Stream quality and benthic macroinvertebrate diversity in the badeye area logone occidental province, southwestern chad.

Théophile Djikoloum Beosso (djikoloumbe@gmail.com)
University of Dschang

Research Article

Keywords: Macroinvertebrates, quality, diversity, Man baptem, Badeye, Chad

Posted Date: August 23rd, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3242518/v1

Abstract

The aim of this study of benthic macroinvertebrates in the south-western Canton Badeye in Chad was to determine their population structure in relation to the physicochemical quality of the water in the Man baptem tributary. A total of 4012 benthic macroinvertebrates in 38 families were identified and counted. Arthropods were the most diverse, with 35 families, and the most abundant (92.32%) of the total, followed by Molluscs (6.65%) and Annelids (1.02%). Insects predominated at all sampling stations (89.40%), followed by Gastropoda (6.75%), Malacostraca (2.85%), Achaete (0.57%) and Oligochaete (0.45%). The preponderance of the Chironomidae, Psychodidae and Physidae families in station A3 implies that the water at this station is of poor quality compared with the other 3 stations. The Shannon-Weaver and Piélou indices are higher at station C3, confirming some of the physicochemical parameter values at this station. Overall, the 4 sampling stations are diverse. The abundance of certain benthic groups such as Chironomidae Diptera in the Man baptem tributary shows that this watercourse is subject to anthropogenic disturbance.

Introduction

Pollution is a serious environmental problem due to waste discharged into waterways. However, sewage systems, septic tanks, factory wastewater and solid waste are the main sources of surface and groundwater pollution in the urban sector. In peri-urban and rural areas, agriculture, through agricultural inputs, also contributes to degrading the quality of groundwater and watercourses (Mahamat et al., 2015). The aquatic compartment, constituting an ultimate receptacle for residues and represents the most affected environment. These dangerous products deteriorate the stands, because poisoning, induce biocenotic disturbances and sometimes even lead to the extinction of certain species (Agbohessi et al., 2011). The Republic of Chad has an immense hydrographic network: Chari, Logone, Lac-Chad, Lac-Fitri, Barh Azoum, etc. This hydrographic network is quite diversified and abounds in many natural resources (RGPH2, 2009). Unfortunately, these rivers, as in other African cities, are experiencing major problems: the regular decline in their volume, the anthropogenic pressure exerted on them and the deterioration of their quality. (Cubaka et al., 2019). This study aims to characterize the diversity, the population structure of benthic macroinvertebrates, and the estimation of water quality in this area. Indeed, aquatic ecosystems are of paramount importance. However, they are subject to strong anthropogenic pressures and galloping demographic growth. Consequently, their monitoring must be done through the evaluation of reliable and effective indicators such as bioindicators, due to their sedentary lifestyle, their great diversity and their variable tolerance to pollution and the degradation of wetlands. (Ben *et al.*, 2014)

In Chad, there is no information on the benthic macrofauna of the Logone River and its tributaries, the preservation of water quality is a necessary means for environmental management, but also for the conservation of biodiversity.. Bioindicators are good tools for assessing the quality of water in aquatic ecosystems (Moisan & Pelletier, 2011). The Province of Logone Occidental is considered the first economic zone of the country. However, the Logone River and its tributaries are experiencing various and considerable anthropogenic pressures following the dumping of industrial and domestic effluents, waste from agricultural activities, bathing, detergent-based detergents, nomadic pastoralists who water their animals and who defecate at the same time in watercourses have degraded water quality and modified the diversity and population of benthic macroinvertebrates. Finally, the consequences of these disturbances could be the reduction of biodiversity and the risk of waterborne diseases within this area (Koumba et al., 2017). These anthropogenic disturbances observed in the sampling sites make it possible to differentiate the richness and abundance of aquatic macroinvertebrates (Cubaka et al., 2019). Macroinvertebrates are the most commonly used organisms for monitoring and assessing the overall health status of aquatic systems (Camara et al., 2014).

The main advantage of using these benthic macroinvertebrates lies in the fact that they are sensitive to physicochemical variables and environmental disturbances. Several studies on benthic macroinvertebrates have shown their importance in the food chain and in aquatic environments (Ngoay-kossy et al., 2018). In order to preserve aquatic biodiversity and contribute to the knowledge of the fauna of benthic macroinvertebrates, an inventory of these organisms was carried out in the rural area of Badeye.

Materials and methods

Study area

The present study was carried out in the Province of Logone Occidental, Department of Lac Way, and Sub-prefecture of Ngondong and precisely in the canton of Badeye, located 36 km from Moundou at the south-western end of Chad. Its geographical location lies between latitude 8° 31' 60" North and longitude 15° 43' 60" East. Located in the eastern part of the Ngondong sub-prefecture, Badeye straddles the Departments of Dodjé and Lac Wey. Its relief is generally flat, with numerous floods from the various surrounding valleys.

The soil is ferralitic, hydromorphic and sandy clay. The area is subject to a Sudan-type climate characterized by two distinct seasons: the first dry season from October to April, and the second rainy season from April to September. Rainfall varies between 900 and 1200mm/year (RGPH2, 2009). Vegetation consists of herbaceous savannahs, trees and semi-wetlands. The area is endowed with surface water and groundwater from traditional wells and human-powered boreholes. The area has considerable agro-pastoral potential, which constitutes the main economic activity (RGPH2, 2009).to carry out this work, four (4) stations from upstream to downstream be selected. These stations were selected on the basis of criteria such as accessibility, anthropogenic activities, microhabitat diversity and stream depth.

The "Man baptèm" stream in the Badeye area has its source in Mangalmi Village, over 12 km away. The Mangalmi stream comes directly from Tapol, more than 18 km away, and originates in the Kon Nangra stream. It crosses the eastern part of Tapol to flow into Doman II. It then crosses the Doïti stream in the Monkon basin to flow into Lake Wey. This watercourse also crosses the Moundou-Baïnamar axis, passing through Tapol at a distance of over 54 km. All along its course, the "Man baptem" receives domestic and agricultural effluent from homes located in its catchment area. To assess the impact of pollution on this watercourse, four (4) sampling stations were selected. These stations are named A1, A2, A3 and A4 respectively. Station A1 is upstream, and stations A2, A3 and A4 are downstream and further away from station A1. Sampling was carried out on a tri-monthly basis, from September 2021 to August 2022.

- Station A1 (08°50'85.3"N, 015°74'52.9" E) coming towards Doït. It is located upstream and serves as a control station, unaffected by human activity. It is surrounded by kapok, karite and small shrubs and grasses.
- Station A2 (08°50'98.7" N, 015°74'64.2" E) is located far from station A1, on the Moundou-Baïnamar axis via Tapol. The area around the station is used for agriculture, with fields of manioc, sesame and red millet. Fishing is also practiced here.
- Station A3 (08°51'47.7" N, 015°74'99.1" E) is located further downstream than the first station. It was chosen to estimate the impact of human activities in this environment. This station receives a large number of people who wash in it, do their laundry, wash their dishes and water the animals that defecate in it. Both banks are used for agricultural purposes, such as growing peanuts, sesame and sorghum. The vegetation consists of mango and fig trees and small shrubs.
- Station A4 (08°51'84.8" N, 015°76'62.2" E) is located further downstream than the first three. It is also on the Douala Paysannat road, not far from the cemetery. The surrounding area is used for farming, with fields of sesame, groundnuts, sorghum and beans. The vegetation consists partly of mango trees and a few grasses. This station is also home to a number of local residents, who wash their clothes and dishes in it, as well as some ruminants that drink and defecate in it.

Benthic macroinvertebrate sampling

Benthic macroinvertebrates were collected according to the standardized protocol. Sampling was carried out taking into account three components of the aquatic habitat: substrate, current speed and station depth.

Sampling was carried out using a dip net consisting of a conical net with a 40 µm mesh opening and 50 cm depth, attached to a 30 cm square metal frame mounted on a 150 cm long steel handle. It was carried out following the multi-habitat approach proposed by (Barbour et al., 1999; Moisan & Pelletier, 2011), which consists in carrying out in each station, in each campaign a total of 20 net shots in different microhabitats characterized by the substrate/velocity pair.

Organisms caught in the mesh were collected using entomological forceps and a hand-held magnifying glass, then placed in pillboxes containing a 95% ethanol solution, labelled with the date, station number and time of collection. The samples obtained were returned to the Animal Physiology and Health Laboratory (LASAN) of the Faculty of Agronomy and Agricultural Sciences (FASA) for identification.

Identification of benthic macroinvertebrates

In the laboratory, specimens were washed under running water on a 400 µm mesh sieve, then preserved in a 95% ethanol solution. Identification and counting were carried out on a station-by-station basis. For each station, the organisms collected were poured into petri dishes and then grouped according to size and morphological characteristics. They were identified using identification keys. These keys are those of (Levêque, 2001; & Tachet et al., 2010), which deal with invertebrates in general. Observations were made with the naked eye and under a Wild M38 stereoscopic binocular loupe with episcopic lighting.

Measurements of water physicochemical parameters

For each station, physicochemical parameters were measured to gain a better understanding of the influence of environmental factors on the distribution of benthic macroinvertebrate structures.

In situ measurements of the water's physicochemical parameters, namely temperature, conductivity and TDS, were determined using an OAKLON portable conductivity meter. pH was measured using a portable HQdl pH meter.

Water samples were taken for nutrient analysis. Water samples were taken at each station in 750 ml plastic bottles and stored in a cooler with ice for transport to the laboratory. In the laboratory, TSS, turbidity, salinity, dissolved oxygen, chlorine, phosphate, nitrite, nitrate and ammoniacal nitrogen were measured using a HACH DR/890 spectrophotometer, and the values expressed in mg/l.

Biochemical Oxygen Demand (BOD5 in mg/l of O2) was measured by respirometer using a LIEBHERE BOD incubator, for 5 days at 20°c, in accordance with AFNOR method NFT 90–103. The rise in mercury in the tube was read every day for 5 days. COD was carried out using a powerful oxidizing agent, organic compounds present in the water. It measures the total organic matter content, including that which is not degradable by bacteria. Values are expressed in mg/l.

Data analysis

The Pearson, Shapiro-wilk correlation tests and the Kolmogorov-Smirov normality test were carried out using SPSS 26 software. They allowed the physicochemical variables to be compared between the different study stations at the significance level $\alpha = 5\%$, both the Principal Component Analysis (PCA) made with the R software made it possible to establish the physicochemical characteristics that better define each sampling station and give it its identity.

Taxonomic richness is the number of distinct taxa present in a sample. It reflects the diversity of a sample and appears to be a good indicator of the health of the benthic community. Taxonomic composition represents the percentage abundance of a taxon or taxon group out of the total abundance of organisms present at a station.

The frequency of occurrence of taxa provides information on the level of constancy of a species or taxon in a given habitat, without any indication of its quantitative importance. Expressed as a percentage (F), it is the quotient of the number of samples in which species i was found (Pi) by the total number of samples during the study period (Pt).

F is given by F (i) = Pi x100/Pt

Using this formula, the following three groups of species can be distinguished according to F values:

Constant species, present in at least 50% of surveys (F ≥ 50%);

Accessory species, present in at least 25% of records (25%≤F < 50%);

Rare species, present in at least 25% of surveys (F < 25%)/.

Shannon and Weaver's (1948) diversity index, commonly used to determine the overall diversity of a stand. It measures the degree of stand organization Independent of sample size, it considers two diversity components separately, namely the number of species and the regularity of their °frequency distribution. This index was calculated using the following formula:

$H\prime = -\sum_{i=0}^{n} pi \log_2 pi$ H': Shannon diversity index; i: a species from the study environment; Pi: proportion of a species I compared to the total number of species (s) in the study environment (or specific richness of the environment), which is calculated as follows:

$$P\,(i) = n_i\ /\ N$$

Where n_i is the number of individuals for species i and N is the total number (individuals of all species).

Piélou's (1966**)** Equitability (E), which reflects the degree e of diversity achieved, makes it possible to study the regularity of the distribution of individuals within species. This index also has the advantage of reflecting the quality of stand organization and varies between 0 and 1. It is close to 1 when stand taxa have identical abundances. It tends towards 0 when almost all the numbers are concentrated on a single taxon. It has been calculated to identify stand equilibrium according to the formula:

$$= \frac{H\prime}{Hmax} = \frac{H\prime}{\log_2 s}$$

Where H' is Shannon's diversity index and S is the number of species observed.

The aim of Principal Component Analysis (PCA) is to graphically present the maximum amount of information in a large table of quantitative data. PCA was applied to environmental data and to metrics describing the structure of the benthic macroinvertebrate population, in order to establish the abiotic and biotic typology of the various sampling stations.

Results

Environmental variables

The spatial values of physicochemical parameters recorded throughout the study are shown in Table 1. Analysis of water temperatures measured at the various stations reveals that station A4 (32°C) has the highest temperature and station A1 (23.80°C) has the lowest, i.e. a thermal amplitude of 8.2°C. PH ranged from 5.47 UC at station A3 to 8.27 UC at station A1. Conductivity values ranged from a low of 36 µS/cm to a high of 96.40µS/cm at station A4. TDS levels varied from 19.10 mg/L at station A2 to 49.50 mg/L at station A4. Turbidity fluctuated around 2 NTU at stations A1, A3 and A4, and 36.60 NTU at station A2.

TSS values ranged from 7.60 mg/L to 216.60 mg/L at stations A1 and A4 respectively. For salinity, the minimum value was 0.03 (A3) and the maximum was 0.06 mg/L (A4). Color ranged from 48.00 Pt.Co (A3) to 641.00 Pt.Co (A1). Suspended solids, pH and electrical conductivity showed a significant difference at P = 0.05 between stations A1, A2, A3 and A4. However, there is a strong correlation between stations A2 and A4. The lowest chloride value was 3.00mg/L (A3) and the highest 23mg/L (A2). Dissolved oxygen levels ranged from 2.12mg/L to 7.18mg/L at stations A4 and A1 respectively. For ammonium, the lowest concentration is 0.30 mg/L at station A1 and the highest is 20.20 mg/L at station A2. Nitrate concentrations in the Man babtem stream ranged from 0.001 mg/L (A1) to 10.30mg/L at (A2) and (A3) each. Minimum nitrite values were 0.001mg/L at stations A1, A2 and A4, and the maximum value was 6.00 mg/L at station A3. Orthophosphate values ranged from 0.10 mg/L to 33.00mg/L at stations A1 and A4 respectively.

BOD5 levels ranged from 5.50 mg/L (A1) to 72.30 mg/L (A2). For COD, the lowest value was 10.80 mg/l at station A1, and the highest was 64.13 at station A2. There is a correlation between dissolved oxygen, nitrate and phosphorus between stations A1, A2, A3 and A4. However, there was no significant difference between these variables and the stations.

Table 1
mean value ± standard deviation of physicochemical variables at the various Man-Baptem study stations (minimum and maximum values in brackets).

Variables	**A1**	**A2**	**A3**	**A4**
Temperature (°C)	24,97 ± 0,84 (23,80 – 25,80)	25,50 ± 0,76 (24,50 – 26,30)	25,50 ± 0,89 (24,90 – 26,50)	27,95 ± 3,0 (25,30–32,00)
PH (U.C)	7,07 ± 1,10 (5,96 – 8,27)	6,33 ± 0,35 (6,10 – 6,86)	5,85 ± 0,38 (5,47 – 6,31)	6,96 ± 0,49 (6,41 – 7,50)
Conductivity (µS/cm)	47,42 ± 11,71 (39,60–64,60)	47,05 ± 11,60 (37,80 – 63,80)	60,80 ± 17,60 (42,00–76,30)	57,15 ± 28,43 (36,00–96,40)
TDS (mg/L)	24,45 ± 5,87 (20,50 – 33,10)	23,40 ± 6,22 (19,10–32,30)	30,95 ± 9,05 (22,10–39,20)	29,45 ± 14,03 (19,50 – 49,50)
Turbidity (NTU)	13,65 ± 11,03 (2,00–28,60)	22,60 ± 10,29 (11,90 – 36,60)	14,77 ± 11,90 (2 ,00–26,80)	11,85 ± 8,20 (2,0–20,80)
Salinity (mg/L)	0,02 ± 0,005 (0,02 – 0,03)	0,02 ± 0,05 (0,2 – 0,3)	0,03 ± 0,005 (0,03 – 0,04)	0,03 ± 0,02 (0,02 – 0,06)
Suspended solids (mg/L)	68,92 ± 109,78 (7,60–233,30)	72,55 ± 71,03 (16,60–176,60)	72,85 ± 93,44 (9,50–210,00)	84,40 ± 90,91 (8,80–216,60)
Coulor (Pt. Co)	266,82 ± 250,10 (121,00-641,00)	308,40 ± 140,35 (98,70–389,92)	212,67 ± 217,01 (48,00–51,50)	230,32 ± 231,53 (67,00-566,70)
Disolved oxygen (mg/L)	5,33 ± 1,45 (3,67 – 7,18)	4,53 ± 0,87 (3,46 – 5,46)	5,03 ± 1,59 (2,97 – 6,83)	4,73 ± 1,78 (2,12 – 5,87)
Chlorure (mg/L)	6,37 ± 2,56 (4,00–10,00)	9,75 ± 8,84 5,00–23,00	8,20 ± 5,16 (3,00–14,00)	7,00 ± 3,16 (4,00–11,00)
$NH4^{+}$ (mg/L)	1,17 ± 0,71 (0,30 – 1,90)	7,40 ± 8,61 (1,60 – 20,20)	5,85 ± 6,32 (2,10–15,30)	2,20 ± 0,57 (1,50 – 2,80)
Nitrate (mg/L)	1,26 ± 2,16 (0,001–4,50	4,90 ± 4,76 (0,50 – 10,30)	6,37 ± 4,57 (0,40 – 10,30)	2,39 ± 2,39 (0,09 – 5,50)
Nitrite (mg/L)	0,004 ± 0,003 (0,001 – 0,009)	0,03 ± 0,04 (0,001 – 0,090)	1,51 ± 2,99 (0,002–6,00)	1,39 ± 2,41 (0,01–5,00)

Variables	A1	A2	A3	A4
Orthophosphates (mg/L)	0,47 ± 0,35 (0,10 – 0,90)	1,30 ± 0,82 (0,4 – 2,40)	1,22 ± 0,60 (0,50 – 1,90)	9,75 ± 15,56 (0,90 – 33,00)
BOD5 (mg/L)	8,87±,64 (5,50 – 11,60)	26,05 ± 30,85 (9,80 – 72,30)	10, 90 ± 4,01 (7,50 – 16,90)	15,50 ± 5,37 (9,90 – 22,00)
COD (mg/L)	17,25 ± 5,23 (10,80 – 23,20)	52,55 ± 64,13 (18,10–148,70)	21,70 ± 8,11 (15,70 – 33,10)	28,50 ± 12,9 (17,60 – 45,80)

The Ascending Hierarchical Classification (HAC) of stations based on the similarity of physicochemical parameters shows that sampling stations in the study area are grouped into two classes (fig: 2). Class I is that of stations A3, A4 and A1. However, station A1 located upstream is considered as a reference, it is distinguished from stations A3 and A4 which are considered too anthropized with similar abiotic characteristics (they directly receive landfills from agricultural inputs and domestic waste). Class II is made up only of the little anthropized station A2 which differs by its physicochemical characteristics compared to the stations A3 and A4.

The Principal Component Analysis (PCA), carried out from the physicochemical variables (Fig. 2) shows on the correlation circle that the conductivity (-0.313), the TDS (-0.317), the Nitrate (-0.35) and dissolved oxygen are negatively correlated with the F1F2 0 axes, suspended solids (SS) (0.37) and color (0.40) are positively correlated with the F2 axis tans disc dissolved oxygen (-0.37) is also negatively correlated on the F2 axis.

Benthic macroinvertebrate population

A total of 4012 individuals including Arthropods (92.32%), 267 Gastropods (6.65%) and 41 Annelids (1.02%) were identified and counted during this study. Insects are the most represented, in 7 orders and 28 families, followed by Gastropods (1.2), Malacostracans (1.1), Oligochaetes (1, 1) and Achaetes (1.1). In terms of quantity, Insects predominate with 89.40% of total abundance, dominated by the Chironomidae family (36.54%), and followed by Gasteropoda (6.75%), Malacostraca (2.85%), Achaetes (0.57%) and Oligochaetes (0.45%).

Benthic macroinvertebrate population structure

Analyses of the numbers of different families show that in station A1, Baetidae and Caenidae are dominant, with (19.04%) and (13.96%) respectively. They are followed by Perlidae (8.46%) and Ephemerythidae (8.18M) of the total abundance. At station A2, the Dysticidae and Hydraenidae families dominate with 10.44% and 9.20% respectively, followed by the Libellulidae (9.02%), Nepidae (7.78%) and Gyrinidae (7.43%). At station A3, Chironomidae predominate (65.71%), followed by Psychodidae (10.33%) and Physidae (8.86%) in relative abundance. Station A4 is dominated by the Dysticidae families (14.18%), followed by Helodidae (13.83%) and Nepidae (10.50%) of total abundance.

Generally speaking, station A3 has the highest abundance, with 54.01% of specimens collected in this river, i.e. 2167 individuals. This station is followed by A1 with 709 individuals (17.61%), then A4 with 571 individuals (14.4 233%), and A2 with 565 individuals (14.08%). In terms of taxonomic diversity, station A4 is the richest. 26 families of benthic macroinvertebrates were counted at stations A1 and A2, with 21 families each, and at station A3 with 22 families.

Figure 3 shows the spatial evolution of the Shannon diversity and Piélou equitability indices. The Shannon index shows that station A2 (H = 3.33 bits/ind) is the most diverse, while station A3 (H = 2.54 bits/ind) is the least diverse. There is a significant difference between station A3 and stations A1, A2 and A4. The highest value of the Equitability index is observed at station A2 (0.92) and the lowest at station A3. Equitability at all stations in the Man ferme stream is close to 1, indicating that benthic macroinvertebrate populations are balanced. According to the Kolmogorov-Smirnov normality test, there is no significant difference between the 4 stations.

Out of a total of 38 families collected in the Man batem stream, 4 macroinvertebrate families are very frequent in station A1 with a frequency of occurrence to 50%, including the Baetidae, Caenidae, Ephemerythidae and Perlidae families. At station A2, only the Dysticidae family is very frequent. At station A3, the most anthropized, 4 families are very frequent. These are the Chironomidae, Psychodidae, Grapsidae and Physidae families. At station A4, two families, Nepidae and Dysticidae, are very frequent. Table 2 shows the different signs of frequency of occurrence of the families collected in the man baptem stream.

Table 2: Frequency of occurrence of macroinvertebrate taxa sampled at the 4 stations of the Man baptem tributary.

Familles	A1	A2	A3	A4
Baetidae	+++	+	+	+
Caenidae	+++	+	+	+
Machadorythidae	-	-	-	+
Ephémérythidae	++	-	-	-
Ephéméridae	+	+	-	-
Népidae	++	++	++	+++
Notonectidae	-	-	-	+
Gerridae	++	-	+	-
Pleidae	+	-	-	+
Veliidae	-	+	+	-
Belostomatidae	-	+	+	++
Mesoveliidae	-	-	+	-
Perlidae	+++	-	-	-
Aeshnidae	++	-	+	+
Coenagrionidae	-	+	+	-
Gomphidae	-	-	-	+
Libellulidae	+	++	+	+
Lestidae	++	-	-	+
Corduliidae	+	-	-	+
Dystidae	+++	+++	++	+++
Helodidae	+++	+	+	++
Hydrophilidae	-	-	+	+
Hydraenidae	++	++	++	+
Géorissidae	+	-	-	-
Spercheidae	+	-	-	-
Gyrinidae	+	+	-	-
Elmidae	-	-	+	-
Philopotamidae	+	-	-	+
Ecnomidae	-	-	-	+
Hydropsychidae	-	+	-	-
Tabanidae	-	++	-	-
Dolichopodidae	-	++	-	-
Chironomidae	-	-	+++	+
Psychodidae	-	-	+++	+
Grapsidae	++	++	+++	++
Physidae	-	++	+++	++
Erpobdellidae	-	-	+	++
Tubificidae	-	-	++	+

- : F =0% (absent taxa)

+: F ≠ 0% and < 25% (rare taxa)

++: 50% > to F ≥ 25% (frequent taxa)

+++: 50% ≥ F (very frequent taxa)

Discussion

Physicochemical characteristics

The values removed from temperature would be due to the ambient temperature of the environment. This confirms those given by Mahamat et al., (2015), on public supply water in the city of N'Djamena in Chad. Man baptem waters are practically neutral, which can be attributed to the nature of the substrate. This result confirms those of (Ngoay-Kossy et al., 2018) in the Nguitto stream in the Central African Republic. The low values of electrical conductivity, TDS, turbidity and salinity in the man baptem stream reflect low mineralization of the water in place of the geological substrate. This concurs with those of (Ngameni et al., 2017) in peri-urban streams in the city of Dschang (Cameroon). The low TSS concentrations at station A1, which is located upstream, are very little anthropized.

This result is similar to that of (Tchakonté, 2016) in the Nsapé stream in Douala. The low dissolved oxygen levels in the stations would be related to the low anthropogenic activities in these stations. This confirms those of (Kengne, 2018) on streams in the West region (Cameroon). The high values of chloride, ammonium, nitrate, nitrite, chloride, orthophosphate, BOD5 and COD in stations A2, A3 and A4 located downstream of the discharge is due to discharges of crop-related fertilizers, domestic waste and detergents into this watercourse. This result is similar to that of (Onana et al., 2014) on the urban tropical stream of Douala (Cameroon). It also corroborates that of (Agblonon et al., 2016) on the stream waters of the middle Alibori River (Benin). The principal component analysis carried out from the physicochemical data highlights the physicochemical variables on which we can base ourselves to define the waters of the Man baptem watershed. These include TDS, Conductivity, Nitrate, Suspended Solids (SS), Color and Dissolved Oxygen. On the other hand, the other parameters are ignored by the physicochemical characterization of this watercourse.

Biological characteristics

The taxonomic richness of macroinvertebrates in Man baptem (38) families is similar to that found in rivers under very low anthropogenic pressure. Our results also corroborate those obtained by (Foto *et al.*, 2012), who identified 38 macroinvertebrate families in the Mefou. The results obtained in this study show that insects are the most abundant. They corroborate several previous studies that have shown the predominance of the insect class in aquatic environments (Koumba et al., 2017). The other classes, namely malacostracans, molluscs, oligochaetes and buoys, are poorly represented. Diptera is the most abundant order in terms of individuals, specifically Chironomidae, followed by Psychodidae at station A3, considered the most anthropized. Ephemeroptera, Odonata, Coleoptera and Hemiptera are poorly represented. The total taxonomic richness is 89 taxa, including 20 at station A1, 21 (A2), 22 (A3) and 26 at station A4. However, (Onana et al., 2014) have shown that the preponderance of Chironomidae, Psychodidae and Planorbidae in station A3 is indicative of a high organic matter load in the water. On the other hand, station A1, which is considered a control station, offers favorable conditions for the proliferation of macoinvertebrates such as Baetidae and Caenidae, which are highly sensitive to the action of pollution. Equitability calculations reveal the balanced nature of the watercourse studied.

This result corroborates that of (Koumba et al., 2017) in the streams of Moukalaba Doudou National Park (Gabon). However, station A3 shows low diversity compared with the other 3 stations, which could be explained by the fact that this station is considered the most anthropized. The frequency of occurrence of taxa exceeding 50% allows us to identify macroinvertebrate taxa that can be qualified as polluosensitive and polluoresistant. At station C1, 3 constant taxa were recorded. These are Caenidae, Baetidae and Perlidae. (Table 2) which are qualified as polluosensitive. This station would provide a favorable environment for these species. These results are similar to those of (Ngameni *et al* 2018) in the streams of Dschang (Cameroon). Station C2, with one constant taxon (Dysticidae) and C4 two constant taxa (Nepidae) and Dysticidae) which are also considered sensitive to pollution. In station C3, the Chironomidae, Psychodidae, Grapsidae and Planorbidae families are omnipresent at this station, where the water is highly mineralized. These results corroborate those of *(*Onana et al., 2014) in Douala streams, which showed that Chironomidae and Psychodidae are characteristic of aquatic environments disturbed by human activities. They can be considered as pollutant-resistant and could serve as bioindicators.

Conclusion

This study has enabled us to characterize the Man baptem stream in terms of environmental and biological parameters. The physicochemical analysis carried out in this tributary shows that water quality is satisfactory at station A1. However, at stations A2, A3 and A4, certain parameters such as orthophosphate, BOD5 and COD have very high levels. This study enabled us to identify benthic macrinvertebrates in the Ngondong Sub-Prefecture (Chad), which is very similar to the structure of these communities in tropical African rivers, characterized by a preponderance of arthropods, and insects in particular. The results accurately contrast upstream reference stations with downstream polluted ones. Station A1 is characterized by a wealth of species (Ephemeroptera, Plecoptera) indicative of good quality water. Station A3, on the other hand, is characterized by a high abundance of species (Diptera Chironomidae, Psychodidae) indicative of an environment impacted by human activities. This study confirms the value of benthic macroinvertebrate bioindication in the Ngondong Sub-Prefecture, and opens up a significant field of research for this region, as well as for all the rivers in Chad.

Declarations

Author contribution

All authors contributed to the study

Design. Material preparation, data collection, and analysis were performed by all authors (DJIKOLOUM BEOSSO Theophile, SEINO Richard Akwanjoh, Norbert TCHAMADEU NGAMENI, MANKEMI A KEDJI Joseph Michael). The first draft of the manuscript was written by DJIKOLOUM BEOSSO Théophile and all the authors commented on the previous versions of the manuscript. All authors have read and approved the final manuscript.

Funding

No funding was obtained for this study.

Data availability

The datasets analyzed during the study are available in the supplementary information file.

Ethical Approval All authors have read, understood, and complied, where applicable, with the statement on "Authors' Ethical Responsibilities" in the Instructions to Authors and are aware that, with minor exceptions, no changes can be made. Be given to authorship once the article is submitted.

Competing interests

The authors declare no competing interests.

Thanks

We would like to thank His Majesty the Badeye Canton Chief Mr. NGUINABAYE for his help in data collection and Mr. ASEAKU Frederick NKAKAH and Mr. MBAITELSSEM Bienvenu for their help in statistical analysis.

References

1. Agbohessi, T.P., Imorou ToKo, I., Yabi, A.J., Dassoundo, C.F.J., Kestomont, P. (2011) Caractérisation des pesticides chimiques utilisés en production cotonnière et impacts sur les indicateurs économiques dans la commune de Banikoara au nor ddu Benin. Int. J. Biol.Chem. Sci., 5(5): 1828–1841
2. Agblonon, M.H.T., Adandedjan, D., Chikou, A., Imorou, T.I., Bonou, C., Youssao I., Laleye, P. (2016). Evaluation de la qualité des eaux des ruisseaux du cours moyen de la riviere Alibori par l'étude des macroinvertebrés benthiques dans le bassin cotonnier du Benin (Afrique de l'Ouest), Int. J. Biol. Chem. Sci. 10 (6): 2461–2476, December 2016
3. Barbour, M.T., Gerritsen, J., Synder, B.D & Stribling, J.B. (1999). Rapid bioassessment protocol for use in stream and wadeable rivers: periphyton, benthic macroinvertebrates and fishs. 2nd edition, U.S. EPA, office of water, Washington, D.C, EPA 841-B-99-002
4. Ben Moussa, A., Chahlaoui, A., Rour &Chahboune, M. (2014). Diversité taxonomique et structure de la macrofaune benthique des eaux superficielles de l'Oued Khoumane moulay idriss Zerhoun, Maroc, *J. Mater Environ Sci*, 5(1) (2014) 183–198
5. Camara, A.I., Diomande, D & Gourene, G. (2014). Impact des eaux usées et de ruissellement sur la biodiversité des macroinvertebrés de la riviere Banco (Parc National; Cote d'Ivoire), *Sci, Vie, Terre, Agron*, Vol.2; N°1 :58–68
6. Cubaka, K.A., Cirimwani, B.L., Bora, U.H., Lwambo, K.J & Baguma, B.G. (2019). Premiers inventaires de la diversité des macroinvertebrés aquatiques du lac Vert, Goma/Nord-Kivu, République Democratique du Congo. Journal of Applied Biosciences 140-14268–14280 https://dx.doi.org/10.4314/jab.v140i1.6

7. Foto Menbohan, S., Koji, E., Ajeagah Gideon, A., Bilong Bilong, C.F. & Njiné, T. (2012). Impact of dam construction on the diversity of benthic macroinvertebrates community in a periurbain stream in Cameroon. *International Journal of Biosciences*. N°11: 137–145
8. Kengne (2018). Bio-evaluation des cours d'eau de la région Ouest Cameroun a l'aide des macroinvertebrés benthiques et construction d'un indice multimetrique régional. These de Doctora/PhD, Université de Yaoundé 1, 174p
9. Koumba, M., Hans, K.M., Aubin, A.K., Christophe, R.Z.K., Blaise, R.M., Jean, D.M., Jacques, F.M. (2017). Diversité familiale des macroinvertebrés et qualité des cours d'eau du Parc National de Moukalaba Doodou (Sud-Ouest du Gabon). Entomologie Faunistique- faunistic Entomology;70, 107–120
10. Levệque, C. (2001). Ecologie de l'écosysteme à la biosphere. Paris, France: Dunod, 502p
11. Mahamat, S.A.M., Maoudombaye, T., Abdelsalam, T., Ndoutamian, G., Loukman, B. (2015) Evaluation de la qualité physicochimique des eaux d'adduction publique de la Société Tchadienne des Eaux a N'djamena au Tchad., J. Appl Biosci *95*:8973–8980
12. Moisan, L & Pelletier, L. (2011). Protocole d'échantillonnage des macroinvertebrés bentiques d'eau douce de Quebec, cours d'eau peu profonds à substrat meuble 2011. Direction de suivi de l'état de l'environnement, Ministere de Developpement Durable, de l'Environnement et des Parcs, ISBN: 978-2-550-61166-0(PDF), 45p
13. Ngoay-Kossy, J.C., Zebaze Togouet, S.H., Wango, S.P., Bolevane, O.S.F., Tchakonté, S & Piscart, C. (2018). Bioindicateur des milieux aquatiques, lotiques en République Centrafricaine: Macroinvertebres Benthiques et préssions anthropiques du cours d'eau Nguitto. *Révue d'Ecologie (Terre et Vie).* Vol. 73 (4), 2018: 603–616
14. Ngameni, T.N., Asanga, P.B.F., Mpoame, M. (2017). Bioévaluation de la qualité des eaux du cours d'eau menoua en zone périurbaine de Dschang, Ouest, Cameroon. *European Scientific Journal*; Vol 13 No 27 (2017) : *ESJ* september; Doi : 10.19044 *esj*.2017.V13n 27p 368
15. Onana, F.M., Zebaze Togouet, S.H., Dassie, D.B.S., Nna, S.C., Mvondo, N., Ngassam, N. (2014). Impact de l'effluent du complexe chimique camerounais (CCC) sur la structure du peuplement de macroinvertebrés benthiques d'un cours d'eau tropical urbain (Douala, Cameroun), European *Journal of Scientifique Research*. ISSN 1450-216X/1450-202X Vol. 121 N_o. 3, 2014, PP. 298–309
16. Pielou, E.C. (1966). The measurement of diversity in different types of biological collections. Journal of Theorical Biology, *13: pp* 131–144
17. RGPH2 (2009). Deuxieme Recensement General de la Population et de l'Habitat au Tchad. Resultats globaux, 89p
18. Shannon, C.E. (1948). A mathematical theory of communication. Bell System Technical Journal, 27 (379–423), 623–656
19. Tachet, H., Bournaud, M., Richoux, P. & Usseglio- Polatera, P. (2010). Invertebrés d'eau douce: Systématique, Ecologie, Biologie. CNRS Edition, Paris, France, 588p

20. Tchakonté, S. (2016). Diversité et structure des peuplements de macroinvertebrés benthiques des cours d’eau urbains et périurbains de Douala (cameroun). These de Doctorat/PhD, Université de Yaoundé 1. 238p

Figures

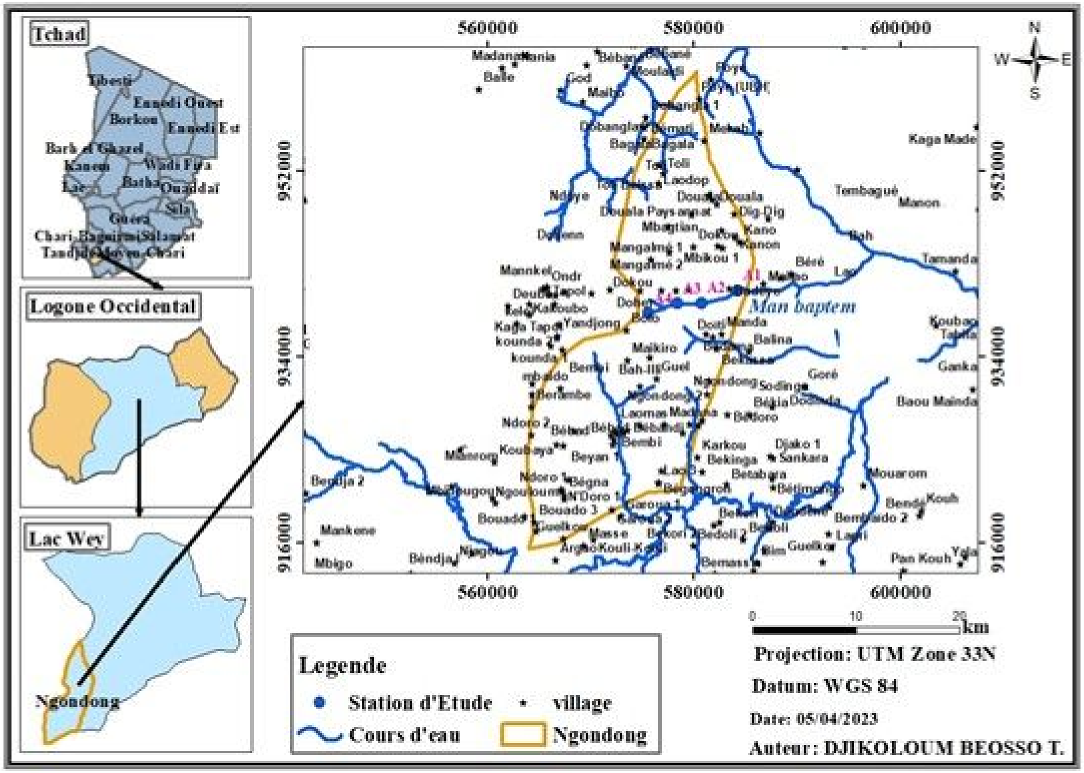

Figure 1

map showing the location of the study area on the Man Baptem River in south-west Chad.

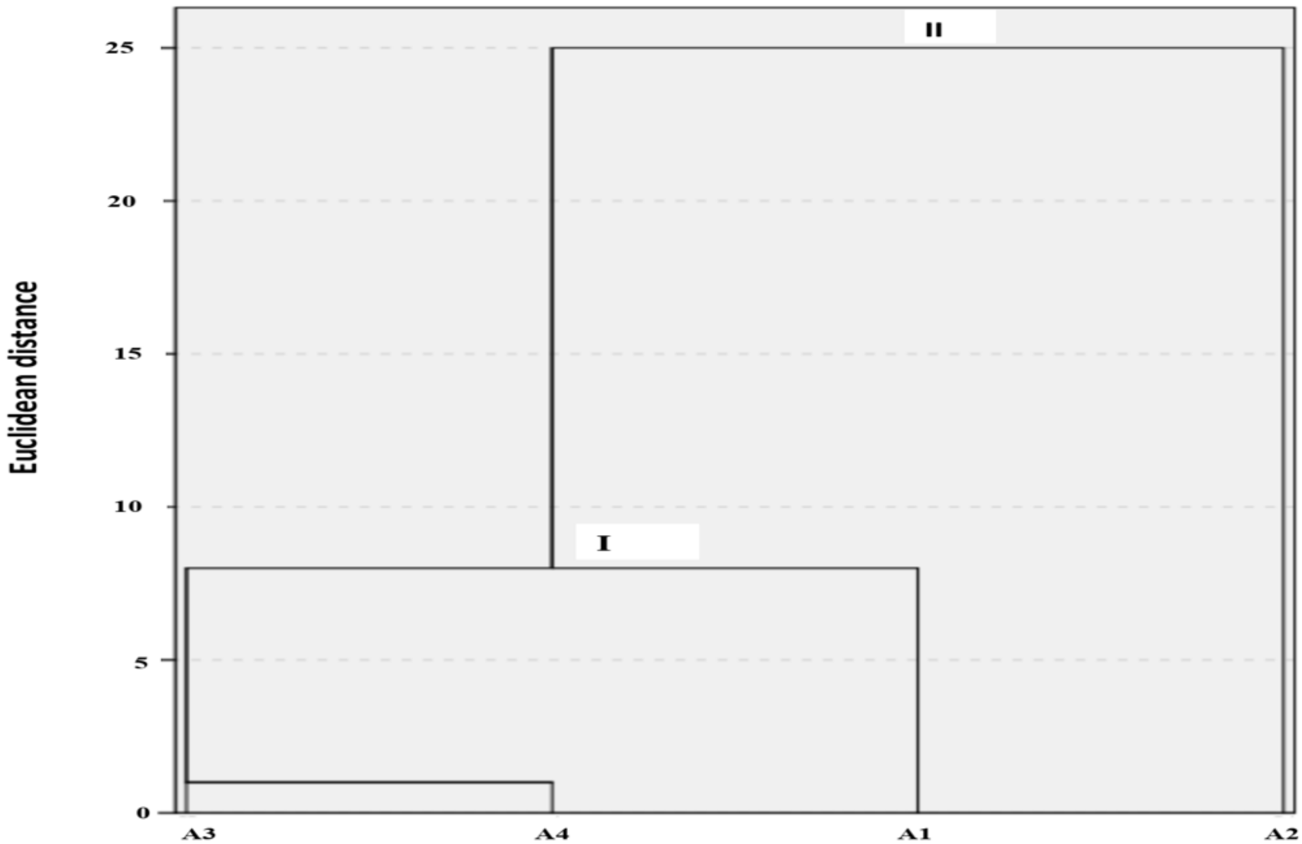

Figure 2

The Hierarchical Ascending Classification (HAC) of the different sampling stations based on the similarity of the physicochemical parameters of the Man baptem watershed.

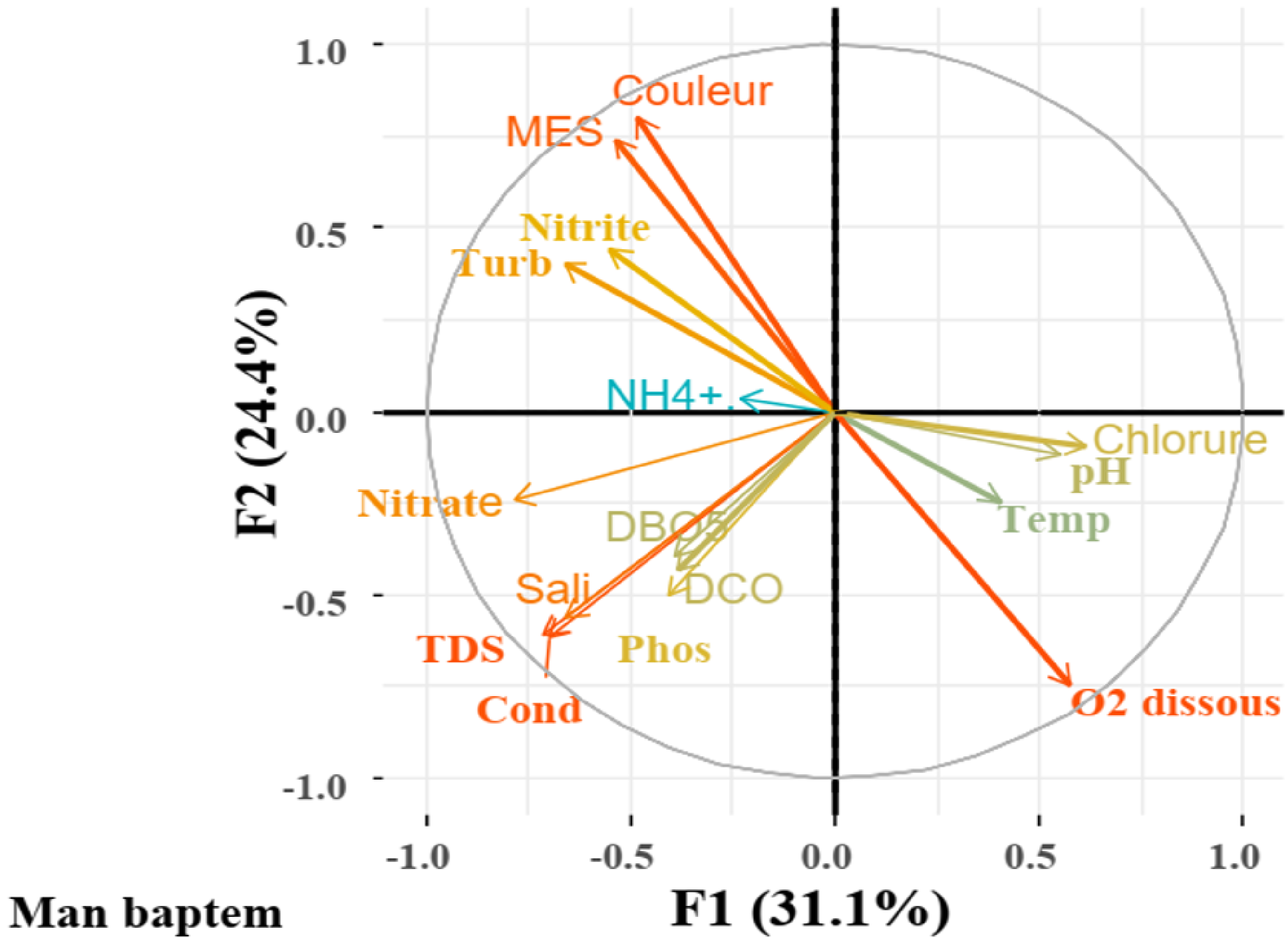

Figure 3

Principal component analysis (PCA) of physicochemical variables measured during the study period

Legend: *MES=Suspended solids; Turb= Turbidity; $NH4^+$= Ammonium; DBO5= Biochemical Oxygen Demand; Sali= Salinity; DCO= Chemical Oxygen Demand; Phos= Orthophosphate; Cond= Conductivity; Temp= Temperature.*

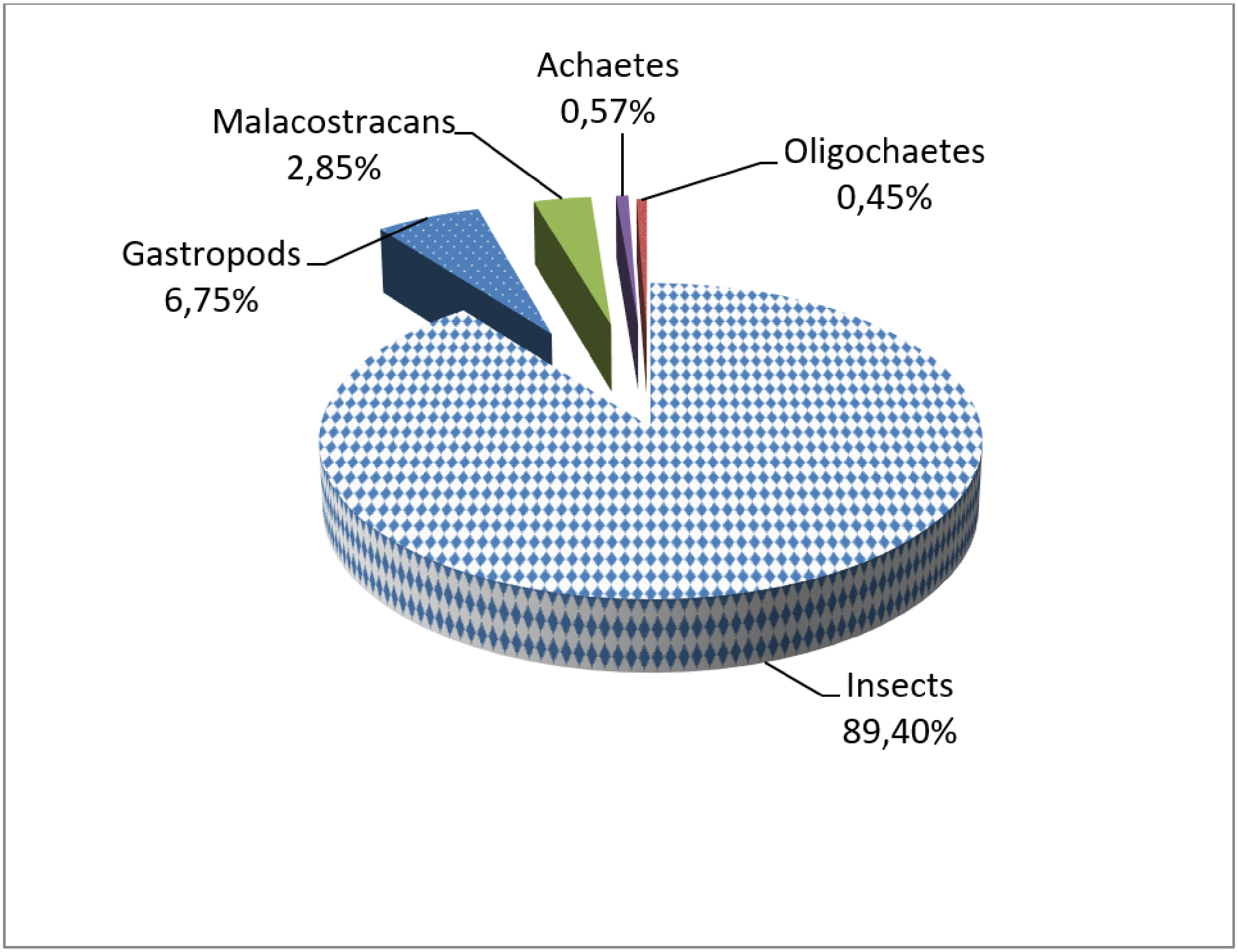

Figure 4

Relative abundance of different benthic macroinvertebrate classes recorded during the study period in Man baptem.

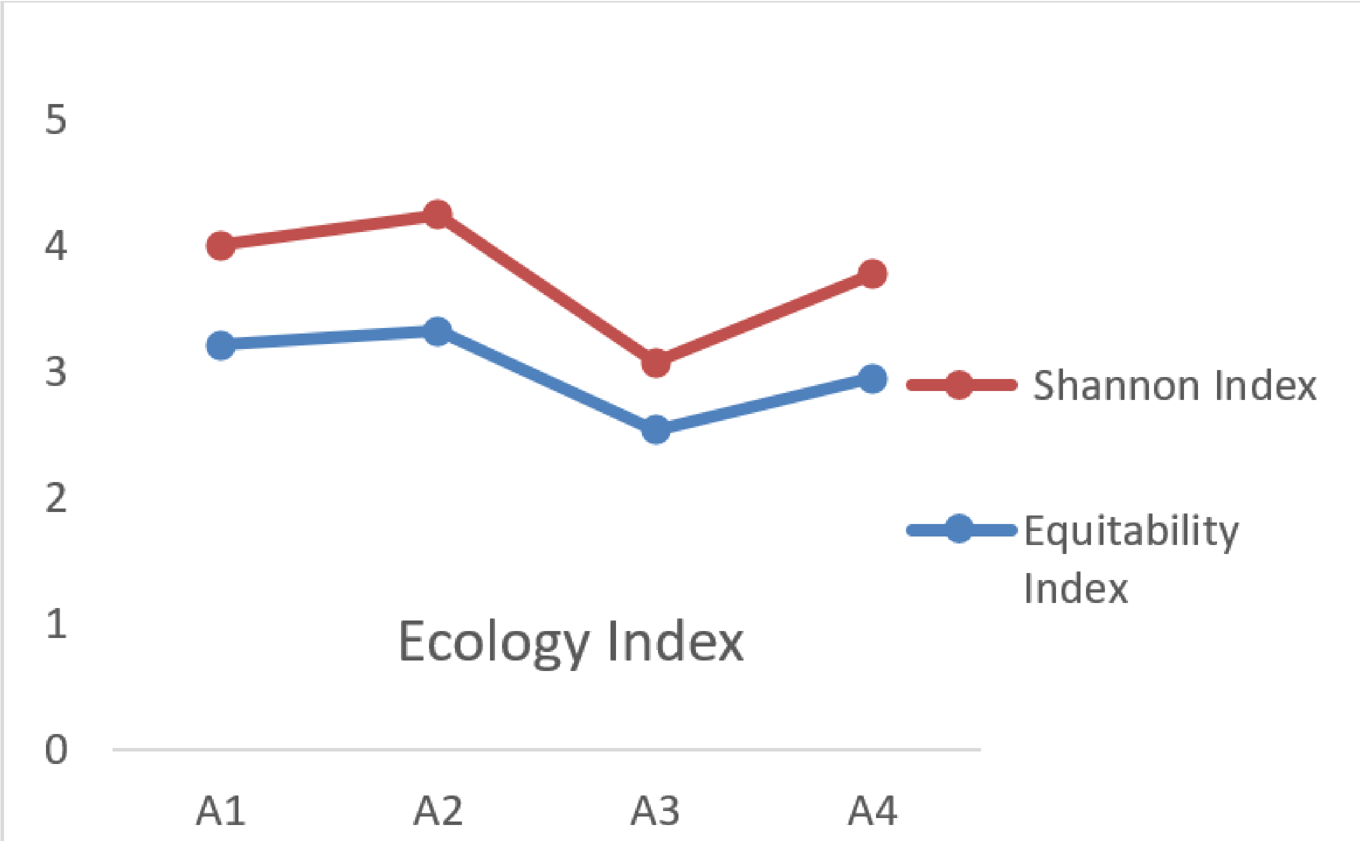

Figure 5

Macroinvertebrate ecological index for the four stations in the Man baptem stream.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- August092.zip