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First report on the macrophyte and benthic macroinvertebrate communities of the Parcours Vita leisure lake of the City of Douala (Cameroon)

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Abstract

Macrophytes and benthic macroinvertebrates, which play a functional role in hydrosystems, area also used as indicators of the quality of aquatic environments. The main objective of this study was to provide an initial overview of the diversity of macrophyte and benthic macroinvertebrate communities, associated with a number of abiotic variables in Parcours Vita Lake, located in the city of Douala in Cameroon. Overall, 24 species of macrophytes belonging to 18 families were recorded. The most represented family was Asteraceae with 03 species. The benthic macroinvertebrate communities were made up of the Arthropod (70.04%) and Mollusc (29.96%) phyla, grouping together 22 families, essentially from the Insect and Gastropod classes. The low values obtained for the Shannon and Weaver diversity indices reflected a major unevenness in the macrophyte and invertebrate communities at the various study stations. The Organic Pollution Index (OPI) revealed a high load of organic matter at station S2 (2.50). Similarly, the load was lower at stations S1 (2.75) and S3 (2.75), corresponding to a high level of organic pollution in the water at all three sites. This study has highlighted the threats to the functional dynamics of Parcours Vita Lake, which could compromise the sustainability of the current fish farming project and the development of an ecotourism activity.

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Introduction

Shallow lakes and water bodies provide a wide range of ecosystem services to society, ranging from the production of water for drinking and housing rich and supply diverse populations of communities living at riverside with fish, crustaceans and other edible species (Janssen *et al*., 2020). Along with other hydrosystems, they are essential elements in the structuring of the landscape and living environment (Lévêque, 1996; Jobin *et al*., 2013). As they can be the cause of some conflicting purposes, management methods that are capable of meeting the needs of conservation, protection and science need to be implemented among others, all at the same time.

Submerged macrophyte communities play a crucial role for lower animals and plants in aquatic ecosystems by providing a complex habitat, shelter, a reproduction zone as well as being substrates and sites of abundant food production for numerous aquatic animals (Zimmer *et al.,* 2000; Rennie and Jackson, 2005). Aquatic macrophytes play an important role in the ecological functioning of hydrosystems, which strongly links them to the conditions of these environments (Daniel and Haury, 1996).

Benthic macroinvertebrate communities are heterogeneous assemblages of numerous phyla. They generally live on the surface and in the first few centimetres of the substrate at the bottom of streams, rivers, lakes, ponds or marshes (Tachet *et al*., 2010; Moisan, 2010; Nyamsi Tchatcho *et al*., 2024). Because of their sedentary nature, varied life cycle, high diversity and variable tolerance to pollution and habitat degradation, benthic macroinvertebrates are also recognised as good indicators of the health of aquatic ecosystems (Tachet *et al*., 2010; Moisan, 2010). The almost universal use of macroinvertebrates in pollution assessment and the multiplicity of existing methods and indices attest to their value in water quality management (Hellawell, 1986).

There are many attributes of macrophytes, operating at different scales that can affect the abundance, diversity and composition of invertebrate communities (Papas, 2007). It is therefore important to gain a better understanding of the impacts of submerged macrophytes on the diversity of benthic invertebrates in the Parcours Vita recreational lake, with a view to ensuring the sustainability of the various developments planned there. In fact, the municipal authorities, together with those in charge of conservation, are considering making this site an area of ecotourism interest due to the presence of a number of Varanids, chelonians, rodents, various birds and herds of monkeys, including cercopithecines, which are on the IUCN red list (Ngouonpe, 2010). In addition, activities are taking place in preparation for the imminent introduction of a large scale fish farming project.

Few studies have reported the influence of macrophytes on the diversity of invertebrates in lacustrine and limnic ecosystems of intertropical zone. Indeed, in many developing countries such as Cameroon, aquatic resource management is still in its early stage (Kouam Kenmogne *et al*., 2006). This article is a contribution to our knowledge of the macrophyte and benthic macroinvertebrate communities that proliferate in Parcours Vita Lake, and the links that develop between the various components and the physico-chemical parameters of the water.

Materials and methods

Presentation of the study area and selection of sampling sites

More precisely in the agroecological forest zone with monomodal rainfall and corresponds administratively to the Douala V district. It lies 30 km from the shore of the Atlantic Ocean, at the bottom of the Gulf of Guinea. Its geographical coordinates are: latitude 4°02'53'' North and longitude 9°42'15'' East, with an altitude of 19 m above sea level (PDU/POS Douala, 2011). The area around the lake is occupied by a rich and dense herbaceous community that covers the slope and foot of the basin slope.

As part of this study, three stations were chosen to represent the different facies of the lake (Fig. 1). Station 1, designated S1, with geographic coordinates of latitude 04°05'01.1''N and longitude 009°44'33.1''E. This is an area that is not very popular with sportspeople but is easily accessible on foot. The entire slope of the lake is covered in grass. This part of the lake is the site bearing the proposed fish farm infrastructures.

Station 2, labeled S2, with geographic coordinates of 04°04'57.6''N latitude and 009°44'35.4''E longitude, is the area where boats are stored (pedal boats, jet skis, etc.). It is also the restaurant areas and restaurant owners discharge their waste directly into the lake at this section. Similarly, near are sports hall and a children's playing ground.

Station 3, marked S3, with geographical coordinates 04°04'55.7''N latitude and 009°44'32.5''E longitude, difficult to access by foot. Here, we can see banana plants, bearing witness to the fact that this area is frequented by a few local residents. In the distance, towards the inner edge of the slope, dwellings can be seen whose waste from activities could end up in the lake due to various types of transport.

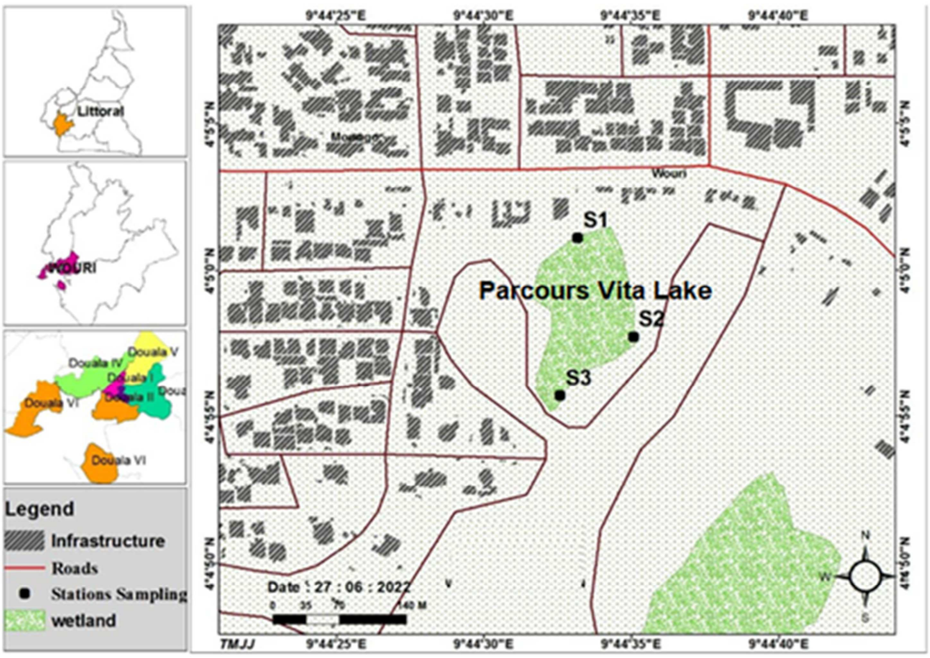

Fig. 1. Map of the studied sites showing Parcours Vita Lake

Data collection and analysis

Water samples for physico-chemical measurements and the collection of macrophytes and benthic macroinvertebrates at the various study stations were taken in 3 campaigns spanned from May to June 2022.

Sampling and analysis of physico-chemical parameters

Physico-chemical parameters were measured both in the field and in the laboratory following the recommendations of APHA (1985) and Rodier *et al.* (2009). Temperature (T°C), pH, dissolved oxygen (O_2), electrical conductivity (Cond), turbidity (Turb), suspended solids (SS) and salinity (Sa) were measured *in situ* using an alcohol thermometer and a HACH HQ30d flexi portable multimeter respectively. In each sampling station, two (2) measurements were made for subsurface (1m) and bottom water to reduce the atmospheric forcing. By so doing, the mean value for the physico-chemical parameter was recorded after averaging these measurements. Equally, the daily mean value was computed by averaging the morning, mid-day and evening measurements. Water samples were also collected following the daily time scale and were carried to the laboratory for further analysis. Samples for analysis of chemical parameters were collected at the same time with the macrophytes and macroinvertebrates.

In the laboratory, orthophosphate ions and forms of nitrogen were measured using the HACH DR/2000 spectrophotometer and BOD_5 by respirometry from water samples taken in the field using 1000-mL double-capped polyethylene bottles. The organic matter load of the water was assessed by calculating the Organic Pollution Index (OPI) (Leclercq and Maquet, 1987).

Macrophyte sampling and analysis

The Macrophyte sampling was carried out in the three (03) stations chosen on the basis of a longitudinal gradient (systematic sampling technic). From one end of each station to the other, a specific and quantitative inventory was carried out using transects (25 m^2). These surveys were carried out in disturbed or undisturbed environments with apparently uniform ecological conditions. The boundaries of the transect to surveys were set so as to avoid areas of contact between them. The choice of transect positions was based on the most significant plant cover from both a qualitative and quantitative point of view, and on accessibility. After the transect had been marked out, the species recorded were assigned an Abundance-Dominance coefficient corresponding to the percentage of spatial cover of each species. From the three (3) transects taken, a total of 2911 individuals plants were counted. Once the unidentified species were collected, they were transported to a herbarium to facilitate the identification of species whose scientific names were not known in the field. All the species names were then classified in a table and the data obtained were translated into simple structure variables (taxonomic richness and Shannon and Weaver's taxonomic diversity index and Piélou's evenness Index).

Sampling and analysis of benthic macroinvertebrates

The benthic macroinvertebrates at these study stations were collected using a 30 cm x 30 cm dip net fitted with a conical net with a mesh opening of 400 µm and a depth of 0.5 m. At each study station, around twenty dip net strokes were made to collect specimens from the various microhabitats identified in the area of the lake embankment. From the 6 samples taken, a total of 227 individuals were counted. The organisms collected were fixed in 10% formalin in glass pillboxes. In the laboratory, the specimens were washed in running water and then preserved in 70° alcohol before being identified and counted. All the benthic macroinvertebrates were determined, under a Wild M5 binocular loupe, up to family, genus or species level, using the identification keys proposed by Durand and Levêque (1991), Tachet *et al.* (2006) and Moisan (2010).

Parameters studied and data processing

Organic pollution index (OPI)

In order to evaluate the organic matter load at each station, the organic pollution index (OPI) was calculated following the protocol described by Leclercq (2001). The OPI was obtained by a mathematical computation of the mean values of ammonium, nitrite and orthophosphate. The principle of the calculation is to assign the mean value of each of these three parameters into the corresponding quality class number and then compute the arithmetic mean value of the number assign to each class to have the OPI value which ranges from 1 to 5.

Macrophytes and macroinvertebrate community structure indices

To characterize the structure of the macroinvertebrate community, we used taxonomic metrics such as: taxonomic richness, EPT index (Ephemeroptera-Plecoptera-Tricoptera), taxonomic abundance, percentage of Chironomids, Sorensen's similarity coefficient. As ecological indices, we calculated, for Macrophytes and Macroinvertebrate community, the Shannon & Weaver diversity index

(H') and the Piélou evenness index (J) with PAST® Software version 1.0.0.0 (Hammer *et al.*, 2001). The Hilsenhoff Biotic Index (HBI) was also calculated using the following formula:

$$\textbf{HBI} = \sum_{i=1}^{n} \frac{\textbf{Xi Ti}}{n}$$

Xi = number of individuals of the i -th taxon; Ti = tolerance of the i -th taxon and n = number of individuals in the sample.

HBI characterizes the sensitivity of organisms to organic pollution. Finally, the Principal Component Analysis to determine the linkage between water quality parameters, Macroinvertebrates and Macrophytes was undertaken using the XLSTAT 2017 software.

Results

Physico-chemical quality of parcours vita lake water

The variation in physico-chemical parameters over the period of observation was obtained and given as an overall assessment of water quality in the Parcours Vita Lake (Table 1). The Anova test applied to the various physico-chemical parameters showed that, with the exception of temperature, pH, dissolved oxygen and electrical conductivity, all the others showed a significant differences (P = 0.05) in their spatial evolution in the lake. The temperature of the water in the Parcours Vita Lake varied between 30.36°C (S3) and 30.40°C (S1), with an average value of 30.38 ± 0.02°C. The water pH showed a basic character, with an average pH value of 8.15 ± 0.26, the extreme values being 8.01 at S3 and 8.26 at S1. The dissolved oxygen content varied between 46.53 mg/l in S2 and 51.167 mg/l in S1, with an average of 48.17 ± 2.60 mg/l. The highest phosphate ion content was obtained in S2 (0.26 mg/l), followed by S3 (0.19 mg/l) and S1 (0.15 mg/l). Changes in ammoniacal nitrogen content were 0.79 mg/l, 0.65 and 0.59 respectively at Stations S1, S2 and S3. With an average value of 1.17 ± 0.00 mg/l, the nitrate ion content showed no variation at the three study stations. The concentration of nitrite ions peaked at S1 (4 mg/l), while the other two (S2 and S3) were at 3 mg/l. Average conductivity was 137.67 ± 0.58µS/cm with 137.33 µS/cm at S1 and S2, and 138.33 µS/cm. Mean turbidity was 40.11 ± 15.45 NTU with 54.33 NTU in S1 and 23.67 NTU in S3. TSS averaged 32.86 ± 1.20 mg/l, with the highest value recorded in S2 (34.20 mg/l) and the lowest in S1 (31.88 mg/l). BOD5 averaged 9.33 ± 0.88 mg O_2/l, with the highest value recorded in S1 (10.00 mg O_2/l) and the lowest in S2 (8.33 mg O_2/l). With an average value of 0.06 ± 0.00 mg/l, water salinity remained constant at the three study stations in the waters of Parcours Vita Lake.

Table 1. Values of physico-chemical parameters obtained at the various study stations level of the study area

Parameters	Study stations			Mean ± sd
	S1	S2	S3	
T°C	30.40	30.39	30.36	30.38 ± 0.02
pH	8.26	8.16	8.01	8.15 ± 0.12
O_2	51.17	46.53	46.80	48.17 ± 2.60
Cond	137.33	138.33	137.33	137.67 ± 0.57
Sal	0.06	0.06	0.06	0.06 ± 0.00
Res	0.01	0.01	0.01	0.01 ± 0.00
MES	31.88	34.20	32.51	32.86 ± 1.20
Turb	54.33	42.33	23.67	40.11 ± 15.45
NO_3^-	1.17	1.17	1.17	1.17 ± 0.00
NO_2^-	4.00	3.00	3.00	3.33 ± 0.58
PO_4^{3-}	0.15	0.26	0.19	0.20 ± 0.05
NH_3	0.59	0.65	0.79	0.68 ± 0.10
DBO_5	10.00	8.33	9.67	9.33 ± 0.88

sd=standard deviation

The Organic Pollution Index (OPI) for the various study stations revealed a higher organic matter load in the water at station S2 (IPOS2=2.50), while the load was lower at stations S1 and S3, with an OPI of 2.75 each (Table 2). However, these values obtained at the three stations correspond to a state of high organic pollution of the water.

Table 2. Average OPI value calculated for each of the sampling stations in the lake

Station	S1	S2	S3
Average OPI	2.75	2.50	2.75
Quality class	High levels of organic pollution		

Macrophyte population of parcours vita lake

Macrophyte species richness

The general physiognomy of the vegetation of Parcours Vita Lake reveals that 24 species of macrophytes belonging to 18 families have been recorded. The most represented family is Asteraceae (03 species), followed by Cyperaceae (02 species), Fabaceae (02 species), Moraceae (02 species) and Poaceae (02 species), while the remaining 13 species each represent 01 different family (Table 3). Quantitatively, the percentage representation of the species inventoried indicates that the Macrophyte population of the lake studied is dominated by the Asteraceae families (12.50%), followed by Cyperaceae, Fabaceae, Moraceae and Poaceae, each with 8.33% of the taxonomic richness. The remaining species each represent 01 family for a percentage of 4.17% (Table 3).

Table 3. Number of individuals of each macrophyte taxon collected at the various sampling stations

Family	Species	S1	S2	S3	Total	Proportion of representativeness (%)
Acanthaceae	*Eremomastax speciosa*	0	2	8	10	4.167
Arecaceae	*Elaeis guineensis*	0	27	9	36	4.167
Asteraceae	*Chromolaena odorata*	92	23	0	115	12.5
	Synedrella nodiflora	279	0	7	286	
	Eclipta prostrata	103	2	6	111	
Commelinaceae	*Commelina cameroonensis*	2	16	0	18	4.167
Convolvalaceae	*Ipomea* sp.	100	50	173	323	4.167
Cyperaceae	*Cyperus* sp.	2	0	0	2	8.333
	Cyperus pinguis	115	89	0	204	
Euphorbiaceae	*Alchornea cordifolia*	76	34	9	119	4.167
Fabaceae	*Centrosema* sp.	32	16	198	246	8.633
	Desmodium adscendens	0	11	0	11	
Melastomataceae	*Dissotis decumbens*	4	0	0	4	4.167
Moraceae	*Ficus microcarpa*	28	0	0	28	8.333
	Ficus sp.	115	0	30	145	
Onagraceae	*Circaca lutetiona*	6	0	90	96	4.167
Oxalidaceae	*Oxalis barrelieri*	13	27	0	40	4.167
Phyllanthaceae	*Phyllanthus amarus*	37	90	0	127	4.167
Poaceae	*Panicum maximum*	90	50	250	390	8.333
	Axonopus compressus	350	23	0	373	
Rubiaceae	*Spermacoce* sp.	0	0	28	28	4.167
Solanaceae	*Solanum torvum*	11	0	64	75	4.167
Tectariaceae	*Arthropteris* sp.	0	102	9	111	4.167
Urticaceae	*Lapotea avaliflora*	10	0	3	13	4.167
	Total	1465	562	884	2911	100%

Macrophyte population structure at the various sampling stations during the study period

The 24 families of macrophytes recorded in the Parcours Vita lake show that the distribution of these plants is almost identical throughout the ecosystem (Fig. 2). However, the most diverse station was S3 (11 families) followed by stations S1 and S2 are diverse (13 families). Observations show that, the structure of the macrophyte population appears stable at stations S1 and S2, with a preponderance of Asteraceae, Commelinaceae, ConvolvaLaceae, Cyperaceae, Fabaceae, Oxalidaceae and Poaceae (Fig. 2). Oppositely, the families Asteraceae, Convolvalaceae, Euphorbiaceae, Fabaceae and Poaceae were present in S1, S2 and S3. On the other hand, the Melastomataceae and Rubiaceae families are only found respectively at stations S1 and S3, which would be favourable for their establishment (Fig. 2).

The value of the Shannon and Weaver taxonomic diversity index varied from one station to another (H'S1=3.7, H'S2=3.41 and H'S3=2.78. The Piélou index is relatively lower at all the sites (J'S1=0.31, J'S2=0.36 and J'S3=0.28), indicate an imbalance in the populations at the various study stations. Generally, values below 0.5 indicate a poor distribution of species throughout the lake, with the domination of certain groups within the populations.

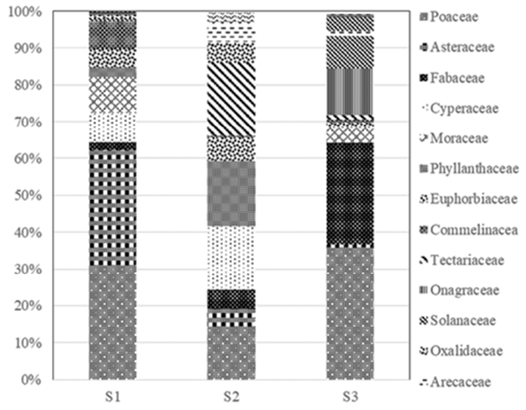

Fig. 2. Distribution of macrophytes by family at different sampling sites

Benthic macroinvertebrate community of the lake parcours vita

Global inventory of the benthic macroinvertebrate population

From the 6 samples taken, a total of 227 individuals were counted and identified for 22 families, 9 orders and 2 classes (Table 4). The benthic macroinvertebrates identified and counted at the various sites in the Parcours Vita Lake belong exclusively to the phyla of Arthropoda (70.04%) and Mollusca (29.96%), and respectively belong to the Insect and Gasteropoda.

Of the 22 benthic invertebrate families identified, 18 (81.82%) belong to the class of Insects, and 4 (18.18%) to the class of Gastropods. The insect taxa of the EFA orders, which are sensitive to pollution and any degradation of the natural environment, are represented by 4 families, or 18.18% of the taxonomic richness (Table 4).

In terms of numbers, Insects dominate this population with 70.04% of the individuals counted, while Gastropods represent 29.96% (Table 4). At the taxonomic level represented by the category of orders, the quantitative distribution of individuals indicates a dominance of Ephemeroptera (21.59%), Hemiptera (21.15%), Coenogasteroptera (15.86%), Basomatoptera (14.10%), Coleoptera (10.57%) and Odonata (8.81%) followed by Plecoptera (4.41%), Trichoptera (3.08%) and Diptera (0.44%) (Fig. 3). EPT taxa (Ephemeroptera, Plecoptera and Trichoptera) make up 29.07% of the taxonomic abundance of the lake (Fig. 3).

Table 4. Number of individuals of each taxa of benthic macroinvertebrates collected at the different sampling sites

Branch	Class	Order	Family	S1	S2	S3	Total
Mollusca	Gasteropoda	Coenogasteropoda	Thiaridae	8	12	16	36
		Basomatophora	Physidae	3	3	4	10
			Planorbidae	5	3	7	15
			Lymnaeidae	2	3	2	7
Arthropoda	Insecta	Coleoptera	Chrysomelidae	1	0	0	1
			Curculionidae	1	0	3	4
			Elmidae	1	1	0	2
			Noteridae	1	0	0	1
			Dytiscidae	0	7	9	16
		Diptera	Simulidae	1	0	0	1
		Hemiptera	Nepidae	0	0	3	3
			Gerridae	7	5	1	13
			Naucoridae	2	8	6	16
			Mesovellidae	2	0	1	3
			Notonectidae	3	5	5	13
		Odonata	Lestidae	3	0	0	3
			Cordulegasteridae	2	0	11	13
			Coenagrionidae	2	0	2	4
		Ephemeroptera	Baetidae	10	14	25	49
		Plecoptera	Perlidae	6	4	0	10
		Trichoptera	Phylopotamidae	0	0	3	3
			Psychomyiidae	0	0	4	4
Total				60	65	102	227

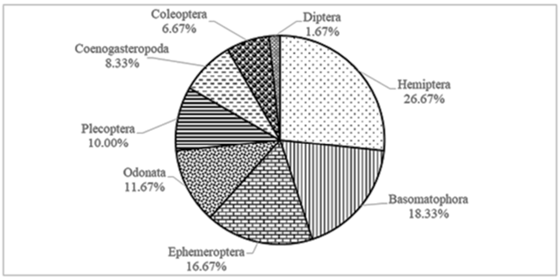

Fig. 3. Distribution of the relative abundance of the different orders of benthic macroinvertebrates

The centesimal frequency of specimens collected indicates that the population of benthic macroinvertebrates in the rivers studied is dominated by the families Baetidae (21. 59%), Thiaridae (15.86%), Dyticidae (7.05%), Naucoridae (7.05%), Planorbidae (6.61%), Gerridae (5.73 %), Notonectidae (5.73%) and Cordulegasteridae (5.73%). The Physidae (4.41%), Perlidae (4.41%) and Lymnaeidae (3.08%) families are considered influential, while the 11 others are considered resident.

Benthic macroinvertebrate population structure at the various sampling stations during the study period

The benthic macroinvertebrates collected from one station to another generally maintained the same distribution by phylum (Table 5), with an average of 68.35±4.99 % Arthropods and 31.64±4.99% Molluscs. However, there was an increase in the proportion of Molluscs at station 3 with 37.25% (Table 5). With 22 families of benthic macroinvertebrates identified, station S1 (19 families) was the richest, followed by station S3 (14 families) and S2 (11 families).

Table 5. Distribution of individuals identified by branch at the various stations in the Parcours Vita Lake

Phylum	Frequency of individuals harvested (%)		
	S1	S2	S3
Arthropods	70.00	72.31	62.75
Mollusca	30.00	27.69	37.25

A relatively stable population structure was observed for the different orders of Macroinvertebrates recorded, with a preponderance of Hemiptera, Ephemeroptera, Coenogasteroptera, Basomatophora and Coleoptera, whose cumulative relative abundance was 76.67% at station S1, 93.85% at station S2 and 80.39% at station S3 (Fig. 4). Odonates were present only at S1 and S3, Plecoptera at S1 and S2, while Diptera and Trichoptera were collected exclusively at S1 and S3 respectively (Fig. 4). Station S3 appears to be more favourable for the establishment of taxa sensitive to pollution and any form of alteration of the environment (7 families of EPT). It is followed by station S1 (6 EPT families) and S2 (4 EPT families) (Fig. 4).

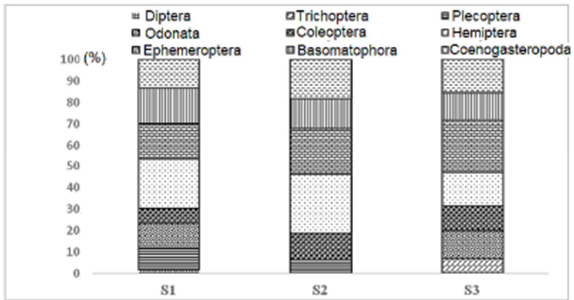

Fig. 4. Seasonal variations in the relative abundance of different orders of benthic macroinvertebrates

Calculation of the Shannon and Weaver taxonomic diversity index (H'S1=3.81, H'S2=3.17 and H'S3=3.46) and the Piélou evenness index (J'S1=0.87, J'S2=0.92 and J'S3=0.91) confirms this relative stability of the population at the various stations selected. The Hilsenhoff biotic index was 4.67, 4.54 and 4.48 respectively at stations S1, S2 and S3, reflecting good water quality with probable organic pollution.

Physicochemical and biological interference in the waters of the parcours vita lake

Principal component analysis reveals a clear demarcation between the three (03) sampling stations. Station 1 (C1S1) is characterised by the preponderance of macrophytes from the Asteraceae, Moraceae, Poaceae and Cyperaceae families (55% of the lake's macrophyte population), which are positively correlated with pollutant-sensitive invertebrates from the Perlidae and

Gerridae families, as well as physic-chemical parameters such as dissolved oxygen content, temperature, pH and turbidity (Fig. 5).

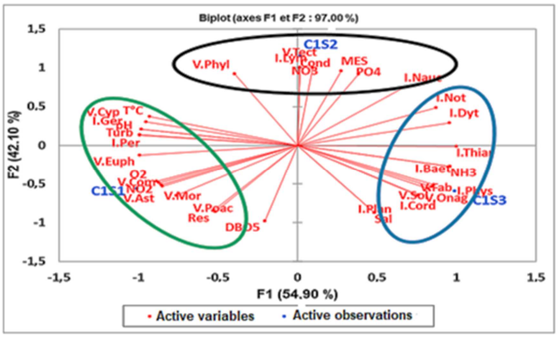

Fig. 5. Principal component analysis (PCA) physico-chemical parameters, Macrophytes and Macroinvertebrates

Station 2 (C1S2) is dominated by Macrophytes of the Phyllanthaceae and Tectariaceae families (18% of the total lake population). These two families of Macrophytes are positively correlated with invertebrates of medium tolerance from the Naucoridae and Lymneidae families, as well as with electrical conductivity, suspended matters (MES) and NO^{3-} and PO_4^{3-} ions (Fig. 5).

Lastly, station 3 (C1S3) revealed the preponderance of three families of macrophytes: Solanaceae, Onagraceae and Fabaceae (27% of the total lake population). They are positively correlated with families of invertebrates of different sensitivities, in particular polluosensors (Cordulegasteridae and Baetidae) and polluotolerants (Dyticidae, Planorbidae, Physidae), as well as ammonia and salinity to a lesser extent (Fig. 5).

Discussion

The temperature of the water in Lac Parcours Vita is particularly warm (30.38±0.02°C), which is consistent with the lentic nature of the environment, where the water is more exposed to solar radiation due to low flow velocities and the shallow nature of the lake (Grégoire and Trencia, 2007; Souchon and Nicolas, 2011). Overall, analysis of the physico-chemistry reveals that the water has a high organic matter load, indicating that the lake is subject to numerous pressures (Pellet, 2005; Morin-Crini, 2017).

Macrophytes found on the Parcours Vita Lake include Asteraceae, Cyperaceae, Euphorbiaceae, Fabaceae and Moraceae. Species richness and diversity values are high from upstream to downstream. Nwamo (2019) came to the same conclusion after working on the Kondi and Tongo Bassa. The more degraded the environment, the less diverse it is Haslam and Wolseley (1987). This assertion makes sense insofar as the observations made on the Parcours Vita Lake reveal the various anthropogenic pressures to which it is subjected in its upstream section. In addition, there is a structuring of macrophytes between upstream and downstream, which is mainly due to the variation in some physico-chemical parameters specific to each station through exogenous inputs of different origins.

However, we can also note the action of floods which transport various mineral and physical elements. This action further damage the vegetation as highlighted by Willby (2000) and hence increases the suspended material and organic loads. Barendregt and Bio (2003) went further, pointing out that light, temperature and velocity, as well as phosphorus, nitrogen and inorganic carbon, are factors that influence macrophytic growth in small rivers. Breugnot *et al.* (2004) confirm this result by stating that macrophyte growth seems to be more sensitive to the physical environment downstream when nutrients are no longer the limiting factor. Chatenet *et al.* (2000) also showed by comparing the Limousin and Elorn (Finistère) rivers, that phytocenoses react strongly to point source pollution, more at the level of sub-associations and facies than in terms of changes in associations.

Benthic macroinvertebrates collected in lake Parcours vita were distributed in favour of the Arthropod phylum (68.35±4.99%), followed by Molluscs (31.64 ±4.99%). This proportion in favour of the development of Molluscs supports the idea that the lake is undergoing anthropisation. Indeed, Foto

Menbohan *et al.* (2010) and Nyamsi Tchatcho (2018) attribute the appearance of Molluscs and Annelids in aquatic ecosystems in the intertropical zone of Africa to anthropisation.

Macrophytes from the families Asteraceae, Moraceae, Poaceae and Cyperaceae were positively correlated with invertebrates from the family Perlidae, whose tolerance status classifies them as very demanding specimens sensitive to the oxygen content of the water (Mandaville, 2002; Moison, 2010; Tachet *et al.*, 2010). Similarly, macrophytes from the Phyllanthaceae and Tectariaceae families were positively correlated with invertebrates of average tolerance from the Naucoridae and Lymneidae families (Mandaville, 2002; Moison, 2010; Tachet *et al.,* 2010). These different colinearities open up new perspectives in terms of bioindication, particularly with regard to the macrophyte species specifically involved in these associations. The existence of a species in a given location very often depends on its ability to settle and adapt to environmental conditions (Nwamo, 2019). The distribution of different plant species within an ecosystem depends on the combined action of all the environmental, chemical, physical and climatic factors (Khedr and El-Demerdach, 1997). In addition, macrophytes as biological indicators offer the advantage of being visible to the naked eye and their taxonomic identification is less time-consuming, abundance can be expressed in terms of cover and, in some cases, remote sensing can be used to determine plant cover (Brabec and Szoszkiewicz, 2006).

Conclusion

This study is a contribution to our knowledge of the communities of benthic macrophytes and macroinvertebrates that proliferate in Parcours Vita Lake, as well as the links that develop between these compartments and the physic-chemical parameters of the water in this body of water in the city of Douala in Cameroon. Analysis of the physico-chemical parameters of water revealed high levels of organic matter overall, indicating that the lake is subject to numerous pressures. In addition, we observed an imbalance in the Macrophyte population at the various study stations with Asteraceae dominating. This may be link to the physico-chemical characteristics specific to the stations studied and in conjunction with exogenous inputs of different origins resulting from various anthropogenic pressures. The benthic macroinvertebrates collected in the Parcours Vita Lake showed a distribution favourable to the emergence of the phylum Mollusca, supporting the idea that the lake is undergoing anthropisation. The principal component analysis, which revealed strong colinearities between macrophyte families and Macroinvertebrate taxa that are indicators of the state of the environment, opens up new perspectives in terms of bioindication for better monitoring of hydrosystems. This preliminary study have highlighted the threats facing the Parcours Vita Lake, which could compromise the sustainability of the fish farming project currently underway, as well as that related to the development of an ecotourism activity on the site.

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