o Division, and extends between 3°25' and 3°40' of latitude Nord and between 11°28' and 11°32' of longitude East. Approximately 14.59 km lengh, the Konglo Stream is oriented in the N-S direction where it flows into Nyong. It flows into a watershed of about 32.59 km perimeter and his dry season width varies from 2.92 to 6.35 m. It receives many small tributaries throughout its course such as Nkengue and Mbebime as well as domestic effluents from the city of Mbalmayo (Figure 1).

- The Konglo Station 1 (K1), with geographic coordinates of 03°34' N and 011°30' E and 672 m height, is located in the upper section at approximately 3.81 Km from the source.
- The Konglo 2 (K2) station, with geographic coordinates of 03°32' N and 011 ° 30' E, is 646 m height and 9.58 km from the source.
- The Konglo 3 station (K3), with geographical coordinates of 03°31' N and 011°31' E and at 642 m height, is located in the lower course, at 13.34 km from the source, after crossing the city of Mbalmayo.

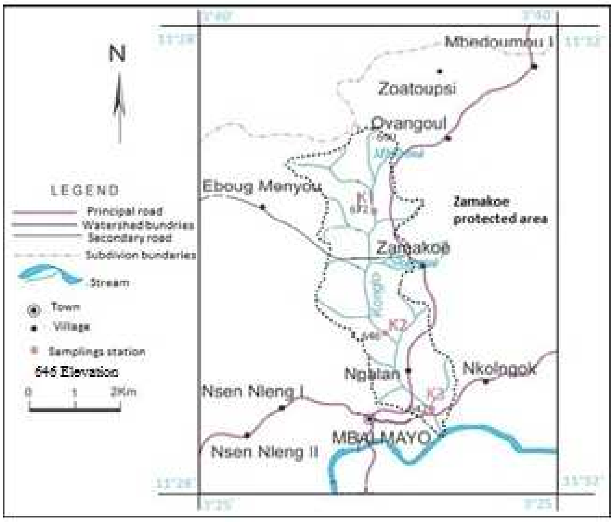


Figure 1: Hydrographic card of Konglo basin (source: topographic card of Yaounde at 1/200000, INC, 1980).

B. *Analysis of physicochemical parameters*

At each sampling station, 15 environmental variables were taken into account. The physico-chemical parameters of water at each sampling station were done in the field and at the laboratory following the [17], [18] standards. For laboratory analyzes, water samples were collected monthly at each station using 250 mL and 1000 mL polyethylene bottles and transported to the laboratory in a refrigerated cabinet. Temperature, electrical conductivity, and TDS were measured in situ with the HANNA Hi 99300 TDS conductivity meter. Dissolved oxygen and pH were measured in situ with a HACH HQ 30d Flexi Oximeter and a HANNA pH meter, respectively. Suspended solids, nitrates, ammonia and phosphates were measured in laboratory using a HACH DR / 2010 spectrophotometer. Alkalinity and total hardness were also measured in laboratory using a Wagtech 7100 photometer. The dissolved carbon dioxide and oxidability were done by volumetrically in laboratory.

C. *Sampling of benthic macroinvertebrates*

The benthic macroinvertebrates were collected using a long-handled kick net (30 x 30 cm side, 400 µm mesh size). Samplings were collected in a 100 m stretch for each station, following Protocol described by [19]. To this end, in each station, 20 drags of the kick net were done in different micro-habitat, each corresponding to a surface of 0.15 m^2 (30 cm x 50 cm). The organisms retained in the net were collected using a pair of fine forceps and placed in plastics sampling bottles with 10% formalin. In the laboratory, the collected specimens were rinsed with tap water using 400 µm net and then stored in 70° ethanol before the identification and counting operations. For identification, the organisms were introduced into petri dishes and grouped according to their size and morphology, then identified, under a stereomicroscope with the use of keys and appropriate literature [20] [21], [22], [23].

D. *Data analyses*

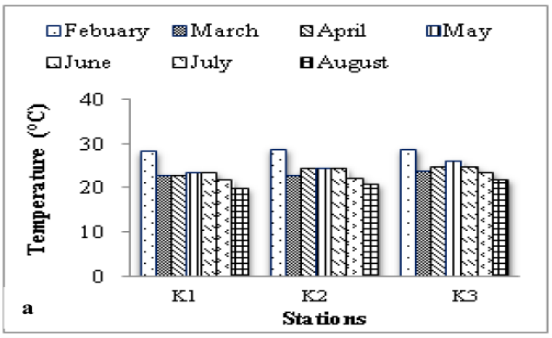
The Kolmogorov-Smirnov test was first applied to check the normality of the distribution before comparing environmental parameters and abundances of benthic macroinvertebrates. The, Kruskal-Wallis test and Mann-Whitney tests were then performed to verify significant differences between spatial and seasonal variations of environmental parameters and biological abundances. XLSTAT 2007 software was used for these statistical analyses with the level of significance $P<0.05$. Relationship between environmental variables and taxonomic abundances of benthic macroinvertebrates was determined by Spearman correlation test and canonical redundancy analysis (RDA) using Canoco for Windows 4.5. The dendrogram was performed to identify a similarity between stations using physicochemical and biological parameters. SPSS software version 16.0 was used for this test. The spatio-temporal evolution of the diversity and structure of the benthic macroinvertebrates community was monitored using metrics such as taxonomic abundance, taxonomic richness, taxonomic diversity, the EPT index, the EPT density / Chironomidae density ratio and Rank-Frequency Diagram of Frontier. The Rank Frequency Diagram of Frontier (RFD) [24] is represented by a graph on which the ranks of species fixed in order of decreasing abundance are plotted on the abscissa, and the absolute or relative frequencies of individuals on the ordinate. The scale used is logarithmic. In this way we obtain the polygons, which give a synthetic image of the population more complete than a simple index of diversity, although not independent of this parameter. The Global Biological Standardized index is calculated according a double-entry table analysis recommended by [19], comprising in abscissa the taxonomic variety classes (classes 1 to 14) and ordinates the indicator faunal groups, classified in decreasing order of sensitivity to pollution (indices 9 to 1). The taxonomic level used here is the family; the value of the index between 1 and 20 is read at the crossing of the line corresponding to the most sensitive faunistic group and the column corresponding to the total number of systematic units in the sample. Some polluo-resistant families may have a genus or species that is more resistant than others to disturbance. Then, the index score can be overestimated. The robustness of the result, *ie* the relevance of the score, is evaluated by removing the first indicator group from the faunal list and determining the IBGN with the next indicator group. The value obtained is then called consolidated IBGN.

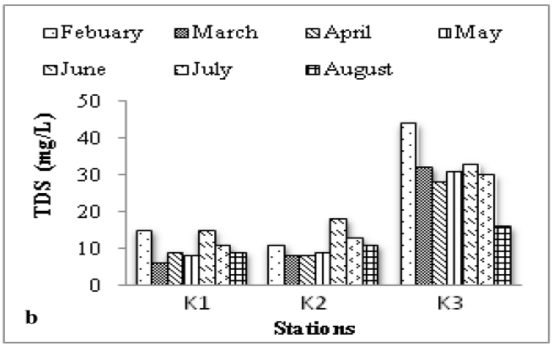
III. Results And Discussion

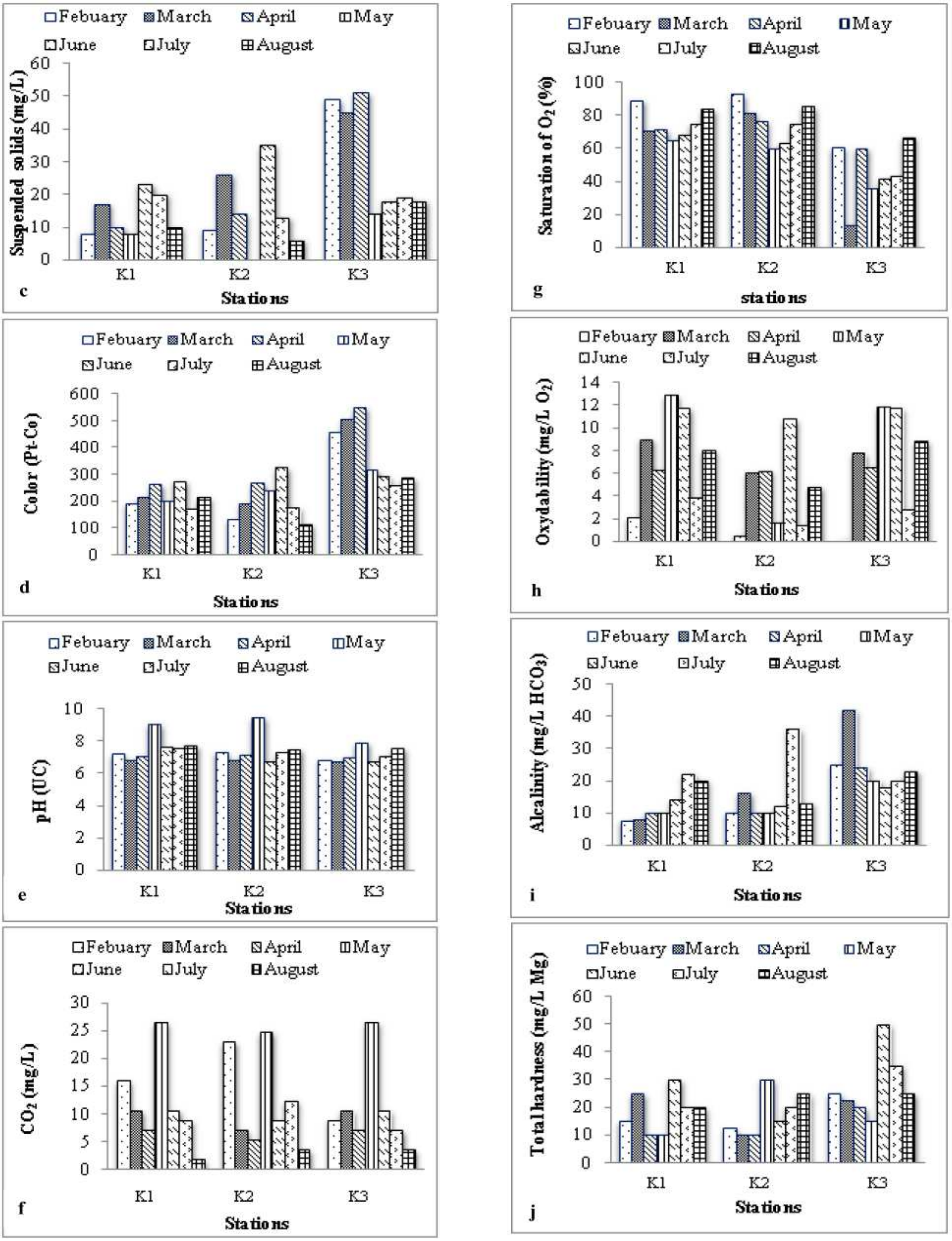
A. Results

- Physicochemical parameters

The temperature varies from 20°C to 28.9°C with an average of 24.2 ± 2.4°C, the highest values being recorded in February (Figure 2a). TDS values range from 6 mg/L to 44 mg / L with an average of 17.38 ± 10.91 mg/L, the highest value being obtained at the station K3 in February (Figure 2b). The SS levels are between 0 mg/L and 51 mg/L with an average of 19.67 ± 14.21 mg/L, and the highest value is observed at the station K3 in April (Figure 2c). . The color varies from 115Pt-Co to 550 Pt-Co with an average of 268.7 ± 114.2 Pt-Co, the highest value being observed at the station K3 in April (Figure 2d). The pH values range from 6.7 CU to 9.46 CU with an average of 7.3 ± 0.7CU, the highest value is recorded at the station K2 in May (Figure 2e). The CO_2 levels varies between 1.76 mg/L and 26.4 mg/L with an average of 11.39 ± 7.52 mg/L, the highest value being observed at the station K1 in May (Figure 2f) . The percentage of saturation of dissolved oxygen varies from 13.60% to 92.60% with a mean oscillating around 65.42 ± 19.17%, the lowest being recorded at the station K3 in March (Figure 2g). The oxidability values range from 0.15 mg/L to 12.85 mg / L with an average of 6.40 ± 4.04 mg/L, the highest value being obtained at the station K1 in May (Figure 2h). The alkalinity values range from 7.5 mg/L to 42 mg/L with an average of 17.64 ± 9.07 mg/L, the highest value being recorded at the station K3 in March (Figure 2i). The total hardness values range from 10 mg / L to 50 mg/L with an average of 21.19 ± 9.83 mg/L. The highest value being obtained at the station K3 in June (Figure 2j). The turbidity is between 10 FTU and 107 FTU with an average of 45 ± 26 FTU, the highest value being recorded at the station K3 in May (Figure 2k). The electrical conductivity ranges between 15 µS / cm and 83 µS/cm with a mean oscillating around 35.76 ± 21.68 µS/cm, the highest value being recorded at the station K3 in February and March (Figure 2l). Nitrate levels range from 0.00 mg/L to 9.68 mg/L with an average of 2.16 ± 2.78 mg/L, the highest value being obtained at the station K2 in February (Figure 2m). Ammonia contents ranges from 0.049 mg / L to 2.501 mg /L with an average of around 0.808 ± 0.639 mg/L, the highest value being observed at the station K1 in August (Figure 2n). Orthophosphate levels ranged from 0.008 mg/L to 0.570 mg/L with an average of 0.113 ± 0.151 mg /L, the highest value being recorded at the station K2 in May (Figure 2o).






Febuary March April May June July August
Suspended solids (mg/L)
K1 K2 K3
c
Stations
Saturation of O_2 (%)
g
stations
Color (Pt-Co)
d
Oxydability (mg/L O_2)
h
pH (UC)
e
Alcalinity (mg/L HCO_3)
i
CO_2 (mg/L)
f
Total hardness (mg/L Mg)
j

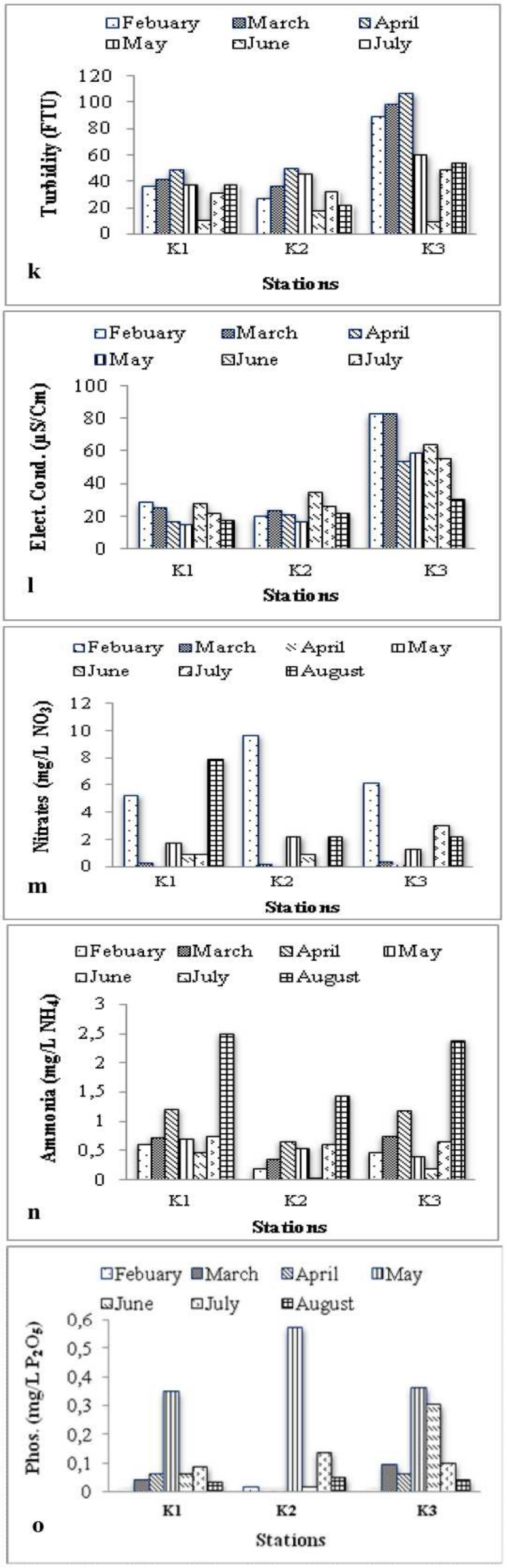


Figure 2: Spatio-temporal evolution of physico-chemical parameters values: Temperature (a); TDS (b); SS (c); Color (d), pH (e); CO_2 (f); % Saturation in O_2 (g); Oxydability (h); Alkalinity (i); Total hardness (j), Turbidity (k); Electrical conductivity (l); Nitrates (m); Ammonia (n) and phosphates (o).

- Relative abundance of benthic macroinvertebrates

A total of 1969 organisms were collected belonging to 16 orders in which 9 were present in all stations. There are Diptera (31.94% relative abundance), Decapoda (21.94%), Coleoptera (21.33%), Odonata (7.01%), Dictyoptera (4.57%). %), Trichoptera (4.52%), Hemiptera (3.14%), Ephemeroptera (1.77%) and Arachnida (1.42%). The other seven orders (Plecoptera, Megaloptera, Haplotaxida, Rhynchobdellida, Eulamellibrancha, Basommatophora, and Mesogastropoda) represent only 2.23% of the relative abundance (Table 1).

Table 1: Relative abundance by station of the different orders of benthic macroinvertebrates in the Konglo stream

Orders (%)	K1	K2	K3	Total (%)
Arachnida	1.17	1.90	1.33	1.42
Decapoda	42.86	58.43	0.27	21.94
Coleoptera	6.56	4.04	33.45	21.33
Dictyoptera	3.98	2.85	5.44	4.57
Diptera	3.04	0.95	54.59	31.94
Hemiptera	9.13	2.61	1.07	3.15
Odonata	16.86	14.01	0.63	7.01
Ephemeroptera	1.64	1.90	1.78	1.78
Trichoptera	13.82	7.13	0.00	4.52
Others	0.94	6.14	1.43	2.34

- Taxonomic richness

Figure 3 shows that benthic macroinvertebrates are unequally distributed along the stream. The station K1 is the most diversified with 36 families. The Decapoda, although represented only by 2 families, dominate with 42.85% of relative abundance, followed by Odonata (16.86%) whit 9 families and Trichoptera (13.81%) with 6 families. The station K2 is also supplanted by the Decapoda (58.43%), followed by Odonata (14.01%) represented respectively by 1 and 7 families. Diptera, less abundant (0.95%), are represented by 3 families. Station K3, less diversified (29 families), is under pressure of Diptera (54.59%), represented by 3 families and dominated by Chironomidae, followed by Coleoptera with 33.45% relative abundance. Here, Decapoda represent only 0.26% of relative abundance.

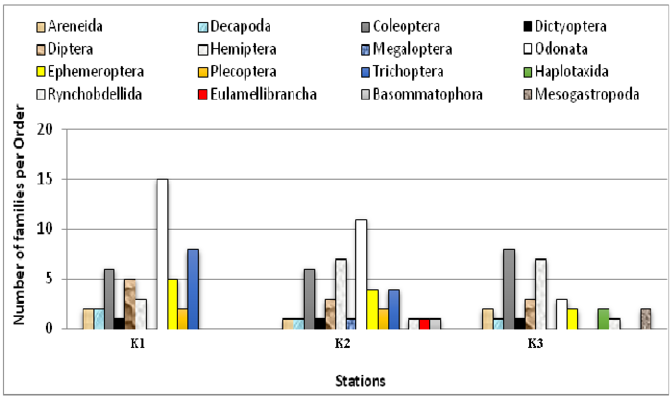


Figure 3: Distribution of taxonomic richness (number of families) per order following the stations

- Structure of benthic macroinvertebrates

The diversity Index of Shannon shows a progressive regression from upstream to downstream. The index values go down from 2.41 bits/ind at the station K1 to 1.54 bits/ind at station K3. The Piélou's equitability index, shows a similar evolution with values decrease from 0.67 to 0.45 from station K1 to station K3 (Figure 4a).

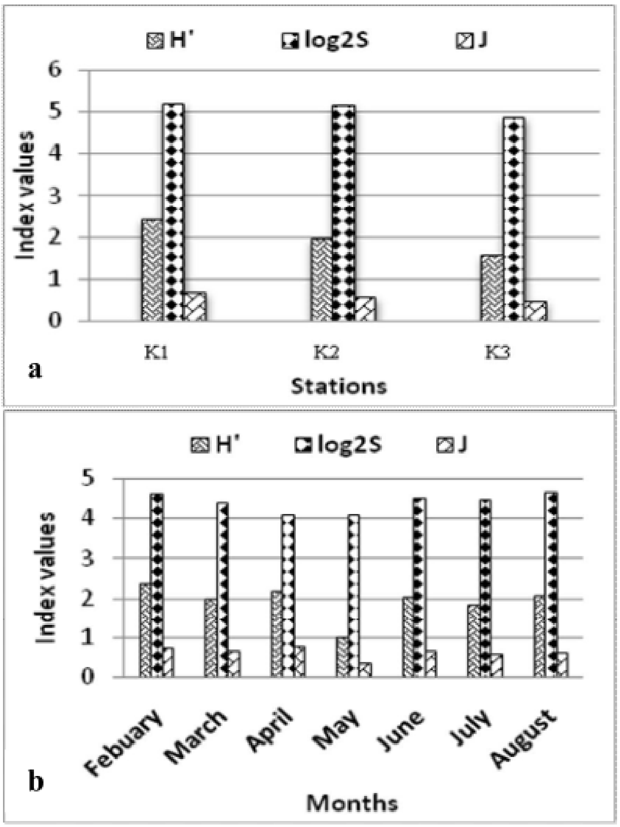


Figure 4: Spatial variation (a) and temporal (b) of H' of Shannon and Weaver, maximal theoretical diversity log_2S and J of Pielou indices.

These two indices vary irregularly, the high values being observed in February in the dry season (H'= 2.37 bits / ind.; J = 0.73) (Figure 4b).

- Variation of rank-frequency diagram of Frontier (RFD)

The spatial profile of RFD based on the relative abundance of families shows that stations K1 and K2 have similar sigmoidal patterns that correspond to the beginning of the ecological succession according to the stage 1 of Frontier dominated by a young population [24]. The straight-line, hyperbolic shape of the station K3 profile shows the stages 2 and 2 of Frontier, corresponding to the maturity of the system which is the beginning of the ageing process dominated by aged population (Figure 5a). This spatial profile shows that diversity is low and dominated by a few species. On the temporal point of view, the RFD profile indicates that the structure of the population does not vary significantly from one month to another (Figure 5b).

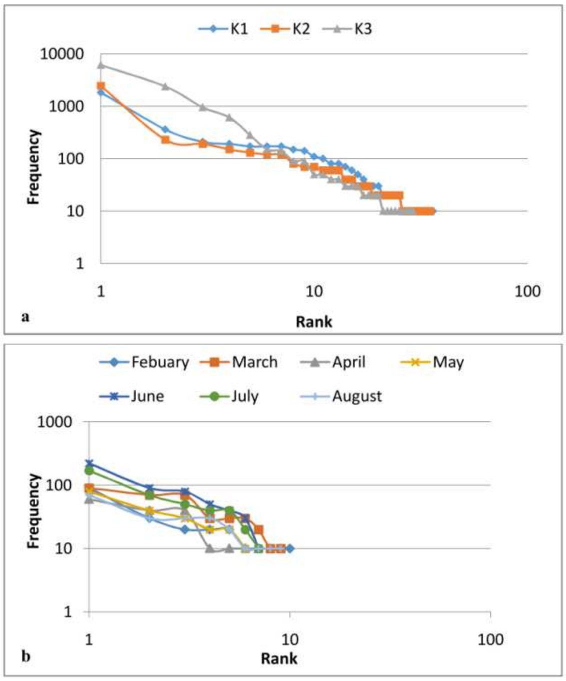


Figure 5: Longitudinal variation (a) and temporal (b) of the rank-frequency diagram of Frontier of benthic macroinvertebrates in Konglo stream

- Coefficient of similarity of Sörensen

The similarity coefficient of Sörensen indicates a low to medium faunal likeness between the stations. The values vary from 27.27% (K1-K3 stations) to 50% (K1-K2 stations) (Table 2).

Table 2: Coefficient of similarity of Sörensen between different stations

Stations	K1-K2	K1-K3	K2-K3
Sorensen's coefficient of similarity	50%	27,27%	37,5%

- Variation of Ephemeroptera-Plecoptera-Trichopetera (EPT) index and EPT/Chironomidae density ratio

Spatially, the EPT index decreases from upstream (12 families) at station K1 to downstream (2 families at station K3). In terms of EPT density, the values also decrease from upstream (7 Ind/m^2) to downstream (2 Ind/m^2) (Table 3).

The ratio of EPT density / Chironomidae density oscillates between 0.2 and 60.8 with an average of 12.67 ± 11.05 spatially (Table 3).

Table 3: Longitudinal variation of EPT index and report of EPT density / Chironomidae density in the Konglo stream

Describers	K 1	K 2	K 3	Mean ± Standard errors
Families number	36	35	29	33,33 ± 3,79
EPT index	12	9	2	7,66 ± 5,13
EPT density (Ind/m^2)	7	4,1	2	4,36 ± 2,51
Chironomidae density (Ind/m^2)	0,4	0,2	60,8	20,46 ± 34,92
EPT density / Chironomidae density	17,5	20,5	0,03	12,67 ± 11,05

- Standardized Global Biological Index (IBGN)

Spatially, the normal IBGN and consolidated IBGN values are higher in upstream (respectively 17 and 13) and in the middle (respectively 18 and 17) compared to the downstream (9), (Figure 6a).

On a temporal point of view, the normal IBGN score and its consolidated form fluctuate irregularly, with the minimum values being observed in May (6 and 5 respectively) and the maximum values in August (normal IBGN = 17) and March (IBGN consolidated = 14) (Figure 6b).

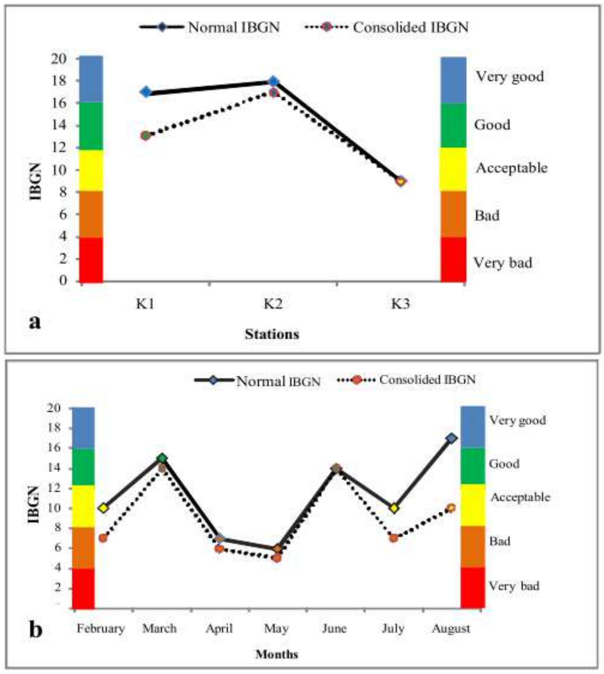


Figure 6: Spatial variation (a) and temporal (b) of the IBGN in the Konglo

- Relationship between environmental variables and benthic macroinvertebrates

The results of redundancy analysis (RDA) revealed that the relationship between bentic macroinvertebrates and their habitat conditions follow mainly the first two axes (F1= 43.2 and F2=12.5) which accounted for 55.5% of the total variance (figure 9). The first axis (F1) shows in positive coordinates Hydrophilidae, Blatidae, Hydrochidae, Crysomelidae, Hirudidae or Libellulidae that are positively and significantly influenced by turbidity, TDS, temperature, suspended solids or alkalinity. In negative coordinates, Atyidae and Coenagrionidae are strongly influenced by dissolved oxygen and phosphates respectively. Following the second axis (F2), Aphelocheiridae and Ceratopogonidae are associated in negative coordinates and influenced by CO_2 and oxydability. In positive coordinates, we observe that Nitrates control mostly Perlodidae, Gyrinidae, Limoniidae, Baetidae and Sialidae.

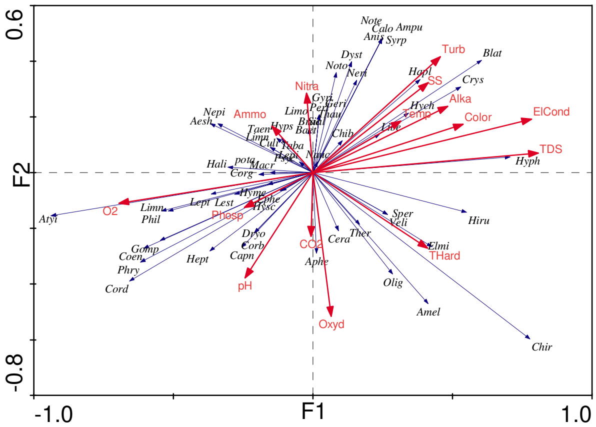


Figure 7: Redundancy analysis biplot showing gathering of benthic macroinvertebrates in response to physic-chemical variables; see the following table 4 for abbreviations

Tableau 4: Abbreviations

Abbreviations	
Tem	*Temperature*
pH	*potential Hydrogen*
ElCond	*Electrical Conductivity*
SS	*Suspended Solids*
CO2	*Dissolved carbon dioxide*
O2	*Dissolved oxygen*
Oxd	*Oxydability*
TDS	*Total Dissolved Solids*
Color	*Color*
Turb	*Turbidity*
Alka	*Alkalinity*
THard	*Total Hardness*
Next abbreviations	
Nitra	*Nitrates*
Phosp	*Phosphates*
Ammo	*Ammonium*
Chib	*Chibionidae*
Ther	*Theriidae*
Dyst	*Dystiscidae*
Dryo	*Dryopidae*
Elmi	*Elmidae*
Crys	*Crysomelidae*
Hali	*Haliplidae*
Hych	*Hydrochidae*
Hysc	*Hydroscapsidae*
Hyph	*Hydrophilidae*
Note	*Noteridae*
Sper	*Spercheidae*
Gyri	*Gyrinidae*
Atyi	*Atyidae*
pota	*potamonidae*
Blat	*Blattidae*
Culi	*Culicidae*
Cera	*Ceratopogonidae*
Limo	*Limoniidae*
Syrp	*Syrphidae*
Taba	*Tabanidae*
Thau	*Thaumaleidae*
Chir	*Chironomidae*
Ephe	*Ephemereillidae*
Amel	*Ameletidae*
Baet	*Baetidae*
Lept	*Leptophlebiidae*
Olig	*Oligoneuriidae*
Hept	*Heptageniidae*
Corb	*Corbiculidae*
Hiru	*Hirudidae*
Hapl	*Haplotaxidae*
Ampu	*Ampullaridae*
Limn	*Limnaeidae*
Neri	*Neritidae*
Geri	*Gerridae*
Anis	*Anisopinae*
Aphe	*Aphelocheiridae*
Hyme	*Hydrometride*
Next abbreviations	
Noto	*Notonectidae*
Nauc	*Naucoridae*
Nepi	*Nepidae*
Veli	*Veliidae*
Aesh	*Aeshnidae*
Calo	*Calopterygidae*
Cord	*Corduliidae*
Corg	*Cordulegastridae*
Coen	*Coenagrionidae*
Libe	*Libellulidae*
Macr	*Macromiidae*
Lest	*Lestidae*

Gomp	*Gomphidae*
Sial	*Sialidae*
Perl	*Perlodidae*
Capn	*Capniidae*
Taen	*Taeniopterigidae*
Limn	*Limnephilidae*
Brac	*Brachycentridae*
Hyps	*Hydropsychidae*
Phil	*Philopotamidae*
Psyc	*Psychomyiidae*
Phry	*Phryganeidae*
Lepi	*Lepidostomatidae*

- Longitudinal characteristics of stream

We note from the figure below (Figure 7) that the lower portion of the Konglo stream is moving away from the features that encompass the upstream portions. Although there was a slight difference between the two upstream portions, the physicochemical and biological characteristics specific to the station K3 are very different from those of the upper parts of the watercourse. Overall, the physicochemical and biological parameters show a much more similarity between stations K1 and K2 than between them and station K3.

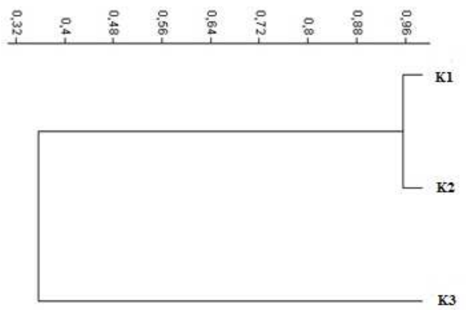


Figure 8: Clusters analysis of the stations on basis of physico-chemical and biological parameters.

B. Discussion

- Physicochemical parameters

The relatively high average temperature in the stream is linked to sunshine and seasonal changes but also to the degradation of organic matter in the water. This temperature is similar to that obtained by [10] and [12] in Nga stream.

The increase of SS, color, turbidity, and TDS values from upstream to downstream reveal according to [25], a continuous input of litter by tributaries and runoff. This variation would also be reinforced at the second sampling station (K2) due to the effect of sand extraction from the upstream bed. Similarly, [18] point out that the waters are more turbid and colored when the density of suspended particles is high. Thus significant and positive correlations were found between the color of the water and the SS on the one hand ($r = 0.650$), then between the color and the TDS, on the other hand ($r = 0.619$).

High pH values in May may be a consequence of the dilution effect of rainwater, reflecting slightly basic water due to the alkaline nature of the soil and exogenous inputs to the watercourse. [26] think that the pH of the water is influenced by the nature of the soil crossed.

The relatively high levels of ammonium throughout this study are related to the double phenomenon of leaching of the field soils and degradation of dead plants and animals [27]. Indeed, according to [18], values greater than 0.3 mg/L of NH4 indicate organic pollution. As for phosphates with levels up to 0.57 mg/L during the rainy seasons, the beginning of enrichment of the water with nutrients is expected because, according to [18], beyond 0.2 mg/L in natural waters, phosphates are considered to be a determining factor in the eutrophication of bodies of water. However, all values below 0.2 mg/L are indicative of good water quality.

The increase of alkalinity and total hardness from upstream to downstream is related to the gradual alteration of sediments containing calcium, magnesium hydrogen carbonates, carbonates and hydroxides [16]. The low values of the electrical conductivity would be the consequence of a weak mineralization of the Konglo waters. According to [28], [29], these low values may indicate low mineralizing activity and, as a result, a small amount of decomposing material.

The high average dissolved oxygen saturation percentage ($62.60 \pm 19.17\%$) would be favorable for the development of benthic macrofauna [28]. Nevertheless, the low oxygen saturation observed at the station K3 in March indicated a discharge point of organic matter in this station. Similarly, the oxidability with an average value of less than 6.5 mg/L is within the normal limits in surface water (3 mg/L and 8 mg/L O_2). For this purpose, [18] state that above 10 mg/L O_2 these waters would be subject to extensive organic pollution. Thus, the relatively high values noted in May and June during the rainy season would be inherent to organic inputs of runoff water.

- Benthic macroinvertebratesabundance

The predominance of insects would reflect a low anthropisation of the watershed. Indeed, [22], [30] state that the majority of aquatic insects are very sensitive to pollution and / or habitat modification. However, the dominance of the Diptera Chironomidae, reflected by a relatively high abundance at the third station (see table 2), suggests that the domestic discharges would be favorable to their development. This assertion is reinforced by the absence at this same station of the orders of insects recognized as the most sensitive such as Ephemeroptera, Plecoptera and Trichoptera. This low representativeness is the result of anthropogenic activities including domestic and urban discharges observed at this station.

The predominance of Atyidae decapods upstream and at the middle would indicate the presence of sand that these environments are favorable to their development [31]. The appearance of some molluscs at stations K2 and K3 would indicate that they are submited to pollution onset. To this end, [30] states that polluted hydrosystems tend to be colonized by saprophilic and polluo-resistant organisms, including molluscs. In general, the Konglo benthic macroinvertebrates population is dominated by Arthropods (98.17%) with a preponderance of decapods at K1 and K2, and Diptera and Coleoptera downstream at K3. These results are almost similar to those obtained by [10] on the Nga stream and testify the good quality of the waters at upstream and middle part of Konglo, the downstream already showing a beginning of pollution with the Mbalmayo town.

- Structure of benthic macroinvertebrates

The low diversity and distribution of the benthic macroinvertebrates in the Konglo Stream seem to be due to the ecological preference of organisms or the disturbance of the environment. Thus, the low diversity of organisms at stations K1 and K2 would be related to the relative dominance of Atyidae at these stations where sandy microhabitats would have more suitable ecological conditions and favorable to an harmonious and considerable development of these macrocrustaceans [32]. The same observation can be made to station K3 where Chironomidae are more represented than other taxa, the decline here being a reflection of a disturbance of the environment. Indeed according to [33], indices H 'and J take low values when a taxon displaces the entire community. Furthermore, we agree with [34] that the relatively high values of these indices in upstream at Station K1 reflect environmental conditions favourable to the establishment and maintenance of a balanced, integrated and capable biological community to adapt to changes [35]. The progressive decline in the values of these indices from upstream to downstream would be justified by adverse effects of human activities on the ecological state of Konglo stream, in particular the extraction of sand at upstream of station K2, followed by lateral contributions of domestic and municipal effluents from the Mbalmayo town before the station K3.

The RFD of Frontier profiles applied to stations K1 and K2 consolidate this illustration by showing that the benthic stand associated with it is at the beginning of ecological succession compared to the K3 station's RFD profile, which highlights stand maturation and a trend aging of the ecosystem. In terms of time, the low values recorded during the rainy season would be inherent to the floods which, by increasing the flow of the stream, would have caused the destabilization of the microhabitats and the drift of the benthic macrofauna. Indeed, according to [36], the lentic facies of a stream constitute an ideal framework for the development of the benthic macrofauna. It is also necessary to note that these same lentic facies can accumulate putrefactive organic matter and become anoxic, preventing the development of aerobic organisms.

The gradual decline of the EPT index from upstream to downstream would be related to the disturbance of microhabitats harboring the benthic macrofauna, in response to mechanical pollution related to the extraction of sand before station K2 and the organic pollution from the lateral inputs of the effluents (station K3) [37]. The low value of the EPT index obtained in April could be explained by the double dilution and drift effect caused by the floods observed during this rainy season [8]. The drop in the EPT / Chironomid density ratio at the K3 station follows the high multiplication of Diptera Chironomidae at this station, reflecting the lateral enrichments in organic matter of this biotope. [3], [9] think that this regression is attributable to the destabilization of most ecological niches.

With regard to IBGN, the strong grades obtained upstream and in the middle part of the stream would support the hypothesis of very good quality of the waters in which we can find sensitive and diversified benthic macrofauna [38], [39]. Downstream at the K3 station, the low IBGN score would indicate average water quality characterized by a benthic macrofauna dominated by polluo-resistant and less diversified species, following reduction of substrates due to the lateral inputs of the effluents [40], [41], [42].

IV. Conclusion

The remarkable presence of the Atyidae Decapods and the highly recognized orders Ephemeroptera-Plecoptera-Trichoptera coupled to the relatively good physicochemical quality of the waters in the two portions of the upper course, indicate a good ecological quality of the waters. In addition, the relatively high diversity in these areas would suggest the diversity of microhabitats favourable to the development of benthic macroinvertebrates. On the other hand, the waters of downstream part are subjected to a beginning of pollution as evidenced by the no less important presence of Chironomidae and the high values of certain physico-chemical indicators of pollution. In the upper and middle reaches, the distribution of taxa follows a beginning of ecological succession, while the lower course is dominated by saproling taxa characterizing a stand that tends toward ecological aging. The Konglo benthic macroinvertebrates community appears to be weakly influenced by sand mining and strongly influenced by organic pollution from domestic discharges.

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