World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Comparative approach of the fauna diversity of benthic macroinvertebrates in a stream on ferralitic soil and equatorial climate at 2 seasons in Cameroon (Central Africa)

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World Journal of Advanced Research and Reviews, 2023, 19(01), 254–264

Publication history: Received on 10 April 2023; revised on 01 July 2023; accepted on 04 July 2023

Article DOI: https://doi.org/10.30574/wjarr.2023.19.1.0934

Abstract

In order to determine the structure of benthic macroinvertebrates fauna in relation with some environmental factors, a study was carried out in the Esoa river at Nkongsamba in the Littoral region of Cameroon from January 2021 to January 2022. Physico-chemical parameters were measured according to APHA and Rodier recommendations, while benthic macroinvertebrates sampling was done out according to the multihabitat approach at a monthly frequency. The physico-chemical analyses revealed very good oxygenation of the water, a tendency of neutrality for the pH (7.79±0.8 UC) and a low and constant temperature (22.61±1.83 °C). The BMI count showed 3732 individuals, including 4 phyla, 6 classes, 14 orders and 69 families and over 80 species. Besides, the class of insects, and in particular the order of Odonata, supplanted the benthic fauna. The Esoa 2 and Esoa 3 stations recorded the highest relative abundance of BMI (37.43% and 36.99% respectively) with a predominance of pollutant taxa, notably the families of Chironomidae, Physidae, Tubificidae and Lumbricidae. On the other hand, the Esoa 1 station, with low relative abundance (25.56%), was more diversified and dominated by polluosensitive taxa, including Ephemeroptera, Plecoptera and Trichoptera. The high values of the Sörensen similarity index (65.62%) showed a high faunal similarity of the Esoa 2 and Esoa 3 stations. The high values of the Shannon and Weaver diversity index (4.6 bits/ind) indicated a high diversity of benthic macroinvertebrates reflecting the good ecological status of the waters of the Esoa stream.

Keywords: Benthic macroinvertebrates; Diversity; Water quality; Esoa river

1. Introduction

Aquatic ecosystems provide drinking, industrial and energy water. Besides their use as a resource, these environments are also essential habitats for biodiversity. Although freshwater accounts for only 0.01% of the world's water, it is essential for the survival of all life on earth and represents to nearly 6% of all counted species [1]. However, the world faces considerable challenges in managing available freshwater equitably, due to high population growth, coupled with galloping urbanization and climate change [2]. Industrialization, paired to the non-rational use of fertilizers and pesticides, as well as the lack of public awareness of the need to preserve environmental integrity, leads to an imbalance in aquatic ecosystems and generates pollutants that can affect these environments [3].

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Freshwaters are in most parts of the world the terminal receptacle of residues in the biosphere [3]. It is therefore essential to ensure adequate quality, availability and access to these resources in order to sustain livelihoods, human well-being, socio-economic development and healthy ecosystems. This requires assessment and monitoring of the physico-chemical and biological quality of water and the relevant legislation. In view of the limitations of physico-chemical analyses, which only give an idea of the contamination at the time of its introduction, analytical methods based on biological assessment which give a general overview of habitat conditions and environmental pressures, are increasingly used.

Different groups of aquatic organisms are used for such assessments, including phytoplankton, zooplankton, macrophytes, phytobenthos and benthic macroinvertebrates. Among them, benthic macroinvertebrates are the most stressed group due to their sedentary nature, varied life cycle, high diversity, variable tolerance to pollution and habitat degradation [4]. Benthic macroinvertebrates (BMIs) are visible to the naked eye, do not have a bony skeleton, such as insects, molluscs, crustaceans and worms, whose temperature varies greatly with the environment, and can live in a variety of habitats throughout their entire life cycle or only a part of their development phase [4]. They incorporate the cumulative and synergistic short-term effects (up to a few years) of multiple physical (habitat modification), biological and chemical disturbances of the hydrosystems.

In recent years, many studies focused on BMIs in Cameroon, in order to assess the health status of streams in urban and peri-urban areas. The impact of anthropogenic activities on the diversity and structure of BMIs has been indicated [5]. Some authors illustrated the ecological factor and Dictyoptera (Blaberidae) association BMIs, in some forest streams of the centre region through ecological and trophic particularities [6]. The impact of anthropogenic activities on water quality and freshwater shrimps diversity and distribution in five rivers in Douala town through anthropisation and absence of sanitation systems has also been noted [7]. The spatiotemporal variation of benthic macroinvertebrates in some tropical forest stream of Nyong catchment through environmental particularities and bioindicators had been pointed by Dzavi et al [8]. Melle et al [9] also indicated the water quality of a lowland and urban stream by analyzing the structure of the BMIs population from specific features. The influence of granulometry on the distribution of benthic macronvertebrates in some streams of the Mvilla and Haut Nyong watersheds from sediments had been shown by Nyame et al [10].

It has often been stated that local (or regional) soil and climatic conditions could significantly impact the survival, diversity, metabolism and reproduction of BMIs in the aquatic systems. Few studies were done on BMIs distribution and diversity in an equatorial climate with two seasons. A better knowledge of the structure of the communities, their similarity and their equipartition in relation with the physico-chemical parameters of the water would give an idea of the fauna diversity of BMIs. The aim of this study was to compare at the equatorial zone of 2 climate seasons, the faunal diversity of BMIs in a stream in ferallitic soil under a two season climate. More specifically, it focus (1) to measure the water physico-chemical parameters of the water; (2) to identify and count the different taxa of BMIs (3) and then to assess the water quality using biocenotic index.

2. Material and methods

2.1. Study environment

Nkongsamba is a fast-growing town in the Littoral region of Cameroon, lying between 4°57' North latitude and 9°56' East longitude. It is the capital of the Moungo division, Nkongsamba district and is located at 145 kilometres from the city of Douala. It was set up as the urban community of Nkongsamba and comprises three communes, including the Nkongsamba 3 township, where our catchment area were located. The population is mostly cosmopolitan estimated at 400,000 inhabitants [11].The Esoa watershed is bounded to the North by the village of Ndogmoa-Eko, to the East by the village of Essel, to the South by the village of Ekel-koo and to the West by the Manjo district. The climate is of the equatorial Guinean type, and Cameroonian sub-type [12]. This climate is characterised by two seasons: a long rainy season from March to October and a short dry season from November to February. Rainfall is abundant and regular, with an estimated annual rainfall of 491 mm. The air temperature is variable with a maximum value of 28°C and a minimum value of 17°C [13]. The terrain is rugged, consisting of hills, plateaus, lowlands and valleys with small streams flowing through them. There are two types of soils: hydromorphic soils, predominantly yellow to ochre-yellow in color, and ferralitic soils, dark in color [14]. There is a sandy texture on the surface, then sandy-clay and sometimes clayey-sandy at depth, and the pH is acidic [14]. The vegetation consists of secondary and tertiary forests, as well as herbaceous and shrubby savannahs.

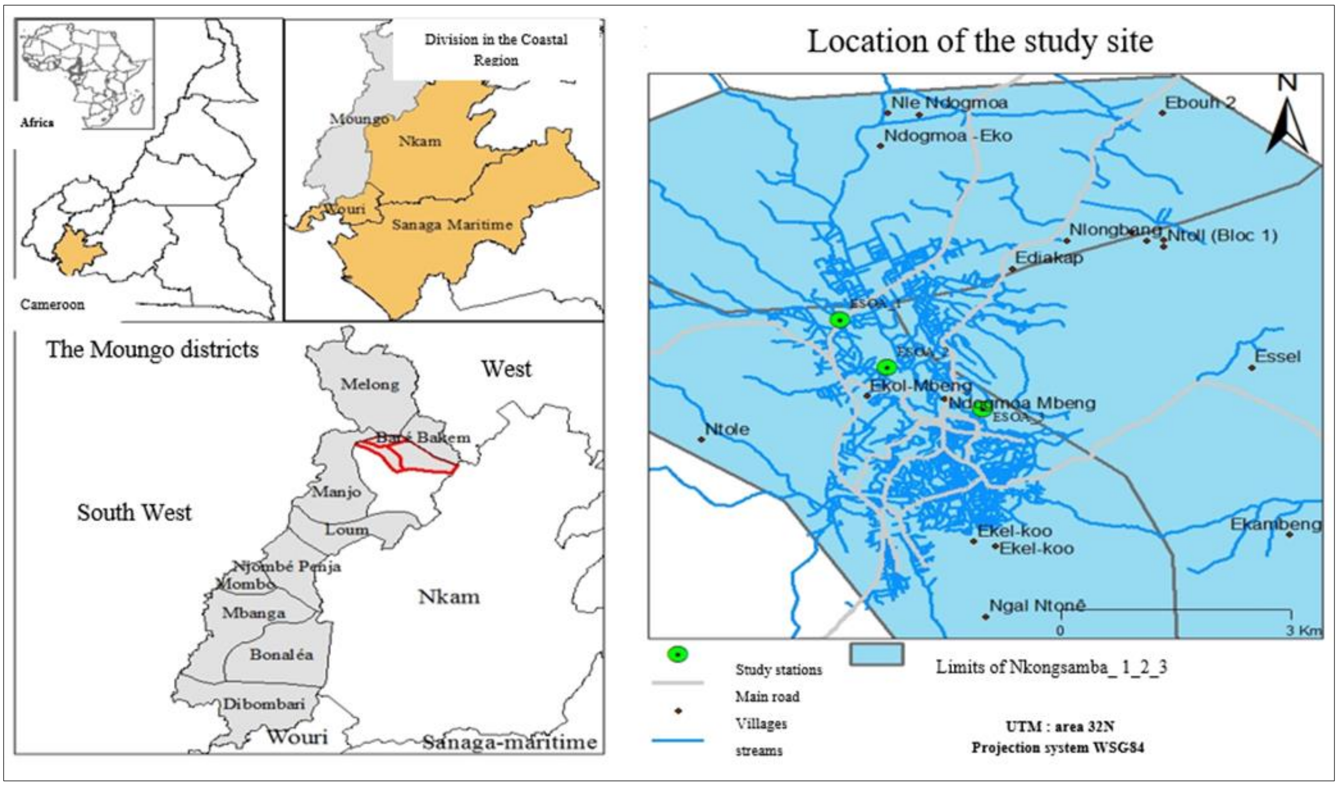

Figure 1 Hydrographic map of the Esoa catchment area with sampling stations (made with QGIS software**)**

2.2. Sampling of environmental variables

Geographical coordinates and altitude were taken in the field using a Garmin 60 S GPS. For hydrological parameters, the width of the water column was measured using a graduated string stretched horizontally from the end of one bank to the other. The depth was measured with a graduated stake. The flow velocity of the water was determined by measuring the distance that the polystyrene block travelled over a given time. Physico-chemical analyses were performed both in the field and the laboratory following standard protocols [15-16]. Temperature, pH, electrical conductivity and total dissolved solids were measured in situ using a HANNA HI 98130 multimeter, dissolved oxygen measured using a HANNA HI 9147 oxymeter. For laboratory analysis, water samples were taken at each station using sterilized 250 ml and 1000 ml polyethylene bottles and transported to the laboratory in a refrigerated chamber. Carbon dioxide, alkalinity and oxydability were measured volumetrically. Turbidity, color, suspended solids, orthophosphates and nitrogen forms were measured using the Hydro Test HR 1000 spectrophotometer.

2.3. Sampling of benthic macroinvertebrates

Benthic macroinvertebrates were collected using a 30 cm square net with a conical net of 500 µm mesh size and 50 cm depth, following the multihabitat approach [17]. At each station, about 20 dip-net hauls were made over a length of about 50 cm, equivalent to an area of about 3 m^2, in different habitats characterized by the substrate/velocity pair. The organisms retained in the net were collected with a pair of fine tweezers and fixed with 10% formalin. The collected specimens were rinsed with tap water to remove the formalin, then preserved in 70° ethanol. The organisms were then placed in petri dishes and grouped according to their size and morphology, then identified at least to the rank of the family, under a Bresser Science ETD-101 binocular loupe, using the identification keys [18-19-20].

2.4. 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 physicochemical variables.

3. Results

3.1. Physico-chemical parameters

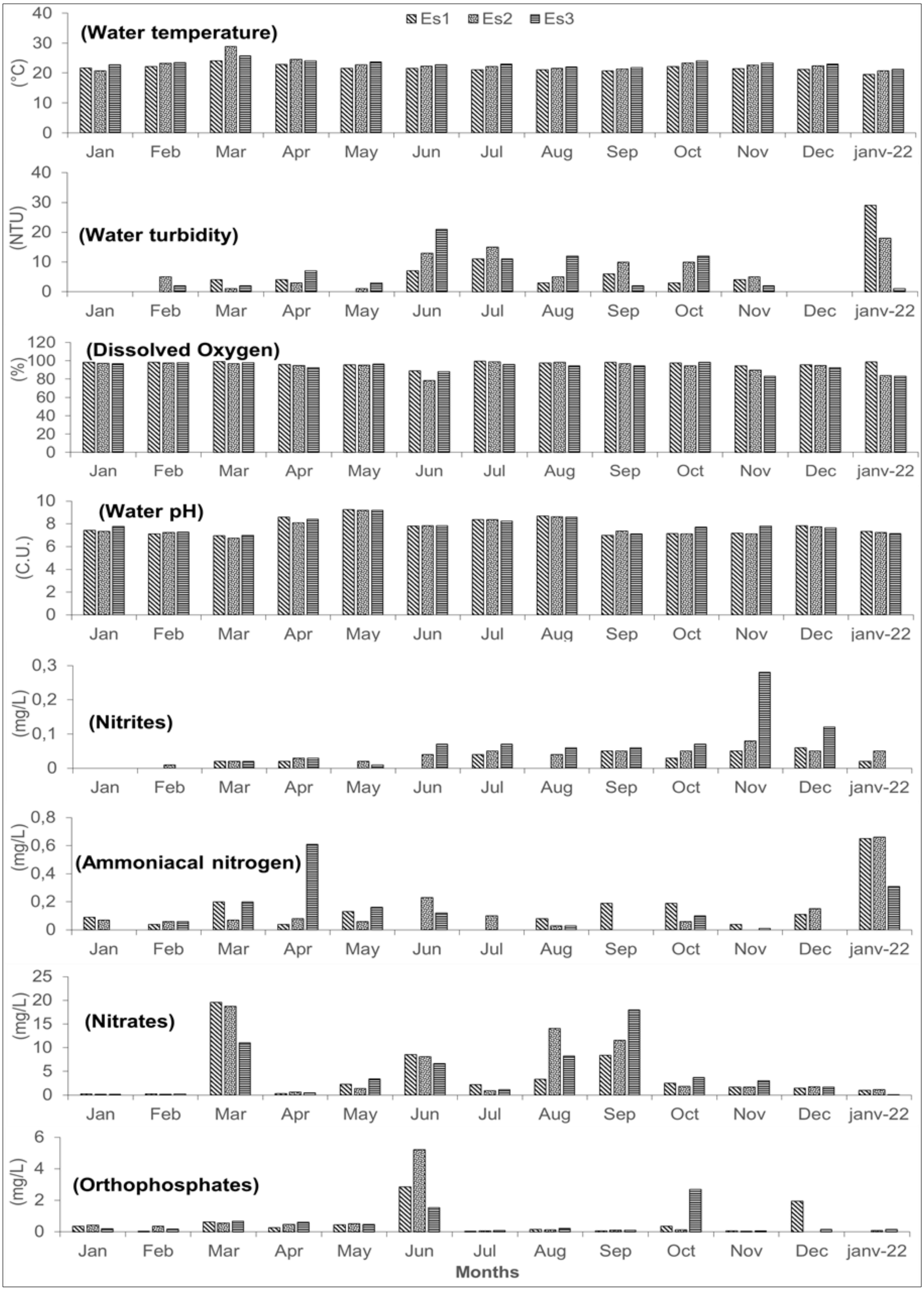

Figure 2 Spatio-temporal variation of physico-chemical parameters in the Esoa stream during the study period.

From one station to another, the temperature varied from 19.5° C to 28.8° C, the extreme values being recorded at the Esoa 1 and Esoa 2 stations in January 2022 and March 2021 respectively (Figure 2). Turbidity values ranged from 0 NTU to 29 NTU, with the maximum value being obtained at the Esoa 1 station in January (2022) (Figure 2). These parameters showed a temporally significant difference ($p \leq 0.05$) between the months of January and March.

The dissolved oxygen values varied from 78.37% (Esoa 2-June) to 99.39% (Esoa 1-July) (Figure 2C). On the other hand, pH fluctuated between 6.73 C.U (March-Esoa 2) and 9.25 C.U (May-Esoa 1) (Figure 2). The Kruskal Wallis test shows no significant difference spatially, but temporally significant differences ($p \leq 0.05$) were observed between March and May.

The ammoniacal nitrogen levels showed an average of 0.15±0.14 mg/l (Figure 2). Nitrites levels varied from 0 to 0.28 mg/l, with the highest value obtained at the Esoa 3 station in November (Figure 2). Nitrates values fluctuate from 0.06 to 19.6 mg/l, with the highest value obtained at the Esoa 1 station in March (Figure 2). Orthophosphates levels fluctuated between 0 mg/l and 5.2mg/l, with the highest value obtained in June at the Esoa 2 station (Figure 2). Furthermore, these parameters showed significant differences temporally, especially nitrites, nitrates and orthophosphates ($p \leq 0.05$) between the months of January and March.

3.1.1. Organic Pollution Index (OPI) (Leclerc, 2001)

The OPI values varied from 2.88 (Esoa 3 and Esoa 2-June) to 4.7 (Esoa 1-February) with an average of 3.5 (Figure 3). Thus, in the whole Esoa river, the OPI indicates a moderate level of organic pollution.

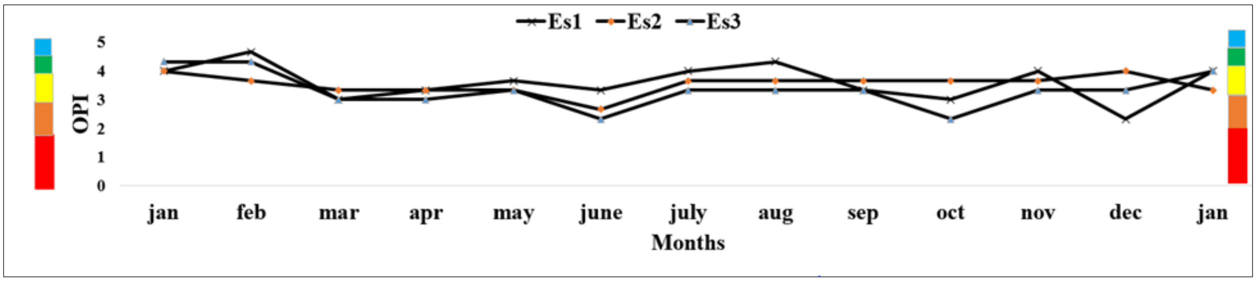

Figure 3 Spatio-temporal variation of OPI in the Esoa stream during the study period

3.2. Biological parameters

3.2.1. Taxonomic richness and abundance of benthic macroinvertebrates

During this study, a total of 3732 individuals belonging to 4 phyla (Molluscs, Arthropods, Annelids and Plathelminthes), 7 classes (Gastropods, Crustacea, Insects, Turbellariidae, Achaetes and Oligochaetes), 14 orders and 69 families were collected. The class of Insects was the most diverse with 8 orders, 59 families and almost 92 genera, followed by Oligochaeta with 2 orders and 4 families, Gastropoda with 1 order and 3 families, and Turbellaria, Crustacea and Achaeta with 1 order and 1 family each. Among the 14 orders recorded, 10 were very frequent, notably Coleoptera with 11 families, followed by Trichoptera and Diptera with 10 families, Odonata, Heteroptera and Ephemeroptera with 9 and 8 families respectively, then Bassomatophora and Haplotaxida with 3 and 2 families respectively then Decapoda and Tricladida with 1 family each.

Spatially, the Esoa 1 station was the most diverse with 50 families and 917 individuals, for a relative abundance of 24.57%, followed by the Esoa 2 station with 46 families and 1466 individuals, for a relative abundance of 39.28% and the Esoa 3 station with 33 families and 1349 individuals, for a relative abundance of 36.14%.

The family of Gerridae predominated at the station Esoa 1, followed by the families of Gyrinidae and Belostomidae with relative abundances of 15.54%, 9.59% and 9.26% respectively. At the Esoa 2 station, the family of Coenagrionidae (*Coenagrion pro parte*) supplanted with 26.94% of relative abundance. Finally, at the station Esoa 3, the family of Physidae (Physa) dominated with 27.94% of relative abundance.

3.2.2. Coefficient of similarity and diversity index

The similarity coefficient of Sörensen varied from 62.5% (Esoa 1 and Esoa 3) to 65.62% (Esoa 2 and Esoa 3), showing a very high similarity of macrofauna at stations Esoa 2 and Esoa 3 (Table 1).

Table 1 Evolution of the similarity coefficient between the stations during the study period

Stations	Esoa 1 & Esoa 2	Esoa 2 & Esoa 3	Esoa 1 & Esoa 3
Similarity coefficient of Sörensen	62.5%	65.62%	60.24%

Spatial and temporal analysis of the benthic macrofauna data in the Esoa river revealed that, spatially, the Shannon and Weaver diversity index H' was higher upstream (4.36 bits/ind at Esoa 1) and decreased progressively downstream (3.22 bits/ind at Esoa 3 a similar variation was observed with the Piélou equitability index (J), which showed values regressing from upstream (0.71 bits/ind at Esoa 1) to downstream (0.52 bits/ind at Esoa 3) (Figure 4).

Temporally, June showed the lowest diversity (3.18 bits/ind) and February the highest (4.15 bits/ind). The values of the Piélou equitability index J ranged from 0.51 bits/ind in June to 0.67 bits/ind in February (Figure 4).

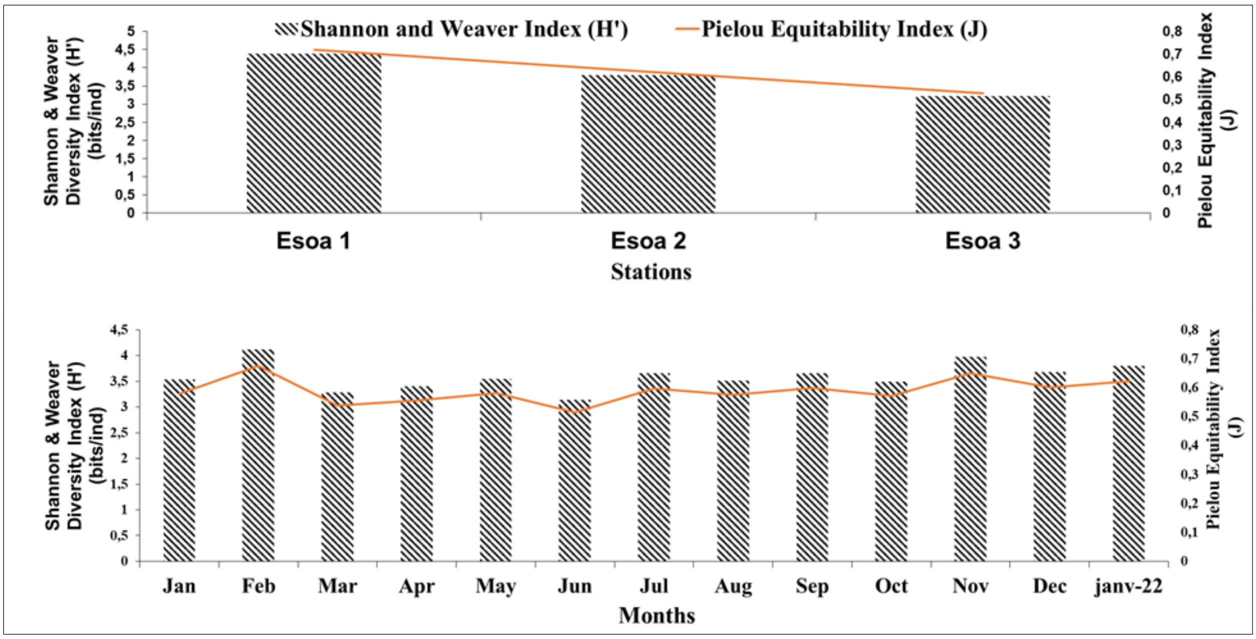

Figure 4 Spatio-temporal variation of Shannon & Weaver diversity (H') and Pielou equitability (J) index during the study period

3.2.3. Correlation coefficient

The analysis of the physico-chemical and biological parameters allowed us to note positive and negative correlations between the physico-chemical and biological factors on one hand and between the biological factors on the other. Thus, significant and positive correlations were observed between temperature and oxydability (r=0.556 ; p=0.01), oxydability and carbon dioxide (r=0.446 ; p=0.01), temperature and nitrites (r=0.619 ; p=0.01), turbidity and color (r=0.453;p=0.01), orthophosphates and carbon dioxyde (r=0.489; p=0.01), carbon dioxyde and Gomphidae (r=0.494; p=0.01), temperature and Physidae (r=0.494; p=0.01), oxydability and Coenagrionidae (r=0.459 ; p=0.03), dissolved oxygen and Perlidae (r=0.409; p=0.1), temperature and Chironomidae (r=0.528; p=0.01), temperature and Physidae (r= 0.494), carbon dioxide and Gyrinidae (r=0.517; p=0.01), Glossiphoniidae and Coenagrionidae (r = 0.441 ; p=0.01), Tubificidae and Coenagrionidae (r=0.573; p=0.01), Scirtidae and Lepidostoatidae (r=0.552 ; p=0.01), Leptoceridae and Pleidae (r=0.530; p=0.01), Aeshnidae and Veliidae (r=0.502; p=0.01), Tubificidae and Chironomidae (r=0.447; p=0.01).

Negative correlations were observed between carbon dioxide and Ephemerellidae (r=-0.460; p=0.03), dissolved oxygen and Dugesiidae (r=-0.467; p=0.03), orthophosphates and Hydropsychidae (r=-0.428; p=0.07), Nitrites and Belostomidae (r=-0.415; p=0.00), Physidae and Belostomidae (r=-0.419; p=0.05), Physidae and Calopterygidae (r=-0.454).

4. Discussion

4.1. Environmental variables

The low temperature fluctuations in the Esoa river were strongly linked to those of the air. Moreover, the low values recorded were due to the microclimate created by the canopy, which reduces the penetration of light rays responsible for the rise in the temperature of the environment. In this respect, Liechti et al [21] pointed out that the temperature of surface waters is closely influenced by the ambient temperature and the seasons. In addition, the localized destruction of the riparian forest at Esoa 2 due to human activities is thought to be responsible for the changes in the thermal regime in this area. Similar observations were reported in the Mefou catchment by Nyamsi [22].

The SEQ-Eau Grid (MEDD and Water Agency [23]have been showed turbidity values line in the very good to poor quality ranges, thus requiring simple treatment. This result is similar to those obtained on the Kondi stream, on the Tongo'a-Bassa stream and on the Ndog Bissolo stream by many authors [24-25-26]. However, the high value of this parameter (29 NTU) obtained in January would be due on the one hand to the input of dissolved organic matter by runoff water and on the other hand to the resuspension of the bottom substrate which would release substances such as humic acids and colloidal substances into the environment.

The high values of dissolved oxygen would be due to the strong photosynthetic activity of the watershed, the natural ventilation induced by the foliage, the presence of riffles and meanders that create conditions of turbulence and recirculation of the waters, favouring their re-oxygenation at the water/air interface [27]. But also the cascades along the Esoa stream that would also favour the mixing and oxygenation of the waters. In this regard, MDDEFP [4] points out that the sills of the watercourses are continuous and the presence of boulders or waterfalls creates a form of sinuosity that improves the structure of the watercourse and promotes its oxygenation. These results are close to those obtained in the peri-urban streams of Douala by Tchakonté [25].

The pH values (6.73C.U-9.25C.U) recorded reflect the slightly acidic to basic nature of the waters of the Esoa stream with an average of 7.83±0.8 C.U. This fluctuation would be linked to various factors such as the geological nature of the soil (hydromorphic and ferralitic), the activity of aquatic organisms, wastewater discharges and various wastes introduced into the riverbed. To this end, many authors point out that the pH of natural waters depends on the geological nature of the underlying rocks and the drained soils [28-29]. Similarly, household wastes contributes to a strong modification of the pH of surface waters have been pointed by Ngambi [30]. This pH is similar to that obtained on the Kondi stream (5.5-10.2) and in the peri-urban streams of the city of Douala (Tongo'a-Bassa and Mgoua) by Domche [31] and Tchakonté [25], but differs from that obtained on the Ndog-Bissolo stream (5.25-7.34) located in the same ecological region by Ndourwe [26].

The average ammonia nitrogen content (0.15±0.14mg/l) indicates good water quality, according to SEQ-Eau grid (MEDD and Water Agency [23]. The low ammoniacal nitrogen content makes the environment capable of hosting a large number of pollutant-sensitive taxa, suitable for recreation and of rather good quality for drinking water production and aquaculture. The peaks in ammonia nitrogen and orthophosphates observed during the rainy season are thought to be related to the influx of accumulated litter, fertilised farmland and wastewater leached by the first rains. In this regard, Hébert et al [32] point out that ammoniacal nitrogen and orthophosphates come mainly from the leaching of fertilized agricultural land, as well as municipal or industrial wastewater. These results are similar to those obtained in anthropized rivers in the coastal region by Onana [24]. However, the relatively low concentrations of ammonia nitrogen would reflect the low mineralization of the waters and the low anthropized character of the watershed. This result is similar to that obtained on the Konglo stream by Dzavi [33], on the Mbeme stream at Mbalmayo by Tchouapi [34] and on the Ndog-Bissolo stream by Ndourwe [26].

The nitrites levels reveal good water quality according to the SEQ-Eau grid (MEDD and Water Agency [23]. The low nitrite values could be justified by low fertilizer use on agricultural land in the Esoa catchment.

4.2. Biological variables

The taxonomic richness of benthic macroinvertebrates (69 families) observed in the Esoa stream is relatively higher than those obtained in the Mgoua watershed stream (57 families) which belongs to the same ecological region by Tchakonté [25]. We also note that this taxonomic richness is higher than that obtained in 5 rivers of the Mfoundi basin notably the Ekozoa, Ewoué, Mingoa, Ntsomo and Tongolo, for a cumulative taxonomic richness of 29 families by Foto Menbohan et al [35]. This would be due to the low level of anthropization in the Esoa catchment compared to the Mfoundi and Mgoua catchments.

The class of insect was the most diverse and abundant, with 77.49% of relative abundance. In fact, this predominance and the great diversity of insects reflect the low anthropogenic character of its catchment area and the very good quality of the water. The relative similarity between the taxonomic richness observed at the different stations is due to the homogeneous character of the microhabitats of this watercourse. According to some authors, most aquatic insects are very sensitive to pollution and/or habitat modification and are therefore the first to disappear in a disturbed environment [36-20-4].

The abundance of Odonata (of 28.65% relative abundance) is linked to the strong riparian vegetation that borders the watercourse and the bridges present downstream of certain stations that considerably reduce the speed of the current and favour their settlement. In this respect, Tachet et al [20] state that Odonata prefer weak currents and develop preferentially in the grass bed.

The absence of Plecoptera at stations Esoa 2 and Esoa 3 is linked to the increase of anthropogenic phenomena observed in the catchment area. Indeed, these species are very sensitive to pollution, which would explain their disappearance at these stations. In this regard, MDDEFP [4] states that these organisms are very sensitive to pollution and prefer well-oxygenated environments. This would justify their presence at the Esoa 1 station, which is relatively unmanaged with a very high oxygenation rate (99.05%).

The abundance of Chironomidae diptera and Molluscs (Physidae) at station Esoa 2 is due to the accumulation of household wastes in the river bed reducing the flow speed and favouring their biodegradation and the enrichment of the environment at the origin of the development of these organisms. The high abundance of Physidae at the Esoa 3 station would be due to the rise in water levels which favours the transport of wastes downstream. This is justified by the peak of the families of Physidae (150) and Chironomidae (83) collected in March and April respectively with the effective return of the rains and by the high values of oxydability obtained at these stations. Moisan et al [37] point out that in polluted hydrosystems, the benthic macrofauna is largely dominated by saprophilic taxa such as Chironomidae, Physidae and Lymnaeidae. Spatially, the decrease from upstream to downstream of the abundance of benthic macroinvertebrates families (50 families at Esoa 1), 46 families (Esoa 2) and 33 families (Esoa 3) can be explained by changes in their habitat. In this regard, Moisan et al [37] point out that the decline of the abundance of benthic macrofauna is linked to the reduction of microhabitats. On the other hand, an opposite trend can be observed in the abundance of individuals with a sinusoidal variation whose peak (1466 individuals) is recorded at the Esoa 2 station. This could be justified by the growth and dominance of saprophilic organisms due to the proliferation of organic matter coming mainly from household wastes.

On a temporal scale, the taxonomic composition of benthic macroinvertebrates is disturbed by hydrological changes between consecutive seasons. Thus, we note that rainy months are generally favourable to an increase of the abundance of benthic macroinvertebrate taxa. This can be seen by a drop of the abundance in November followed by a recovery with a peak at Esoa 3 in March. This observation was also made by Foto Menbohan et al [38], who point out that the stability of the meteorological factors would be in favour of the high taxonomic diversity of benthic macroinvertebrates.

The Esoa 1 and Esoa 2 stations, on the other hand, show the highest diversity. However, they are faunistically dissimilar as shown by Sörensen's similarity index, which reveals rather high similarity between the macrofauna of stations Esoa 2 and Esoa 3 (65.62%).

The low values of Shannon and Weaver's diversity index and Piélou's equitability J at station Esoa 3 would be explained by the high abundance of the families of Coenagrionidae (*Coenagrion pro parte*) and Physidae (*Physa sp*) which stand out with a relative abundance of 42.36%. These results corroborate with those of Lévêque et al [39] who state that the Shannon and Weaver diversity index H' decreases when a taxon has a very high relative abundance.

Similarly, this remarkable specific diversity (H') observed in the upper and middle reaches of the Esoa river is linked to the relative integrity of this hydrosystem. Indeed, Fisher et al [40] and Dajoz [41] emphasise that an index of diversity is higher when the environmental conditions favour the installation and maintenance of a balanced, integrated biological community capable of adapting to changes. These high values would reflect the more or less equitable distribution of macroinvertebrates communities along the watercourse. Despite the variations of abundance observed between stations, the Kruskal-Wallis test carried out between months and stations did not indicate a significant difference at the 0.05 significance level.

5. Conclusion

The Esoa river, a tributary of the Moungo, is located in the peri-urban area of the Nkongsamba district and winds through a mountainous watershed of the dense secondary forest type. Physico-chemical analyses show very good oxygenation, a neutral pH, low values of nitrogenous forms and electrical conductivity, average temperature values and low values of orthophosphates reflecting a good quality of the river. Furthermore, the presence of Plecoptera upstream (Esoa 1 station) known as very sensitive to pollution, confirm the Esoa river status although the domination at the middle course and downstream of Chironomidae and Physidae who are polluoresistant taxa.

Compliance with ethical standards

Acknowledgments

The authors thank the authorities of the Laboratory of Hydrobiology and Environment (LHE) of the Department of Animal Biology and Physiology of Faculty of Sciences of university of Yaounde I for the material made available to us as well as all the students who assisted us during the sampling campaigns and during the manipulations.

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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