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Seasonal Dynamics 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. This study aims 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-habit/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 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 the unaided eye. They are found in most aquatic ecosystems, which 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 is because of their vital role in the aquatic food (Mbete et al. 2021). Macroinvertebrates mainly comprise insects, crustaceans, mollusks (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, making them suitable for assessing the status of aquatic ecosystems (Nyamsi Tchatcho 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 habitat (Woodcock & Huryn 2007, Kamagate

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 microhabit/indats, 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).

MATERIALS AND METHODS

Study Area

With an area of around 47,191 km^2, the South Region is divided into four Departments: the Mvila, the Dja and Lobo, the Ocean, and the Ntem Valley (INS 2018). This region is bordered to the northwest by the Littoral Region, to the north by the Center 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 Gulf of Guinea borders the region's western flank. 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 ferralitic soils on Gneiss cover most of the territory and red ferralitic 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) (Fig. 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,

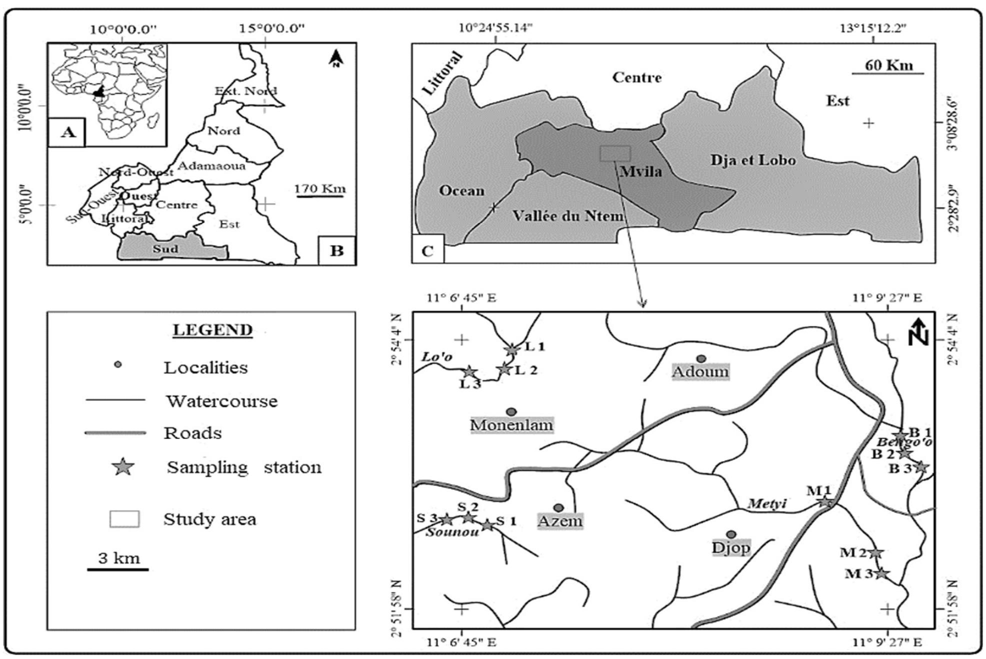

Fig. 1: Sampling stations in different streams in Mvila Division (INC 1979) modified.

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).

Sampling and Identification of Benthic Macroinvertebrates

Sampling of benthic macroinvertebrates was conducted monthly from December 2018 to December 2019 using the multi-habit/indat approach (Stark et al. 2001). A 30 cm square dip net fitted with a 400 µm conical mesh was used at a depth of 50 cm. At each station and sampling event, approximately twenty dip net strokes were made over an area of about 3 m^2. Organisms caught in the net were collected with 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 were placed in 90 mm-diameter Petri dishes. Grouped by general characteristics, size, and morphology, they were identified and counted under a WILD M3B binocular magnifier with episcopic illumination, using identification keys and books by Tachet et al. (2006), Heidemann & Seidenbusch (2002), De Moor et al. (2003), Stals & De Moor (2007) and Moisan (2006).

Data Analysis

The data collected during this study were 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:

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

Pi = 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): omnipresent species when $C = 100\%$; regular species when $100 > C \geq 75\%$; constant species when $75 > C \geq 50\%$; accessory species when $50 > C \geq 25\%$ and rare or accidental species when $25 > C \geq 0\%$.

The Shannon and Weaver diversity index was used to estimate the taxonomic diversity of the benthic macroinvertebrate population, using the formula:

$$H' = -\sum_{i=1}^{n} P_i \log_2 P_i$$

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

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 11°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

The Shannon and 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).

$$D = \Sigma\ [ni\ (ni-1)]/[N\ (N-1)]$$

ni = 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). The formula defines it:

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

$|A \cap B|$ = 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.

RESULTS AND DISCUSSION

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 2). 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).

Seasonal Variation of Taxonomic Richness and the Frequency of Occurrence of Benthic Macroinvertebrates Taxa

Seasonal variations in the frequency of occurrence of benthic macroinvertebrate taxa are shown below. It can be seen that the LDS has the greatest taxonomic richness,

Table 2: Relative abundance of benthic macroinvertebrate 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

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).

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

The Shannon & Weaver diversity index fluctuates seasonally around an average of 4.07 ± 0.42 bit.ind^{-1}. The lowest value (3.52 bit.ind^{-1}) was recorded during the SDS, while the highest value (4.46 bit.ind^{-1}) was obtained during the SRS.

Table 3: Frequency of occurrence of benthic macroinvertebrate 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

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).

Benthic Macroinvertebrates Rarefaction Curves

The rarefaction curve (Fig. 2) shows a distinct evolution of diversity between the long dry season (LDS) and others. During each season, maximum richness is not reached due to the appearance of new taxa, depending on the sampling effort. The sampling efforts are 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,

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

respectively). The LDS has the highest taxonomic richness (111 taxa) with high abundance (3116 individuals).

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

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 Tchakonte (2016). According to the study that was carried out by Tchakonte (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 an increase in velocity, flow, and water column. This would have destroyed 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-adapted organisms. These observations are contrary to those of Moretti & Callisto (2005) and 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

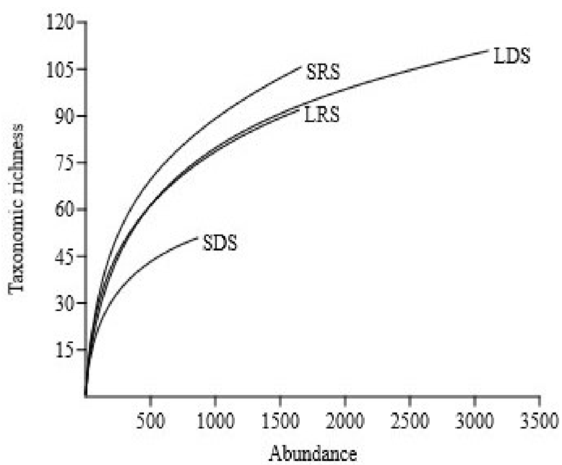

Fig. 2: Rarefaction curves of taxonomic richness of benthic macroinvertebrates.

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 indicates that benthic macroinvertebrates are more diverse in SRS and less diverse in SDS. The higher diversity in SRS may be attributed to environmental stability, as waters during this season are less concentrated, creating optimal conditions for organism proliferation. Similarly, Pielou's equitability is highest in SRS, suggesting not only greater diversity but also a tendency towards even distribution among species. Jaccard's similarity index reveals that benthic macroinvertebrate populations vary between seasons. The lower Jaccard index between LDS-LRS and SDS-LRS can be mainly attributed to differences in water velocity and column depth. During the dry seasons, the water column is significantly lower compared to the rainy season, leading to the drift of species not adapted to higher current speeds. Additionally, heavy rainfall during LRS causes disturbances, such as the destruction of microhabitats and indats, and the renewal of the bottom substrate.

CONCLUSIONS

This study aimed to evaluate the seasonal dynamics of benthic macrofauna in four equatorial forest streams (Metyi, Bengo, Sounou, and Lo'o) in the Mvila Division. A high abundance of aquatic macroinvertebrates (3,404 individuals) was recorded during the long dry season (LDS), predominantly decapods. This abundance was driven by environmental conditions that favored organism development, including a shallow water column and 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 seasonally. The highest values were recorded during the SRS season, due to environmental conditions favorable to the multiplication and growth of organisms. Jaccard's similarity index showed low similarity values between seasons. The lower Jaccard index values observed between LDS-LRS and SDS-LRS are mainly explained by water column depth and flow speed. During the two dry seasons, the water column is generally very low compared with that observed during the main rainy season.

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