

Seasonal Dynamic of Benthic Macroinvertebrates in Four Equatorial Forest Streams in the Mvila Division, Southern Cameroon

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ABSTRACT

Seasonal variations are responsible for many of the disturbances observed in watercourses. The aim of this study is to evaluate the seasonal dynamics of benthic macrofauna in the Metyi, Bengo, Sounou, and Lo'o watercourses in the Mvila Division. Sampling of benthic macroinvertebrates was carried out in 12 stations using the multi-habitat/indat approach, using a 30 cm square dip net fitted. 3404 individuals of benthic macroinvertebrates (43.48% relative abundance) were counted in long dry season (LDS), 1839 individuals (23.49% relative abundance) in short rainy season (SRS), 1696 individuals (21.67% relative abundance) in long rainy season (LRS) and 889 individuals of benthic macroinvertebrates (11.36% relative abundance) in short dry season (SDS). In terms of diversity, a total of 174 taxa were identified: 111 in the LDS, 106 in the SRS, 92 in the LRS and 51 in the SDS. Shannon and Weaver's diversity index showed the lowest value in SDS, while its highest value was recorded during SRS, as was Pielou J Equitability index. The similarity index suggests that the seasons differ from one another. The LDS had the highest species richness and the abundance, while the SRS had the highest diversity value according to Shannon and Weaver.

INTRODUCTION

Benthic macroinvertebrates are organisms without backbones that can be seen with unaided eyes. They are found in most aquatic ecosystems, this is attributed to the diversity. Aquatic macroinvertebrates spend part or the entire life cycle in water. They are an essential component of aquatic ecosystems, this because of their vital role in the aquatic food (Mbete et al. 2021). Macroinvertebrates mainly comprise insects, crustaceans, molluscs (especially gastropods and bivalves) and annelids (glassworms). Class insecta, is the most diverse taxonomic group. It is composed of larvae and some aquatic adults, the main orders being

Ephemeroptera, Plecoptera, Odonata, Hemiptera, Lepidoptera, Coleoptera, Trichoptera, Diptera, and Dictyoptera (Biram et al. 2018; Nwaha 2023).

Benthic macroinvertebrates are widely used for biomonitoring of lotic systems, as they possess several attributes of good environmental indicators (Zongo et al. 2023; Biram et al. 2024). Aquatic macroinvertebrates are highly sensitive to variations in environmental conditions, hence make them suitable for assessing the status of aquatic ecosystems (Nyamsi Tchactho et al. 2014; Tampo et al. 2020; Bancé et al. 2021; Silga et al. 2022). The health of a watercourse is assessed using benthic macroinvertebrate communities based on the presence or absence of the species that comprise them. Their community structure is normally used as an indicator of streams health and the quality of habita (Woodcock & Huryn 2007; Kamagaté 2021; Song et al. 2024). Seasonal variations are reflected within lotic ecosystems by a change in the physicochemical and hydrological characteristics of watercourses, often resulting from the intensification of anthropogenic activities. These variations, which generally lead to profound changes in the bed of watercourses to the extent of disturbing the nature and distribution of microhabitats, are likely to modify the structure of the benthic macroinvertebrate population. The aim of this study was therefore to assess the seasonal dynamics of aquatic macroinvertebrates in four forest rivers (Metyi, Ndongo, Sounou and Lo'o).

2. MATERIALS AND METHODS

2.1. Study Area

With an area of around 47,191 Km², the South Region is divided into four Departments: the Mvila, the Dja and Lobo, the Ocean and the Ntem Valley (INS 2018). These Region is bordered to the northwest by the Littoral Region, to the north by the Centre Region and to the east by the East Region. The southern part of the Region borders three countries: Equatorial Guinea, Gabon and the Republic of Congo. The region's western flank is bordered by the Gulf of Guinea. The climate is characterized by four seasons: two rainy seasons: mid-March to June (short rainy season) and late August to mid-November (long rainy season); and two dry seasons: late November to mid-March (long dry season) and July to mid-August (short dry season). Rainfall is abundant and temperatures moderate (Suchel 1987; INS 2018). Relief in the southern region is dominated by the southern Cameroonian plateau, with altitudes ranging from 0 m to 1000 m. In the southern region, yellow ferrallitic soils on Gneiss cover most of the territory and red ferrallitic soils and a sedimentary plain along the coast (Ewane 2005; INS 2018). Vegetation is characterized by dense rainforest, of which there are two (02) main types: dense rainforest with two variants (Congolese or Dja evergreen forest and low-altitude coastal rainforest) and dense rainforest with one semi-deciduous, medium-altitude variant (swamp forest) (Ewane 2005; OMD 2010) (Figure 1). Two major basins make up the bulk of the southern region's hydrographic network: the Atlantic basin, with rivers such as the So'o, which originates near Sangmélima; the 460 km-long Ntem, which originates in Gabon; and the Lokoundje, which joins the Atlantic Ocean near the Nyong estuary. The Congo basin is represented in the region by the Dja river, which rises south-east of Abong-Mbang; the Lobé and Kienké rivers, which reach the Atlantic Ocean via a series of waterfalls (OMD 2010).

This study was conducted in two phases. The first phase consisted of prospecting and selecting stations according to the following criteria: accessibility, representativeness of compartments, presence of microhabitats, and absence of external sources of pollution. Twelve sampling stations belonging to four watercourses were selected in two localities in the Mvila division. These localities were Mvam Essakoe, which has two watercourses (Bengo and Metyi), and Azem, which has two watercourses (Sounou and Lo'o). The second phase of the study involved collecting macroinvertebrate samples, with two samples collected per season. (Table 1).

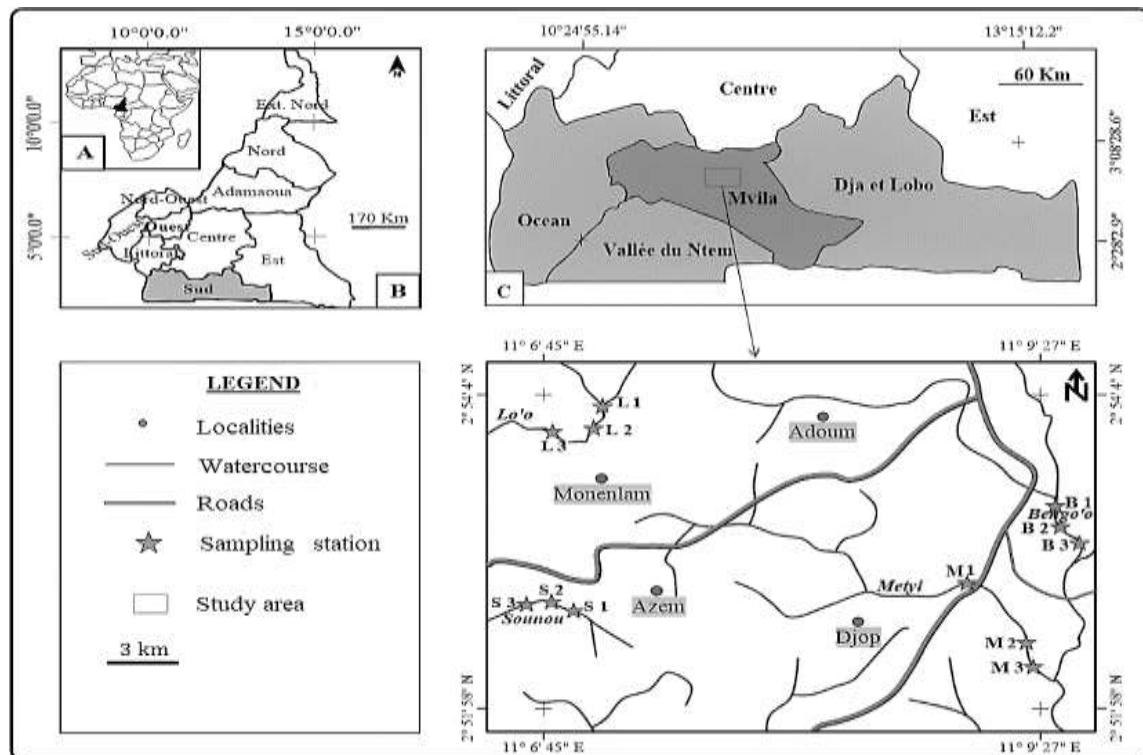


Figure 1 : Sampling station in different Stream in Mvila Division (INC 1979) modified

Table 1: Characteristics of the sampling stations

| Watercourse | Station code | Altitudes | Geographic coordinates | Dominant substrate | Vegetation |
|-------------|--------------|-----------|---------------------------------|------------------------|---------------------------------------|
| Metyi | M1 | 564 m | 02°52'22.7" N 011°09'19.8" E | Gravel and coarse sand | Herbaceous and dense |
| | M2 | 560 m | 02°52'50.6" N 011°09'03.3" E | Gravel and coarse sand | Herbaceous |
| | M3 | 559 m | 02°52'28.2" N 011°09'22.0" E | Fine sand | Large trees and vines |
| Bengo | B1 | 578 m | 02°53'18.2" N 011°09'28.2" E | Coarse sand | Large trees and palm |
| | B2 | 577.5 m | 02°53'08.3" N 011°09'24.9" E | Coarse sand | Tall trees, shrubs, palms and grasses |
| | B3 | 574 m | 02°53'03.9" N 011°09'28.8" E | Coarse sand | Tall trees Raffia and lianas |
| Sounou | S1 | 581 m | 02°52'36.7" N 011°06'53.8" E | Coarse sand | Large trees and shrubs |
| | S2 | 576 m | 02°52'41.8" N 011°06'45.4" E | Coarse sand | Large trees and shrubs |
| | S3 | 570 m | 02°52'43.3" N 011°06'41.4" E | Coarse sand | Large trees and shrubs |
| Lo'o | L1 | 594 m | 02°53'48.7" N 011°06'47.5" E | Coarse sand and gravel | Large trees and shrubs |
| | L2 | 585 m | 02°53'53.7" N 011°06'53.4" E | Coarse sand | Large trees and shrubs |
| | L3 | 579 m | 02°59'48.6" N 011°06'58.7" E | Coarse sand and gravel | Large trees and shrubs |

2.2. Sampling and Identification of Benthic Macroinvertebrates

Sampling of benthic macroinvertebrates was carried out using the multi-habitat/indat approach (Stark et al. 2001) monthly from December 2018 to December 2019, using a 30 cm square dip net fitted with a 400 μm conical mesh at 50 cm depth. For each station and each sampling episode, around twenty dip net strokes were made over an approximate area of 3 m^2 . Organisms caught in the net were collected with a pair of fine forceps and fixed in 10% formalin. In the laboratory, captured individuals were

washed in running water and then preserved in 70° ethanol. For each station, organisms are placed in 90 mm-diameter petri dishes. Grouped according to their general characteristics, size and morphology, they were identified and counted under a WILD M3B binocular magnifier with episcopic illumination, using the identification keys and books by Tachet et al. (2006), Heide-mann and Seidenbusch (2002); De Moor et al. (2003); Stals and De Moor (2007) and Moisan (2006).

2.3. Data Analysis

The data collected during this study was processed and analyzed using standard statistical software. The frequency of occurrence or constancy noted "C" is the ratio expressed as a percentage between the number (p) of samples (or samplings) in which species i appears out of the total number (P) of samples. This index is based on the Presence/Absence matrix and is calculated according to the formula:

$$C (\%) = P_i/P \times 100$$

P_i = number of samples in which species i is represented; P = total number of samples.

Depending on the value of C, five groups of species can be distinguished (Dufrêne and Legendre, 1997): C=100%, omnipresent species; C =] 100; 75], regular species; C=] 75; 50], constant species; C =] 50; 25], accessory species; C =] 25; 0[, rare or accidental species.

The Shannon & Weaver diversity index was used to estimate the taxonomic diversity of the benthic macroinvertebrate popula-

tion, using the formula: $H' = - \sum_{i=1}^n P_i \log_2 P_i$

H' = Shannon & Weaver index; P = proportion of the i^{th} taxon in the total number of organisms; n = number of taxa.

The Shannon & Weaver diversity index ranges from 0 (settlement dominated by a single taxon) to $\log_2 S$ (all taxa equally represented), where S is the total number of taxa in the sample.

Pielou equitability index (J) is used to measure the equi-partitioning of species in a stand in relation to a theoretical equal distribution for all species. Equitability values range from 0 (dominance of one taxon) to 1 (equirrepartition of taxa).

$$J = \frac{H'}{\log_2 S}$$

J = Pielou equitability index; H' = Shannon & Weaver index; S : total number of taxa in the sample).

Simpson's Index (D) provides information on the dominance of one or more species. It is calculated according to the following formula (Grall and Coïc 2005).

$$D = \sum [n_i (n_i - 1)] / [N (N - 1)]$$

n_i = number of individuals in species i ; N = total number of individuals in the sample.

It expresses the imbalance in abundance between species. When D tends towards 0, it expresses maximum diversity, i.e. taxon dominance, and when D tends towards 1, diversity is minimal, with strong dominance of one or two taxa.

Jaccard's similarity index (J): This index was calculated to assess the similarity between macroinvertebrate communities in different seasons. Its value ranges from 0 (different communities) to 1 (similar communities). It is defined by the formula:

$$J_{(A,B)} = \frac{|A \cap B|}{|A \cup B|} \quad \Rightarrow \quad J_{(A,B)} = \frac{|A \cap B|}{|A| + |B| - |A \cap B|}$$

$|A \cap B|$ = number of taxa common to both seasons (A and B);

$|A|$ = number of taxa in season A; $|B|$ = number of taxa in season B

The rarefaction method developed by Sanders is widely used to assess diversity within ecosystems (Grall and Coïc 2005). It estimates the number of species for a given number of individuals. Its main advantage is that it does not depend on sample size.

It was evaluated using PAST software version 4.03.

3. RESULTS

3.1. Seasonal Variation in Taxonomic Richness and Overall Relative Abundance of Benthic Macroinvertebrates

During this study, the Long Dry Season (LDS) presented the greatest absolute abundance of benthic macroinvertebrates, with 3,404 organisms or 43.48% relative abundance. Next comes the Short Rainy Season (SRS) with 1839 organisms or 23.49% relative abundance. The Long Rainy Season (LRS), with 1696 organisms or 21.67% relative abundance, comes third. Finally comes the Short Dry Season (SSD), with 889 individuals or 11.36% relative abundance.

During the LDS, Decapods predominated, with 1128 individuals or 33.1% relative abundance, followed by Coleoptera with 824 individuals or 24.2% relative abundance, and Heteroptera with 807 individuals or 23.7% relative abundance. Odonata came next, with 215 individuals (6.3% relative abundance). Ephemeroptera, Plecoptera and Trichoptera count 103 individuals (3.0% relative abundance), 36 individuals (1.1% relative abundance) and 109 individuals (3.2% relative abundance) respectively.

During the SRS, Decapods dominated the macroinvertebrate population with 595 individuals (32.4%), followed by Coleoptera with 423 individuals (23.0% relative abundance) and Heteroptera with 361 individuals (19.6% relative abundance). Ephemeroptera, Plecoptera and Trichoptera accounted for 169 individuals (9.2% relative abundance), 40 individuals (2.2% relative abundance) and 36 individuals (2.0% relative abundance) respectively.

During the SDS, Decapods and Coleoptera once again predominated, with 328 individuals (36.9% relative abundance) and 305 individuals (34.3% relative abundance) respectively. Next come Heteroptera and Odonata, with 131 individuals (14.7% relative abundance) and 78 individuals (8.8% relative abundance) respectively. Ephemeroptera, Plecoptera and Trichoptera account for 8 individuals (0.9% relative abundance), 16 individuals (1.8% relative abundance) and 3 individuals (0.3% relative abundance) respectively (Table II). As in other seasons, the LRS was characterized by the predominance of Decapods and Coleoptera, with 552 individuals (32.5% relative abundance) and 298 individuals (17.6% relative abundance) respectively. Heteroptera counted 281 individuals or 16.6% relative abundance, while Odonata numbered 169 individuals or 10.0% relative abundance. Ephemeroptera, Plecoptera and Trichoptera accounted for 293 individuals (17.3% relative abundance), 14 individuals (0.8% relative abundance) and 46 individuals (2.7% relative abundance) respectively (Table 2).

Table 2: Relative abundance of benthic macroinvertebrates orders collected each season.

| Orders | Long dry season (LDS) | | Short rainy season (SRS) | | Short dry season (SDS) | | Long rainy season (LRS) | |
|-----------------|-----------------------|------------------------|--------------------------|------------------------|------------------------|------------------------|-------------------------|------------------------|
| | Absolute abundance | relative abundance (%) | Absolute abundance | relative abundance (%) | Absolute abundance | relative abundance (%) | Absolute abundance | relative abundance (%) |
| Decapoda | 1128 | 33.1 | 595 | 32.4 | 328 | 36.9 | 552 | 32.6 |
| Coleoptera | 824 | 24.2 | 423 | 23.0 | 305 | 34.3 | 298 | 17.6 |
| Heteroptera | 807 | 23.7 | 361 | 19.6 | 131 | 14.7 | 281 | 16.6 |
| Odonata | 215 | 6.3 | 140 | 7.6 | 78 | 8.8 | 169 | 10.0 |
| Trichoptera | 109 | 3.2 | 36 | 2.0 | 3 | 0.3 | 46 | 2.7 |
| Caenogastropoda | 108 | 3.2 | 51 | 2.7 | 13 | 1.5 | 5 | 0.3 |
| Ephemeroptera | 103 | 3.0 | 169 | 9.2 | 8 | 0.9 | 293 | 17.3 |
| Bivalvia | 42 | 1.2 | 14 | 0.8 | 2 | 0.2 | 4 | 0.2 |
| Plecoptera | 36 | 1.0 | 40 | 2.2 | 16 | 1.8 | 14 | 0.8 |
| Diptera | 31 | 0.9 | 8 | 0.4 | 5 | 0.6 | 29 | 1.7 |
| Oligochaeta | 1 | 0.03 | 2 | 0.1 | 0 | 0.0 | 5 | 0.3 |

3.2. Seasonal variation of taxonomic richness and the frequency of occurrence of benthic macroinvertebrates taxa

Seasonal variations in the frequency of occurrence of benthic macroinvertebrates taxa are shown below. It can be seen that the LDS has the greatest taxonomic richness followed by the SRS LDS and SDS respectively. During the LDS, a total of 111 taxa were identified, including 52 rare taxa (46.85% relative abundance), 27 accessory taxa (24.82% relative abundance), 17 constant taxa (15.32% relative abundance) and 15 ubiquitous taxa (13.51% relative abundance). During the SRS, 106 taxa were identified, including 59 rare taxa (55.66% relative abundance), 17 accessory taxa (16.04% relative abundance), 15 constant taxa (14.15% relative abundance) and 15 ubiquitous taxa (14.15% relative abundance). During the SDS, a total of 51 taxa were counted, corresponding to the group of ubiquitous taxa. Finally, during the LRS, 92 taxa were counted, including 42 rare taxa (45.65% relative abundance), 21 accessory taxa (22.83% relative abundance), 12 constant taxa (13.04% relative abundance) and 17 ubiquitous taxa (18.48% relative abundance) (Table 3).

Table 3 : Frequency of occurrence of benthic macroinvertebrates taxa by season during the study period

| | LDS | SRS | SDS | LRS |
|-----------------|-----|-----|-----|-----|
| rare taxa | 52 | 59 | 0 | 42 |
| accessory taxa | 27 | 17 | 0 | 21 |
| constant taxa | 17 | 15 | 0 | 12 |
| ubiquitous taxa | 15 | 15 | 51 | 17 |
| Total | 111 | 106 | 51 | 92 |

3.3. Seasonal Variations in Shannon & Weaver Index, Pielou Equitability, Simpson Index and Species Richness

The Shannon & Weaver diversity index fluctuate seasonally around an average of 4.07 ± 0.42 bit/ind. The lowest value (3.52 bit/ind) was recorded during the SDS, while the highest value (4.46 bit/ind) was obtained during the SRS. According to the Kruskal Wallis test, there was no significant difference between these values ($p = 0.39$). Equitability J of Pielou varied from 0.58 in LDS to 0.66 during SRS and LRS, for a mean of 0.63 ± 0.04 . The Kruskal Wallis test showed no significant difference between the different Pielou index values ($p = 0.39$). Simpson dominance index ranged from 0.82 at SDS to 0.88 at SRS and LRS. These values swirl around a mean of 0.85 ± 0.03 . No significant difference was observed between the different Simpson values ($p = 0.39$). Species richness ranged from 51 species during SDS to 111 species during LRS and SRS. This species richness fluctuates around an average of 90 ± 27.21 species (Table 4).

Table 4 : Seasonal variation of the Shannon & Weaver index, Pielou equitability and Simpson's index during the study period

| | LDS | SRS | SDS | LRS |
|------------------------|------|------|------|------|
| Shannon & Weaver index | 3.97 | 4.46 | 3.52 | 4.33 |
| Pielou Equitability | 0.58 | 0.66 | 0.62 | 0.66 |
| Simpson's index | 0.84 | 0.88 | 0.82 | 0.88 |
| $\log_2 (S)$ | 6.79 | 6.73 | 5.67 | 6.52 |

3.4. Benthic Macroinvertebrates Rarefaction Curves

The rarefaction curve (Figure 2) shows a distinct evolution of diversity between the long dry season (LDS) and others. During the each season, maximum richness is not reached due to the appearance of new taxon depending on the sampling effort. The sampling efforts is needed. For each season, the curve of the SDS is characterized by a low taxonomic richness (51 taxa) with a low abundance of organisms (871 individuals). The LRS and SRS show roughly the same abundance (1696 and 1839 individuals respectively) but with very different taxonomic richness (92 and 106 taxa respectively). The LDS has the highest taxonomic richness (111 taxa) with high abundance (3116 individuals).

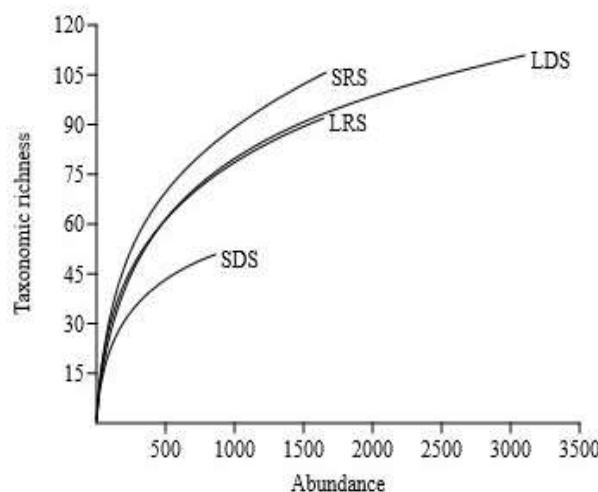


Figure 2: Rarefaction curves of taxonomic richness of benthic macroinvertebrates

3.5. Jaccard Similarity Index

Table 5 shows Jaccard's similarity index values for the different seasons of the study period. It should be noted that the level of similarity between the different seasons varies from 0.33 (LDS-LRS; SDS-LRS) to 0.47 (LDS-SRS). These values are well below 1, suggesting that the seasons differ from one another (Table 5).

Table 5: Jaccard Similarité Index for the different study seasons

| | LDS | SRS | SDS | LRS |
|-----|------|------|------|------|
| LDS | 0 | 0.47 | 0.38 | 0.33 |
| SRS | 0.47 | 0 | 0.35 | 0.38 |
| SDS | 0.38 | 0.35 | 0 | 0.33 |
| LRS | 0.33 | 0.38 | 0.33 | 0 |

4. DISCUSSION

The greatest abundance of benthic macroinvertebrates was obtained during the long dry season (43.48% relative abundance). This high abundance is attributed to the relatively stable environmental conditions during this period, particularly the low water levels and reduced flow velocity. Indeed, during the long dry season (LDS), it was easier and more convenient to sample all compartments of the station. These results are similar to those of Kamagate (2021) in the upper Cavally basin under the influence of mining

activities (West. Côte d'Ivoire); but different from those obtained by Allouko (2019) in the Aghien lagoon in Côte d'Ivoire, according to which the long rainy season presents the highest abundance, followed by the dry season. The high abundance of macroinvertebrates during the LDS rhythms with the highest species richness (111 taxa). This high species richness reflects the abundance and diversity of ecological niches in these rivers during this period. These observations are similar to those made by Kengne Fotsing (2018) in some rivers in the Western region, but are at odds with the observations of Tchakonté (2016). According to the study that was carried out by Tchakonté (2016), the rainy season is generally associated with an increase in microhabit/indats and nutrients, thus offering the best conditions for organisms to develop and proliferate. The low taxonomic richness observed during the rainy seasons (LRS and SRS) may be attributed to increase in velocity, flow and water column. This would have resulted in the destruction of certain microhabit/indats favorable to certain organisms, or in the drifting of organisms. In fact, during the rainy seasons, the torrential flow of water in the various streams was responsible for the drift of a large number of microhabit/indats formed during the dry season, and consequently the drift of non-adapte organisms. These observations are contrary to those of Moretti & Callisto (2005); Callisto & Goulart (2005), who emphasize that the rainy seasons offer a fairly well-diversified macroinvertebrate population in relation to their relative abundances. In the same vein, Xu et al (2014) noted that rainy months are often associated with greater taxonomic diversity in benthic macroinvertebrate populations. The high abundance of decapods is due to their cosmopolitanism, their great capacity to adapt to different environmental conditions and satisfactory water oxygenation. Dzavi et al. (2022); Nwaha (2023). The results obtained during this study are similar to those of Gwos et al. (2022), in 4 streams in the East Cameroon region. i.e. 33.34% crustaceans.

Furthermore, the predominance of decapods during the LDS is linked to the abundance of litter that serves as a refuge for them (Tachet et al. 2006), as well as to the low flow velocity of the water during this season. The very low abundance of oligochaetes in all seasons reflects the low level of organic pollution in the various watercourses, and consequently the very low level of anthropization.

The Shannon & Weaver index shows that benthic macroinvertebrates are more diverse in SRS, and less diverse in SDS. The high diversity of benthic macroinvertebrates in SRS could be attributed to the stability of the environment. Indeed, during SRS, waters appear to be less concentrated, offering the best conditions for organisms to flourish. Similarly. Pielou equitability has the highest value in SRS. This means that not only are organisms more diversified during this season, they also show a tendency towards equirepartition. Jaccard's similarity index shows that benthic macroinvertebrates populations harvested throughout the study period differ from season to season. The lower value of Jaccard's index observed between LDS-LRS and SDS-LRS could be explained mainly by speed and water column. Indeed, during the two dry seasons, the water column is generally very low compared to that observed during the main rainy season. The immediate consequence of this difference is the drifting of species not adapted to the high velocity of the water current. In addition, the heavy rainfall observed during the LRS causes disturbances in the watercourses, such as the destruction of several microhabit/indats and the renewal of the bottom substrate.

5. CONCLUSIONS

The aims of this study was to evaluate the seasonal dynamics of benthic macrofauna in four equatorial forest streams (Metyi, Bengo, Sounou and Lo'o) of the Mvila Division. A high abundance of aquatic macroinvertebrates (3,404 individuals) was obtained during the long dry season (LDS), predominantly decapods. This was due to environmental conditions that favored the development of organisms, such as the shallow water column coupled with low water flow velocity. In terms of species richness, the LDS was the

most dominant, with 111 taxa. These results reflect the abundance and diversity of ecological niches in these rivers during the LDS. Regarding biocenotic indices, The Shannon & Weaver diversity index and Pielou equitability varied from season to season. The highest values were recorded during the SRS season due to environmental conditions favorable to the multiplication and growth of organisms during that time. Jaccard's similarity index shows low similarity values between the different seasons. The lower Jaccard index value observed between LDS-LRS and SDS-LRS is mainly explained by speed and the water column. During the two dry seasons, the water column is generally very low compared to that observed during the main rainy season.

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“Conceptualization, MN and JD.; methodology, MN, MATZ; software, MN and RND; validation, MN, JD, MATZ, WCNB and RND; formal analysis, MN, WCNB and RND; investigation, MN, MATZ, WCNB and RND; resources, MN.; data curation, JD; writing—original draft preparation, MN.; writing—review and editing, MN; visualization, JD.; supervision, JD. All authors have read and agreed to the published version of the manuscript.”

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Conflicts of Interest:

All authors of this work declare on their honor that there is no conflict of interest.

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