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Distribution, composition and impact of environmental factors on benthic macroinvertebrates functional feeding groups and ecosystem attributes in river Yaah (East Lekie)

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Abstract

From July 2022 to May 2023, a study was carried out in the Lékié division (Center region) and its objective was to evaluate the composition and distribution of benthic macroinvertebrates functional feeding groups in relation to the characteristics of environmental factors and determine the ecosystem attributes of the Yaah watercourse. For that, in three sampling stations, the collection of water samples for analysis and benthic macroinvertebrates were carried out according to standard methods. The grouping of benthic macroinvertebrates into functional feeding groups was done thanks to the keys and appropriate works. A total of 730 benthic macroinvertebrates belonging to 38 families were identified and the families of Belostomidae (11.51%) and Libellulidae (10.96%) were the most dominant. The 38 families of benthic macroinvertebrates identified were grouped into 5 trophic functional groups, predators (63.29%) and Shredders (22.19%) were largely predominant. The distribution of collectors varied from YA 1 to YA 3. The abundance relative of Shredders decreased from upstream to downstream while that of filters increased earlier and these variations were consistent with the River Continuum Concept. The electrical conductivity was influenced positively the distribution of scrapers and gathering collectors while the suspended solids negatively influenced the distribution of shredders and positively the distribution of predators. The watercourses sampled were heterotrophic, conducive to the development of shredders and dominated by Coarse Particulate Organic Matter and predators.

Keywords: Functional Feeding Group; Benthic Macroinvertebrates; Parameters Physicochemical; Ecosystem Attributes

1. Introduction

Benthic macroinvertebrates are aquatic organisms that are visible to the naked eye, which do not do not have a bony or cartilaginous skeleton and which colonize the bottom of aquatic environments during all or at least part of their life cycle [1]. The functional feeding groups (FFG) are a classification approach, based on criteria morphological and which group benthic macroinvertebrates according to the mechanisms and behavioral and adaptive characteristics of food acquisition [2]. The different trophic functional groups of benthic macroinvertebrates are: shredders, scrapers, filtering

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collectors, gathering collectors and predators [2]. The Knowledge of benthic macroinvertebrates functional feeding groups of watercourses is important because it allows us to understand the processing of organic matter, the flow energy, trophic relationships and management activities necessary to minimize the disruption of ecosystem functioning [3,4]. THE Anthropogenic activities result in loss of diversity, composition and changes major in the structures and functional organization of river macroinvertebrates [5,6]. In Africa and mainly in Cameroon, the composition and distribution of trophic functional groups of benthic macroinvertebrates remain poorly understood and far from complete despite the work undertaken by [7]. In order to overcome the lack of information on the composition and the distribution benthic macroinvertebrates functional feeding groups, this work aims objective of describing the composition and distribution of benthic macroinvertebrates functional feeding groups in relation to environmental characteristics and determine the attributes of the ecosystems of the Yaah watercourse in the Lékié department. More mainly it is a question of the distribution and composition of benthic macroinvertebrates functional feeding groups, the influences of physicochemical parameters on the distribution benthic macroinvertebrates functional feeding groups and ecosystem attributes.

2. Material and methods

2.1. Description of the study area

Located in the Central Cameroon region, the Lékié division (figure 1) has an area of approximately 3000 km² and has geographic coordinates of 3°47'- 4°30' North latitude and 11°5'-11°43' East longitude. The climate is hot and humid “Guinean” type (four seasons of unequal duration) with average temperatures of 25°C and rainfall of 1,500 to 2,000 mm [8]. The soils vary depending on the locality, but are ferralitic, ferruginous and sandy [9]. The relief is essentially made up of hilly and steep mountain ranges located at altitudes of 500 to 1000 m [8]. The vegetation is that of the degraded equatorial forest. The activities practiced are: agropastoral activities and the anarchic exploitation of precious species. The hydrographic regime consists of the Sanaga watershed and its tributaries.

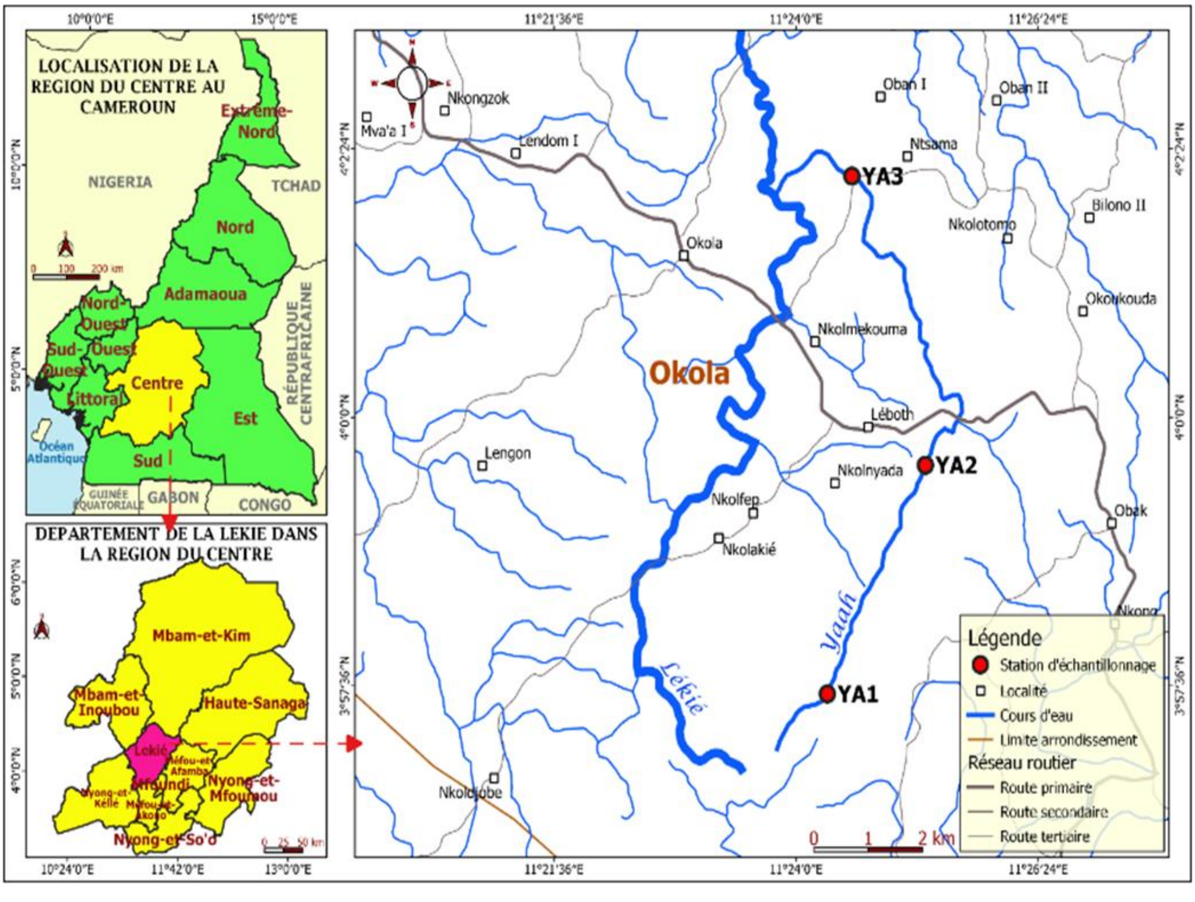

Figure 1 Map of the geographical location of the Lékié department

2.2. Sampling and measurement of physicochemical and biological variables

2.2.1. Sampling period and description of the study site

Sampling took place from July 2022 to June 2023 according to a biseasonal frequency in the Yaah watercourse located in the district of Okola. 3 stations were chosen on the basis of representativeness, accessibility and the presence of microhabitats. The Yaah river has a length of approximately 14.1 km. It rises at the top of a hill inside the rocks in the village Nkolnyada and flows into the Lékié river in the village Ntsama. Three sampling stations chosen are:

- **Yaah 1 (YA 1):** It is located in the village Nkolnyada at latitudes N. 03°59.079′, longitudes E. 011°25.036′ and at an altitude of 595 m. The substrate of the sampled biotope is composed of sand and silt and organic particles. The leaves of riparian plants litter the bed of the watercourse. Agriculture, washing, fishing and sand harvesting are the main anthropogenic activities carried out (Figure 2A).
- **Yaah 2 (YA 2):** It is located in the village Nkolnyada-cheferie at latitudes N 03°59.573′, longitudes E. 011°25.282′ and at an altitude of 652 m. The substrate of the sampled biotope was composed mainly of sand and organic detritus. The leaves of riparian plants litter the bed of the watercourse. Agriculture (coffee, mango, safou), laundry and fishing are the main anthropogenic activities (Figure 2B).
- **Yaah 3 (YA 3):** It is located in the village Ntsama at latitudes 04°02.157′North and longitude 011°24.554′East and at an altitude of 600 m. The substrate of the sampled biotope was composed of silt, mud and detrital materials. The leaves of riparian plants litter the bed of the watercourse. Land use was agricultural. (Figure 2C).

Figure 2 Images of crenal stations A) YA 1, B) YA 2, C) YA 3

2.2.2. Sampling and measurement of physicochemical parameters variables

For this purpose, in the field the temperature, pH and electrical conductivity and Dissolved Oxygen were measured using a LAQUA HORIBA PC 220 brand multiparameter. Other variables such as suspended solids, nitrates, phosphates and ammonium were measured in the laboratory using a HACH DR/2010 spectrophotometer. Oxidizability was measured in the laboratory by volumetry of [10].

Sampling of biological variables

The collection of benthic macroinvertebrates was carried out using a square-shaped trout measuring 30 cm on a side, fitted with a conical net 400 µm mesh opening and 50 cm depth, following the multihabitat approach [11]. In the laboratory, the specimens were washed in tap water then preserved in ethanol at 70°. By station, the organisms were grouped according to their size and morphology and identified at the lowest possible taxonomic level (Mainly family) under a Wild M5 binocular magnifying glass, using the following keys and works: [12,13]. [14] and [15] showed that the identification of benthic macroinvertebrates at the family level was sufficient for studies on functional diversity.

2.3. Data analyzes

2.3.1. Tests de kruskal - Wallis H and Mann – Whitney U tests

The Kruskal Wallis H test associated with the Mann-Whitney U test made it possible to compare the physicochemical and biological parameters. Spearman's rank correlations made it possible to evaluate the influences of physicochemical parameters on the distribution of functional feeding groups. The analyzes were carried out using SPSS 20.0 software and the results assessed at the security threshold of 99% ($P < 0.01$) and 95% ($P < 0.05$). The determination of ecosystem attributes was done using the formulas in Table 1.

2.3.2. Diversity index

The Shannon-Wiever index (H') is the most often used and the most recommended by different authors [21]. It allows diversity to be expressed by taking into account the number of species and the abundance of individuals of all species in the sample. It is calculated by the following formula.

$$\boldsymbol{H'} = -\sum_{\boldsymbol{n=1}}^{\infty}(\mathbf{Pi\ Log2\ Pi})$$

Where : Pi = proportional abundance of species i: pi = ni /N; S = total number of species; ni = number of individuals of a specie in the sample N= total number of individuals of all species in the sample.

The Piélou equitability of a sample represents the ratio of the observed specific diversity to the theoretical maximum diversity that can be obtained with the same number of species [21]. With: S= taxonomic richness H'= Shannon and Weaver index

$$\boldsymbol{J} = \frac{\mathbf{H'}}{\mathbf{Log2\ \ S}}$$

2.3.3. Ecosystem attributes

Table 1 Examples of for stream functional feeding group ratios serving as surrogates ecosystem attributes Modified from [16].

Ecosystem attribute	**Symbols**	**FFG ratio**	**Criteria levels**
Autotrophy/ Heterotrophy index	Primary production/Respiration community	$\frac{\text{Scrapers}}{\text{Shredders} + \text{Total Collector}}$	Autotroph > 0.75
Shredder index	Coarse Particulate Organic Matter/ Fine Particulate Organic Matter	$\frac{\text{Shredders}}{\text{Total Collectors}}$	Shredder availability > 0.25
Filtering collector index	Fine Particulate Organic Matter in transport/ Fine Particulate Organic Matter deposited in benthos	$\frac{\text{Filtering Collectors}}{\text{Gathering Collectors}}$	TFPOM higher than normal > 0.5
Stable channel	Habitat stability index	$\frac{\text{Scrappers} + \text{Filtering Collectors}}{\text{Shredders} + \text{Gathering Collectors}}$	Stable substrates > 0.5
Top-down control	Top-down predator control to prey	$\frac{\text{predator}}{\text{Scrappers} + \text{Shredders} + \text{Total Collectors}}$	Expected predator-prey balance = 0.10 – 0.20

3. Results

3.1. Environmental parameters

Table 2 Mean values and standard deviation of environmental parameters from the different sampling stations

		YAA 1	YAA 2	YAA 3
Temperature (°C)	Min-Max	20,9-22,5	21,6-23	21,75-23,8
	Mean ± σ	21,83± 0,67	22,18± 0,61	22,81± 0,84
pH (UA)	Min-Max	7,10-7,66	6,77-7,36	6,65-7,25
	Mean ± σ	7,39± 0,30	7,07± 0,25	7,00± 0,27
Electrical Conductivity (µS/cm)	Min-Max	31,25-43,02	30,85-87,45	38,9-92,65
	Mean ± σ	37,97±5,55	49,7±26,64	54,9±25,29
nitrates (mg/l)	Min-Max	0,4-2,15	0,4-1,3	1,1-2,75
	Mean ± σ	0,94±0,81	0,98±0,39	1,7±0,7
Ammonium (mg/l)	Min-Max	0,16-0,44	0,2-0,56	0,22-0,41
	Mean ± σ	0,25±0,12	0,32±0,16	0,33±0,09
oxidizability (mg/l)	Min-Max	3,22-11,74	5,33-10,47	5,5-10,25
	Mean ± σ	8,27±3,59	7,41±2,35	7,62±2,01
Dissolved Oxygen (% of saturation)	Min-Max	60,8-83,6	78,55-86,05	58,9-95,66
	Mean ± σ	74,63±9,72	82,5±3,35	78,31±15,23
Suspended solids (mg/l)	Min-Max	7,0-25,0	8,5-11,5	10,5-16,5
	Mean ± σ	12,5±8,38	9,5±1,41	12,75±2,62
Phosphate (mg/l)	Min-Max	0,47-0,66	0,34-0,95	0,3-0,78
	Mean ± σ	0,60±0,09	0,54±0,28	0,44±0,22

The table 2 Mean values and standard deviation of environmental parameters from the different sampling stations presents the water temperature ranged from 20.9°C at station YA 1 during the long dry season to 23.8°C at station YA 3 during the short rainy season with an average of 22.27 ± 0 .77 °C. Regarding the pH, the extremums are respectively 6.65 UC (YA 3; SRS) and 7.66 UC (YA 1; SRS) and the average value of 7.15 ± 0.31 UC. Speaking of electrical conductivity its limit values are respectively 30.85 µS/cm (YA 2; SRS) and 92.65 µS/cm (YA 3; LDS) and the average value is 47.52 ± 20.77 µS/ cm. The extreme values of Dissolved Oxygen were recorded at station YA 3. These values are 58.9 % (LRS) and 95.66 % (SDS) and the average value is 78.47 ± 10,14 %. Suspended solids values range from 7 mg/l (YA 1; SDS and LRS) to 16,5 mg/l (YA 3; LRS) and the average value is 11,58 ± 4.87 mg/l. The extreme values of oxidizability were obtained at station YA 1 and are respectively 3.22 mg/l (GSS) and 11.74 mg/l (GSP) and the average value is 7.77 ± 2.51 mg/l. Water nitrate levels increased from 0.4 mg/l at station YA 2 during the short dry season and the long rainy season to 2.75 mg/l at station YA 2 and during the short season. of rain with an average of 1.2 ± 0.71 mg/l. Ammonium levels in water are between 0.16 mg/l (YA 1; SDS) and 0.56 mg/l (YA 2; LDS). The average value is 0.31 ± 0.12 mg/l. Phosphates levels in water are between 0.3 mg/l (YA 3; SRS) and 0.56 mg/l (YA 2; LDS). The average value is 0.31 ± 0.12 mg/l. For all physicochemical parameters studied, the Kruskal-Wallis test shows no significant difference in spatiotemporal terms ($p > 0.05$).

3.1.1. Presentation of benthic macroinertébrate communities

In this study a total of 730 benthic macroinvertebrates belonging to 3 phyla, 4 Classes, 11 orders and 38 families were identified. The figure 3 shows that the families of Belostomidae and Libellulidae dominated the population with respective relative abundances of 11.56%. and 10.96% (figure 3).

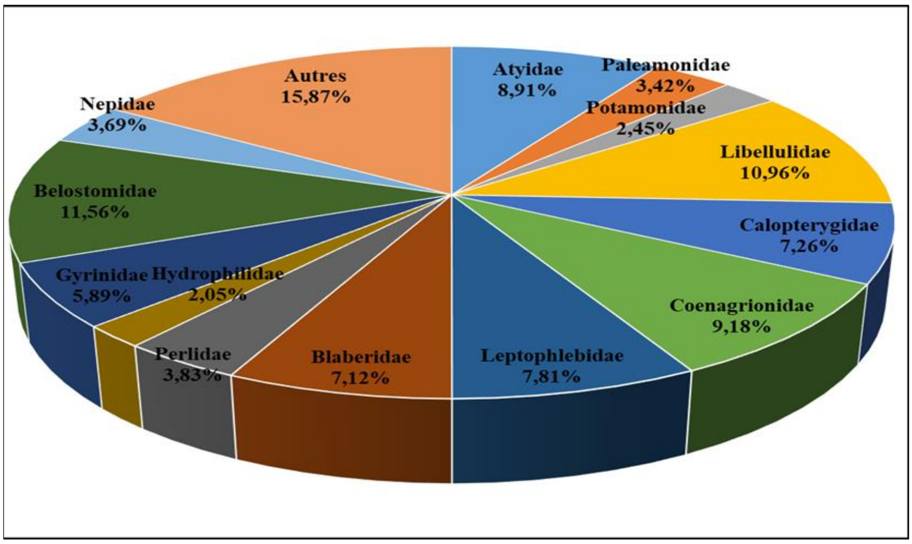

Figure 3 Relative abundance of benthic macroinvertebrates functional groups of river Yaah

3.1.2. Presentation of benthic macroinertébrate functional feeding groups

Table 3 Families and the Functional Feeding Groups of macroinvertebrates from the Yaah river

Family	Functional Feeding Groups	References	YA 1	YAA2	YAA 3	Occurrences
Hydrobiidae	Scrapers	[17]	2	2	0	66,67%
Elmidae	Scrapers	[17]	2	2	0	66,67%
Hygrobiidae	Scrapers	[18]	2	3	0	66,67%
Dryopidae	Scrapers	[18]	0	0	2	33,33%
Hydropsychidae	Filtering collectors	[2]	0	2	4	66,67%
Oligoneuriidae	Filtering collectors	[18]	0	4	4	66,67%
Simulidae	Filtering collectors	[17]	0	0	4	33,33%
Blaberidae	Shedders	[18]	5	30	17	100 %
Atyidae	Shedders	[17]	44	3	18	100 %
Potamonidae	Shedders	[17]	3	11	4	100 %
Haliplidae	Shedders	[18]	0	0	2	33,33%
Paleamonidae	Shedders	[17]	23	2	0	66,67%
Chironomidae	Gathering collectors	[17]	0	2	2	66,67%
lumbricidae	Gathering collectors	[18]	0	2	0	33,33%
Ecnomidae	Gathering collectors	[19]	0	2	1	66,67%
Caenidae	Gathering collectors	[17]	0	0	3	33,33%
Leptophlebidae	Gathering collectors	[17]	3	11	43	100 %
Baetidae	Gathering collectors	[17]	0	2	2	66,67%
Perlidae	Prédators	[19]	5	7	16	100 %
Athericidae	Prédators	[17]	0	0	2	33,33%
empididae	Prédators	[19]	0	0	2	33,33%
Hydrophilidae	Prédators	[19]	5	2	8	100 %
Gyrinidae	Prédators	[2]	8	12	23	100 %

Dytiscidae	Prédators	[2]	3	0	7	33,33%
Gerridae	Prédators	[2]	0	0	3	33,33%
Belostomidae	Prédators	[17]	53	12	19	100 %
Nepidae	Prédators	[2]	8	6	13	100 %
Hydrometridae	Prédators	[2]	2	1	0	66,67%
Mesoveliidae	Prédators	[2]	0	2	0	33,33%
Naucoridae	Prédators	[17]	9	1	3	66,67%
Vellidae	Prédators	[2]	6	0	2	66,67%
Libellulidae	Prédators	[17]	10	40	30	100 %
Aeshnidae	Prédators	[17]	0	0	2	33,33%
Gomphidae	Prédators	[17]	4	2	3	100 %
Calopterygidae	Prédators	[17]	3	35	15	100 %
Lestidae	Prédators	[17]	0	2	2	66,67%
Coenagrionidae	Prédators	[17]	13	27	27	100 %
Corduliidae	Prédators	[17]	5	1	1	100 %
38			218	228	284	

Table 3 shows that the 38 families of benthic macroinvertebrates identified were grouped into 5 functional feeding groups : the Scrapers (Hydrobiidae, Elmidae, Hygrobiidae and Dryopidae), filtering collectors (Hydropsychidae, Oligoneuriidae and Simulidae), the gathering collectors (Chironomidae, Lumbricidae, Ecnomidae, Caenidae, Leptophlebidae and Baetidae), the Shredders (Blaberidae, Atyidae, Potamonidae, Haliplidae, Paleamonidae) and the predators (Perlidae, Athericidae, Empididae, Hydrophilidae, Gyrinidae, Dytiscidae, Gerridae, Belostomidae, Nepidae, Hydrometridae , Mesoveliida, Naucoridae, Vellidae, Libellulidae, Aeshnidae, Gomphidae, Calopterygidae, Lestidae, Coenagrionidae and Corduliidae).

3.1.3. Proportions of different functional feeding groups

The circular diagram representation of the five trophic functional groups of benthic macroinvertebrates obtained shows the predominance of predators (63.29%) and shredders (22.19%). Gathering collectors (10,00%), filtering collectors (2.47%) and scrapers (2.05%) had the lowest relative abundances (Figure 4).

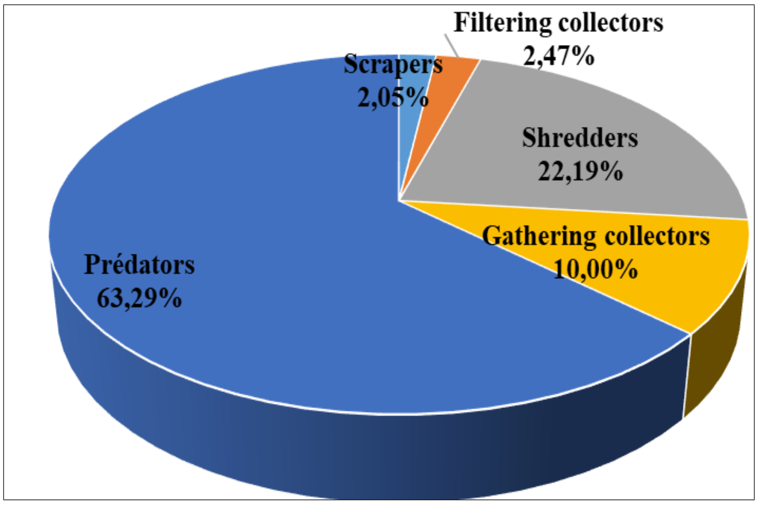

Figure 4 Relative abundance of Macroinvertebrate Functional feeding groups of river Yaah

3.1.4. Distribution of absolute abundances of benthic macroinvertebrates functional feeding groups

Table 4 Abundance of functional feeding groups (FFGs) of macro invertebrates in YA 1, YA 2 and YA 3 along Yaah river

Functional Feeding Groups	YA 1	YA 2	YA 3	min	max	Mean ± σ
Scrapers	6	7	2	2	7	5±2
Filtering collectors	0	6	12	0	12	6±6
Shredders	75	46	41	41	75	54±18
Gathering collectors	3	19	51	3	51	24±23
Prédators	134	150	178	134	178	154±22

The Table 4 shows the Abundance of functional feeding groups (FFGs) of macro invertebrates in YA 1, YA 2 and YA 3 along Yaah river. The predators are largely predominant in all three stations with a minimum value of 134 organisms at station YA 1, a maximum value of 178 organisms at station YA 3 and an average of 154±22 organisms. This dominance of predators is followed by shredders at station YA 1 and YA 2 and Gathering collectors at station YA 3. The absolute abundance of Shredders is high at station YA 1 (75 organisms), low at station YA 3 (41 organisms) and average is 54±18 organisms. The Filtering collectors are missing at station at the station YA 1 and have a high absolute abundance at the station YA 3 (12 organisms). The low abundance of Scrapers was recorded at station YA 3 (2 organisms), high abundance was observed at YA 2 (7 organisms) and the values average is 5±2 organisms. The Gathering collectors have low abundance at station YA 1 (3 organisms), a higher abundance at station and the YA 2 (51 organisms) and average value of 24±23 organisms.

3.1.5. Distribution of families by benthic macroinvertebrates functional feeding groups

Table 5 Number of families sampled by functional feeding groups in Yaah river stations.

Functional Feeding Groups	YA 1	YA 2	YA 3	min	max	Mean ± σ
Scrapers	3	3	1	1	3	2±1
Filtering collectors	0	2	3	0	3	1±1
Shedders	4	4	4	4	4	4±0
Gathering collectors	1	5	5	1	5	3±2
Predators	14	14	18	14	18	15±2

The Table 5 shows the number of families benthic macroinvertebrates functional feeding groups by station. Of the families grouped into scrapers, the station YA 3 has one family, the stations YA 1 et YA 2 each have 3 families and the average is 2±1 families. The stations YA 2 and YA 3 have respectively 2 and 3 families among those grouped together in filtering collectors. 4 families of 5 grouped Shredders were collected in each station. Of the families grouped into Gathering collectors only one was collected at station YA 1 and five at stations YA 2 and YA 3 and average is 3±2 families. At station YA 1 and YA 2 14 families sampled were grouped among predators and 18 families at station YA 3 and average is 15±2 families.

3.1.6. Variation in relative abundance of benthic macroinvertebrates functional feeding groups

Figure 5 shows that the relative abundances of scrapers and predators increase from YA 1 to YA 2 before decreasing at station YA 3. The relative abundances of shredders decrease from upstream to downstream while the relative abundances Filtering collectors increase from upstream to downstream. The Kruskal-Wallis H test is not significant difference between the season. the relative abundances Gathering collectors increase from upstream to downstream and Mann-Whitney U test shows that YA 1 is different from YA 3.

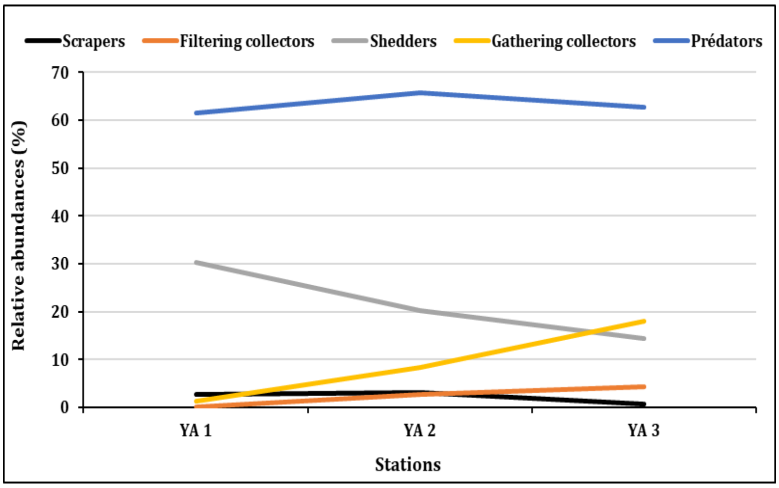

Figure 5 Distribution of functional feeding group of river Yaah

3.1.7. Diversity of benthic macroinvertebrates functional feeding groups

Table 6 Diversity indices of benthic macroinvertebrates functional feeding groups

Functional Feeding Groups	Simpson_1-D			Shannon_H			Equitability_J		
	YA 1	YA 2	YA 3	YA 1	YA 2	YA 3	YA 1	YA 2	YA 3
Scrapers	0,66	0,65	0	1,09	1,07	0	1	0,98	/
Filtering collectors	/	0,44	0,67	/	0,63	1,09	/	0,91	1
Shedders	0,55	0,51	0,62	0,98	0,93	1,10	0,71	0,67	0,79
Gathering collectors	0	0,62	0,28	0	1,264	0,64	/	0,78	0,39
Prédators	0,80	0,82	0,89	2,15	2,007	2,46	0,81	0,76	0,85

Table 6 shows that the values of the Simpson indices (1-D), Shannon and Weaver diversity and the Piélou equitability of the different functional groups of benthic macroinvertebrates vary from one station to another. The scrapers are diversified and evenly distributed at stations YA 1 and YA 2 but this diversity is zero at station YA 3 because of the presence of a single family : dryopidae. The Filtering collectors were absent at station YA 2 and are diversified and evenly distributed at stations YA 2 and YA3.The Shredders are quite diversified and are fairly well distributed across all the stations. The diversity of Gathering collectors sucks at the station YA 1 because of the presence of a single family (Leptophlebidae). But They are quite diverse and well distributed at station YA2 and weakly at station YA 3. the predators are diversified and well distributed across all stations.

Table 7 Correlation between environmental variables of benthic macroinvertebrates functional feeding groups

Functional Feeding Groups	Electrical conductivity	Suspended solids	ammonium	oxidizability
Scrapers	0,591*	0,019	0,05	0,603*
Filtering collectors	-0,008	0,027	0,172	-0,086
Shredders	-0,126	-0,714**	0,252	-0,203
Gathering collectors	0,577*	0,118	0,473	-0,089
Predators	-0,378	0,587*	-0,685*	0,049

The table 7 shows the Spearman correlations carried out between physicochemical variables and the relative abundances of benthic macroinvertebrates functional feeding groups show that scrapers are positively and significantly correlated with electrical conductivity and oxidizability ($P < 0.05$). There is a negative and significant correlation between Shredders and Suspended solids ($P < 0.01$). The Gathering collectors are positively and significantly correlated with electrical conductivity ($P < 0.05$) and predators are significantly and negatively correlated with Ammonium and positively with suspended solids ($P < 0.05$).

3.1.8. Functional feeding group ratio as surrogates for ecosystem attributes

Table 8 Ecosystem attributes based on ratio to functional feeding groups during the investigation period in river Yaah.

	YA 1	**YA 2**	**YA 3**
Primary production/Respiration community	0,09	0,1	0,02
Coarse Particulate Organic Matter/ Fine Particulate Organic Matter	22,03	1,84	0,65
Fine Particulate Organic Matter in transport/ Fine Particulate Organic Matter deposited in benthos	0	0,32	0,24
Habitat stability index	0,09	0,2	0,15
Top-down predator control to prey	1,78	1,92	1,68

The table 8 shows indicating ecosystem attributes based on ratio to functional feeding groups. The P/R ratio is less than 0.75 in all stations, suggesting that the study area is heterotrophic. All stations had a CPOM/FPOM ratio greater than 0.25 which indicates these areas are functional. The TFPOM/BFPOM ratio is greater than 0.5 in all the stations showing that the fine particles were mainly located on the sediments at the stations. The channel stability index is less than 0.5 in all stations showing that the stations are not stable and suitable habitats for feeding groups of benthic macroinvertebrates. All stations have a P/P ratio greater than 0.2 indicating the predominance of predators.

4. Discussion

The low temperature value obtained at station YA 1 during the study period (20.9-°C) would result from the low air temperature due to the mountainous terrain. For this purpose, [20] emphasize that the temperature of running water follows that of the air. The pH of the YA 1 station tend towards neutrality, which corroborates with the results of [21] on Mv and Sg watercourses of Mvila. The high conductivity values obtained at station Ya 3 (92.65 µS/cm) could be explained by the high mineralization of the water due to the degradation of the organic matter present in the environment. According to [10], conductivity is higher downstream of rivers. However, these values remain low [10] reflecting low mineralization of the watercourse [22]. The high ammoniacal nitrogen values of 0.95 mg/l obtained at station YA 2 could be explained by the presence of organic matter of plant origin (dead leaves, wood, etc.). According to [10] Ammonium in surface waters may originate from plant matter in rivers. The maximum content of suspended matter in water (16.5 mg/l) is less than 25 mg/l, therefore ideal for lotic environments. According to [10] Outside of flood periods, the suspended solids content is almost always less than 25 mg/L.

This study showed that there was a wide diversity of functional feeding groups, namely: Filtering collectors, Scrapers, Shredders, predators and Gathering collectors. The same observation was made by [2, 7]. Results showed that predators were the predominant functional feeding group with relative abundance (63.29%) followed by Shredders (22.19%) and scrapers had the lowest relative abundance (2.05%). These results contrast with those obtained by [7] where we noted the predominance of Gathering collectors, [23] where we noted the predominance of Filtering collectors. The predominance of predators could be explained by the availability of prey in each site and the presence of riparian vegetation which was used by certain predators such as Odonata as a hunting ground for food [24]. Good riparian quality sites have higher abundances of predators feeding functional groups [25]. The proportion of shredders is not consistent with the comments of [26] who states that certain studies have revealed that tropical rivers host few or almost no shredders compared to temperate rivers. This difference could be explained according to [27] by the fact that certain tropical watercourses devoid of shredders insects host equivalent taxa which ensure the decomposition of litter and this is the case of families Atyidae, Paleamonidae and Potamonidae which represent a very large proportion of Shredders. The low relative abundance of scrapers could be explained by the low speed of the water current which facilitates the sedimentation and burial of algae and the absence of coarse substrates which ensure better immobility over time and more stable colonization. Indeed, scrapers feed on periphyton, non-filamentous algae, particularly diatoms, attached to stable surfaces [17]. The relative abundance of Filtering collectors is zero at station YA 1 and decreases from station YA 2 to YA 3 while the relative abundance of Shredders decreases from upstream to downstream. According to [28] in waterways, dead leaves are easily washed away, colonized and decomposed by microorganisms, and consumed by Shredders and these processes lead to the production of fine particulate organic matter (FPOM), which is consumed by a series of collecting organisms. In addition, the input of coarse organic particles (leaf litter) is generally high in the upper part of the watercourse, which affects the relative density of Shredders [28]. The distributions of scrapers and predators do not conform to the RCC which predicts an increase in scrapers from upstream to downstream and a slight decrease in the relative abundance of predators and a decrease in collectors. According to [29], the application of the RCC model to tropical rivers generally led to divergent conclusions. The increase in upstream Gathering collectors could be explained by the increase in the intensity of agriculture from upstream to downstream. According to [30], open stations with a large part of the river basin drain agricultural land where particulate organic matter tends to be high, providing sufficient FPOM. Predators are positively and significantly correlated with suspended matter. Indeed among predators, families Libellulidae, Belostomidae, Calopterygidae and Coenagrionidae were more dominant and [31, 32] found a positive correlation between these families and suspended solids.

Functional group classification is also useful for examining ecologically relevant associations at the community level with physical habitat [23]. The P/R ratio shows that all sampled stations were purely heterotrophic. Recorded heterotrophic conditions show that the carbon comes from the decomposition of riparian organic matter that enters or falls into the river and not from algal blooms [33]. These results do not differ from those obtained by [2, 23]. The predominance of heterotrophy over autotrophy could be explained by the absence of microhabitats and nutritional resources which would favor the development of periphytons which constitute the diet of scrapers. The CPOM/FPOM ratio greater than 0.25 shows that the study area was favorable to shedders. CPOM/FPOM ratio decrease from upstream to downstream and conforms to RCC which describes that the values of the ratio CPOM/FPOM decrease as river order increase. These result are similar to those obtained by [28]. The TFPOM/BFPOM report showed that the fine particles found in the YA 1 stations were mainly fixed in the sediments. In fact, the low speed of the water current favors the sedimentation of suspended particles becoming available to collectors. Furthermore, unlike Filtering collectors who are not very diversified and sensitive, collectors are more diversified and more resistant.

5. Conclusion

At end of this work, 5 benthics macroinvertébrates functional feeding groups identified and among them the predators and shedders were largely predominant in all stations sampled. The distribution of Filtering collectors, Shredders and Predators respect the RCC predictions. Suspended solids disadvantaged shedders and favored predators. Some river ecosystem attributes of Yaah River headwater support macroinvertebrate life and are not in accordance with RCC. Overall, results offered evidence that RCC may predict macroinvertebrate benthic community structures in terms of functional feeding groups.

Compliance with ethical standards

Disclosure of Conflict of interest

No conflicts of interest to be disclosed.

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