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Occurrence and nutrient retention of aquatic macrophytes in roadside streams in the Mount Cameroon region

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Abstract

Roadside streams in the Mount Cameroon region are predisposed to nutrient enrichment from different anthropogenic activities carried out around catchment areas. The composition and diversity of aquatic macrophytes in three roadside streams in the MCR, the biomass, and nutrient accumulation of the most abundant aquatic macrophytes in one of the streams were assessed in order to better understand and quantify the benefits accruing from these macrophytes. Vegetation sampling was carried out along the transects at 50 m intervals, within which plots were laid. Quadrats of 1m by 1m were sub-sampled within each plot and all plants were identified and enumerated. Water, sediment, and plant samples were collected and analysed for nutrients using standard procedures (nitrogen and phosphorus). The results show that the aquatic vegetation of the roadside streams is limited to emergent (> 98%) and floating-leaved life forms. A total of 47 aquatic macrophytes from 18 plant families were identified from the 3 studied wetlands in the Mount Cameroon region. Plant taxa with many representative species included Poaceae (8 species), Araceae (6), Acanthaceae (5), and Asteraceae (4). A high Shannon-Wiener diversity was recorded across study sites ($H \geq 2.9$) with the highest in Ombe and the least in Bota. *P. purpureum* showed significantly higher biomass ($p < 0.05$) compared to the other macrophytes. It had the highest fresh weight and dry weights (FW: 12.8±1.45 kg/m2 and DW: 0.81± 0.11kg/m2) relative to *C. benghalensis* and *I. aquatica*.TN content was highest in *C. benghalensis* (12.92 ± 0.67 g/kg). *P. pupureum* and *I. aquatica* didn't differ significantly in their nitrogen content ($P \leq 0.05$) while all three species contained high phosphorus concentrations in their above-ground tissues. TP storage was in the order *C. benghalensis >P. purpureum>I. aquatica*. This suggests that aquatic macrophytes play vital roles in retaining phosphorus and nitrogen hence affecting water quality and nutrient dynamics of these streams. These nutrient-rich plants can be removed from the aquatic system by harvesting and used as fodder to prevent nutrient release into the water column through decomposition after plant dieback.

Keywords: Aquatic macrophytes; Diversity; Nutrient storage; Biomass accumulation

1. Introduction

Loss of biodiversity in both aquatic and terrestrial ecosystems is of global concern, with anthropogenic activities and climatic change documented as the major drivers of change [1][2]. As a result, most ecosystems have lost their biological uniqueness, leading to biotic homogenization (similarity among different communities) [3][4] and increased community dissimilarities known as biotic differentiation. Aquatic macrophytes include both vascular and non-vascular plants which could be floating, submerged or emerged in shallow waters and influence the physical, chemical and biological environment [5]. Macrophytes generally colonize shallow ecosystems such as streams, rivers, lakes, ponds, marine environments, and even rapids and falls as in the case of Podostemaceae [6] and constitute important ecological engineers which influence ecological processes (e.g., nutrient cycling, habitat, and food provision to fishes and

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zooplankton, water purification and ecological attributes of other biotic aquatic attached assemblages like species diversity and composition). Owing to their high rate of biomass production, macrophytes have primarily been characterized as an important food resource for aquatic organisms, providing both living (grazing food webs) and dead organic matter (detritivorous food webs) [7].

Macrophytes are important contributors to primary production in scales larger than other primary producers [8] and hence influencing nutrient dynamics of the systems they colonize. Several studies have documented their role in the nutrient dynamics of sediments and water they colonize [9][10][11] hence suggesting a positive relationship between functional macrophyte communities and environmental parameters [4].

Macrophytes and sediments of lotic and lentic systems play a very important role in reducing the transport of nutrients, by absorbing and incorporating them into the tissues of aquatic plants. The properties of bottom sediments determine the nutrient concentration and heavy metals in macrophytes [12]. Hence the degradation of habitat and water quality of most aquatic resources is reflected in changes in their abundance and composition.

Despite these fascinating roles played by macrophytes, they remain threatened and are vulnerable to different land use practices [1][13]. With the increasing incidence of eutrophication and pollution of wetlands largely due to anthropogenic activities, it is necessary that the taxonomic uniqueness of each ecosystem is documented so that changes can be monitored and managed by the implementation of relevant policies governing the resource in question. If significant associations between these macrophytes and water quality are well established, thresholds for macrophytes and other aquatic assemblages can be determined for the optimum functioning of these biotic elements.

A hand full of studies have been documented on aquatic macrophytes in Cameroon, ranging from the identification of endemic aquatic taxa like Podostemaceae in rivers and rapids in the different regions of Cameroon [6], the role of aquatic plants in nutrient and heavy metallic uptake in both lotic and lentic ecosystems [14] [15] and their role in phytoremediation [16] [17][18].

The Southwest coast of Cameroon is characterized by many watersheds, giving rise to many streams, rivers, and springs whose floristic composition and physicochemical parameters remain largely undocumented [19]. These streams and wetlands are subjected to a plethora of stressors that are believed to influence their taxonomic distinctiveness and nutrient dynamics. This study was limited to three streams associated with car washing activities along the Buea-Limbe stretch of road. The Ombe, Bota, and Mile 15 wetlands are major car-washing points along the Buea-Limbe highway in Fako Division. Although car-washing activities have been going on in these wetlands for a very long time, very little is known about their water quality, the taxonomic distinctiveness of the aquatic macrophytes, and their relationship with water parameters. Ndemanou [20] recorded high concentrations of organic pollutants in Ombe, Bota, and Mile 15 car washing points but the dynamics of these parameters were not investigated. This study was therefore aimed at assessing the diversity and occurrence of aquatic macrophytes in Mile 15, Ombe, and Bota wetlands in the Mount Cameroon region, ii) to determine the physico-chemical properties of water in these wetlands, and iii) to assess total nitrogen and phosphorus uptake of three common macrophyte species in Bota.

2. Material and methods

2.1. Description of study site

Fako division located between latitudes 4^0 4’ and 4^0 2’ N and longitudes 8^0 7’ and 9^0 25’ E is characterized by rich volcanic soils which have attracted large agricultural plantations like the CDC (Cameroon Development Corporation) which harbour huge agricultural biodiversity. Fako division has a population density of 222.8/km^2 with a surface area of 2060 km^2 (Figure 1). The high population influx coupled with limited employment opportunities has triggered an over-reliance on natural resources, with car washing activities undertaken directly in roadside streams throughout the year.

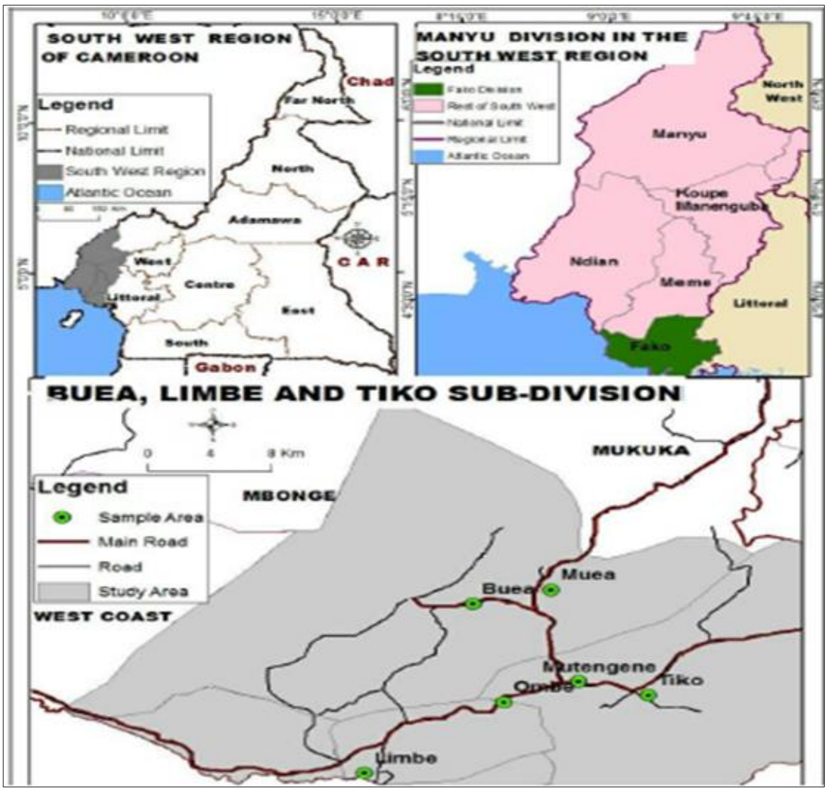

Figure 1 Location of study sites

2.2. Ecological Sampling

2.2.1. Determination of physico-chemical parameters

Collection of water samples

Sets of three water samples were collected at the top 10cm in each of the sampling sites of the wetland (the collection was from 6 different points and bulked to form a composite sample). At each point, temperature, TDS, pH, and conductivity were determined *in situ* using the portable Hanna HI 9829 multiparameter tester. Sediments were collected using a plastic shovel and put in zip-lock bags and transported to the laboratory for analyses. A total of 6 water samples were collected, (n=2) for each site. At the laboratory, the water samples were analyzed for nutrients (calcium, magnesium, chlorides, phosphates, nitrates, and heavy metals like lead, cadmium, zinc, copper, and iron.

Sediments

Composite sediment samples (1.5 kg, n = 2) were collected from each site using a plastic shovel. Sediments were collected from the littoral zones on both banks and the center of the wetland (500 g each), from a depth of 5–10 cm in an area of approximately 20 cm by 20 cm, collected and pooled. This was repeated twice (n = 2) at each site. The samples were placed in clean polyethylene zip-lock bags for transportation to the Life Sciences Laboratory of the University of Buea, Cameroon.

Macrophyte sampling

Two transects of 500m were laid at each wetland site. Vegetation sampling was done along the transect at 50 m intervals, within which plots were laid. Quadrats of 1m by 1m were sub-sampled within each plot and all plants were identified and enumerated by experts from the Limbe Botanical Garden. Each stream segment was divided into 10 plots, transects perpendicular to the shoreline made within each plot, and 1 m x 1 m quadrats demarcated along each transect. A total of 150 quadrats were censored, with 50 quadrats censored for each stream. The aquatic plant species present in each quadrat were recorded. The frequency (number of quadrats in which it occurred / total number of quadrats sampled) was calculated for each species sampled.

At the peak of the growing season (May/June), stands of dominant species were chosen for biomass assessment and determination of nutrient contents. For each species and for each plot within a given river segment, one 50 cm x 50 cm sample was randomly harvested at the ground level. These were washed and oven-dried at 70°C to constant weight. The samples were weighed to get the dry weight while for total nitrogen and phosphorous determination, 50 g of oven-dried plant material were ground, sieved, and mineralized by perchloric acid digestion, and the nitrogen and phosphorus contents were determined colorimetrically according to [21]. The plant N and P storage values were calculated by multiplying the N or P content by the dry weight.

$$\text{Nutrient storage}(g/m^2) = \text{biomass} \times \text{nutrient content} \qquad (1)$$

The nutrient content is the TN or TP content of the plant samples.

2.3. Data analyses

Data in this study are presented as mean ± standard error. Comparisons of biomass and nutrient storage between different plant species were conducted using one-way ANOVA, multiple comparisons were performed with posthoc Tukey tests. Differences between means were deemed significant if $P < 0.05$.

2.4. Diversity indices

Shannon-Wiener Index was used to determine the tree diversity, calculated as follows:

$$H' = -\Sigma(ni\ N)\ln(ni\ N) \quad [26] \qquad (2)$$

Where;

H = Index of species diversity,
Pi = Proportion of total sample belonging
to i^{th} species,
n = number of species,
ln = natural log.

SØrenson's similarity index [28]

$$Cj = 2C / a + b \quad [9] \qquad (3)$$

Where; C is the number of species common to both sites,
a is the number of species in site A and
b is the number of species in site B.

3. Results

3.1. Occurrence and Diversity of aquatic macrophytes in Bota, Ombe, and Mile 15 streams in the Mount Cameroon region

A total of 47 aquatic macrophytes were identified in Bota, Ombe, and Mile 15 wetlands in the Mount Cameroon region (Table 1). These were from 18 plant families. Plant taxa with many representative species included Poaceae (8 species), Araceae (6), Acanthaceae (5,) and Asteraceae (4). A vast majority of these aquatic macrophytes were emergent, with just 2 species floating (*Nymphaea lotus* was found in Bota and Ombe, while *Ludwigia adscendens* occurred only in Mile 15). The only submerged macrophyte recorded during the study, *Anubias barteri* (Araceae) was observed in Ombe. The most floristically rich wetland was Ombe wetland, with a Shannon-Wiener diversity index of 3.23, followed by Mile 15 (H= 3.14) while Bota had the least Shannon diversity (H = 2.90). These sites differed in their taxonomic richness. A total of 24 plant species were identified in Bota, and the most dominant species included *Commelina benghalensis* L. (15.33), *Nymphaea lotus* (10.54), *Pennisetum purpureum* (8.02), *Ipomoea aquatica* (7.13) with the highest relative abundances. *Commelina benghalensis* occurred in extensive uniform stands along the edge of the channel interspersed with *Pennisetum* while the entire water surface was dominated *by Nymphaea lotus*.

In Mile 15, a total of 28 species were recorded. This site was as well dominated by C. *benghalensis* (12.33), *I. aquatica* (8.63), *P. purpureum* (7.28), and *Ageratum conyzoides* (5.94). Large stands of these species were observed along the banks of the stream. The Ombe wetland was dominated C. *benghalensis* (11.68), I. *aquatica* (5.82), P. *purpureum* (4.84) and *N. lotus* (4.55) (Table 1).

Table 1 Abundance of aquatic macrophytes across study sites in the Mount Cameroon region

Species	**BOTA**		**MILE 15**		**OMBE**	
	A	**RA (%)**	**A**	**RA (%)**	**A**	**RA (%)**
Colocasia esculentus	23	1.38	0	0.00	46	2.25
Ageratum conyzoides	62	3.71	93	5.94	78	3.81
Vernonia calvoana	79	4.73	23	1.47	65	3.18
Diplocyclos palmatus	22	1.32	41	2.62	70	3.42
Zehneria scabra	94	5.63	0	0.00	0	0.00
Momordica foetida	67	4.01	64	4.09	59	2.88
Aneilema umbrosum	47	2.81	22	1.41	70	3.42
Commelina benghalensis	256	15.33	193	12.33	239	11.68
Desmodium adscendens	70	4.19	45	2.88	23	1.12
Ludwigia abyssinica	46	2.75	0	0.00	22	1.08
Urena lobata	23	1.38	0	0.00	0	0.00
Coix-lacryma jobi	90	5.39	0	0.00	0	0.00
Echinochloa pyramydalis	87	5.21	47	3.00	0	0.00
Echinochloa crus-galli	45	2.69	34	2.17	0	0.00
Leersia hexandra	86	5.15	25	1.60	60	2.93
Panicum maximum	26	1.56	62	3.96	0	0.00
Pennisetum purpureum	134	8.02	114	7.28	99	4.84
Dryopteris cycadina	23	1.38	62	3.96	0	0.00
Piper umbellatum	25	1.50	23	1.47	0	0.00
Polygonium hydropiper	12	0.72	0	0.00	0	0.00
Polygonium lanigerum	22	1.32	0	0.00	0	0.00
Ipomoea aquatica	119	7.13	135	8.63	119	5.82
Nymphaea lotus	176	10.54	0	0.00	93	4.55
Musa sapientum	36	2.16	0	0.00	0	0.00
Asystasia intusa	0	0.00	83	5.30	0	0.00
Ruellia strepens	0	0.00	50	3.19	72	3.52
Brillantaisia nitens	0	0.00	34	2.17	58	2.83
Alocasia macrorrhizos	0	0.00	47	3.00	0	0.00
Xanthosoma sagittifolium	0	0.00	58	3.71	0	0.00
Colocasia esculenta	0	0.00	22	1.41	0	0.00
Emilia coccinea	0	0.00	23	1.47	51	2.49
Ipomoea alba	0	0.00	74	4.73	0	0.00
Costus scaber	0	0.00	57	3.64	85	4.15

Cyperus distans	0	0.00	54	3.45	134	6.55
Ludwigia adscendens	0	0.00	23	1.47	0	0.00
Ludwigia stolonifera	0	0.00	34	2.17	0	0.00
Paspalum conjugatum	0	0.00	23	1.47	47	2.30
Asystasia gangetica	0	0.00	0	0.00	77	3.76
Strobilanthes heyneanus	0	0.00	0	0.00	68	3.32
Achyranthes aspera	0	0.00	0	0.00	48	2.35
Amaranthus blitum	0	0.00	0	0.00	23	1.12
Raffia farinifera	0	0.00	0	0.00	26	1.27
Anubias barteri	0	0.00	0	0.00	63	3.08
Chromolaena odorata	0	0.00	0	0.00	56	2.74
Cyperus papyrus	0	0.00	0	0.00	71	3.47
Panicum sellowii	0	0.00	0	0.00	79	3.86
Costus afer	0	0.00	0	0.00	45	2.20

Common aquatic plant species which were present in all three study sites were *Ageratum conyzoides*, *Vernonia calvoana*, *Momordica foetida*, *C. benghalensis*, *Desmodium adscendens*, *Leersia hexandra*, P. *purpureum*, and *I. aquatica*. Some species were also observed only in some streams and not in others. The Ombe wetland had the largest number of species that were unique to it (10 species). These included 2 species of Acanthaceae (*Asystasia giantica* and *Strobilanthes heyneanus*), 2 species of Amaranthaceae (*Achyranthes aspera*, *Amaranthus blitum*), *Anubias barteri* (Araceae), *Raffia farinifera* (Arecaceae), *Chromolaena odorata* (Asteraceae), *Costus afer* (Costaceae), *Cyperus papyrus* (Cyperaceae) and *Panicum sellowii* (Poaceae).

A total of six aquatic macrophytes were unique to Mile 15. These included *Asystasia intusa* (Acanthaceae), 3 species of Araceae (*Alocasia macrorrhizos*, *Xanthosoma sagitifolium,* and *Colocasia esculenta*), *Ipomoea alba* (Convovulaceae) and *Ludwigia stolonifera* (Onagraceae). Lastly in Bota, the six unique species were *Urena* lo*bata (Malvaceae), Zehneria scabra (Curcubitaceae), Musa sapientum (Musaceae), Coix-lacryma jobi* (Poaceae), and 2 species of Polygonaceae (*Polygonium hydropiper* and *Polygonium lanigerum*). This site also had the entire water surface colonized *by N. lotus*.

Table 2 Occurrence of aquatic macrophytes across study sites in the Mount Cameroon region

S/N	Family	Species	Form	BOTA	MILE 15	OMBE
1	Acanthaceae	*Asystasia intusa*	E	-	+	-
2	Acanthaceae	*Ruellia strepens*	E	-	+	+
3	Acanthaceae	*Brillantaisia nitens*	E	-	+	+
4	*Acanthaceae*	*Asystasia gangetica*	E	-	-	+
5	*Acanthaceae*	*Strobilanthes heyneanus*	E	-	-	+
6	Amaranthaceae	*Achyranthes aspera*	E	-	-	+
7	Amaranthaceae	*Amaranthus blitum*	E	-	-	+
8	*Araceae*	*Anubias barteri*	S	-	-	+
9	Araceae	*Colocasia esculentus*	E	+	-	+
10	*Araceae*	*Alocasia macrorrhizos*	E	-	+	-
11	*Araceae*	*Xanthosoma sagittifolium*	E	-	+	-
12	*Araceae*	*Colocasia esculenta*	E	-	+	-

13	*Arecaceae*	*Raffia farinifera*	E	-	-	+
14	*Asteraceae*	*Ageratum conyzoides*	E	+	+	+
15	*Asteraceae*	*Vernonia calvoana*	E	+	+	+
16	*Asteraceae*	*Emilia coccinea*	E	-	+	+
17	*Asteraceae*	*Chromolaena odorata*	E	-	-	+
18	Cucurbitaceae	*Diplocyclos palmatus*	C	+	+	+
19	*Cucurbitaceae*	*Zehneria scabra*	C	+	-	-
20	*Cucurbitaceae*	*Momordica foetida*	C	+	+	+
21	Commelinaceae	*Aneilema umbrosum*	E	+	+	+
22	*Commelinaceae*	*Commelina benghalensis*	E	+	+	+
23	Convovulaceae	*Ipomoea muricata*	C	+	+	+
24	*Convovulaceae*	*Ipomoea alba*	C	-	+	-
25	*Costaceae*	*Costus scaber*	E	-	+	+
26	*Costaceae*	*Costus afer*	E	-	-	+
27	Cyperaceae	*Cyperus papyrus*	E	-	-	+
28	*Cyperaceae*	*Cyperus distans*	E	-	+	+
29	*Fabaceae*	*Desmodium adscendens*	E	+	+	+
30	*Malvaceae*	*Urena lobata*	E	+	-	-
31	*Musaceae*	*Musa sapientum*	E	+	-	-
32	Nymphaeaceae	*Nymphaea lotus*	F	+	-	+
33	Onagraceae	*Ludwigia abyssinica*	E	+	-	+
34	Onagraceae	*Ludwigia adscendens*	F	-	+	-
35	Onagraceae	*Ludwigia stolonifera*		-	+	-
36	*Poaceae*	*Coix-lacryma jobi*	E	+	-	-
37	*Poaceae*	*Echinochloa pyramydalis*	E	+	+	-
38	*Poaceae*	*Echinochloa crus-galli*	E	+	+	-
39	*Poaceae*	*Leersia hexandra*	E	+	+	+
40	*Poaceae*	*Panicum maximum*	E	+	+	-
41	*Poaceae*	*Pennisetum purpureum*	E	+	+	+
42	*Poaceae*	*Paspalum conjugatum*	E	-	+	+
43	*Poaceae*	*Panicum sellowii*	E	-	-	+
44	*Pteridaceae*	*Dryopteris cycadina*	E	+	+	-
45	*Piperaceae*	*Piper umbellatum*	E	+	+	-
46	Polygonaceae	*Polygonium hydropiper*	E	+	-	-
47	Polygonaceae	*Polygonium lanigerum*	E	+	-	-

*E= Emergent S=Submergent F= Floating C= creeping

3.1.1. Similarity and dissimilarity across study sites

There was a relatively higher similarity in terms of the species composition between Bota and Mile 15 as revealed by Sorenson's Index of similarity (0.58) as opposed to the high dissimilarity between Ombe and Mile 15 (0.72) (Table 3).

Table 3 Sorenson's similarity index matrix

	BOTA	MILE 15	OMBE
BOTA	1	0.58	0.49
MILE 15	0.58	1	0.28
OMBE	0.49	0.28	1

3.2. Water quality of Bota, Mile 15, and Ombe streams in the Mount Cameroon region

The physicochemical parameters of the streams under study are presented in Table 4. These wetlands were characterized by slightly alkaline pH, moderate dissolved oxygen, turbidities, and conductivity levels (Table 4). In terms of hardness, Bota wetland had the highest (36.9 ± 1.6) while Mile 15 and Ombe were not different statistically (p>0.01).

Table 4 Physicochemical parameters of water in Bota, Mile 15, and Ombe streams in the Mount Cameroon region

Physicochemical parameter/Units	Bota	Mile 15	Ombe	P-value	Significance
pH	7.65 ± 0.34^{a}	6.57 ± 0.35^{b}	7.66 ± 0.21^{a}	< 0.001	***
Temperature (^{0}C)	28.14 ± 0.28^{b}	29.04 ± 0.42^{a}	27.56 ± 0.27^{c}	< 0.001	***
DO (mg/L)	5.82 ± 0.30^{a}	6.66 ± 1.27^{a}	5.56 ± 0.62^{a}	0.134	ns
Conductivity	192.8 ± 69.9^{a}	213.9 ± 77.8^{a}	$\pm 39.5^{a}$	0.809	ns
Turbidity (NTU)	34.9 ± 25.8^{a}	139.4 ± 157.5^{a}	31.5 ± 32.9^{a}	0.162	ns
Hardness	36.9 ± 1.6^{a}	24.7 ± 4.31^{b}	19.8 ± 7.5^{b}	0.001	**
BOD5 (mgO_2/l)	20.98 ± 6.17^{ab}	31.12 ± 8.96^{a}	16.64 ± 6.25^{a}	0.023	*
COD	82.34 ± 12.74^{a}	99.4 ± 13.82^{a}	65.9 ± 29.2^{a}	0.063	ns
TSS	102.5 ± 64.9^{a}	93.4 ± 87.7^{a}	16.9 ± 16.76^{a}	0.106	ns
Sediments					
TN (mg/kg)	3.59 ± 0.88^{a}	2.83 ± 0.91^{a}	1.06 ± 0.16^{a}	0.726	ns
Avail. P (mg/kg)	98.50 ± 1.27^{a}	57.30 ± 1.18^{b}	53.84 ± 1.12^{b}	< 0.001	***
OM %	8.09 ± 1.5^{a}	3.9 ± 1.2^{b}	4.05 ± 1.5^{b}	< 0.001	***

Means that do not share a letter within a row are significantly different from each other; OM: Organic matter, TN: total nitrogen, TSS: Total Suspended Solids, COD: Chemical Oxygen Demand, DO: Dissolved Oxygen, Avail. P: available phosphorus

Significant differences occurred in calcium content across sites, with the highest concentration recorded in Bota (16.34± 1.45 mg/l) and the least in Ombe (12.48 ± 2.19 mg/l). A similar trend was observed for magnesium and chlorides. Except for lead, the concentrations of cadmium, zinc, copper, and iron were significantly different across sites with Bota and Mile 15 having the highest concentrations (Table 5). All heavy metals analysed (Pb, Cd, Fe, Cu, and Zn) were detected in all three streams, and iron was the most abundant heavy metal.

Correlations between the physicochemical parameters and macrophyte abundance revealed some significant associations between parameters (Table 6). Strong positive correlations were made between TSS and water conductivity (r=0.80), TSS and Turbidity (r=0.76), Turbidity and TSS (r=0.76), and conductivity and TSS (0.80). Apart from the positive correlation between abundance and pH, macrophyte abundance generally correlated negatively with water temperature (r=-0.66), alkalinity (r = -0.45), and BOD (r = -0.55).

Table 5 Ionic and heavy metal concentration of water in Bota, Mile 15, and Ombe streams in the Mount Cameroon region

Physicochemical parameter	Bota	Mile 15	Ombe	P-value	Significance
Ca	16.34 ± 1.45[a]	7.82 ± 0.98[b]	12.48 ± 2.19[c]	< 0.001	***
Mg	3.58 ± 0.51[a]	1.62 ± 0.16[b]	1.54 ± 0.47[b]	< 0.001	***
chlorides	43.04 ± 11.68 [b]	57.61 ± 3.29[a]	26.8 ± 4.89[c]	< 0.001	***
Phosphates	0.55 ± 0.27[a]	0.49 ± 0.18[a]	0.3 ± 0.12[a]	0.170	ns
Nitrates	3.59 ± 0.88[a]	2.83 ± 0.91[a]	1.06 ± 0.16[a]	0.102	ns
Heavy metals					
Pb	0.04 ± 0.03[a]	0.02 ± 0.03[a]	0.07 ± 0.04[a]	0.102	ns
Cd	0.003 ± 0.001[ab]	0.005 ± 0.003[a]	0.002 ± 0.0005[b]	0.015	*
Zn	0.21 ± 0.12[b]	1.80 ± 1.07[a]	0.005 ± 0.003[b]	0.001	**
Cu	0.02 ± 0.005[b]	0.19 ± 0.11[a]	0.02 ± 0.01[b]	0.001	**
Fe	2.71 ± 0.99[ab]	5.7 ± 3.17[a]	2.09 ± 1.26[b]	0.036	*

Means that do not share a letter within a row are significantly different from each other

Table 6 Correlation between physicochemical parameters, species diversity, and abundance

	pH	Temp	DO	Cond	Turb	Hard	Alk	BOD	COD	TSS	H'	Abu
pH	1											
Temp	-0.75	1										
DO	-0.46	0.24	1									
Cond	0.05	0.39	-0.53	1								
Turb	-0.48	0.61	-0.39	0.77	1							
Hard	0.22	0.27	-0.22	0.15	-0.01	1						
Alk	-0.30	0.82	-0.01	0.58	0.53	0.64	1					
BOD	-0.51	0.86	-0.19	0.74	0.86	0.24	0.80	1				
COD	-0.37	0.83	-0.16	0.64	0.64	0.47	0.81	0.90	1			
TSS	-0.14	0.60	-0.41	0.80	0.76	0.48	0.81	0.80	0.68	1		
H'	0.07	-0.44	0.06	-0.14	-0.16	-0.67	-0.65	-0.41	-0.41	-0.57	1	
Abu	0.59	-0.66	-0.24	-0.02	-0.29	-0.06	-0.45	-0.55	-0.44	-0.24	0.60	1

Alk: Alkalinity BOD: Biological Oxygen Demand, COD: Chemical Oxygen Demand, TSS: Total Suspended Solids, H´: Shannon's diversity, Abu: Abundance, Turb: Turbidity, Cond: Conductivity, Hard: Hardness

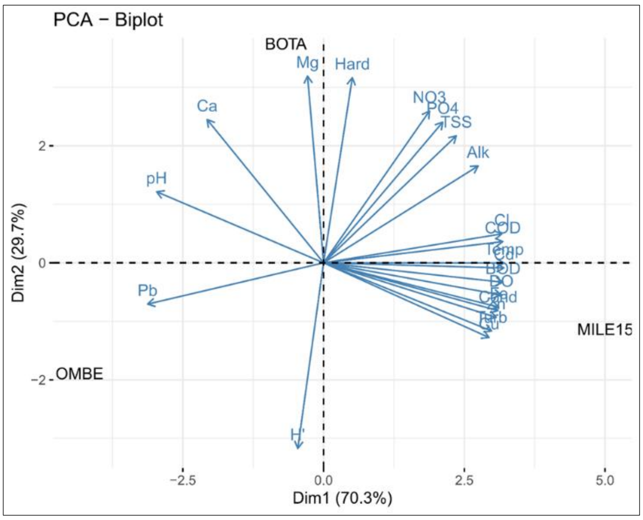

Figure 2 Principal component analysis of physicochemical parameters across sites

3.3. Above-ground biomass and nutrient storage in plant species

Among the dominant macrophytes, *P. purpureum* showed significantly higher productivity ($p < 0.05$) compared to the other macrophytes. It had the highest fresh and dry weights (FW: 12.8±1.45 kg/m^2 and DW: 0.81± 0.11kg/m^2) relative to C*. benghalensis* and *I. aquatica* (Table 7). This was followed by *I. aquatica* which had a fresh weight of 8.56 ± 1.40 kg/m^2, greater than that of *C. benghalensis* (6.09 ± 1.29 kg/m^2) but these two differed in terms of dry weight, with *C. benghalensis* having a higher dry weight (0.7 ± 0.12 kg/m^2) than I. aquatica (0.46 ± 0.14 kg/m^2). With respect to the nutrient content within these plants, TN content was highest in *C. benghalensis* (12.92 ± 0.67 g/kg**).** *P. pupureum* and *I. aquatica* didn't differ significantly in their nitrogen content ($P \leq 0.05$). For Total P, all three species contained high phosphorus concentrations in their above-ground tissues. There were no significant differences among them.

With respect to nutrient storage, the highest TP storage was in the order P. *purpureum*>*C. benghalensis* > I. *aquatica*. TN storage was highest in *C. benghalensis*, followed by P. *purpureum* and I. *aquatica*. P. purpureum had the largest biomass for both fresh and dry weights.

Table 7 Biomass And Nutrient Concentration In Macrophytes In Bota Wetland

	Fresh biomass (Kg/m^2)	**Dry biomass (Kg/m^2)**	**TN content g/kg**	**TP content g/kg**	**TN storage g/m^2**	**TP storage g/m^2**
Commelina benghalensis	6.09±1.29	0.79±0.12	12.92 ± 0.67^a	10.03 ± 1.30^a	10.2 ± 0.04	7.9 ±0.07
Ipomoea aquatica	8.56±1.40	0.46± 0.14	9.97 ± 0.58^b	9.52 ± 1.02^a	4.61 ±0.02	4.4 ± 0.1
Pennisetum purpureum	12.8±1.45	0.81± 0.11	10.74 ± 0.46^b	10.27 ± 1.72^a	8.7 ±0.9	8.26 ±0.1

Means that do not share a letter within a row are significantly different from each other

4. Discussion

4.1. Physicochemical parameters of water and sediments in Bota, Mile 15 and Ombe

The water and sediments of these streams were characterized by slightly alkaline pH, and high organic matter content (especially in Bota wetland). These streams are flowing on the iron-rich volcanic basaltic rocks which make up the Mount Cameroon region. Some of these minerals found in the soils and rocks in this region are leached into the water column, thus explaining the high iron content recorded during the study. This is in line with the findings of [22] who recorded high levels of minerals like iron in water sources in the Mount Cameroon region. High chloride, magnesium, and calcium were recorded in this study. These findings are corroborated by [19] whose results confirmed physicochemical contamination of some water resources in the same Division.

Low levels of BOD recorded in the study sites reveal moderate levels of organic matter in the stream sediments. High phosphorus and nitrogen were recorded in the water column. These 3 streams are natural streams with pristine waters flowing from the forests around Mount Cameroon into human-dominated landscapes of Limbe, Ombe, and Mile 15 which are exposed to poor domestic waste disposal practices, car washing activities, and diffuse pollution from the large agro-plantations which exist around them.

4.2. Aquatic macrophyte composition and diversity across sites

The prevailing physicochemical parameters of the streams influence the growth, composition, and abundance of the aquatic macrophytes. Aquatic macrophytes being primary producers require light, water, and carbon in the process of photosynthesis to synthesize major compounds like carbohydrates. They also need both micro and macronutrients, including P and N. Variation in the concentrations of these nutrients affect their growth and development and also their diversity. Plants differ in their responses to abiotic stressors and parameters such as pH, nutrients, and temperatures and this determines their abundance.

Negative correlations were made between macrophyte abundance and water turbidity ($r = -0.29$). The presence of rooted aquatic macrophytes influences sediment stabilization and reduces nutrient re-suspension, thus reducing the turbidity of the water body. The high abundances of certain taxa indicate their tolerance to the prevailing hydrological conditions of these wetlands. Of the 47 species of aquatic plants encountered during this study, more than 70% are commonly described tropical hydrophytes that exist in families such as Nymphaeaceae, Convolvulaceae, Poaceae, Cyperaceae, Arecaceae, Araceae, Commelinaceae, Curcubitaceae and Polygonaceae, etc. Obligate hydrophytes as well as a few terrestrial species were encountered such as the species of Acanthaceae and Amaranthaceae. Plant families with the highest species representation included Poaceae (8), Acanthaceae (5), Araceae (5) Asteraceae (4), and Curcubitaceae (3).

In all three sites, C. *benghalensis*, I. *aquatica,* and *P. purpureum* occurred as the most common and abundant species. These species colonized the shores characterized by slow-flowing waters and muddy substrates where they formed dense stands. Similar findings were made by [17] who reported these species in the Buea municipality, Cameroon.

Only two floating macrophyte species were recorded-*Nymphaea lotus* is common in eutrophic waters with high nitrogen and phosphorus levels. Floating-leaved macrophytes were present in Bota and Ombe due to the slow and still water currents that necessitated their establishment. *Anubias barteri* (Araceae) was the only submerged macrophyte encountered in the study. This is due to the deep nature and organic matter content in the Ombe stream.

4.3. Phosphorus and nitrogen retention in above-ground tissues

Phosphorus and nitrogen retention in above-ground tissues was dependent on their concentrations in both sediment and water column. High tissue phosphorus levels were recorded in all three species (P. *purpureum*, I. *aquatica,* and C. *benghalensis*). These 3 species did not differ in the concentration of total phosphorus in their tissues. This could be attributed to these macrophytes having a good root penetration into the sediments which necessitated optimum phosphorus uptake. The high concentration of phosphorus in water reflects high phosphorus availability in sediments. Similar findings were made by [16] who found that the phosphorus content of plant tissues increased with increasing amounts of phosphorus in sediments in an eutrophic river in Bamenda, Cameroon**.** Thus, the luxuriant growth of *P. purpureum* along the stream edges could be attributed to the high nutrient concentration in the sediments. These two nutrients which are usually limited in most ecosystems drive key metabolic reactions in plants such as amino acid synthesis, and ATP formation and they are therefore responsible for the vigorous growth and development of plants. P is an essential nutrient, both as a component of several key plant structural compounds and as a catalyst in numerous metabolic reactions in living tissues.

TN storage ability differed in all three species in the rank order *C. benghalensis* > *P. purpureum* ≥ *I. aquatica*. Differences could be attributed to differences in their taxa, growth forms, and nitrogen use efficiency across the 3 species. Findings from this study are corroborated by those of [16] who recorded high TN in *I. aquatica* and *C. benghalensis* in the Northwest region, of Cameroon. Similar findings were demonstrated by [23] who found that *I. aquatica* could be used to reduce N and P loads under saline and alkaline conditions in the Ningxia irrigation area in China. Theibaut and Muller [24] suggested that these differences in nutrient retention between species could be due to differences in their morphologies, anatomy, nutrient requirements, and storage abilities.

4.4. Implication for management

Findings from this study suggest that macrophytes sequester large amounts of nutrients (nitrogen and phosphorus) during their growth and development. This can be used to effectively manage the high nutrient fluxes in aquatic ecosystems like streams which by virtue of their movement (lotic nature) are responsible for the inflow of nutrients in pristine natural waters. All three species were found to accumulate large amounts of nitrogen and phosphorus, although they differed in their nitrogen storage ability*.* *C. benghalensis* is a high accumulator of nitrogen followed by P. *purpureum* and *I. aquatica*. These species' nutrient retention, coupled with their large biomass production rates can be promising to effectively control eutrophication. The removal of large biomass is a huge nutrient export technique that can remove tons of nitrogen and phosphorus during eutrophication events. If well controlled, this can effectively control or manage the nutrient budget of these ecosystems.

5. Conclusion

Forty-seven species of aquatic macrophytes were recorded in 3 streams along the Limbe-Buea highway. Macrophytes are important reservoirs of nitrogen and phosphorus. High concentrations of nitrogen and phosphorus were stored in the above-ground tissues of *C. benghalensis*, *P. purpureum,* and I. *aquatica*. The three species didn't differ in their phosphorus content but differed in their nitrogen contents as well as the retention rates or storage of these nutrients. *C. benghalensis* is more effective in retaining and accumulating phosphorus in its tissues and can therefore be a good species for the phytoremediation of polluted water bodies with high concentrations of N and P. This is mostly as a result of their comparatively high biomass production rate and high nutrient retention properties. Comparatively, *I. aquatica* showed the lowest nutrient storage and therefore *P. purpureum* and *C. benghalensis* could be recommended for phytoremediation of nutrient-polluted water bodies.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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