EJTAS
ISSN 2786-7447
EUROPEAN JOURNAL OF THEORETICAL AND APPLIED SCIENCES
OPEN ACCESS
PEER REVIEWED

Ecological Influence of Organic Pollution on the Distribution of Benthic Macroinvertebrates in Some Control Forest Watercourses in Cameroon

Eric Belmond Biram à Ngon
Research centre for water and climate change, Institute of Geological and Mining Research, Cameroon

Josephine Ndjama
Research centre for water and climate change, Institute of Geological and Mining Research, Cameroon

Sylvie Chinche Belenfe
Department of Fisheries and Aquatic Resources Management, University of Buea, Cameroon

Jean Dzavi
Research Center for water and Climate Change, Institute of geological and mining Research, Cameroon

Mathias Nwaha
Laboratory of Hydrobiology and Environment, University of Yaounde I, Cameroon

Donald L'or Nyame Mbia
Laboratory of Hydrobiology and Environment, University of Yaounde I, Cameroon

Carine Melle Epoundi
Laboratory of Hydrobiology and Environment, University of Yaounde I, Cameroon

Wilfried Christiane Betsi
Laboratory of Hydrobiology and Environment, University of Yaounde I, Cameroon

Samuel Foto Menbohan
Laboratory of Hydrobiology and Environment, University of Yaounde I, Cameroon

Suggested Citation

Biram à Ngon, E.B., Ndjama, J., Chinche Belenfe, S., Dzavi, J., Nwaha, M., Nyame Mbia, D.L., Melle Epoundi, C., Betsi, W.C. & Foto Menbohan, S. (2024). Ecological Influence of Organic Pollution on the Distribution of Benthic Macroinvertebrates in Some Control Forest Watercourses in Cameroon. *European Journal of Theoretical and Applied Sciences, 2*(2), 597-604.
DOI: 10.59324/ejtas.2024.2(2).52

Abstract:

Monitoring of water quality and distribution of some benthic macroinvertebrates was carried out in a few control watercourses in the Mefou watershed, from August 2022 to June 2023 with the aim of identifying some ecological factors that influence the distribution of benthic organisms in forest areas. The evaluation of granulometric and physicochemical quality was carried out following the appropriate methods and the collection of benthic organisms following the multihabitat approach. The analysis of the particle size parameters shows that the coarse fraction dominates all the points explored, although the beginning of siltation was observed in the middle part of the Abouda and Fam rivers. Physico-chemical analyses revealed a relatively stable environment with well-oxygenated water, low values of organic pollution indicator parameters and low and constant temperatures throughout the watersheds. The analysis of the biological structure shows a total of 8483 individuals collected, all belonging to the arthropod phylum and the insect class. From the orders obtained, Hemiptera dominate

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the benthic fauna with 6 identified families. The organisational structure of the benthic community was analysed through the calculation of diversity and fairness indices and allows us to affirm that the benthic macroinvertebrate community is diverse and well organised.

Keywords: *Water quality, ecological indice, benthic macroinvertebrates, biological diversity.*

Introduction

Ecosystems with multiple functions, and forest aquatic environments constitute excellent preservatives that host nearly 80% of terrestrial biodiversity and provide information on various events that occur over time. The flora and fauna present are very rich, and include a large number of endemic, rare or very remarkable species, the vegetation is very diverse, the phytocenoses are luxuriant and offer the greatest forest potential (Biram à Ngon, 2019; Hajji et al., 2013). Therefore, for a good understanding of the functioning and maintenance of the ecological balance of this environment, it is necessary to carry out regular inventories in order to analyse the evolution of different biological groups which populate these environments. Attention to the study of biodiversity has spurred interest in monitoring macroinvertebrate diversity since these groups dominate terrestrial and freshwater ecosystems and are used as indicators of the health of these ecosystems (Dzavi et al., 2021; Foto Menbohan et al., 2023; Nyame Mbia et al., 2023, Nwaha et al., 2023).

As part of this work, we were interested in the study of insect orders that exhibit great sensitivity to any change in environmental conditions and therefore the great diversity of habitats are highly recommended for large-scale biogeography studies. To contribute to a better knowledge of these groups of organisms, we deemed it useful to take interest in the ecological influences that would modify the living conditions of these organisms. This concern implies that adequate measures be taken to permanently monitor the quality of aquatic environments and more precisely those of forest environments which constitute a real niche of biological information for the evaluation of the health of waterways. To do this, we based ourselves on information previously collected in the study area and we supplemented this work with field missions. This study constitutes an informative database that can serve as a basis of comparison for subsequent studies and increases knowledge of the biological diversity that populates Cameroonian forest watercourses.

Material and Methods

The work was carried out in the ecological region of Central-South Forest of Cameroon and is located between 3°30'- 3°58' North latitude and 11°20'- 11°40' East longitude. For this work, four sub-basins belonging to the Mefou watershed (Abouda, Nga, Fam, and Nkoumou) were selected and 11 sampling stations chosen, based on accessibility, thickness of the column of water, presence of riffles, running flats and microhabitats. With an average altitude of around 750 m, its relief is generally rugged and the urban area extends over several hills 25 to 50 m high above the plateau. The climate is equatorial with bimodal rainfall characterized by moderate precipitation (1576 mm/year) oscillating between 1500 and 1700 mm per year, with temperatures that vary little over time. There are four seasons, unevenly distributed and of varying length from one year to the next. The vegetation is of the secondary dense forest type and the hydrographic network is important with water flowing towards the Nyong (Suchel, 1972).

Sampling

The principle is based on the sampling of benthic fauna at a station, according to a standardized sampling method which takes into account microhabitats, defined by the nature of the substrate and the speed of 'flow. This essentially, on qualitative sampling using a 30 cm square net with a conical net of 500 µm mesh size and 50 cm depth, following the multihabitat

approach proposed by (Stark et al., 2001). At each station, about 20 dip-net hauls were made over a length of about 50 cm, equivalent to an area of about 3m2, in different habitats characterised by the substrate/velocity pair. The choice of study stations was based on the desire to have points distributed across the entire hydrographic network in order to optimize the diversity of the habitats chosen and the ecosystems prospected and to have a large variability in the thermal and hydrological characteristics likely to occur to act on the geographical distribution of species.

Data Analysis

The Kruskal Wallis and Man Whitney tests were used to compare the mean values of the different parameters between stations and from one month to another. These tests were carried out using SPSS software version 20.0. Analyses of the diversity and structure of benthic macroinvertebrates were carried out using the calculation of abundance (N), taxonomic richness index, Shannon and Weaver diversity index (H'), and the Piélou Equitability index (J). All this was done using PAST software. The Principal component analysis (PCA) was performed to search for affinities between biological and physico-chemical variables. The IPO made it possible to easily determine the extent of organic pollution.

Results and Discussion

Hydrological Parameters

The hydrological data obtained showed high values in the Nga watercourse. Thus, the width of the bed (6.95 m) and the depth of the water (82.25 cm) are essentially high in this watercourse. The flow speed recorded values reaching 0.64m/s in the Nga, with low values recorded in the Abouda and Nkoumou rivers with data of the order of 0.18m/s. Particle size variables such as the thickness of the loose substrate have higher values at the Ng3 station. However, the relative congestion is greater in Nk1, Nk2, Ng1 and Fa1 stations with rates of 6.31%; 4.51%; 4.51% and 4.49% respectively. The most lower rates are recorded at Ab1, Ab2 and Ab3 stations with respective values of 1.06%; 0.83% and 0.05%. Overall, Ab1, Ab2, Nk1, Nk3, Ng1 and Ng2 stations are essentially dominated by a coarse substrate (sand and rocks). In addition, Ng3 station presents the largest fine fraction of the sample.

Physico-Chemical Parameters

The collection of physico-chemical data shows relatively low values in all watersheds. Thus, the temperature values remained low throughout the study with an average of 22.41°C ± 0.74°C. The suspended solids contents showed average values of 12.89 mg/L ± 6.69 mg/L in the Abouda watercourse. In the Fam watercourse, the highest values (65 mg/L and 51 mg/L) were obtained. In the Nkoumou river, the suspended solids values ranged between 1 mg/L and 69 mg/L. Nga for its part recordeds values which are between 2 mg/L and 70 mg/L.

The turbidity profiles in the different watercourses are significantly similar. In the Abouda river, the values are around an average of 24.77 ± 15.18 NTU, in the Fam river the average turbidity value is 57.68 ± 5.54 NTU. In the Nkoumou river, turbidity values vary between 3 NTU and 169 NTU with an average of (36.77± 28.79 NTU). In the Nga river, these values vary between 4 NTU and 252 NTU.

The dissolved CO2 contents in the Abouda watercourse showed values between 1.76 mg/L and 15.84 mg/, with an average of 7.264 ± 0.995 mg/L. In the Fam, the levels vary from 1.76 mg/L to 14.08 mg/L, the average being 7.313 ± 0.977 mg/L. In Nkoumou, the levels range between 1.76 mg/L and 12.32 mg/L, with an average of 7.805 ± 0.901 mg/L. In Nga, the values vary between 1.76 mg/L and 14.08 mg/L with an average of 8.115 ± 1.044 mg/L. The variation profile of dissolved oxygen saturation rate presented the same configuration, with peaks obtained in the Abouda river (98%) and (96%) in the Nkoumou. No significant difference was observed.

The values of Oxidizability fluctuated between 0.79 mg/L and 11.6 mg/L in the Abouda river. The observed values do not present significant differences, with an average of 5.97± 1.11 mg/L.

In Nkoumou, the values fluctuate between 1.12 mg/L and 29 mg/L. In the Fam watercourse, the oxidizability contents of the water are high with an average of 19 ± 5.48 mg/L. In the Nga, these values are low and are organized around an average of 7.03 ± 5.48 mg/L. In the Abouda river, nitrate levels vary between 0.016 mg/L and 3.1 mg/L, for an average of 1.119 ± 0.266 mg/L. In the Fam, the data fluctuate between 0.004 mg/L and 2.4 mg/L with an avarage of 0.939 ± 0.244 mg/L. In the Nkoumou river, the levels are between 0.001 mg/L and 3.1 mg/L and an average of 1.072 ± 0.258 mg/L. In Nga, the values ranged from 0.001 mg/ to 3.2 mg/L with an average of 1.06 ± 0.249 mg/L. In the Abouda watercourse, the variation profile of orthophosphate contents oscillates between 0.01 and 1.1 mg/L with an average of 0.366 ± 0.078 mg/L. In the Fam, these values vary from 0.03 mg/L to 0.96 mg/L, with an average of 0.317 ± 0.076 mg/L. In the Nkoumou river, the values vary between 0.01 mg/L and 0.9 mg/L with an average of 0.253 ± 0.065 mg/L. Levels in the Nga river fluctuate between 0.01 mg/L and 0.91 mg/L with an average of 0.238 ± 0.062 mg/L (Fig 1).

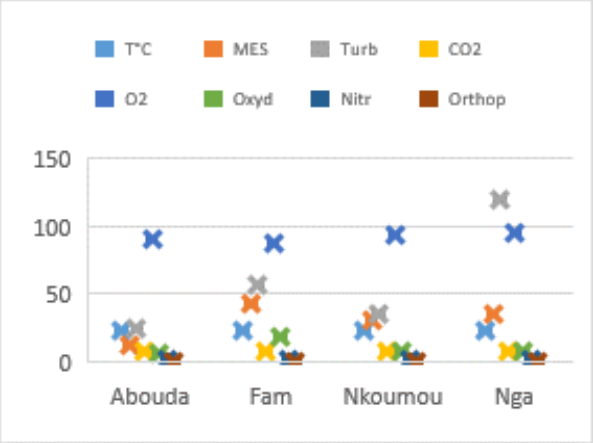

Figure 1. Variation Profile of Physico-Chemical Parameters in the Watercourses Studied

Inventory of Taxa

In the 11 sampled stations, 8483 individuals were collected. These individuals belong to the phylum Arthropoda, the class Insecta and the orders Hemiptera, Ephemeroptera, Plecoptera, Trichoptera and Dictyoptera. Among the orders listed, the Hemiptera are the most represented with 6 families including Veliidae, Naucoridae, Nepidae, Hydrometridae, Gerridae and Pleidae and 10 genera (*Rhagovelia* sp., *Paraphrynovelia* sp., *Naucoris* sp., *Ranatra* sp. , *Hydrometra* sp., *Naboaudelus* sp., *Eurymetra* sp., *Limnogonus* sp., *Gerris* sp. and *Plea* sp.) were recorded with a total of 3202 individuals. It is followed by the order Ephemeroptera with 4 families including Ephemeridae, Ephemerellidae, Pothamanthidae and Caenidae and 4 genera including *Ephemera* sp., *Ephemerella* sp., *Pothmanthus* sp. and *Caenis* sp. for a total number of 2576 individuals. Regarding the order Trichoptera, it is represented by three families, namely, Hydropsychidae, Philopotamidae and Brachycentridae, with three identified genera including the genera *Hydropsyche* sp., *Philopotamantes* sp. and *Brachycentrus* sp., with a total of 1651 individuals. The Plecoptera order is represented by a single family (Perlidae) and a single genus (*Perla* sp.), with a total of 295 individuals, the other 749 individuals are made up of Dictyopterans.

Analysis of Ecological Factors that Influence the Distribution of Benthic Organisms

Discriminant Factor Analysis (DFA) applied to all the sub-watersheds made it possible to group the watercourses on the basis of ecological variables into three affinity nuclei. Group 1 (Grp1) isolates the Abouda and Nkoumou watercourses, which are distinguished from the others by high dissolved oxygen contents, low pH values and a predominantly coarse bottom substrate. Group 2 (Grp 2) characterizes the Fam watercourse which is distinguished by relatively high values of turbidity and oxidizability, electrical conductivity and nitrates. Group 3 (Grp 3) discriminates between the Nga watercourse and parameters such as dissolved phosphate and CO2 (Figure 2). The organization of benthic organisms made it possible to note the grouping of dictyoptera and polluossensitive benthic macroinvertebrates like *Ephemera* sp., *plea* sp. and *Rhagovelia* sp. around groups 1 and 2.

As for group 3, *Naucoris* sp. and *Eurymetra* sp. showed affinities for this group.

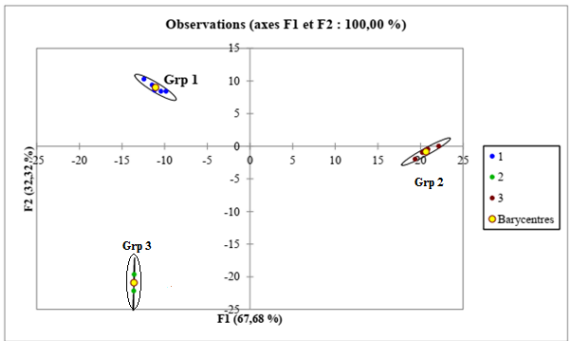

Figure 2. Organisation of Benthic Macroinvertebrates

The study of correlations using Principal Component Analysis (PCA) makes it possible to distinguish the hydromorphological, physico-chemical and particle size parameters which influence the distribution of organisms in watercourses (Figure. 3). Most of the total variance is provided on the first two factorial axes F1 (34.41%) and F2 (21.71%), which combine 56.12% of the total inertia. In the correlation circle, the taxa collected (Hydropsychidae, Ephemerellidae, Blaberidae, Perlidae and Caenidae) are positively correlated with each other and positively correlated with the dissolved oxygen saturation rate. Thus, of all the ecological parameters considered, the dissolved oxygen content of water appears to be the main factor which influences the distribution of organisms in the different watercourses considered. Similarly, Naucoridae are significantly and positively correlated with high flow velocity, high temperatures, and high oxidizability values.

The shallow depth, the width of the bed and the low MES values are positively and significantly correlated to the F2 axis. On the other hand, the taxa Rhagoveliidae and Veliidae are significantly and negatively correlated to CO2, although all these variables are negatively correlated with the F2 axis. Furthermore, the overall organisation of the taxa shows that the family Blaberidae require more dissolved oxygen content of water than Perlidae, Ephemeridae, Gerridae and Ephemerellidae.

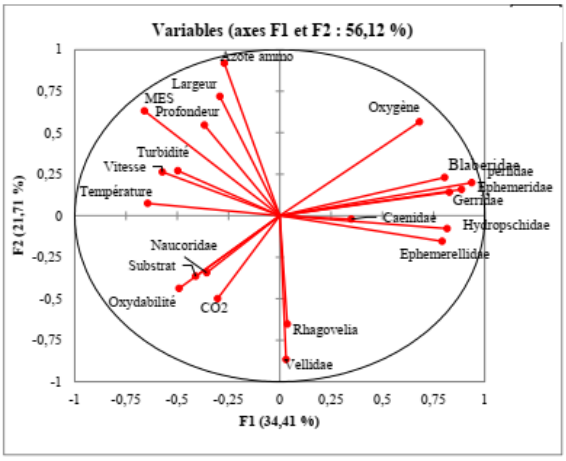

Figure 3. Coralation Between Organism and Ecological Parameters

The results of the calculation of the organic pollution index (IPO) obtained from the concentrations of organic pollution indicator elements are presented in (Figure 4). This index presents values which oscillate between 3.75 (moderate pollution) and 4.75 (zero pollution). Overall, it appears that the watercourses surveyed are subject to low organic pollution. The representation of the evolution of organic pollution within the different stations constituting the watercourses surveyed shows that all the values are included in the moderate to zero quality zone.

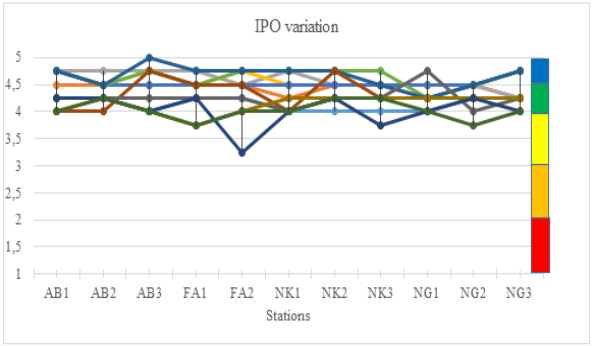

Figure 4. Variation of the IPO in the Prospected Watercourses

Analysis of Correlations and Diversity Indices

A positive and significant correlations were obtained between SS and oxidizability ($r = 0.27$; $p < 0.05$), dissolved oxygen saturation rate of water and Blaberidae, Pleidae, Ephemeridae and Ephemerellidae ($r = 0.47$; 0.59; 0.54; 0.53; $P < 0.05$).

The values of the Shannon and Weaver diversity indices and the Piélou fairness present a sawtooth evolution within the stations. In the Abouda river, the Shannon and Weaver indices and Piélou equitability increase from upstream to downstream, and shows that station Ab3 is the most diverse. In the Fam and Nkoumou, these indices decrease from upstream towards with a high value at station Ng2. (Figure 5). Across all sub-watersheds, these indices take relatively high values in the Abouda river, followed by the Nga and Nkoumou rivers. The same is true of the Simpson similarity index.

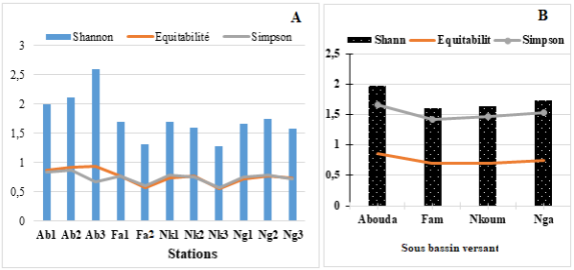

Figure 5. Variation Shannon and Weaver Diversity Indices

Discussion

The hydrological data record shows variations in the composition and sedimentary structuring of a station and a watercourse, this testifying to the structural heterogeneity of the beds of the different watercourses. In watercourses with a coarse substrate, faunal diversity appeared greater, compared to that of watercourses with a muddy substrate. Indeed, in the stations of watercourses with a predominantly coarse substrate, biological diversity was found to be greater than that of the stations of watercourses with a predominantly muddy substrate. These observations corroborate the work of Liwouwou et al., 2018 in the Rembo Bongo, Ogooué and Nyanga watercourses, which conclude that in the watercourses at the head of the watershed, the assembly of coarse substrate is favorable to the aquatic life and maintaining greater biological diversity, reflecting the good ecological quality of the environment (Biram à Ngon et al., 2018). As a living and feeding environment, the coarse substrate of watercourses constitutes, with plant supports and woody debris, a favorable place of life for many species making up aquatic biocenoses, which promotes storage or the circulation of water, dissolved substances, organic matter and living organisms. This observation corroborates the statements of Tachet et al. (2006) which reveal that in waterways, the vast majority of invertebrate species have larval stages which are buried in the first centimeters of the substrate (burrowing larvae). Other species will occupy the interstices between the sediments, still others will adapt their morphology in order to occupy the internal face of the shelter made up of coarse elements of the substrate. The work of Foto Menbohan et al. (2017) and Mboye et al. (2018) on the Mabounié show that there is indeed a strong relationship between the size of the sediments and the benthic biological communities. The great diversity obtained in stations Ab3, Nk3 and Fa1 could be attributed to the diversification of microhabitats offered by the type of substrate obtained at these stations. The result is in agreement with the work of Evrard and Micha. (1995) which showed that stations with great physical heterogeneity of substrate, and having an average particle diameter of between 40 and 50 mm, are characterized by a wealth and faunal diversity similar to those resulting from optimal colonization of the substrate by macroinvertebrates. The abiotic characterisation of watercourses revealed that the physico-chemical quality varies significantly and shows some signs of deterioration in water quality, although all of the parameters analyzed were within the range of good ecological quality. Thus, the relatively low temperature values (20.2 - 23.9°C) recorded in these watercourses would be due to the presence of a large plant cover which dominates all of the stations, making

penetration of light rays to the surface of watercourse difficult, responsible for warming the water. These data are much lower than those of Tchakonté et al. (2014) but are similar to those of Dias et al. (2008), Ndjama et al. (2017) and Biram à Ngon. (2019). Oxygen saturation presents satisfactory values with averages above 75.3%. The good saturation of the water could be attributed to the low warming of the water, coupled with the high photosynthetic activity, natural ventilation and the presence of riffles and meanders which create conditions of turbulence and recirculation of water, leading to reoxygenation at the water/air interface (Fernandes et al., 2014). In addition, the stability and low anthropization of these forest environments contribute to maintaining good oxygenation of the waters (Nwaha et al., 2023; Betsi et al., 2023). The organizational structure of the macroinvertebrate community was analyzed through the calculation of diversity indices (Shannon and Weaver), the equitability of Piélou and the Sörensen similarity coefficient. High values of the Shannon and Weaver diversity index and the equitability of Piélou in the prospected watercourses, allow us to affirm that the benthic macroinvertebrate community is diverse and well organized. Indeed, it is established that watercourses located in forest areas are under the influence of the canopy and present a high biological diversity. The work of Foto Menbohan et al. (2021; 2023) carried out in certain watercourses in the Eastern region of Cameroon also showed that the diversity indices were higher in forest sites with a strong canopy.

Conclusion

Monitoring the ecological quality of a few sample forest watercourses in the Central region made it possible to highlight some ecological variables which influence the distribution of benthic organisms. The analysis of abiotic variables reveals a coarse particle size proportion which dominates all of the courtyard beds and elements which promote optimal colonization. As for physico-chemical analyses, the waters showed good oxygenation and low organic pollution indicator values. The macrobenthic fauna is rich and diverse with a remarkable presence of bioindicator groups.

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