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Macrophytes and macroinvertebrates species composition, distribution and diversity in wetlands in Bamenda (North-West Region, Cameroon)

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ABSTRACT: Knowledge of macrophytes and macroinvertebrates composition in a changing environment is essential for wetland monitoring. This paper assesses the biodiversity in two wetlands of different trophic levels in the Bamenda town at three different stations. Macrophytes and macroinvertebrates diversities were assessed respectively through Braun-Blanquet and multi-habitat approaches. The water physico-chemistry of these wetlands was also determined following standard protocols for water analysis. Based on the water quality, the principal correspondence analysis showed that station 3 stands out from the others with high organic and mineral parameters. A total of 19 families of macrophytes belonging to 35 genera and 42 species were identified. The Shannon –weaver's Diversity index varies from 2.48 (station 2) to 1.90 (station 3) indicating a reduction of the plant diversity with the increase of human pollution. The dominant and common species identified in the study sites are: *Alternanthera sessilis, Commelina benghalensis, Echinochloa pyramidalis* and *Pennisetum pupureum*. These species tolerate the organic pollution, and could be used in the context of bio-purification of wastewater. Concerning macroinvertebrates, they belong to 1 phylum, 4 classes, 9 orders, 35 families and 55 genera. The most abundant class was the insects with 97% of the total fauna followed by the class Annelids which represented 3%. The abundant family was Gerridae represented by 7 genera. A negative correlation was found between water pollution and biodiversity meanwhile a positive correlation was found between macrophytes presence and macroinvertebrate diversity.

KEYWORDS: Bamenda, Macrophytes, macro-invertebrates, pollution, Wetlands.

1 INTRODUCTION

A wetland is a transition area between an aquatic and a terrestrial system where the water table is at or near the surface for part of the year. It is an ecosystem with great ecological value, with a rich biocenosis that consists of complex community structures with high biological value. It encompasses a range of habitats amongst which streams, rivers, marshes, etc. Unfortunately, their special typology makes them fragile and vulnerable to environmental changes, especially those related to anthropogenic perturbations which often imply the irreversible degradation of their biota [1]. Consequently, the biodiversity of most wetlands is reduced and their biogeochemical cycles altered.

Macrophytes and macroinvertebrates play an important role in the functioning of wetlands ecosystems. They are important to produce oxygen, control the water quality by buffering nutrient influx, stabilizing sediment and sheltering growth of aquatic organisms [2] They are important indicators of environmental conditions and long-term ecological changes as they are sensitive to physical and chemical changes in the ecosystem [3]. On the other hand, invasive macrophyte species have a negative aspect as they affect the function, structure, and composition of aquatic ecosystems [4]. Different groups of macroinvertebrates are excellent indicators of human activities, especially pollution. Most of them have quite narrow ecological requirements and are particularly useful as bio-indicators in determining the characteristics of aquatic environments ([5], [6]), as well as identifying segments of polluted rivers which undergo the process of self-purification [7]. The function of macrophytes and macroinvertebrates in wetlands ecosystems is related to their species composition, distribution, abundance, and diversity

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which in turn depend on various environmental factors such as light, water temperature, substrate composition, disturbance and quality of the wetlands water ([8], [9]). Assessing the taxonomic composition and abundance of macrophytes and macroinvertebrates in wetlands is therefore important in the determination of the ecological status of wetlands ecosystem. However, few studies on wetlands in Cameroon have focused on macrophyte and macroinvertebrate abundance and diversity mainly because of the accessibility to these habitats and the technical constraints of their study ([10]; [11]; [12]). Furthermore, the macrophyte – macroinvertebrate – water physico-chemistry correlation is less documented. This work therefore is a contribution towards the knowledge on the distribution of macrophytes and macroinvertebrates species in two small streams wetlands in the Bamenda town (North-West Region).

2 MATERIALS AND METHODS

2.1 STUDY AREA

Bamenda (5°56' - 6°00' N and 10°08' - 10º12' E) is the head quarter of the Mezam Division in the North-West Region of Cameroon. It covers a total surface area of 391 km^2. Its relief consists of interspersed plateaus with deep valleys. Its vegetation consists of an altered Guinean Savannah type with a high anthropogenic influence. There are two topographic units separated by a high, scarp-oriented NE-SW. Above the cliff, stands the upper plateau which is mainly Bamenda I and represents 10% of the total area of the city. Altitudes vary between 1472 m and 1573 m. The climate is of the tropical highland humid type characterized by two seasons: the rainy season is generally longer and lasts for 8 months (mid-March to mid- October) and the short dry season lasts for 4 months (mid-October to mid –March) [13]. The average annual temperature is 19.93 °C. The town has a rich hydrographical network with intense human activities and high population along the different watercourses in the watershed.

This work was carried out on two streams in the Bamenda central town and the sampling done in three stations: two stations on the stream Achichem (upstream and downstream) at Up-Station and one station on the river Menteh at Mile 3 Nkwen (Figure 1).

STATION 1

Station 1 wetland is a slow running water course taking its source from the mountain rock of Up station. the stream at some few meters away from its source is bordered by houses on its left side and crop farms at its right. It is receiving liquid waste from the residential house and agricultural intrants after rain fall runoff. This site is in Bamenda I at the coordinates 05°55'05" N and 010°12'14.6" E.

STATION 2

It is located 05°56'46.7"N and 010°58'22.2"E and is characterized by a small open water area with a low velocity; a variety of surrounding plants at the bank of the stream next to people houses and vague fields at the surrounds. The wetland receives wastes from direct dumping of refuse from houses and restaurants around it, as well as domestic waters by the neighboring population.

STATION 3

Mile 3 wetland is located along the Bamenda–Bambui highway at the coordinates 05°59'00" N and 10°30'4" E. It is bordered by the largest carwash facility in Bamenda3 municipality which impacts directly its water physico-chemical quality. It is also characterized by a fast-flowing stream, human settlement and agricultural lands influence.

3 METHODOLOGY

MEASUREMENTS OF PHYSICO-CHEMICAL PARAMETERS

Physico-chemical parameters were measured in-situ and in the laboratory following standard protocols as described by [14]. Water sampling was done in points where macrophytes and macroinvertebrates inventory were carried out.

IN SITU MEASUREMENTS

The temperature (°C) of the wetlands, pH, salinity (ppm), electrical conductivity (µS/cm), Total Dissolved Solids (TDS in mg/L) and dissolved oxygen were measured in situ, using a multiparameter from Waterproof TESTER Humeau.

MEASUREMENTS IN THE LABORATORY

Physico-chemical parameters measured in the laboratory included Suspended solids, turbidity, color, alkalinity, dissolved carbon, oxydability, $NH_4^{+,}$ $NO_3^{-,}$ $PO_4^{3-,}$ $Ca^{2+,}$ $Na^{+,}$ k^+ and Mg^{2+}. Water samples were collected without bubbles, at each station and for every sampling point using 250- and 1000-ml polyethylene bottles with double corks. Sample were transported refrigerated to the laboratory for analysis. Carbon dioxide (CO_2), alkalinity and Oxydability were done by the volumetric method. The determination of other parameters was done by the colorimetric method using a DR/3900 spectrophotometer following procedures described by [14].

MACROPHYTE INVENTORY

Floristic inventory in the different streams was done using quadrats methods delimited along line transects as described by Braun-Blanquet. Transects were laid in areas of conspicuous vegetation. Within each transect, quadrats of 1m x 1m were mapped out and wherein macrophytes abundance and cover were estimated. Plants were identified in-situ for those that were known. Unidentified species were collected and identified at the National Herbarium in Yaounde.

SAMPLING OF THE BENTHIC FAUNA

The sampling of macro-invertebrates was done following the multi-habitat approach proposed by [15]. It consisted in carrying out in each station, a total of 20 hauls in various micro-habitats characterized by a ratio between the substrate and speed of flow of the river as well as where macrophytes were abundant. The material used for the collection of this macro-fauna was a benthic sampler net, made from a metal framework with a dimension of 30 cm x 30 cm, mounted on a steel handle of 150 cm long, and provided with a taper thread of 400 µm of mesh and 50 cm of depth. To this effect, the net was deposited inside water and made to touch the bottom of the stream and it was hauled over a distance of 50 cm upstream, in the direction opposite to the water current. The surface sampled for 20 hauls is equal to a distance of about 3 $m^{2,}$ for a station which is approximately equal to100 m in length. Each time, the contents of the net was washed in a square sieve which measures 40 cm on each side and 400 µm mesh. The specimens were collected using a pair of fine pincers and a hand lens, then fixed in a small bottle containing 10 % formalin.

SORTING, IDENTIFICATION AND COUNTING OF THE ORGANISMS COLLECTED

In the laboratory, the contents of the bottles were transferred into a sieve of 400 µm mesh, and then rinsed with water to remove the formalin. The organisms were then collected using fine probes, gathered in limp of Petri dishes on the basis of their morphological nature, counted and preserved in labeled pills containing 95° ethanol. The specimens were identified to the least possible taxonomic level, under a binocular magnifying lens (model Olympus SZ30) under an episcopic lighting system as well as an optical microscope (ZEISS model) and an inverted microscope (model Olympus CK 2 UL WCD). The identification was done using different identification keys ([16] and [17]).

4 DATA ANALYSIS

ANALYSIS OF THE COMMUNITY OF MACROPHYTES

For each species, the abundance-dominance index was determined, which enabled the calculation of its mean recovery (RM) and presence index following the respective formulae:

$$RMi = (Ri/\text{Total number of records}) \times 100 \quad (1)$$

where Ri is the recovery of this species in a given environment.

$$Pi = RMi/\sum RM \quad (2)$$

The presence index (Pi) corresponds to the average recovery of species i over the total recovery of individuals.

ANALYSIS OF THE COMMUNITY OF MACRO-INVERTEBRATES

TAXONOMIC RICHNESS, ABUNDANCE AND POPULATION DENSITY OF MACRO-INVERTEBRATES

The surface density (Di) expressed in ind./m^2 was calculated according to the formula

$$Di = \frac{Ni}{S} \quad (3)$$

where Ni represents the number of individuals belonging to species i while S corresponds to the surface area sampled.

SHANNON'S DIVERSITY INDEX

The diversity or specific richness of the environment was determined using Shannon-Weaver's index (H').

$$H' = \sum_{i=1}^{S}(pi\ log2\ pi))$$

Where H'= diversity or specific richness;

pi = proportion of each species or taxon within a given population;

S = total number of species or of taxa;

H' is expressed in units of information per individual or bits per individual (bits/ind.) and its values lie between 0 and Log2S.

Species similarity between stations was determined using Sörensen similarity coefficient (Ss).

$$Ss = \frac{2a}{2a+b+C} \quad (5)$$

Where Ss = Sorenson similarity coefficient;

a = number of species common to all sites/category;

b = number of species unique to first site/category;

c = number of species unique to second site/category.

The relationship between macrophytes, macroinvertebrates species abundance and physicochemical variables was evaluated by the Pearson correlation test performed using the software XLSTAT 2016.

5 RESULTS

PHYSICOCHEMICAL PARAMETERS OF THE STUDY SITES

The various water physicochemical parameters as obtained in the three stations are presented in table 1. Concerning the physical parameters (temperature, suspended solids, turbidity and color), it appears that station 3 (mile 3 Nkwen river) had the highest values with an average temperature of 23°C ± 0.2, and Station 1 the lowest. For suspended solids, the lowest concentration (30.5 mg/L) was recorded at station 3 and the highest (65.5 mg/L) was obtained at station 1. Low values of turbidity and color were recorded at station 1 and the highest at station 3.

As for chemical pollution, station 1 was the most alkaline with an average pH of 8.43 ± 0.31 as compared to station 1 (7.8 ±0.13) and station 3 (7.4 ±0.15). Station 3 was characterized by hard water (15.42 ± 0.3 mg/L), alkaline water (16 ± 2 mg/L), average oxygenation (30 ± 0.9 mg/L) average electrical conductivity (125.5 ± 0.6 µS/cm), TDS (89.2 ± 0.25 mg/L) and salinity (56.9 ± 0.25 ppm). However, it has high average concentrations of Na^+ (8.63 ± 0.21 mg/L) and K^+ (13.3 ± 0.36 mg/L) ions. The minimum concentrations of electrical conductivity, salinity, calcium hardness, dissolved oxygen, Na+ and K+ ions were obtained at station 1 and the maximum concentrations at station 3. As for alkalinity, the minimum concentration was recorded at station 2 and the maximum at station 3.

Concerning organic pollution, station 2 was the most enriched in oxidizable organic matter (4.3 ± 0.26 mg/L) and ammoniacal nitrogen (1.1 ± 0.2 mg/L). Station 3 was the most enriched in nitrate and orthophosphate with average concentrations of 6.78 ± 0.35 mg/L and 3.05 ± 0.05 mg/L respectively. The minimum concentrations of nitrates and orthophosphates were recorded at station 2 and the maximum at station 3. As for ammonia nitrogen, the lowest concentrations were recorded at station 1 and the highest at station 3.

SPECIES COMPOSITION, ABUNDANCE AND DISTRIBUTION

BENTHIC MACROINVERTEBRATES

In terms of biological analysis, the different benthic macroinvertebrates collected during this study are presented in Table 2. A total of 1191 individuals of benthic macroinvertebrates were collected. These organisms belong to 1 phylum, 4 classes, 9 orders, 35 families and more than 55 genera. The most abundant class was that of insects with 97% of the total fauna followed by the class Annelids which represented 3% (Figure 3a). The order Odonata was the most abundant with 43% followed by Hemiptera (22%) and Ephemenoptera (19%) (Figure 3b). The most abundant family was Gerridae represented by 7 genera (*Pleiobates, Limnoporus, Limnogonus, Ventidius, Aquarius, Metrocoris, Rheumatogonus* and *Trepobates*). It was followed by the family *Hydrophilidae, Dytiscidae* and *Libellulidae,* each represented by 3 genera.

FLORISTIC RICHNESS

A total of 42 species of macrophytes were recorded. The distribution of these species per study site was 37% each for sites 1 and 2, and 26% for site 3 (Figure 3a). These species were divided into 19 families and 35 genera. The most abundant family during this survey was the Asteraceae family with 8 species followed by the Fabaceae family with 6 species (Figure 3b). The most current species collected in all sites were *Amaranthus spinosus, Commelina benghalensis and Lapportea cordifolia* (Table 2). In terms of number of species, site 2 was the most diverse with 22 species of macrophytes, followed by site 3 with 17 species. Overall, the Shannon and Weaver diversity index of macrophytes was variable and low in the study sites. It was 2.48 bit/ind for site 2, 1.90 bit/ind for site 1 and 2 bit/ind for site 3. Sorensen's similarity index was 0.24 for sites 1 and 2; 0.21 for sites 1 and 3 and 0.17 for sites 2 and 3.

RELATIONSHIP BETWEEN PHYSICOCHEMICAL PARAMETERS, MACROINVERTEBRATE AND MACROPHYTE DIVERSITIES

Significant positive and negative correlations were obtained between physicochemical parameters, benthic macroinvertebrates and macrophytes (Table 4).

Temperature was positively correlated with macroinvertebrates of the genus *Gyrinus,* and negatively with those of the genus *Caropteryx, Rheumatogonus* and *Chironomus*. With macrophytes it was negatively correlated with the species *Commelina benghalensis* ($p < 0.01$) and the species *Ludwigia abyssinica* ($p < 0.05$).

Suspended solids were positively correlated to members of the genus *Laccophilus* and *Chironomus* and the macrophyte species *Dalbergia hostilis* ($p < 0.01$).

Turbidity was positively correlated with macroinvertebrates of the genus *Gyrinus* and *Brachycerus* and negatively with the genus *Rheumatogonus* ($p < 0.01$). With macrophytes it was negatively and positively correlated with the species *Pennisetum purpureum* and *Sida alba* ($p < 0.05$) respectively.

Color was positively correlated with macroinvertebrates belonging to the genera *Gyrinus* and *Chironomus* and negatively with the macrophyte species *Centella asiatica* ($p < 0.05$).

The pH was negatively correlated with the *Pantala* genus (macroinverterbrate) and positively with the macrophytes *Ageratum conyzoides* and *Pennisetum purpureum* ($p < 0.05$).

Electrical conductivity was negatively correlated with organisms of the family Potamolidae, the genera *Laccophilus* and *Rheumatogonus* and then positively with organisms belonging to the genus *Acentrella*. It was negatively correlated with the macrophyte species *Crotalaria* sp ($p < 0.01$).

Suspended solids were positively correlated with the genus *Georissue* belonging to MIB ($p < 0.01$), and with the species *Portulaca oleracea* belonging to macrophytes ($p < 0.05$).

A significant and positive correlation was obtained between dissolved CO_2 and macroinvertebrates of the genus *Belostoma* and the macrophyte species *Alchornea cordiflora* and *Crotalaria* sp. ($p < 0.01$).

Positive and significant correlations were obtained between K^+ ions and the macrophyte species *Ageratum conyzoides, Ludwigia abyssinica* and *Portulaca oleracea*.

Nitrate ions were significantly correlated with the macroinvertebrate *Laccophilus* and positively with the genera *Pantala* and *Hetaerina* ($p < 0.01$). With macrophytes they were correlated with the species *Commelina benghalensis* and *Emilia coccinea* ($p < 0.05$).

Orthoposphates correlated positively with the genera *Pantala, Hetaerina, Rhagovelia* and *Brachycerus* and with the macrophyte species *Centella asiatica* and *Sida alba* ($p < 0.05$).

Ammonia nitrogen was negatively and positively correlated with macroinvertebrates of the genus *Georissue, Rheumatogonus, Notonecta* and *Brachycerus* ($p < 0.01$) and with the macrophytes *Dalbergia hostilis* and *Leucaena leucocephala* ($p < 0.05$).

6 DISCUSSION

WATER QUALITY

From comparing the various water physico-chemical parameters, station 1 and Station 2 in up-station were not significantly different, but differed from station 3, except for temperature and pH. Their values failed between values compatible with live (20- 30°C and 6.5 -9 for temperature and pH respectively.

Physical parameters such as electrical conductivity, salinity, total dissolved solids, suspended solids and color are all within the guidelines for natural waters [14]. However, station 3 in general exhibit higher values of these parameters as compared to station 1 and 2 at up-station probably as a result of increase anthropogenic pollution.

Nutrient content (NO_3^-; PO_4^{3-}; Na^+; Ca^{2+}; Mg^{2+}; K^+) in stations 1 and 2 are of the same order but lower in value compared to station 3 where organic pollution due to human activities might have contributed to increase them. Such increase of organic and mineral pollution of station 3. Biological parameters (dissolved oxygen, dissolved carbon and oxydability) have values that are higher in stations 1 and 2 compared to site 3. This can be explained by the fact that pollution always reduces the oxygen content in the milieu because of microbial activity and chemical oxygen fixations as station 3 was more polluted than stations 1 and 2.

MACROINVERTEBRATES COMMUNITIES' STRUCTURE

Agricultural activities coupled with high urbanization, through the use of fertilizers, organic manures wastes, often lead to the nutrient enrichment of water and sediment, which affects the macroinvertebrates community [18]. This might have affected the overall diversity in these stations. Regarding macroinvertebrates, 55 taxa were identified in the three stations. These taxa are low compared to the 178 taxa obtained by [19] in the urban and suburban streams of Douala and the 197 taxa gotten by [20] in the urban and sub-urban streams of Yaoundé. This could be justified by the high urbanization and anthropogenic activities in the Bamenda town. This data is supported by several authors in that, the number of benthic macro invertebrate species reduces drastically with increase anthropogenic activities. Furthermore, among the current threats to biodiversity, urbanization is of prime importance and is currently the second largest cause of ecosystem destruction in the world [21].

The differences in diversity observed in the different urban towns could be explained by the fact that, the streams in Yaounde receives essentially organic pollutant while those of Bamenda town, besides receiving the organic pollutants, there also collect larger agricultural waste from the different farms since farming is the main activity of the population. The high abundance of Arthropods that is largely dominated by Insects, confirm their bio plasticity and their ability to colonize a high variety of ecological niches [22].

Generally, we noted a low variation in the taxonomic richness of the station. This taxonomic richness of taxa reduces from less polluted stations (station 1 and 2) to highly polluted ones (station 3) although not substantially (33 taxa in station 1, 34 taxa in station 2 and 32 taxa in station 3). The low taxonomic richness observed in the 3 stations could be linked to the fact that, water originates and flows at the periphery of urban settlements. These stations have heterogeneous microhabitats which accommodate a large number of taxa. The presence of some tolerant groups like the Plecoptera, certain families of Odonata (Ashnidae, Gomphidae), Coleptera (Dytiscidae, Gyrinidae, Haliplidae, Hhydrochidae), Hemiptera (Hydrometridae, mesoveliidae, Gerridae) and the rare subfamilies of Chironomidae (Tanypodinae and Orthocladiinae) show that these streams although under anthropogenic pressure are still of good and acceptable physicochemical quality and shows acceptable ecological quality. This concurs with the conclusions of [23] and [24] who observed that some of these groups have an average sensitivity to an increase in organic pollution.

MACROPHYPTES COMMUNITIES' STRUCTURE

Specific richness and diversity are multivariate analyses integrating the physiognomy of the vegetation in the environment [25]. The specific richness obtained is 42 species. But, [13] obtained a lower value (28 species) in the Mezam river (Bamenda) with the predominance of some species like *Leersia hexandra, Echinochloa pyramidalis* and *Commelina benghalensis* during the dry season. These results are lower than those obtained by [27] along the Kondi river (97 species, grouped in 77 genera and 42 families) and similar to those obtained by [26] (42 species) in the Kambo river. The Asteraceae are the most diversified family. These results are different from those obtained by [27] in the river Kondi (Douala) and [26] in the river Kambo (Douala) who showed that Poaceae family is the most diversified with respectively 14 species, 5 species and 7 species. The most dominant species are *Echinochloa pyramidalis, Commelina benghalensis* and *Pennisetum purpureum*. These results are similar to those obtained by Tita *et al*. (2012) who showed that the Mezam river (Bamenda) was dominated by *Leersia hexandra, Echinochloa pyramidalis, Pennisetum purpureum* and *Coix lacryma-joli*. They also showed that dominant species were ranked in abundance as *Leersia hexandra* > *Commelina benghalensis* > *Echinochloa pyramidalis*.

Shannon-Weaver index obtained in the study sites are below those obtained by Priso *et al.* (2012) in the Kondi river (3.11-3.80), [26] in the Kambo river (1.76-2.96) and [27] in the Kribi river (2.37-6.68). The occurrence of *Commelina benghalensis, Alchornea cordifolia, Laportea ovalifolia, Amaranthus spinosus* may be due to their high tolerance capacity to the polluted area [28]. In effect, such factors generally do not permit the development of vascular plants and may be responsible, at least in part, for lack of in-stream vegetation [13] The distribution of plants is not randomly in the aquatic ecosystem, but grouped in association whose element substantially have the same ecological requirement [29]. Thus, the absence of certain macrophytes in the study sites would be due to the abiotic condition of their biotope.

7 CONCLUSION

Bamenda streams are of less diversified biodiversity with waters of variable physico-chemistry. The three stations have a number of predominant macrophytes such as are *Echinochloa pyramidalis, Commelina benghalensis* and *Pennisetum purpureum whose adaptations to different water pollution levels suggest their possible use in water vegetated treatment systems.*

The average water quality associated to the almost low biodiversity of macrophytes and macroinvertebrates also suggest a monitoring of these stream to prevent their eutrophication

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