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Macro invertebrate communities of Mékrou river in Benin and their relationship with environmental factors

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Abstract
Given the intensive use of pesticides, strong urbanization and population explosion, rivers have become a receptacle of solid and liquid waste causing ecotoxicological risk. This study aims to characterize the biodiversity of macroinvertebrates inthe Mékrou River in order to determine the parameters influencing their distribution. The physico-chemical parameters were measured by standard methods while the inventory of macroinvertebrates was done by using a surber net of a 500 -µm mesh and an area of 1/20 m². Data were collected at eight stations during floods. We used principal component analysis and canonical correspondence analysis to realize the abiotic typology of the stations and to correlate the biotic and abiotic data. Taxonomic richness, abundance and the observation frequency were used to describe the macroinvertebrate community. Apart from phosphate, other physicochemical parameters have values that are relatively compatible with aquatic life. The captured macrofauna is composed of 4747 macroinvertebrate individuals belonging to 26 families, 13 orders and 04 classes. The community is largely dominated by Insects constituting 94.88% of the total richness. Worms represent 3.14% of the total richness. Molluscs and Arachnids were the most marginal classes of the population. Diptera were the most abundant order and Chironomidae were the most prominent family. The predominance of Diptera, especially Chironomidae at the expense of Ephemeroptera and Trichoptera, would probably reflect the poor quality of the waters of Mekrou River. The predominance of Diptera, especially Chironomidae at the expense of Ephemeroptera and Trichoptera, would probably reflect the poor quality of the waters of the Mékrou River. The correspondence established between the families and the physicochemical parameters indicated that the distribution is influenced by the temperature, the conductivity, the TDS, the phosphates and the transparency.

Keywords: Aquatic macroinvertebrates, water physico-chemical parameters, water quality, mékrou river

Introduction
Macroinvertebrate communities are widely used as indicators of stream ecosystem health because they include a wide range of species, each with relatively well-known sensitivity or tolerance to stream conditions [28]. They are considered as good indicators of aquatic ecosystem health because of their sedentary lifestyles, their varied life cycles, their great diversity and their variable tolerance to pollution and habitat degradation [35,28]. In addition, their richness, diversity and taxonomic composition are used to make conclusions about pollution loads [14, 28]. Today, due to intense anthropogenic activities, aquatic ecosystems are undergoing enormous disturbances, degrading the ecology of aquatic ecosystems [2]. These anthropogenic disturbances have a direct impact on the richness, diversity, structure and the distribution of macroinvertebrates [[24,10]. These macroinvertebrates occupy a fundamental position within aquatic food webs and play a vital ecological role in these ecosystems [18]. Despite the alarming state of degradation of aquatic ecosystems and the importance of macroinvertebrates, very few studies have focused on the study of these organisms in Bénin, especially in the north of the country.In North Bénin, the only studies that have studied macroinvertebrates are those of Imorou Toko *et al*. (2012) [22] in the reservoirs and streams of the cotton basin; Chikou *et al.* (2018) [12]; Agblonon Houelome *et al*. (2017) [3] on the Alibori River and Abahi *et al*. (2018) [1] on the upper part of the Ouémé River. Thus, no macroinvertebrate data exist on the Mékrou River. However, the use of any biological community as bioindication requires the characterization of its diversity and structure [5].

In addition, the Mékrou River is one of the three rivers of the Benin cotton basin whose waters are the main drains of plant protection products used in cotton production. Therefore, the objective of this study is to characterize the biodiversity of macroinvertebrates in order to identify the physicochemical parameters structuring this community.

Materials and Methods

Study area

Mékrou River, 410 km long, is one of the three main tributaries of the Niger River in Bénin, which originates at an altitude of about 460 m, on the north-eastern flanks of the Birni Mountains. The basin of the Mékrou River has an area of 10500 km^2 of which 5034 km^2 at its head. It is one of the rivers of the Bénin cotton basin and crosses the communes of Kandi, Karimama, Banikoara, Kérou, Kouandé and Pehunco. The slope of the river bed is moderate: from the feet of the Bimi Mountains to the confluence with the Niger, it is on average 0.45 m/km. The hydrographic network is generally very sparse except in the upstream part. The only tributaries of this river are those from the Atakora: Tikudarou, Yaourou and Kourou (572 km^2). The Mékrou River is located in the Sudanian zone between 9° N and 12° N and is influenced by the tropical climate characterized by the succession in the year of a single rainy season from April to October and a single dry season from November to March, marked by the preponderance of the harmattan. The average rainfall varies between 900 and 1100 mm [8].

Sampling stations

A total of 08 stations were selected on the Mékrou River after prospecting. They were chosen based on the sustainability of the water, altitude, accessibility in all seasons, the depth and speed of the water [1]. Table 1 shows the characteristics of these different stations and figure 1 the study area with the stations.

Table 1: Characteristics of sampling stations of Mékrou River

Stations	Code	Altitude (m)	Geographic coordinates	
Mékrou 1	Mek1	276	N : 11°21'00	E : 02°19'32
Mékrou 2	Mek2	278	N : 11°20'21'	E : 02°22'86'
Mékrou 3	Mek3	285	N : 11°16'82'	E : 02°24'75'
Mékrou 4	Mek4	294	N : 11°13'40'	E : 02°21'39'
Mékrou 5	Mek5	296	N : 11°10'51'	E : 02°17'48'
Mékrou 6	Mek6	300	N : 11°10'58'	E : 02°17'49'
Mékrou 7	Mek7	307	N : 11°09'72'	E : 02°17'24'
Mékrou 8	Mek8	320	N : 11°04'17'	E : 02°13'66'

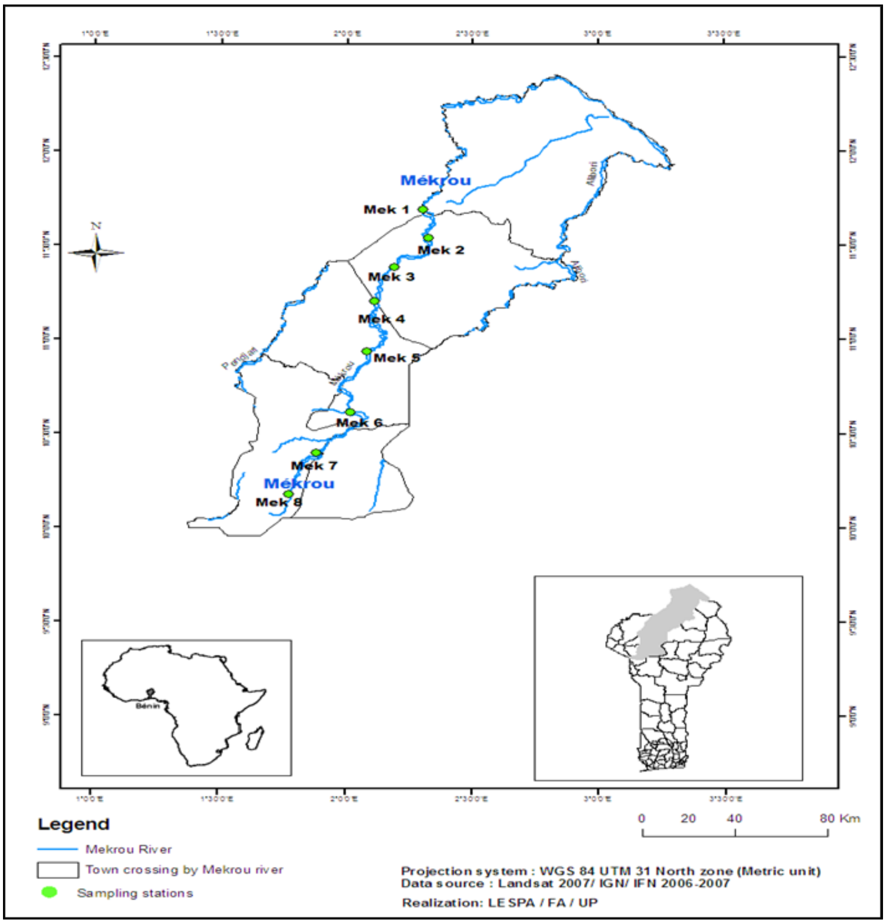

Fig 1: Study area with the stations

Measurement of water physico-chemical parameters

The measurements of physical parameters (temperature, depth, transparency, TDS, conductivity, pH, oxygen) were carried out in situ very early in the morning between 08:00 and 12:00. The water temperature, TDS and conductivity were determined using a portable conductivity meter (HANNA HI 99300). The pH was measured with a portable pH meter (HANNA HI 98107). A Secchi disk is used to measure the transparency and the depth of the water of the stations. The water samples were made at each station in 500 ml plastic bottles decontaminated and stored in a cooler containing ice for transport to the laboratory for analysis of the dissolved substances. The determination of the concentration of dissolved elements of the water samples was carried out in the Laboratory of Hygiene, Sanitation, Ecotoxicology and Environmental Health (HECOTES) using a spectrophotometer DR 6000. The chemical parameters such as ammonium, nitrite and phosphate were respectively measured by the Nessler method [6], the iron sulphate method and the Vanadomolybdic method with persulfate digestion.

Sampling of macroinvertebrates

The benthic macroinvertebrates were sampled at the 08 stations. They were taken using a Surber sampler with a 500 -µm mesh. Twelve samples with a unit area of 1/20 m^2 were done per station: (08) eight on the dominant habitats and (04) on the marginal habitats as recommended by the standard IBGN and already used in the North of Bénin by Abahi *et al*. (2018) [1]. The organisms collected in the surber sampler were sent to the laboratory.

Macroinvertebrates identification

In the laboratory, the captured macroinvertebrates were rinsed in order to rid them of the formalin and then they were sorted station by station under a binocular dissecting microscope. After the sorting, we grouped them according to their class up to their family apart from oligochaetes, nemathelmintes, hydracarians, hydrozoans, sponges, bryozoans and nemerteans that are kept aside such as Abahi *et al*. (2018) [1] has done. The taxonomic determination was made using the following keys: "benthic macroinvertebrates of the streams of "la Nouvelle-Calédonie", "Identification guide of the main benthic macroinvertebrates of freshwater from Quebec written, "Freshwater invertebrates: Systematics, biology, ecology" and "Aquatic entomology" after which macroinvertebrates were enumerated and then stored in pillboxes containing 70% alcohol.

Macroinvertebrate data processing

Taxonomic richness, absolute abundance, relative abundance and frequency of observation of families were used to describe the macroinvertebrate community. The frequency of observation (FO) of families: The frequency of occurrence which gives information on the preferences of a family was determined as follows:

$$FO = \frac{(Fi \times 100)}{Ft}$$

With, F_i = number of stations containing the family and F_t = total number of studied stations. Three families were thus distinguished as Abahi *et al*. (2018) [1] has previously demonstrated. We have very frequent families (F≥50%), frequent families (25%≤F≤50%) and the rare families (F≥25%).

Statistics analysis of data

The obtained data was processed using Excel 2010 software and R3.4.4 software [32]. The taxonomic richness, taxonomic abundance, average values of the physico-chemical parameters were calculated pereach station.Parametricand non-parametric tests (test t student and test of Kruskal-Wallis) were used to evaluate the variability of the taxonomic richness of the abundances and diversity indices at the 5% threshold with the R3.4.2 software [32]. Moreover, the factorial correspondence analysis (FCA) was used for grouping the stationsaccordingto the similarity association of macroinvertebrates families. In addition, a canonical correspondence analysis (CCA) was performed using PAST statistical package [20].

Results

Mékrou river water quality

Table 2 shows the results of physicochemical parameters of the Mékrou River waters. It indicates that the lowest temperature value 24.97 ° C was recorded at the Mékrou 3 station and the highest 30.27 ° C at the Mékrou 1 station. The maximum depth of 56.33 cm was measured at Mekrou 1 (downstream) while the minimum of 12.33 cm was recorded at Mékrou 8 (upstream). But the transparency of the water is minimal (12.33 cm) at the Mékrou 8 station and maximum (42 cm) at the Mékrou 1 station. The pH fluctuates between 6.8 and 8.4. Thus, the minimum value was recorded at the Mékrou 5 station while the maximum value was observed at the Mékrou 1 station. As for the conductivity and the TDS, they presented the same trend with average values that increased overall from upstream to downstream. The conductivity values ranged from 34.67 to 166 µS/cm and that of the TDS from 17.33 to 83 mg/l. Thus, the low values of these parameters were recorded at the Mékrou 2 station and the high values at the Mékrou 3 station. The low values of phosphates (5.97 mg/l) were recorded at the Mékrou 3 station and the high values (9.85 mg / l) at the Mékrou 7 station while the high ammonium values were recorded at Mekrou 5 station (0.31 mg / l) and the low were obtained at Mékrou 7 station (0 mg/l). The Mékrou River is devoid of any trace of nitrite. In general, physicochemical parameters quality of the studied waters did not vary from one station to another.

Table 2: Mean values of physico-chemical variables recorded at each sampling station during the study

Stations	Mek1	Mek2	Mek3	Mek4	Mek5	Mek6	Mek7	Mek8	p
Temperature (°C)	30.27	29.13	24.97	29.8	25.5	25.63	26.87	28.97	0.48
Conductivity	72	34.67	166	36	65.33	68	65.33	52	0.42
TDS	36	17.33	83	18	32.67	34	31.67	26	0.49
Transparency	42	16	13.67	31.67	13.33	13	14	12.33	0.49
pH	8.4	7.4	7.83	7.4	6.8	6.93	7.4	7.4	0.77
Depth	56.33	18.67	13.67	29.67	13.67	13	14	12.33	0.51
Ammonium	0.13	0.04	0.03	0.04	0.31	0.08	0	0.04	0.43
Nitrites	0	0	0	0	0	0	0	0	-
Phosphates	8.44	8.23	5.97	7.58	9.13	7.56	9.85	8.46	0.43

Typologie of stations

A principal component analysis (PCA) reveals that most of the information contained in the variables is controlled at 76.86% by the first two dimensions (1 and 2) (Figure 2). Temperature, transparency and depth contributed more to the formation of the first axis while pH, conductivity are related to the second axis. The correlation circle (Figure 2) indicates that temperature, transparency, and depth are strongly and positively correlated with dimension 1, whereas conductivity and TDS are strongly and negatively correlated with this dimension. PH, conductivity and TDS are positively correlated with dimension 2 whereas phosphate is negatively correlated with this dimension. The hierarchical ascending classification (Figure 3) allowed to group the stations into three groups and to highlight the following associations: (i) The Mékrou 3 station group characterized by high values of conductivity and TDS; (ii) the group of Mékrou 1 and Mékrou 4 stations having high values of temperature, transparency, depth and pH; and (iii) the group of Mékrou 2, Mékrou 5, Mékrou 6, Mékrou 7 and Mékrou 8 stations marked by the high phosphate and ammonium values.

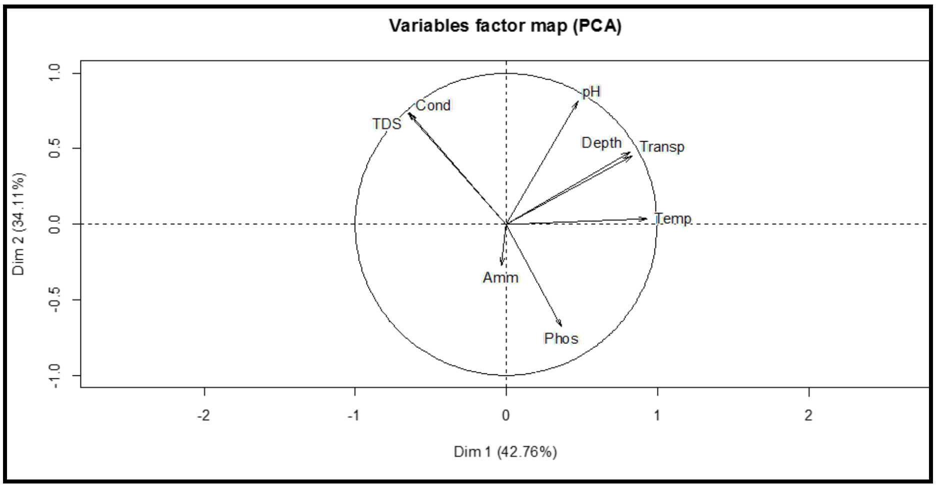

Fig 2: Positioning of the physico-chemicals paramètres on the dimensions.

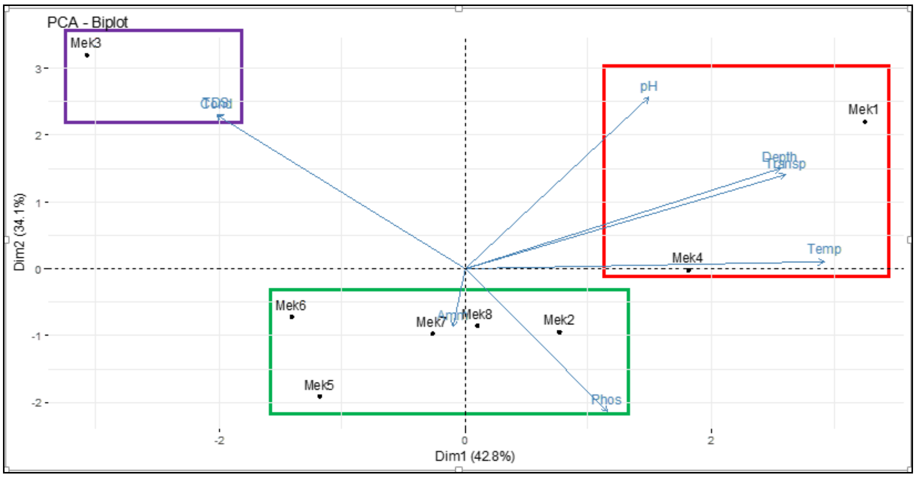

Fig 3: Distribution of physico-chemical parameters and stations

Global composition of macroinvertebrates of the Mékrou River

The study identified 4747 macroinvertebrate individuals belonging to 26 families, 13 orders and 04 classes. Four classes of macroinvertebrates were harvested during the study. These are Insects (94.88%), Worms (3.14%), Mollusks (1.81%) and Arachnids (0.17%) (Figure 4).

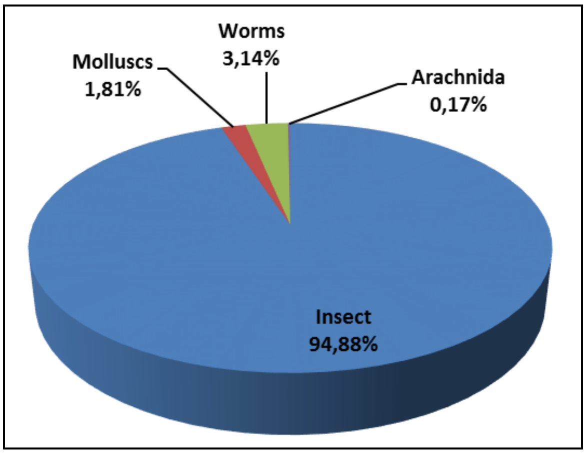

Fig 4: Relative abondance (%) of macroinvertebrates classes

Taxonomic composition of classes

Class of insects

The entomofauna was very rich with 4504 individuals, 18 families and 07 orders. This class is dominated by Diptera containing 4 families and 4048 individuals, or 89.88% of the insect richness. They were followed by Trichoptera and Odonata with 2 families and 148 individuals respectively; 3 families and 134 individuals thus constituting 4.02% and 2.98% of the insect richness. Coleoptera, Heteroptera, Lepidoptera and Ephemeroptera represent respectively 1.22%; 1.20%; 0.49% and 0.22% of the insect richness.

Class of worms

The worms (3, 14%) represent the second most important order with 149 individuals divided into three orders namely the order of Achetes, the order of Oligochaetes and the order of Nemathelminths. They each have a family, which are respectively: the Lumbriculida family (62.42%), the Glossiphoniidae family (30.20%) and the nematode family (7.38%).

Class of molluscs

The malacofauna contains a total of 86 individuals, 4 families including 3 families of gastropods and one of the bivalves respectively constituting 66.28 and 33.72% of the richness of the molluscs.

Class of arachnids

Hydracarians are the only order of captured Arachnids. Among (08) eight, Hydracarans represent 0.17% of sampled macroinvertebrates.

Relative abundance of orders and families

Figure 5 shows the relative abundance of macroinvertebrate orders. It reveals that the Diptera order was the most abundant with 85.27% of the total population. Then come Trichoptera and Odonata with respectively 3.81% and 2.82% of the total number of harvested individuals. The other orders are the marginal communities with relative abundances lower than 02%. Regarding families, Chironomidae were the most dominant family with 80.37% of the total richness. Followed by Chaoboridae (3.71%) and Hydropsychidae (3.12%). Other families were less represented and together make up 12.8% of the total richness (Figure 6).

Fig 5 : Relative abundance (%) of macroinvertebrate orders

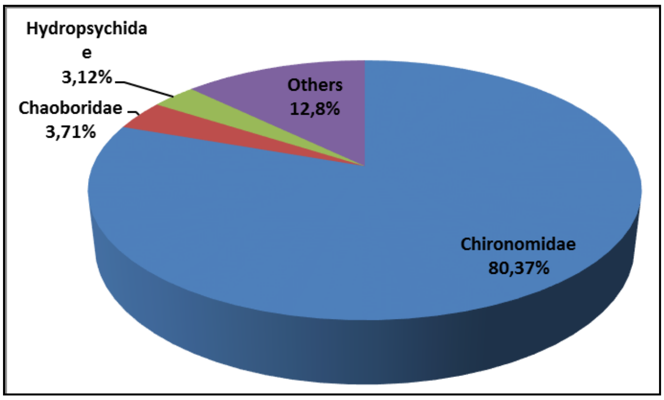

Fig 6: Relative abundance (%) of macroinvertebrate families

Spatial variation of the richness and taxonomic abundance

A total of 4747 macroinvertebrate individuals were captured during the study. Overall, absolute abundance increases from the Mékrou 8 station (502 individuals) to the Mékrou 6 station (882 individuals) before decreasing at the Mékrou 5 station (170 individuals). An identical trend was recorded from the Mékrou 4 station to Mékrou 1 station. As for taxonomic richness, it is inversely proportional to absolute abundance (Figure 7). In addition, values of richness and abundance showed significant differences between stations.

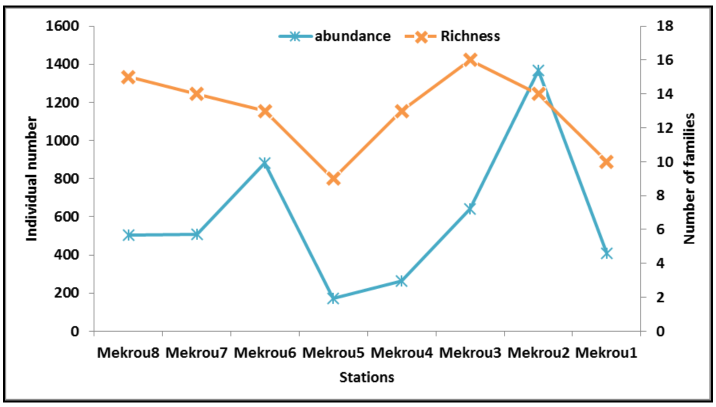

Fig 7: Spatial variation of taxonomic richness and abundance

Frequency of occurrence of macroinvertebrates

The frequency of occurrence of families was calculated from the presence-absence matrix of macroinvertebrates (Table 3). Thus, 53.84% of families (14 families) were very frequent families whereas, 5 families are frequent families (19.23%). Finally, the other seven families are rare families and constitute 26.92% of captured families.

Table 3: Observation Frequency (FO) of macroinvertebrate families

Very frequente families (F ≥ 50%)	Frequente families (50%>F ≥ 25%)	Rare families (F< 25%)
Ceratopogonidae	Simuliidae	Helicopsychidae
Hydropsychidae	Veliidae	Caenidae
Dytiscidae	Corixidae	Elmidae
Chironomidae	Gerridae	Chaoboridae
Lestidae	Planorbidae	Gomphidae
Libelludiae		Sphaeriidae
Glossiphoniidae		Limnaeidae
Notonectidae		
Pyralidae		
Physidae		
Lumbriculida		
Ephemerellidae		
Nemathelminthes		
Hydracariens		

Relationship between macroinvertebrates and physico-chemical parameters

A canonical correspondence analysis (CCA) was performed between physicochemical parameters and macroinvertebrate densities (Figure 8). The information contained in the variables is controlled at 80.78% by the system of axis 1 and 2. Temperature, conductivity, TDS, phosphates and transparency influence more the distribution of macroinvertebrates. The first axis opposes the Mékrou 4 station to the other stations while the axis 2 opposes the Mékrou 3, Mékrou 5, Mékrou 6 stations to the Mékrou 1, Mékrou 2, Mékrou 4, Mékrou 7 and Mékrou 8 stations. The first axis is positively and strongly correlated with the following families: Chaoboridae, Caenidae, Corixidae, Gerridae, Libelludiae and Lumbriculida and variables: temperature, transparency and depth while strongly and negatively related to Simuliidae, Gomphidae, Sphaeriidae, Hydracariens, Nemathelminthes, Glossiphoniidae, Chironomidae, Notonectidae and conductivity and TDS. As for the second axis, it is positively and strongly related to the family Elmidae, conductivity and TDS while it is strongly and negatively associated with Helicopsychidae, Planorbidae, Limnaeidae, Sphaeriidae, Temperature and Phosphates.

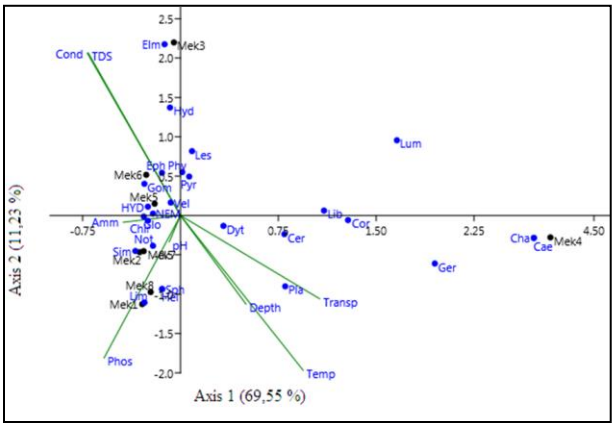

Fig 8: Canonical correspondence analysis of macroinvertebrate families, environmental variables and the sampling stations

Discussion

Physico-chemical

The measured water temperatures of the Mékrou River are slightly higher than those recorded by Zinsou *et al*. (2016a) [38] for the same period in the Ouémé delta. Guigemde *et al*. (2003) [19] in the Massili Basin, observed similar values (18.6° C to 39.2 °C) to those recorded in this study. The pH of the Mékrou river water is between 6.8 and 8.4 and is therefore within the tolerable limit (6.5 and 8.5) which characterizes the waters where life develops optimally [21]. The observed pH values in our study are similar to those measured by Buhungu *et al*. (2018) [9] by studying the water quality of the Kinyankonge River in Burundi. The conductivity and TDS values recorded at the Bétou and Affon stations are identical to those reported in the Ouémé delta by Zinsou *et al*. (2016a) [38] but higher than those observed by Arimoro *et al*. (2015) [7] on the Ogba River in Nigeria. The obtained average values in this study are within the range of the IBGE standard (50 and 1500 µS/cm), which characterizes natural water [21]. The phosphate values recorded are much higher than those reported on the Ogba River in Nigeria by Arimoro *et al*. (2015) [7] and on the Agnéby River in Côte d'Ivoire by Diomandé *et al*. (2009) [13]. Phosphate is the most important limiting factor for aquatic productivity whose absence leads to the depletion of aquatic ecosystems. Therefore, the phosphate is to be watched closely because it represents a great factor of eutrophication of the courses and bodies of water [36, 26]. The phosphate concentrations found in this study (5.97 - 9.85 mg/l) are higher than those of natural origin and undisturbed living conditions [11] and indicate that the Mékrou River is in a bad ecological status [27]. The high phosphate values recorded in this study are due to excessive organic matter inputs from agricultural leaching, laundry water discharges and domestic effluent discharges. As for the ammonium values recorded in the study, they are lower than the values reported by Zinsou *et al*. (2016a) [38] in the Ouémé delta and by Koudenoukpo *et al*. (2017); Chikou, *et al*. (2017) [26, 12]. The recorded values do not exceed the permissible limits set for surface water (0.2 mg/l) [11] which is 0.5 mg/l for consumption [37]. Thus, the obtained ammonium contents are not vulnerable for the Mékrou River. In addition, the assembly of the Mékrou 2, Mékrou 5, Mékrou 6, Mékrou 7 and Mékrou 8 stations characterized by high phosphate and ammonium values could be attributed to a strong anthropisation of these stations close to homes, which are more subject to agricultural leaching, discharge of laundry water and discharges of domestic effluents. Thus, human activities are responsible for high concentrations of nutrients and contribute to the imbalance of the natural mechanisms for recycling these nutrients in the aquatic environment [34].

Macroinvertebrate community of the Mékrou River

The study of macroinvertebrates in the Mékrou River captured 4747 individuals belonging to 26 families and 13 orders. The observed number of individuals is much higher than those obtained respectively by Imorou Toko *et al*. (2012) [22] and Zinsou *et al*. (2016b) [39] in the Benin cotton basin and in Ouémé delta. On the other hand, it is weaker and far from that obtained by Alhou *et al*. (2009) [4] on the Niger River. As for taxonomic richness, the recorded number (26 families) is close to that of Zinsou *et al*. (2016b) [39], Diomandé *et al*. (2009) [13], Imorou Toko *et al*. (2012) [22] and Abahi *et al*. (2018) [1] who reported taxonomic richness ranging from 26 to 28 families. On the other hand, Foto *et al*. (2010) [15] and Ngoay-Kossy *et al*. (2018) [29] observed respectively 59 and 39 families on the Nga watercourse in Cameroon and on the Nguitto River in the Central African Republic. Thus, the low observed taxonomic richness would reflect the poor quality of the river because a high taxonomic richness is indicative of the good health of a watercourse [28]. In addition, the macroinvertebrate community of the Mékrou River was mainly dominated by Diptera (85.27%) with a predominance of Chironomidae representing more than 80.37% of total abundance. These results are characteristic of streams located in anthropized areas and are consistent with the results obtained by Abahi *et al*. (2018) [1] on the upper part of the Ouémé River and by Imorou Toko *et al*. (2012) [22] in the Benin cotton basin. The diversity of the observed Diptera order and especially of the Chironomidae family indicates the strong presence of organic matter in the stream; consequences of intense human activities [16, 30]. These activities located near ecosystems have led to high levels of wastewater, pesticides and fertilizers in the rivers. They disrupt benthic communities and contribute to the reduction of species' richness and even the distribution of species [33, 31]. These results are confirmed by the low presence of Ephemeroptera, Trichoptera and the absence of Plecoptera. Similar work in rivers indicates a decrease in the diversity of pollution-sensitive orders (Ephemeroptera, Plecoptera, Trichoptera) and a better adaptation of pollution-tolerant families to anthropogenic activities [29, 23, 25]. Nevertheless, the presence of individuals belonging to the pollution-sensitive family: Ephemerellidae, Caenidae, Hydropsychidae and Helicopsychidae in this river announces a possible recovery; especially since at least two (Ephemerellidae and Hydropsychidae) of these families are very frequent families ($F \geq 50\%$). Moreover, the correlation established between the families and the physico-chemical parameters from the canonical correspondence analysis shows on the one hand that the distribution is influenced by temperature, conductivity, TDS, phosphates and transparency and on the other hand a negative correlation between ammonium, phosphate, pH and the following pollution-sensitive families: Chironomidae, Simuliidae, Limnaeidae, Sphaeriidae, Glossiphoniidae and Notonectidae. This correlation reflects the vulnerability of these families despite their high value of pollution tolerance [17].

Conclusion

The study of the water quality of the Mékrou River indicated that the main physicochemical parameters except phosphate have values that are relatively compatible with aquatic life. The absence of traces of nitrite in the stream argues for good quality but reversed by the high levels of phosphorus compounds, responsible for the eutrophication of rivers. These high phosphate concentrations resulting from human activities along the river. This study also identified 4747 individuals of macroinvertebrates divided into four classes, the most diversified being insects (94.88%) and the Chironomidae family (80.37%) was the most dominant family. The correlation between macroinvertebrates and physico-chemical parameters revealed the vulnerability of families that are pollution-sensitive to organic and phosphorus pollution. Thus, a regular monitoring of nutrient concentrations in the river is necessary for its conservation in order to avoid the loss of biodiversity.

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