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(RESEARCH ARTICLE)

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Hierarchization of anthropic pollution and polluosensibility of groups of benthic macroinvertebrates in the watercourses of Mvila (Southern region of Cameroon)

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Abstract

For five months, a study was carried out in the Mvila department (Southern Cameroon region), it's objective was to evaluate the pollution sensitivity of benthic macroinvertebrates in three stations in crenal zones and at different degrees of anthropization. For this, two methods were associated, one consisting of taking samples and analyzing the water, was carried out following the techniques recommended and the other involved capturing the organisms, their counts and identifications, was carried out according to standard methods. The average values of conductivity and pH showed significant differences only in the urban station. The Shannon and Piélou indices were higher in the peri-urban station and finally the frequencies of occurrence, correlations and relative abundances revealed that within the same order, certain species are more polluosensitive than others. Indeed, on a spatial level the species: *Phyllomacromia* sp*; Ranastra linearis; Potadoma* sp and *Macrobrachium sp* prefer forest watercourses, then the species *Lestinogomphus* sp and *Caridina africana* prefer peri-urban environments and finally the species. *Laccotrephes* sp*, Melanoides tubeculata* sp prefer urban waterways.

Keywords: Macroinvertebrates; Bio sensibility; Water quality; Watercourses; urbanization

1. Introduction

Water is part of humanity's heritage, that is why its protection, its development and the development of usable resources, while respecting natural balances are of general interest [1]. In nature, the lotic environment constitutes a flow of running water in a natural bed originally, fed by a spring and presenting a sufficient flow for most of the year. Thus the continuum of watercourses is subdivided into three main parts: the crenon or upper course located near the source, the rhithron (middle course) and the potamon (upper course) [2]. Thus the water quality of a crenon can categorize the state of health of the lotic environment. These areas are generally characterized by: good water quality, low thickness of the water column, a narrow bed [3] and are therefore preferential habitats for certain groups of benthic macroinvertebrates (BMI). BMIs are cosmopolitan organisms from the bottoms of hydrosystems: they can be: molluscs, annelids, decapods and especially insects, this fauna is more or less sensitive to water alteration, thus testifying to it's quality and the diversity of habitats. Numerous investigations on the bioassessment of rivers based on BMI indicator groups have already been carried out [4,5,6,7,8,9]. To our knowledge, there is very little work on the description and prioritization of the pollution sensitivity of species within the same genus in areas oftenly recognized as ecologically healthy. In Cameroon, water pollution is a difficult challenge to overcome by public authorities, the two main phenomena responsible are industrialization and rapid and anarchic urbanization [10] taking place without taking into account the conservation of pre-existing hydrosystems. In South Cameroon, rivers are supplied with water from sources located in various areas of the locality (forest, peri-urban and urban). The objective of this work was therefore to show

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the existing relationship between the degree of anthropization and the pollution tolerance of certain BMI species within the same taxonomic order.

2. Material and methods

2.1. Study area

2.1.1. Geographic location

The South region of Cameroon is one of the ten regions in Cameroon (Figure 1). Mvila is one of its subdivisions and it's head quarter is the town of Ebolowa, it extends between latitude 02°36'06.94'' and 03°04'14.58'' North and longitudes 10°34'26.66'' and 12°15'36.93'' East. The landscape of the Mvila department is typical of the South Cameroonian forest plateau, the average altitude between 600m and 800m influenced by a humid tropical climate with four seasons: the long rainy season from September to November, the long dry season from December to February, the short rainy season from March to June and the short dry season from July to August. The average annual temperature is around 24 °C, its economy is essentially based on agriculture, subsistence farming remains the main activity of local populations, cassava, plantain, macabo, peanuts, corn etc are the basis of food, however cocoa is the main cash crop grown in this department. On a hydrographic basis, the Mvila department is watered by three watersheds: the Nyoñg basin, the Ntem basin and the Lokoundje basin [11].

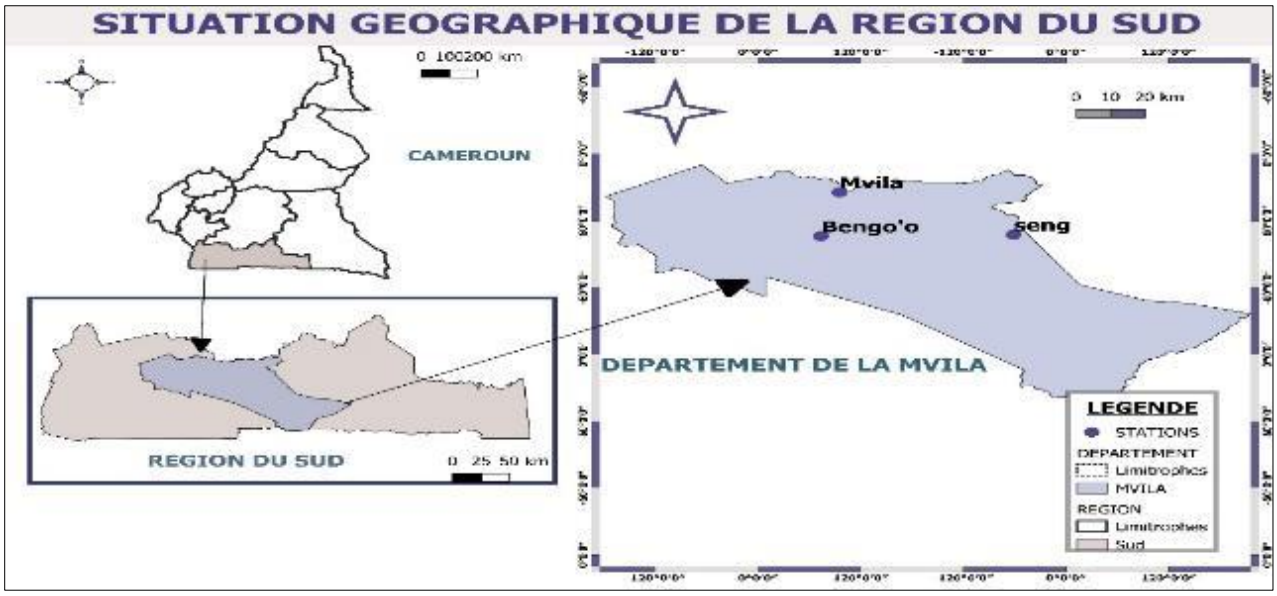

Figure 1 Map of the geographical location of the Mvila department

2.1.2. Sampling station

With geographical coordinates (03°05'52.8''N and 011°11'37.7''E) the Mvila (Mv) station (figure 2A) is an isolated station in the heart of the forest in the district of Biwong-Bané and located approximately 1Km from the main road of the village Mvog-evoudou. It is covered by a canopy, its bed is dominated by coarse rocks, boulders and on its banks, we can see shrubs and dotted with various plants. Due to its difficult access and total absence of any anthropogenic activity, it will be considered as a control station throughout this work.

With geographical coordinates (02°55'32.6''N and 011°39'4.4''E) the Señg (Sn) station (Figure 2B) is located in the subdivision of Mengong, 25Km from the town of Ebolowa not far of the National road number 2 in the village of Ebobola and approximately 200m from the houses. It is an area which is not very influenced by anthropogenic activities, it is characterized by a small waterfall upstream, the surrounding vegetation is almost always flooded.

With geographical coordinates (02°55'14.1''N and 011°08'42.3''E) the Bengo'o (Bg) station (Figure 2C) is located in the subdivision of Ebolowa-I in the lowland, its source was created with concrete blocks. Its grassy banks often undergo development through organized land clearing sessions, which often results in its bed becoming lined with plant debris.

There is a plantation on one of its banks and it is not uncommon to see local residents carrying out washing in this station.

Figure 2 Images of crenal stations A) Mvila, B) Señg, C) Bengo'o

2.2. Materials and methods

Depending on the work carried out, several techniques were carried out:

2.3. Geolocation

The recording of geographical data from each station and their altitudes were measured using a Garmin GPS model e-trex 10 and the geographical map was produced with Qgis software version 3.10.

2.4. Measurements of average width and water speed (V)

In each station, the average width in (m) was measured using a measuring tape, which was stretched from one bank to the other and measured in three sectors of each sampling station and the average width noted (Lm) which corresponds to the average of the three values. The speed was obtained according to the formula. Also, with a chronometer, the time (t) necessary for a polyethylene float to cover a section of 1m distance (d) was taken. This was repeated thrice which permitted us to obtain an average speed (Vm) specific to each of the stations.

2.5. Measurements of environmental parameters

In situ, parameters such as pH and conductivity were measured using a Horiba model laqua brand multiparameter. Still on the field, dissolved oxygen was taken using a brand Hach model HQ30d oxymeter. On the other hand, other parameters such as color, orthophosphates and nitrites were measured in the laboratory using a HydroTest HT 1000 brand spectrophotometer at wavelengths 204, 320 and 270 respectively.

2.6. Biocenotic indicators

2.6.1. Diversity indices

Diversity takes into account not only the number of species but also the distribution of individuals within different groups of macroinvertebrates.

2.6.2. Shannon-Wiever index (in bits per individual)

The Shannon-Wiever index (H') is the most often used and the most recommended by different authors [12]. It allows diversity to be expressed by taking into account the number of species and the abundance of individuals of all species in the sample. It is calculated by the following formula.

$$H' = -\sum_{i=1}^{S} \text{Pi} \log 2 \text{ Pi}$$

Where: Pi = proportional abundance of species i: pi = ni /N;

S = total number of species;
ni = number of individuals of a specie in the sample
N= total number of individuals of all species in the sample

2.6.3. Equitability of Piélou

The Piélou equitability of a sample represents the ratio of the observed specific diversity to the theoretical maximum diversity that can be obtained with the same number of species [13].

$$J = \frac{H'}{log2\ S}$$

With: S= taxonomic richness H'= Shannon and Weaver index

2.6.4. Dominance index

The frequency of occurrence F (in %) is the constancy of a species or taxon in a given habitat, without any indication of its quantitative importance [14]. According to [15], this index is based on the presence/absence matrix and is calculated according to the relationship:

$$F = \frac{Pi\ \times 100}{Pt}$$

Where: Pt = total number of samples, Pi = number of samples where taxon i is present. The interpretation linked to this index are: omnipresent taxa (F= 100%); regular taxa (75 ≤ F < 100); constant taxa (50 ≤ F < 75); accessory taxa (25 ≤ F < 50); rare taxa (0 ≤ F < 25).

2.7. Biological Measurements

In the field, benthic macroinvertebrates were captured in the various micro-habitats of each sampling station using a tumbler as recommended by [16], then sorting was carried out with entomological forceps, finally the collected organisms were fixed in formalin at a concentration of 10% before the counting and identification operations. In the laboratory, the animals were rinsed with water and stored in 70% alcohol. The count was carried out and identification was possible using identification keys in particular: [17,18,19,20,21,22]. The organisms were measured in centimeters (cm) with a digital caliper brand "Digital caliper" and the drawings were made using Coreldraw software version 3.2.

3. Results

3.1. Hydrological parameter

The results of the hydrological parameter values studied coupled with those concerning proximity to homes were different from one station to another (Table 1).

Table 1 Characteristics linked to the degree of urbanization and the morphology of stations

	Mvila (Mv)	**Señg (Sg)**	**Bengo'o (Bg)**
Location	**Non urbane and forestry**	**Peri-urban and little forestry**	**Urban and non forestry**
Nature of bed	Granite blocks and very coarse grained sand	Humus and little laterite	Vase and plants débris
Proximity to homes (m)	1000	200	20
Altitude (m)	750	662	610
L_m (m)	1.3	1.3	0.5
V_m (m/s)	0.92	0.15	0.22

L_m: average width; V_m: average speed; (Mv): Mvila station; (Sg): Señg station and (Bg): Bengo'o station; (m): metre; (s): second

The results on proximity showed that the station (Mv) is the highest in terms of altitude (750m), moreover it is located in the forest and the furthest from homes, its accessibility is very difficult and therefore, it is almost not in contact with the local population (Table 1). However, the station (Bg) is the most visited by the population due to its proximity (20m) and its altitude (610m).

3.2. Environmental parameters

Environmental parameters were recorded for five months (january-may) at the different

Table 2 Mean values and standard deviation of environmental parameters from the different sampling stations

parameters	Mvila (Mv)	Señg (Sg)	Bengo'o (Bg)
pH (UC)	7.34± 0.53[a]	7.23± 0.39[a]	6.22± 0.30[b]
conductivity (µs/cm)	25.38± 5.76[a]	27.13± 7.85[a]	53.21± 6.60[b]
colour (pt/co)	96.33± 73.95[a]	131.6± 110.34[a]	106.16± 87.42[a]
O_2 (% of saturation)	80.78± 10.00[a]	87± 3.21[a]	73.53± 16.70[a]
PO^{3-}_4 (mg/l)	1.00± 0.76[a]	1.21± 0.79[a]	1.40± 1.04[a]
NO_2^- (mg/l)	0.021± 0.029[a]	0.03± 0.03[a]	0.03± 0.028[a]

a and b : Similarity indicators of standard dispersion (by comparing, if a and b then the values are different)

During the 5 months of work, a certain number of physicochemical parameters (Table 2) were measured, and their averages were summarized in a table.

The average values of pH and conductivity fluctuated from 6.22± 0.30 UA in the urban station (Bg) to 7.34± 0.53 UA in the forest station (Mv) and from 25.38± 5 .76 µs/cm to 53.21± 6.60 µs/cm in the same stations. In this regard, pH and electrical conductivity were the only parameters where significant differences were observed between the stations. Indeed, for these two parameters, no significant difference was observed between the forest (Mv) and peri-urban (Sg) stations, however, the latter were significantly different at the urban station (Bg). The color values varied from 96.33± 73.95 pt/co in the station (Mv) to 131.6± 110.34 pt/co in the peri-urban station (Sg). With a value of 87± 3.21% saturation, the dissolved oxygen content was highest in the peri-urban station (Sg) and the lowest was noted in the urban station (73.53± 16.70% of saturation). The values of orthophosphate and nitrite varied very little throughout this study, from what emerges from these parameters, the lowest values were measured in the forest station (Mv) with values 1.00 ± 0.76 mg/l and 0.021± 0.029 mg/l respectively and on the other hand, the highest were recorded in the urban station (Bg) 1.40± 1.04mg/l and 0.03± 0.028mg/l respectively (Table 2).

3.3. Biological parameters

From this work, 662 organisms were captured including 315 individuals in Mvila, 100 in Señg and finally 247 individuals in Bengo'o. The dominant orders were: the order of Decapods (224 individuals), the order of Heteroptera (149 individuals) and the order of Odonata (175 individuals) respectively. The Kolmogorov test coupled with the Mann-Whitney test revealed differences in terms of abundance between stations (Mv) and (Sg) ($p = 0.004$) but none between stations (Mv) and (Bg) ($p = 0.019$). The captured organisms were grouped into 9 orders overall and distributed into 36.5% decapods; 28.5% odonata; 24.26% Heteroptera; 6.3% beetles; 2.4% molluscs; 0.65% mayfly; 0.48% diptera and oligochaete and finally 0.3% turbellaria (Figure 3).

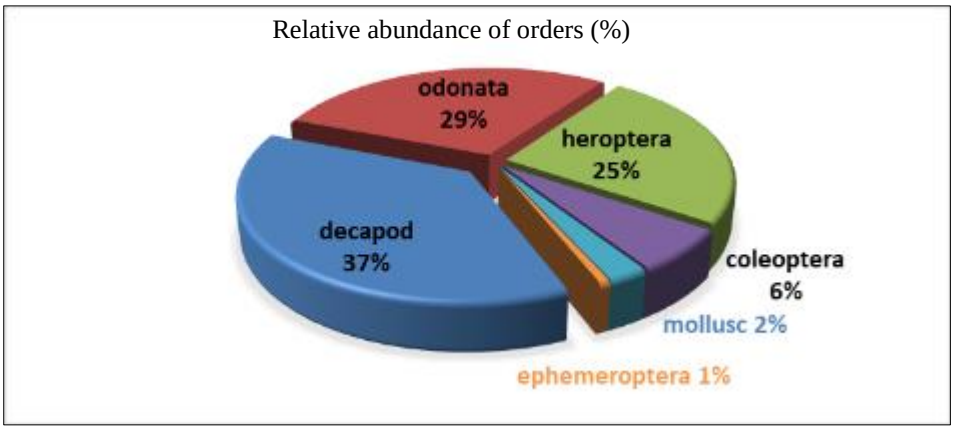

Figure 3 Relative abundance of orders collected

Table 3 Representation of the faunal descriptors of the stations

	Mvila	Señg	Bengo'o
S	13	9	15
H’	1.13	1.53	1.46
J	0.70	0.79	0.70
ẋ	63	20	49.4
Decapod	83.48%	5.36%	11.16%
Heteroptera	46.3%	24.16%	29.53%
Odonata	8%	18.86%	73.14%
Coleoptera	59.01%	8.2%	32.78%
Mollusc	39.13%	39.13%	21.74%

(S) : taxonomic richness ; (H’) : Shannon and Weaver diversity; (J): Piélou equitability;(ẋ): the average of the organisms

The values of the number of families (S) varied from one station to another, it was higher (15 families) in the urban station (Bg) and lower in the peri-urban station (Sg) with (9 families), The Shannon diversity index showed that the equipartition of diversity taking into account the number of individuals and the number of species was more observed in the station (Sg) (H'=1.53 bit/ind) and lower in the station (Mv) (H'= 1.13 bit/ind), Likewise, the distribution of individuals within species was also higher in the same stations (J= 0, 79). At the end of the five descents, the average of the organisms collected varied considerably between 63 in the station (mv) and 20 in the station (Sg) (Table 3).

3.3.1. Spatiotemporal distribution of some families of macroinvertebrates

Table 4 Abundance over time (%)

	Mvila	Señg	Bengo’o
Phyllomacromia sp *(*Corduliidae*)*	100	0.00	0.00
Lestinogomphus sp *(*Gomphidae*)*	1.09	98.90	0.00
Orthetrum spp *(*Libellulidae*)*	0.18	0.18	99.62
Ranastra sp *(*Nepidae*)*	100	0.00	0.00
Laccotrephes sp *(*nepidae*)*	0.00	0.00	100

Caridina sp *(*Atyidae*)*	18.16	61.76	8.82
Macrobrachium sp *(*Paleomonidae*)*	91.50	0.00	8.50
Potadoma sp *(*Thiaridae*)*	100	0.00	0.00
Melanoides sp *(*Thiaridae*)*	0.00	35	65

During the investigations carried out, it was noted that certain species favored very specific sites (Table 4), these are mainly four orders: Odonata, Heteroptera, decapods and molluscs. The genera *phyllomacromia, macrobrachium* and *potadoma* are more observed in the forest stream (Mv). In the watercourse (Sg) the *lestinogompus* and *caridina* were the most collected and finally the genera *orthetrum* and *melanoides* are more present in the watercourse (Bg).

Odonata

Odonata represent 28.5% of the community, they are mainly represented by three families (Figure 4). Affectionate with forest environments, the corduliidae are odonata with a relatively spherical and flattened shape, very little hair covers their bodies and their small heads bear a horn, small eyes and short antennae. The thorax bears three pairs of very long thin legs suitable for walking. The little gomphidae have a very elongated and flattened body sometimes ending in a very elongated epiproct, short robust legs allow it to bury itself in the sediments and these odonata covered with little hair, are equipped with small eyes often triangular in shape, a flattened mask is an exclusive criterion of this family, in this work, this family presented a preference for the peri-urban station. The family libellulidae have varied shapes, preferring urban waters señg, the species *Orthetrum caffrum* has a shape of a rod covered with hairs with small bulging eyes.

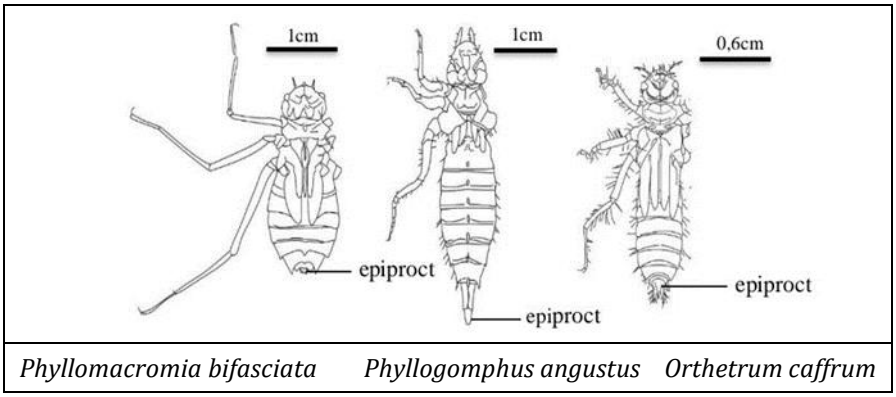

Figure 4 Morphological differences in odonata (dorsal view)

Heteroptera

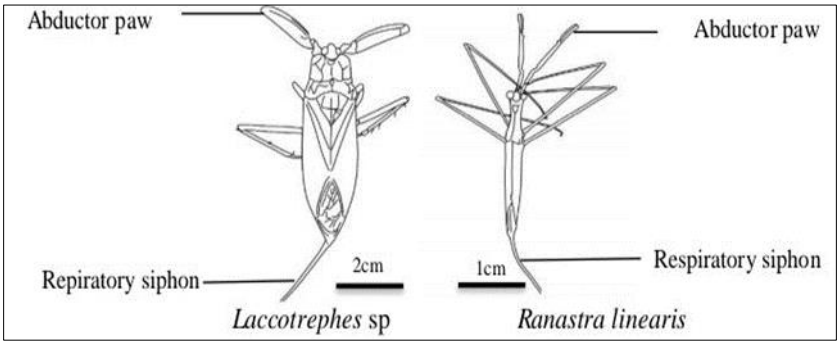

Figure 5 Morphological differences in Hemiptera (dorsal view)

The Heteroptera represent 24.26% of the community, this order is characterized by families of various forms, the Nepidae family is a taxon of large organisms, the organisms belonging to this family see their first pairs of legs transformed into abductor leg (Figure 5). The genus *laccotrephes* is a leaf-shaped nepidae ending in a very long siphon with very robust front legs, this organism is fond of the señg urban watercourse. Affecting relatively forest

environments, the ranastra genus has a cylindrical shape with a structure that mimics that of a dried stem, the eyes are globular and above all the legs are very long and thin.

Gastropods thiaridae

The thiaridae are of different shape with an opening position dextral or senetre (Figure 6): the genus *potadoma* was most observed in the forest stream Mvila, the general shape is that of a rounded cone, smooth with a blunt apex very often without a point. The genus melanoides has the shape of a tapered and rough cone with a point, they are much more present in urban and peri-urban waters.

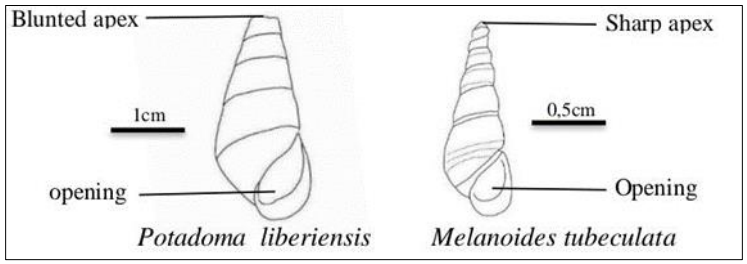

Figure 6 Morphological differences in molluscs (axial view)

Decapod

Atyidae and palaemonidae are morphologically quite similar (Figure 7), the main difference lies in the fact that the palaemonidae are equipped with a pair of robust pereiopods longer than that encountered in the atyidae.

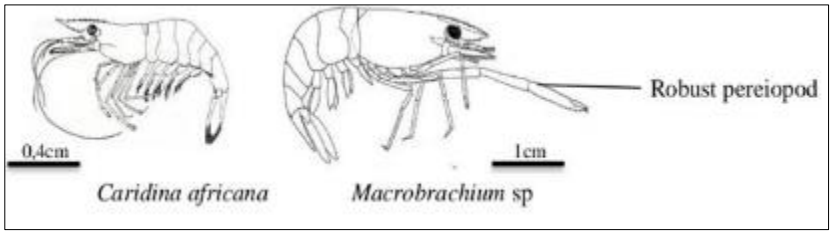

Figure 7 Morphological differences in decapods (lateral view)

3.3.2. Occurrence frequency

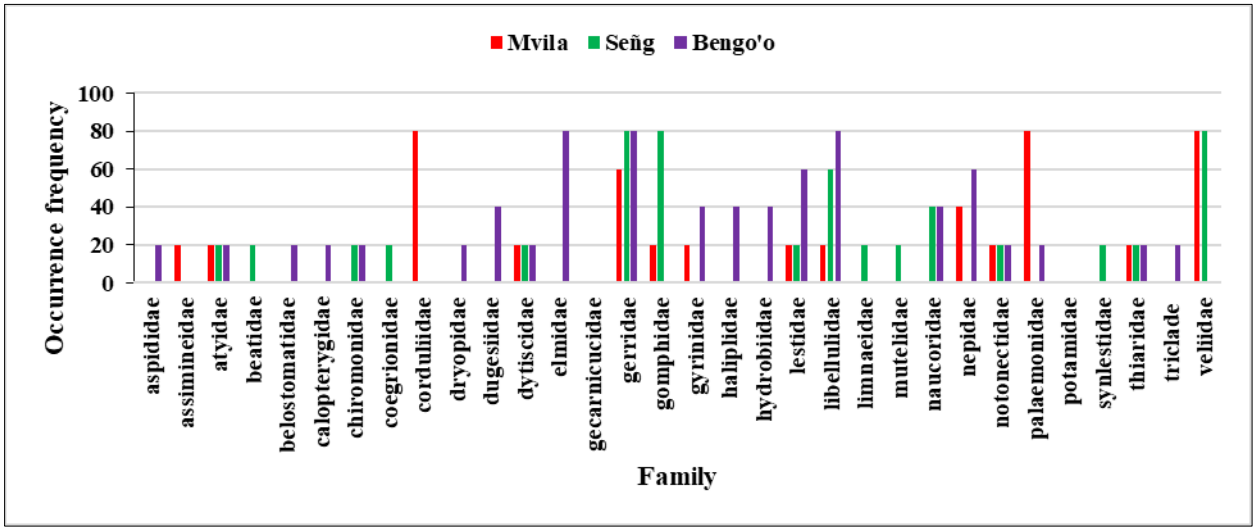

Figure 8 Occurence frequency of the different families according to stations

For each station, the frequency of occurrence varied between 0% and 80% with 0% (no observation), 20% (1 observation out of 5 samples), 40% (2 observations out of 5 samples), 60% (3 observations out of 5 samples) and 80% (4 observations out of 5 samples), (Figure 8) and we note an absence of omnipresent species.

In the station (mv), the frequency of occurrence presented 3 regular families (corduliidae, palaemonidae, and veliidae), 1 constant family (gerridae), 1 accessory family (nepidae) and 27 families qualified as rare. As for the station (Sg), 3 regular families (gomphidae, gerridae and veliidae), 1 constant family (libellulidae), 1 accessory family (naucoridae) and also 27 rare families were observed. Finally, in the urban station (Bg), 3 families were regular (libellulidae, elmidae and gerridae), 2 constant families (lestidae and nepidae), 4 accessories (dugessiidae, gyrinidae, haliplidae, hydrobiidae and naucoridae) and 23 rare families.

3.3.3. Correlation of some biotic and abiotic compounds in the station

Table 5 Correlation of some biotic and abiotic compounds

Elément 1	Elément 2	Value of (r)
pH	libellulidae	-0.74*
pH	dugesiidae	-0.52*
O_2	elmidae	-0.6*
conductivité	libellulidae	0.52*
PO_3^{4-}	notonectidae	0.6*
thiaridae	driopidae	0.53*
libellulidae	dugesiidae	0.58*
palaemonidae	veliidae	0.72**
assimineidae	corduliidae	0.7**
palaemonidae	corduliidae	0.7**

(*): the correlation is significant at the 0.05 level; (**): the correlation is significant at the 0.01 level and (r): correlation coefficient

Certain abiotic parameters at the occurrence of pH and dissolved oxygen present a negative correlation with the families libellulidae, dugessiidae and elmidae. conductivity and orthophosphate were shown to have a positive trend with the families libellulidae and notonectidae respectively. Also family couples revealed a positive correlation depending on the degree of significance, the thiarid-driopidae and libellulidae-dugesiidae couples are positively correlated at the 0.05 level and the palaemonidae-veliidae, assimineidae-corduliidae and palaemonidae-corduliidae couples have very significantly correlated at the 0.01 level (Table 5).

4. Discussion

The pH of the Mv and Sg stations tend towards neutrality, which corroborates with the results of [23] on the forest stations in the Nguitto watercourse but this was not the case with the Bengo'o urban station where a rather acidic pH was recorded, this may be due to the strong presence of plant debris in the bed of this watercourse. Indeed, the degradation of organic matter by microorganisms is accompanied by a decrease in oxygen and pH, thus making the water acidic [24]. As for oxygen, the highest value was observed in the señg station and was most probably due to the presence of a fall upstream which favored mixing with the atmospheric air. The values of nitrites and phosphates were considerably low in the three stations, this result which contrasts with that of [25] during his work on the typology and biological quality of macroinvertebrates and zooplankton in Douala in the wouri (coastal region), this can be explained by the fact that the South Cameroon region is an area that is still very little industrialized, its demographic density still remains low compared to that of Douala.

In the forest station the most dominant order was that of the decapods where the family palaemonidae was the most abundant and regularly present. This result differs from that obtained by [26] in the crenal stations. forests (N1 and N2) in the Nguitto watercourse, they had rather observed a dominance of the order Heteroptera family of notonectidae this could be due to the pH because according to [27], a neutral pH is a sine qua non condition for good cohabitation of decapods. However, the pH of the Nguitto watercourse tended towards acidity so it was possible that the high acidity

level could disrupt the viability of the crustaceans. The presence of atyidae in the Bengo'o station seems to be normal since all the stations are located in the minor beds of watercourses very often known as areas little exposed to pollution. However, their absolute abundance in the urban station shows that they tolerate stress better compared to the palaemonidae family. Finally, in this station, the Spearman test noted a very significant difference between the palaemonidae and Corduliidae families which seems to be associated with forest fasciates.

In the Bengo'o station, the relative abundance of the orders of the community shows a high value of odonates, according to [28] odonates are very cosmopolitan due to the fact that they have varied modes of locomotion (climber, walker and burrower). The libellulidae family is the majority there, certain genera of this family like muddy beds. However, an affinity of certain species for a type of habitat has been noted. The corduliidae of the species *Phyllomacromia* sp has been observed more in undisturbed forest areas, it is perhaps in this context that [29] describe this family as being rheophilic and adapted to running, flowing and spring waters. and whose survival is greatly affected by deforestation and pollution. In the same vein, gomphids of the *Phyllogomphus* sp species adapt very well to the peri-urban site characterized by an abundant quantity of humus and at a low speed. The species *Orthetrum* sp favors the urban station, this libellulidae is well known as having a rheophobic character adapted to areas with permanent water, it is in the same sawing that [30] affirm that the genus *orthetrum* is much more observed in stations which have not been the subject of restoration, which then leads us to believe that the urban station is not being sufficiently taken care of despite being the closest to homes.

In the peri-urban station, despite their low proportions compared to decapods in the forest station and odonates in the urban station, molluscs represent the most abundant order. It also has the highest Shannon and Piélou indices, which implies a better equidistribution of the different wildlife communities in this station. Certain species of thiaridae also revealed preferences for a certain type of biotope, the *Potadoma* sp specie was exclusively encountered in the forest station and this result is close to that obtained by [31] on the study of the malacological diversity of the rivers of the Kalunguta village in the DRC which can be explained by the fact that the DRC is the country which covers the largest area of the Congo basin characterized by a wide Equatorial forest, this ecosystem is close to that where Seng station is located, the landscape of which is closer to that of a forest area. The same dynamics was observed in the nepidae species *Laccotrephes* sp was encountered in the urban station while the species *Ranastra* sp was observed in the station which could envisage different tolerances between these two species of nepidae and this contradicts the results of [32,33,34] who had assigned the same tolerance rating (5) to all hemiptera of the family nepidae.

5. Conclusion

Although the three stations studied are located in the crenal zone of the watershed, it is now evident that the scale of human activities considerably influences the aquatic ecosystem. The forest, which is the original type of vegetation in the South Cameroon region, is gradually replaced by infrastructure and this results in the regression of certain very polluting species (*Phyllomacromia* sp, *Potadoma* sp, *Ranastra* sp and *Macrobrachium* sp*)* in favor of other species of the same genus and less polluosensitive such as (*Orthetrum* sp*, Laccotrephe* sp*, Melanoides* sp). Further studies on the biology and ecology of benthic macroinvertebrate species will be of paramount importance to refine the species-microhabitat relationship with a view to improving the assessment of the state of health of hydrosystems.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this document.

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