Epiphytic algae on dominant macrophytes in lotic ecosystems in the Eastern flanks of Mount Cameroon

ABSTRACT

Aims: This study was designed to assess quantitative estimates of epiphyte biomass and diversity on the dominant macrophytes in two rivers in the Eastern flanks of Mount Cameroon.
Place and Duration of Study: Two sets of water samples were collected at the top 10cm of the rivers for nutrient and chlorophyll a determination. A single preliminary collection of algal epiphytes from partially submerged aquatic macrophytes was carried out from the littoral zone of Ndongo and Limbe rivers, between May and June 2023.
Methodology: The sedimentation technique was employed in the study. Three slides were prepared for each aquatic macrophyte sample for microscopic analysis. Identification was done by comparative morphology using relevant journals and textbooks.
Results: All variables related to water clarity (TSS, Phytoplankton Chl a, HC) assessed during the study were similar in both rivers. Water clarity based on HC values was below 6 mg/l implying both rivers were clear during the study period. Epiphytic algae identified were recorded from 4 main divisions, namely Bacillariophyta, Chlorophyta, Cyanophyta and Euglenophyta. The highest algal diversity in Ndongo was recorded from *Commelina benghalensis* (H=3.45) with 41 algal species identified. *Justicia* in Ndongo river had the lowest algal species richness (24) with an algal diversity of 2.91. *Nymphaea* had the highest algal diversity (H=3.36) and algal species richness (36) in Limbe river. Algal species richness was the same in the two other plant hosts *Commelina benghalensis* and *Colocasia esculentus* (29 species per host). The highest algal chlorophyll a was recorded on *Nymphaea* (621μg/g dry weight) and *Commelina benghalensis* (644μg/g) in Limbe and Ndongo respectively. Lowest epiphyte **Chlorophyll** a was recorded in J*usticia secunda* in Ndongo (607 μg/g).

Conclusion: All macrophytes studied harbored a large algal flora demonstrating their diverse ecological roles carried out in these rivers. ***Nymphaea lotus*** and ***Commelina benghalensis*** in Limbe and Ndongo rivers had the highest epiphytic algal biomass.

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Keywords: [microalgae, aquatic angiosperms, chlorophyll a, Nymphaea, Commelina, Colocasia, Justicia, Ndongo River, Limbe River}

1. INTRODUCTION

Stream biofilms play a unique and key role in aquatic ecosystems due to their involvement in biogeochemical cycles through primary production, ecosystem metabolism, nutrient uptake and trophic interactions [1]. Biofilms are complex in their structure and function, and are composed of autotrophic microalgae dominated by diatoms, green algae and cyanobacteria, as well as heterotrophic organisms such as bacteria, protozoa, and fungi [2]. Biofilm grows on various substrates in the stream, including macrophytes (epiphyton), on woody debris (epidendron or epixylon), stone and gravel (epilithon), on sand (episammon), on mud (epipelon) and their development is controlled by a complex array of factors and interactions with irradiance, nutrient availability, physical disturbance and grazing being the most important [3][4].

Epiphytic algae are a group of algae found attached on plants, usually submerged aquatic plants [5]. They are very important primary producers and constitute a good food source for fishes, insects and other aquatic invertebrates inhabiting the waters [6] [7]. These microscopic organisms play vital roles in carbon fixation, allelopathy amongst others [8][9]. They are also known as good biological indicators of environmental conditions [10] [11] [12] [13]. Their fast growth rates, ecological preferences and tolerance ranges, sessile nature are some contributing factors to this quality [14] [15] [16].

Epiphytism is an important ecological component in both marine and freshwater environments [17]. The need to study epiphytic algae arises from their ecological significance and functions. They can modulate the aquatic environment by absorbing nutrients, there by changing the chemical composition in water. Their photosynthetic activities also cause diurnal fluctuations in carbon dioxide and oxygen levels with subsequent pH variation [18] [19]. Microalgae such as the cyanobacteria have nitrogen fixation abilities [20]. Epiphytic algae according to some authors account for more primary production than their macrophytic host [21] [22] and are also involved in trophic interactions [23].

The very obvious negative impacts of these organisms include the hindrance of light penetration thereby reducing solar radiation from getting to the waters [24], competition for nutrients with the resultant effect of the suppression of **growth of macrophytes** by algae [25].

Host plant specificity and environmental factors are known to influence epiphytic community dynamics [26]. Although contested over time, some authors have concluded that some hosts may be neutral but others can significantly influence epiphytic community structure while other studies demonstrated that various factors influencing epiphytic communities response are interactive [27].

Attached photoautotrophs have received very little attention in Cameroon. *Commelina benghalensis* and *Nymphaea lotus* are among the dominant aquatic plants in the Mount Cameroon Region [28]. They possess agricultural values; some serve as animal forage, source of medicine and are thus valuable aquatic plants in the region. This study was designed to assess quantitative estimates of **epiphytic** biomass and diversity in two rivers in the Eastern flanks of Mount Cameroon, specifically to address the question of whether or not **epiphytic** biomass would vary depending on macrophytic species, water column nutrients or major physicochemical characteristics of these two prominent rivers.

2. MATERIALS AND METHODS

2.1 Study site

Limbe and Ndongo rivers are two prominent rivers in the cities of Limbe and Buea (the administrative and regional headquarters of Fako Division respectively, with the former being the largest. Limbe River takes its rise from Mt Cameroon, through Mile 4, Mile 2, Middle farms, Botanic Garden and into the Atlantic Ocean. It has steep slopes, about 43% causing the river to have a high flow rate along the slopes of Mount Cameroon [29].

Ndongo river on the other hand is located down the Mount Cameroon between latitude 4°07' and 4°10' North and longitude 9°14' and 9°21' East and is not as large as Limbe river. It has a relatively lower speed as it flows through the city of Buea, basically from Biaka through the University of Buea Campus to Mile 16 where it finally flows through Mutengene to the Tiko creeks [30] [31]. It has a rocky streambed and sandy in most places with its banks completely colonized by dense vegetation of aquatic plants, both lower and higher plants. The climate is characterized by two seasons, a short dry season from December to February and a long rainy season from March to November with abundant precipitation between 7000 mm to 12000 mm per year [32].

Limbe on the other hand is found on the plains and southeastern slopes of the ridge of Mount Cameroon separating the Rio del Rey and Douala basins. It has a population of about 130000 inhabitants. Limbe experiences a subequatorial climate (hot and humid throughout) with mainly two distinct seasons; a rainy season between April to October and a dry season from November to March with a mean annual rainfall of about 3,100 ±1,100 mm standard

deviation [29]. The annual rainfall is high, with yearly precipitations varying from 1,500 mm to 6,000 mm in the last 34 years for different stations. The mean annual temperature is ~26 °C and shows only limited variations of ~4° throughout the year. Humidity is generally above 85%. These characteristics correspond to the Tropical Monsoon Climate according to the Köppen climate classification scheme [33].

Stands of grasses, commelinids and aroids are found throughout the entire length of these rivers with some major aquatic vascular plant families dominating like the Poaceae, Araceae, Commelinaceae, **Cucurbitaceae** and **Euphorbiaceae** [28]. Portions of the river having a low velocity due to siltation have large stands of *Nymphaea lotus* floating on the surface.

2.2. Measurement of physicochemical parameters

Temperature, pH, conductivity, Total dissolved solutes, dissolved oxygen, salinity were measured *in situ* using the multi-parameter Hanna probe. Temperature was expressed in °C, TDS in ppm and EC in µS/cm, DO was expressed in mg/L, Salinity expressed in g/L. Readings were collected at 6 am.

Two sets of water samples were collected at the top 10cm of the rivers for nutrient and chlorophyll a determination. These were collected at different points along the rivers to form a composite sample. Samples were collected in triplicates in 1L sampling bottles which were immediately put in coolers containing ice blocks and transported to the Laboratory of the University of Yaounde 1, Cameroon.

Sampling bottles for river water chlorophyll a (Chl a) determination were wrapped with aluminum foil and transported to the Life Science Laboratory of the University of Buea, Cameroon.

2.3 Determination of nitrate and phosphate concentration

Nitrates were determined by distillation and colorimetry. The filtered samples were buffered at a pH of 9.5 with a borate for the hydrolysis of cyanates and organic nitrogen compounds and **were** then distilled into a solution of boric acid. The ammonium in the distillate was determined colorimetrically. A second distillation carried with the addition of Devanda alloy powder gave the nitrate content in the solution as described by [34]. Phosphates were determined using molybdenum blue-ascorbic acid method by adding phenolphthalein indicator followed by drop-wise addition of 5 M sulphuric acid, ammonium molybdate and ascorbic acid was then added and mixed thoroughly as described in [34].

2.4 Chlorophyll a and water colour determination

One hundred millilites (100 ml) of water samples of Limbe and Ndongo rivers were filtered through the Whatman GF/F filter paper with a pore size of 0.47micro meters with the aid of a water jet vacuum pump. Filter papers containing algal samples were cut into tiny pieces and 10 ml of cold acetone (90%) was added into the test tubes. This was kept for 24 hours in the dark. The mixture was ground to homogenous slurry, which was centrifuged at 2100 rpm for 10 minutes to separate the solution from the filter paper. Chlorophyll a was then determined using 722S spectrophotometer (B-BRAN Scientific Instrument Company, England) by

measuring the absorbance of the solution at 665nm and 750nm, before and after acidification with 0.1 M HCl for 2 minutes. Chlorophyll *a* content of the epiphyte suspension was also determined as described above.

Chlorophyll a was calculated using the following formula [35]

$$Chlorophyll\ a\ (ug1-1) = \frac{11.99(A665 - A750)S}{Vp} \ldots\ldots\ldots (1)$$

Where:

A665 = absorbance at 665nm,

A750 = absorbance at 750nm,

S = solvent extraction volume (ml),

V = the sample volume in litres

p = the path length of cell, cm

The colour of the water caused by humic compounds was measured with filtered (GF/F) water in 5 cm cuvettes at 400 nm. The resulting absorption was converted into equivalents of humic compounds (HC) using the formula

HC (mg/l)= A 400nm x 20/0.39…… (2)

For ranges between 1 to 6 mg/l of humic compounds, the water is considered clear; between 6 and 12 mg/l, yellow; and above 12 mg/l, brown. The amount of total suspended solids (TSS) was determined by filtration of up to 250 ml of stream water on pre-weighed GF/F Whatman filters.

2.5 Epiphytic algal sampling, preparation and identification

A single preliminary collection of algal epiphytes from partially submerged aquatic macrophytes was carried out from the littoral zones of Ndongo and Limbe rivers. A total of 5 plant samples were harvested for each plant species and these were washed immediately after collection and with the help of a tooth brush, all the algae attached on the submerged leaves, stems and roots were carefully collected in a 1L bottle as described by [36]. Fifty millilitres of the scraped sample was reserved for laboratory identification and enumeration.

The sedimentation technique was employed in the study. The 50 ml reserved for laboratory studies was preserved using 2-3 drops of Lugol's iodine and kept to sediment for 24 hours and the supernatant carefully extracted or removed 45ml, leaving behind 5ml of concentrated algae. Three slides were prepared for each aquatic macrophyte sample for microscopic analysis. Identification was done by comparative morphology using relevant journals and textbooks [36] [37]. The epiphytic algal species were identified **using** [38] and [39] [40]. The relative abundance of each taxon is estimated as follows: Rare, present in < 25% of the examined algae, Common, present in 25–49% of the examined algae, and Abundant, present in > 50% of the examined algae.

2.6 Data Analysis

Data was compiled with Microsoft Excel 2021. **Mean** estimation and calculation of standard errors of physicochemical parameters were computed using R statistical package.

Shannon-Wiener diversity (H)

Shannon - Weiner (1949) diversity index of phytoplankton and plant species within the different sites were equally determined using the following formula

$$Shannon\ H' = \sum_{i=1}^{i=s} pilnpi \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where,

H' = Index of species diversity,

Pi = Proportion of total sample belonging to i^{th} species,

ln = natural log.

3. RESULTS AND DISCUSSION

Results of water chemistry analysis are presented in Table 1. Generally both rivers did not differ in their physicochemical characteristics like temperature, pH, conductivity and nitrate levels (Table 1). All variables related to water clarity (TSS, Phytoplankton Chl a) assessed during the study were similar in both rivers. Water clarity based on HC (humic compounds) values **was** below 6 mg/l implying both rivers were clear during the study period. Both Ndongo and Limbe rivers are therefore clear fresh water, having an average temperature range of 22-22.9^{o}C. The results on pH indicated that both rivers were neutral to slightly alkaline within the pH range of 7 and 8. This is within the range set for good aquatic productivity 6.5 – 8.5 [41]. This is corroborated by other findings in streams and rivers within the same agro ecological zone, AEZ IV (monomodal equatorial agro ecological zone of Cameroon) [30].

The dissolved oxygen (DO) and water chlorophyll a concentration of both rivers did not differ significantly. Moderate DO levels recorded in both rivers signify that both rivers had a good ecological health and could be good habitat for aerobic species. Both rivers had statistically similar conductivity levels (241 ± 1.7 mS/cm) as opposed to 244 ±1.57 mS/cm in Limbe river. Similar findings were made by [30] who characterized the some limnological variables of Ndongo River.

Higher phosphate levels were recorded in Ndongo River (1.8 ± 0.13 mg/l) as opposed to Limbe River (1.2 ±0.13 mg/l). This could be due to the fact that this river flows through settlement and other **land uses**, thus exposing it to phosphate pollution. Higher phosphate levels have been recorded in [29] who worked on water quality of some streams and rivers within Limbe municipality.

Table 1: Variation of water physicochemical parameters across study sites

Parameter	Ndongo	Limbe	P-value
Temperature (°C)	22.9 ± 0.81	22 ± 1	0.327^{ns}
pH	8.1 ± 0.01	7.7 ± 0.17	0.072^{ns}
Conductivity (mS/cm)	241.8 ± 1.7	244.7 ± 1.53	0.866 ns
NO_3 (mg/l)	1.4 ± 0.1	1.32 ± 0.09	0.297^{ns}
PO_4 (mg/l)	1.8 ± 0.13	1.2 ± 0.13	0.008**
TDS (mg/l)	133.4 ± 3.8	130.0 ± 5.57	0.797ns
DO (mg/l)	6.53 ± 0.12	6.48 ± 0.59	0.899^{ns}
Phytoplankton Chl-a (µg/l)	30.33 ± 2.52	26.9 ± 1.65	0.143^{ns}
HC (mg/l)	5.73 ± 0.91	4.07 ± 0.42	0.102^{ns}

3.2. Algal diversity per host

Epiphytic algae have a vital role to play with respect to primary production, nutrient conversion and sustain major biotic interactions like grazing by other members of the higher trophic levels. Epiphyte species composition may also differ significantly between different macrophytes living under the same environmental conditions as a result of variations in host plant life forms.

Results of the epiphytic algal distribution per host in Limbe and Ndongo rivers are presented in Figure 2. Epiphytic algae were identified from 4 main divisions, namely Bacillariophyta, Chlorophyta, Cyanophyta and Euglenophyta. Algal diversity and species richness differed per host plant in both rivers (Tables 2 &3). The highest algal diversity in Ndongo was recorded from *Commelina benghalensis* (CS) (H=3.45) with 41 algal species identified. *Justicia secunda* (JS) in Ndongo River had the lowest algal species richness (24) with an algal diversity of 2.91.

Table 2: Algal diversity per host in the Ndongo river, Buea

Algal host	Abundance	Species richness (S)	Species evenness (J)	Species diversity (H)
CS	170	41	0.93	3.45
CE	105	27	0.90	2.97
JS	85	24	0.92	2.91

Nymphaea lotus (NS) had the highest algal diversity (H=3.36) and algal species richness (36) in Limbe River. Algal species richness was the same in the two other plant hosts *Commelina benghalensis* and *Colocasia esculenta* (CE) (29 species per host) (Table 3).

Table 3: Algal diversity per host in the Limbe river, Cameroon

Algal host	Abundance	Species richness (S)	Species evenness (J)	Species diversity (H)
CS	117	29	0.91	3.08
CE	108	29	0.93	3.13
NS	138	36	0.94	3.36

The distribution of the recorded algal divisions in the host plants are shown in Figure 3. CS recorded highest species richness in terms of Chlorophyta (15), Bacillariophyta (14), and Cyanophyta (10) in Ndongo **River**. The other two host plant studied recorded similar species numbers with respect to these divisions (Figure 1).

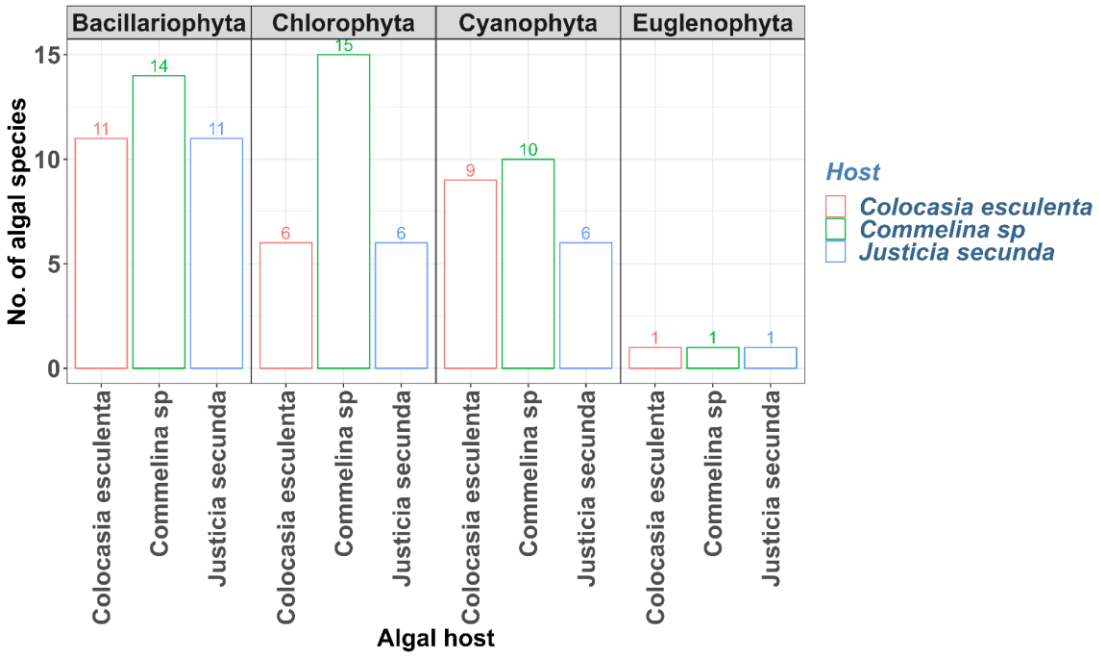

Figure 1: Distribution of algal species richness per division by algal host in the Ndongo stream

While in Limbe river, *Nymphaea* ***lotus*** had the highest algal species of Chlorophyta (13), Bacillariophyta (12), Cyanophyta (10) and Euglenophyta (2) (Figure 2).

3.1.2 *Epiphytic Algal occurrence*

Algal occurrence differed with respect to different algal divisions as follows:

Seven diatom species had a 100% occurrence, as they were found on all host plants in the study. These included ***Navicula*** *absoluta, N. distans, N. palea, Pinnularia divergens, Synedra*

acus, Cymbella naviculiformis and Achnanthidium ***minutissimum****.* Species like ***Aulacoseira*** *granulata* occurred only in Limbe **River**.

A total of 15 species of algae were from Chlorophyta, all of them occurred on C. *benghalensis* in Ndongo. These included *Actinastrum hantzschii, Ankistrodesmus acicularis, Chlamydomonas* ***reinhardtii****, Cosmarium angulosum, Scenedesmus acuminatus, Stauridium tetras* and *Ulothrix sp*.

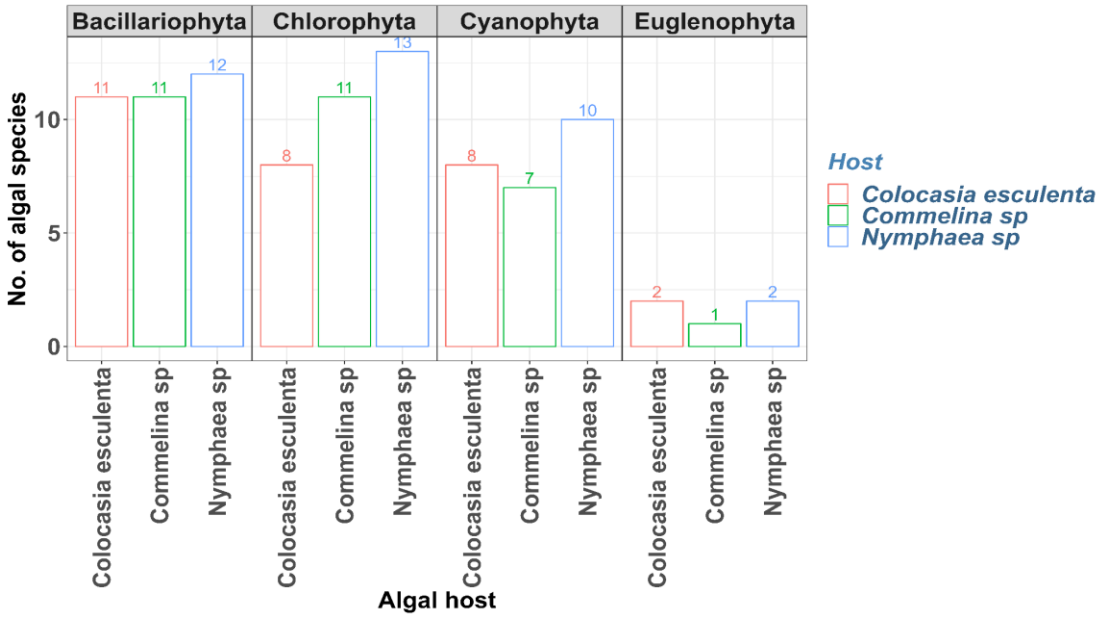

Figure 2: Distribution of algal species richness per division by algal host in the Limbe River

The algal occurrence in both rivers is presented on Table 4 with a total number of 41 epiphytic algae recorded four algal divisions from both rivers.

Table 4: Epiphytic algal occurrence on dominant macrophytes in Ndongo and Limbe rivers, Cameroon

	NDONGO			**LIMBE RIVER**		
ALGAL TAXA	***Commelina benghalensis***	***Colocasia esculenta***	***Justicia secunda***	***Commelina benghalensis***	***Colocasia esculenta***	***Nymphaea lotus***
Anabaena naviculoides F.E.Fritsch	+	+				
Aphanocapsa thermalis Brügger			+			
Arthospira platensis Gomont	+	+	+	+	+	+
Calothrix braunii Bornet & Flahault		+		+	+	+
Chroococcus minor (Kützing) Nägeli	+		+	+	+	+
Cylindrospermum catenatum Ralfs ex **Bornet & Flahault Bornet & Flahault**	+					
Lyngbya lagerheimii Gomont ex Gomont	+	+		+	+	+
Merismopedia convoluta Brébisson ex Kützing	+	+		+	+	
M. tenuissima Lemmermann		+	+	+	+	
Microcystis flos-aquae (Wi rock) Kirchner	+	+	+	+	+	+
Nostoc sp.	+					
Oscillatoria brevis Kützing ex Gomont	+					+

O. formosa Bory ex Gomont						+
O. subbrevis Schmidle			+			
Phormidium ***articulatum*** (N.L.Gardner) **Anagnostidis** & Komárek	+					+
P. chlorinum (Kützing ex Gomont). Umezaki & Watanabe		+				+
Pseudanabaena limnetica (Lemmer- man) Komárek		+			+	+
No. of Cyanophyta	10	9	6	7	8	10
ALGAL TAXA	***Commelina benghalensis***	***Colocasia esculenta***	***Justicia secunda***	***Commelina benghalensis***	***Colocasia esculenta***	***Nymphaea lotus***
Chlorophyta						
Actinastrum hantzschii Lagerheim	+			+	+	+
Ankistrodesmus acicularis (Braun) Korshikov	+			+	+	+
A. angustus C.Bernard		+				
A. falcatus (Corda) Ralfs.	+					
Chlamydomonas ***reinhardtii*** P.A.Dangeard	+			+	+	+
Chlorella vulgaris Beijerinck	+		+			
Coelastrum microporum Nägeli		+				
Cosmarium angulosum Brébisson	+			+	+	+

C. granatum var. ***nordstedtii*** Hansgir*g*			+			
Desmodesmus serratus (Corda) S.S.An, Friedl & E.Hegewald				+		
Dictyosphaerium ehrenbergianum Nageli		+				
Kirchneriella contorta (Schmidle) Bohlin				+		
Monoraphidium arcuatum (Korshikov) Hindák			+			
Mougeotia sp.	+					+
Oedogonium calliandrum **L.R.Hoffmann**	+					+
Oocystis lacustris Chodat				+		
Pediastrum boryanum (Turpin) Meneghini	+				+	+
P. duplex Meyen	+					+
S. acuminatus (Lagerheim) Chodat	+			+	+	+
S. acutus Meyen			+			
S. quadricauda Turpin	+					+
Spirogyra communis (Hassall) Kützing	+					
Stauridium tetras (Ehrenberg) E Hegewald	+	+	+	+	+	+
***Stauridium tenue* (C.Agardh) Kützing.**		+				
Tetraedron minimum (A.Braun) Hansgirg						+

Ulothrix sp.	+	+	+	+	+	+
No. of Chlorophyta	**15**	**6**	**6**	**11**	**8**	**13**
Bacillariophyta						
Achnanthidium minutissimum (**Kützing**) Czarnecki	+	+	+	+	+	+
Amphora inariensis Krammer	+					+
Aulacoseira *granulata* (Ehrenberg) Simonsen				+	+	+
A. italica (Ehrenberg) Simonsen						
Bacillaria paradoxa J.F.Gmelin, nom. illeg.	+					
Cocconeis placentula Ehrenberg	+	+				
Cyclotella *caspia* Grunow				+		
C. quillensis L.W. Bailey					+	
C. striata **(Kützing) Grunow**	+		+			
Cyclotella meneghiniana Kützing						+
Cymbella ***affinis*** Kutzing	+	+	+	+	+	+
C. naviculiformis Auerswald ex Heiberg	+	+	+	+	+	+
Fragilaria capucina Desmazières		+				
Gomphonema angustum C.Agardh	+	+	+	+	+	+

G. minutum (C.Agardh) C.Agardh			+			
G. truncatum Ehrenberg	+					
Navicula absoluta Hustedt	+	+	+	+	+	+
N. distans (W.Smith) Ralfs	+	+	+	+	+	+
N. palea (Kützing) W.Smith	+	+	+	+	+	+
Pinnularia divergens W.Smith	+	+	+	+	+	+
Synedra acus Kützing	+	+	+	+	+	+
No. of Bacillariophyta	**14**	**11**	**11**	**11**	**11**	**12**
Euglenophyta						
Euglena sp.	+	+	+	+	+	+
Phacus acuminatus Stokes					+	+
No. of Euglenophyta	**1**	**1**	**1**	**1**	**2**	**2**
Total no. of species	**40**	**27**	**24**	**30**	**29**	**37**

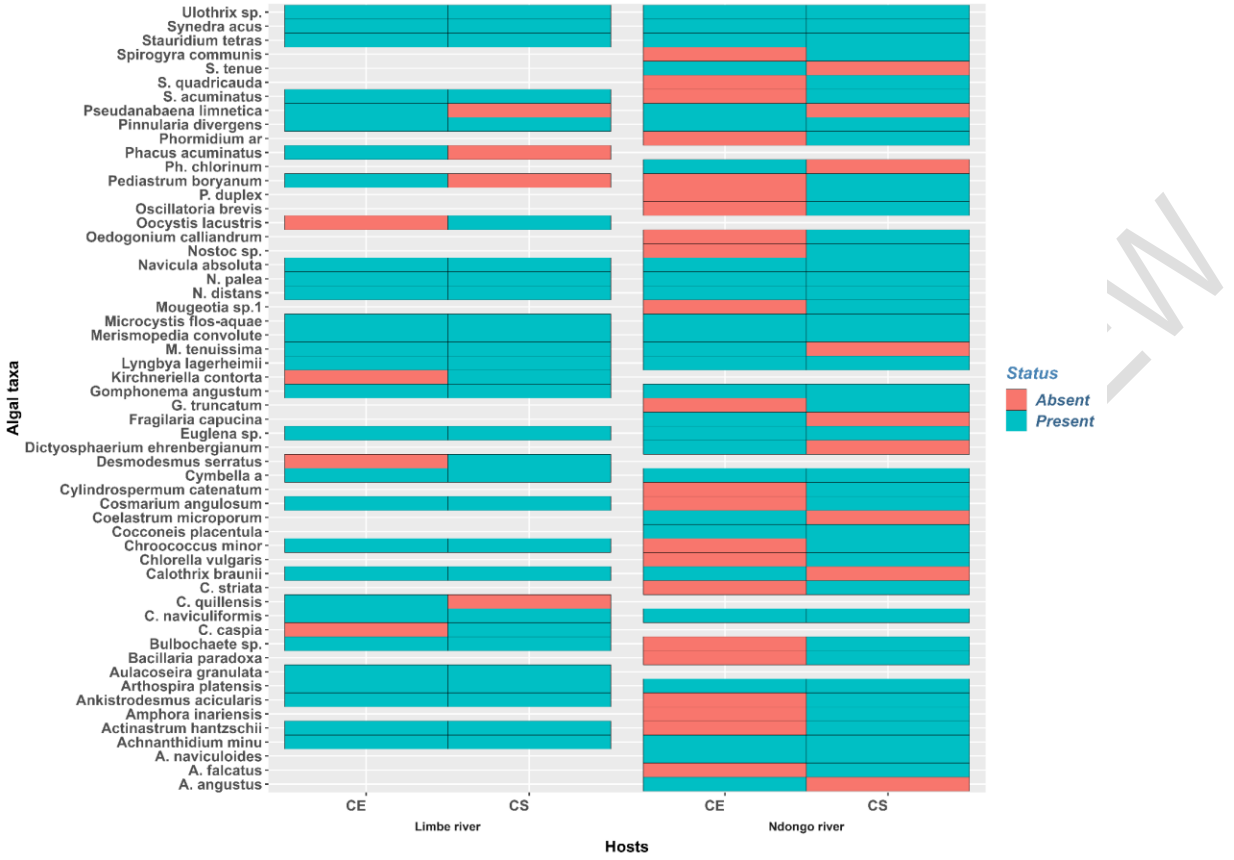

Figure 3: Algal occurrence across host species in the Limbe and Ndongo rivers

Epiphytic algal composition and diversity

3.3 Variation of mean algal biomass (Epiphyte chlorophyll a) across plant hosts in Limbe and Ndongo rivers

A relatively high variability in epiphytic biomass as represented by chlorophyll a was recorded in both rivers (Figures 4 and 5). The highest algal chlorophyll a was recorded on *Nymphaea* ***lotus*** (621 **µg**/g dry weight) and *Commelina* ***benghalensis*** (644 **µg**/g) in Limbe and Ndongo respectively. Lowest epiphyte chlorophyll a was recorded in *Justicia* ***secunda*** in Ndongo (607 **µg**/g dry weight).

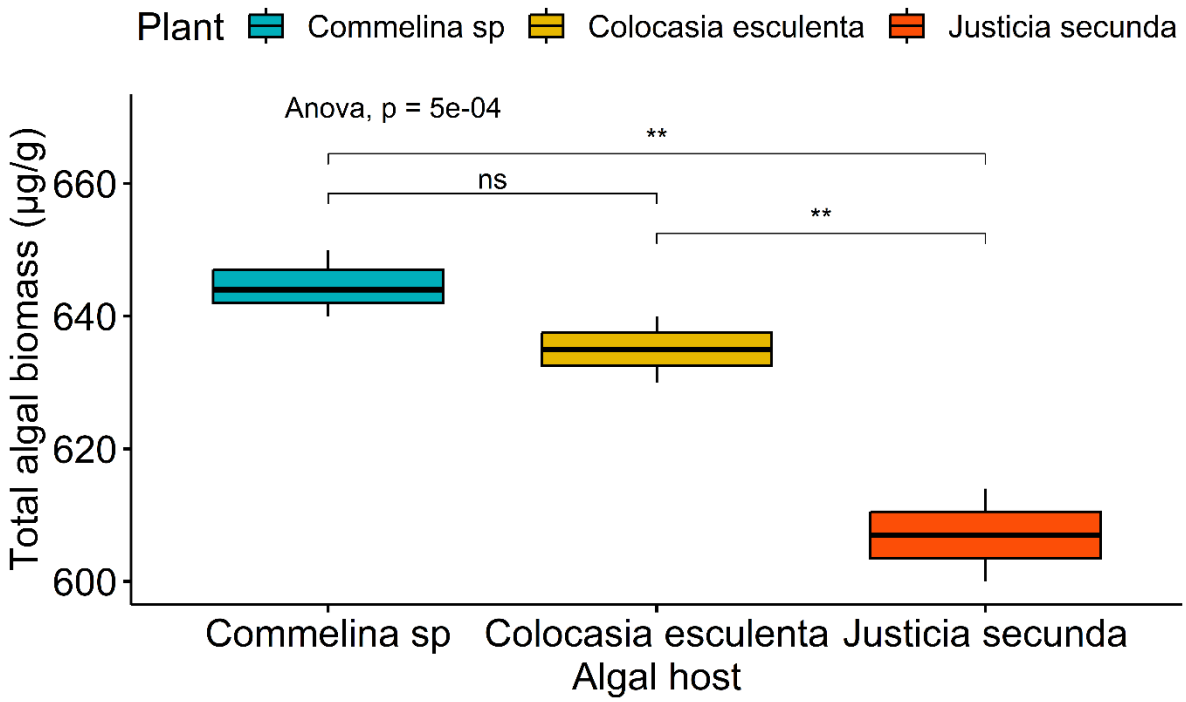

Figure 4: Variation of mean total algal biomass (Chl a) across algal hosts in the Ndongo River

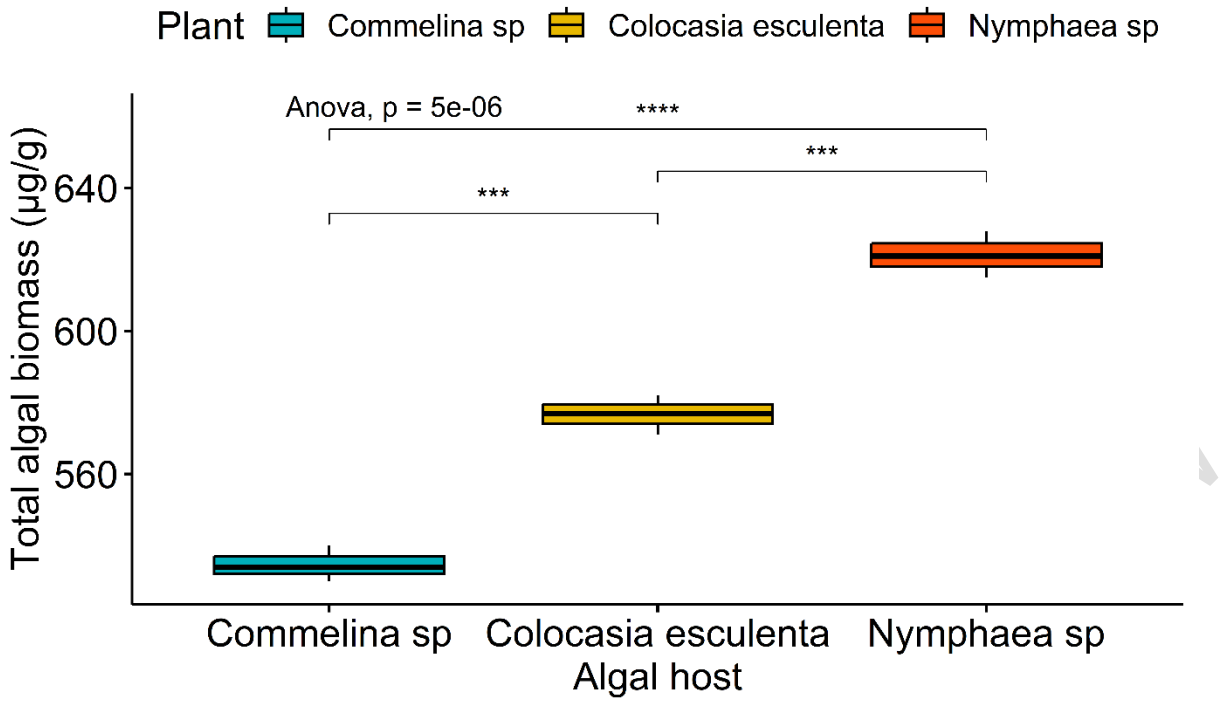

Figure 5: Variation of mean total algal biomass (Chl a) across algal hosts in the Limbe River

Results indicated that algal biomass in terms of chlorophyll a varied significantly with host plants in both rivers, *Nymphaea lotus* (Nymphaeaceae) and *Commelina benghalensis* (Commelinaceae) having the highest algal biomass. This could be explained by the floating and submergent habits of these plants which increased the contact period in the water body as opposed to plants like *Justicia secunda* (Acanthaceae) which were dominant in Ndongo River but had the lowest epiphytic chlorophyll a. *Justicia* sp has with very slim stems and were limited to the peripheries of the water body. The slimness of its stem offered a small surface for algal colonization. *Colocasia* sp also had a relatively higher algal biomass and this could be attributed to its larger pseudo-stem which provided a larger area for algal colonization.

Other factors that may affect algal diversity and abundance of epiphytic algae include nutrients, light availability and the hydrological regime [25]. The very high percent cover of *Nymphaea* on the surface of Limbe River could reduce the amount of light penetration in to the water body and hence contributing to the lower algal biomass that was recorded on *Commelina benghalensis* in that river. The very diverse algal flora **were** recorded in both rivers indicate the high productivity of these aquatic habitats. Chiefly dominated by Bacillariophyta, only pennate diatoms were ubiquitous. These included ***Navicula*** *absoluta, N. distans, N. palea, Pinnularia divergens, Synedra acus, Cymbella naviculiformis and Achnanthidium* ***minutissimum****.* Similar findings were made by [40] who attributed their cosmopolitan nature to the fact that these species readily adapt to changing abiotic conditions. Most of the pennate diatoms possess attachment discs, which enable them to resist being washed away by fast-flowing waters. *Aulacoseira granulata*, a centric diatom was found to occur only in Limbe River indicating possible levels of pollution of this river.

Chlorophyta species that **were identified** during the study have been recorded as pollution indicators (*Actinastrum hantzschii, Ankistrodesmus acicularis, Chlamydomonas* ***reinhardtii****, Cosmarium angulosum, Scenedesmus acuminatus, Stauridium tetras and Ulothrix sp.*) [37].

4. CONCLUSION

Aquatic macrophytes **harbour** a diverse flora of epiphytic algae. *Nymphaea lotus, Commelina benghalensis, Colocasia esculenta and Justicia secunda* examined during the study all possessed epiphytic algae. Significant variations in chlorophyll a (algal biomass) associated with these macrophytes revealed the fact that, differences in host plants' architecture could account for such differences.

The biomass associated with such aquatic plants could influence the trophic status of those rivers should they be dislodged into the water column. The epiphytic chlorophyll a was higher than phytoplankton chlorophyll a of the water column, implying that these macrophytes could as well be seen as sinks for fish food and also very important in the conservation of freshwater invertebrates such as filter feeders.

CONSENT (WHERE EVER APPLICABLE)

Both authors (Awo and Fonge) have seen and approved the final version of the manuscript being submitted. This article is the authors' original work, has not received prior publication and is not under consideration for publication elsewhere.

REFERENCES

1. Xia, P., Yan, D., Sun, R., Song, X., Lin, T., & Yi, Y. (2020). Community composition and correlations between bacteria and algae within epiphytic biofilms on submerged macrophytes in a plateau lake, southwest China. *Science of the Total Environment*, *727*, 138398.
2. Guo, K., Wu, N., Li, W., Baattrup-Pedersen, A., & Riis, T. (2021). Microbial biofilm community dynamics in five lowland streams. *Science of the Total Environment*, *798*, 149169.
3. Weigelhofer, G., Jirón, T. S., Yeh, T.-C., Steniczka, G., & Pucher, M. (2020). Dissolved organic matter quality and biofilm composition affect microbial organic matter uptake in stream flumes. *Water*, *12*(11), 3246.
4. Calapez, A. R., Elias, C. L., Alves, A., Almeida, S. F. P., Brito, A. G., & Feio, M. J. (2020). Shifts in biofilms' composition induced by flow stagnation, sewage contamination and grazing. *Ecological Indicators*, *111*, 106006.
5. Al-Ghanimy, D. B. G. (2020). Study of epipelic algae and epiphytic algae in Al-Sadir River, Al-Najaf, Iraq. *Eurasia J Biosci*, *14*(1), 763–772.
6. Nieder, C., Liao, C., Lee, C., Clements, K. D., & Liu, S. (2022). Novel field observations of coral reef fishes feeding on epiphytic and epizoic organisms associated with the allelopathic seaweed Galaxaura divaricata. *Ecology and Evolution*, *12*(11), e9529.
7. Cazzanelli, M., Castillo, M. M., Soria-Barreto, M., Ochoa-Gaona, S., Sepúlveda-Lozada, A., Patiño-Espinosa, S. G., Jiménez-Pérez, N. C., & Rodiles-Hernández, R. (2023). Epiphytes support aquatic consumers of a large floodplain lake ecosystem in the southern Gulf of Mexico. *Aquatic Sciences*, *85*(4), 114.
8. Marino, R., Hayn, M., Howarth, R. W., Giblin, A. E., McGlathery, K. J., & Berg, P. (2023). Nitrogen fixation associated with epiphytes on the seagrass Zostera marina in a temperate lagoon with moderate to high nitrogen loads. *Biogeochemistry*, 1–16.
9. Lv, T., Wang, H., Wang, Q., Li, D., Gao, C., Zhang, T., Lei, X., & Liu, C. (2023). Invasive submerged plant has a stronger inhibitory effect on epiphytic algae than native plant. *Biological Invasions*, 1–14.
10. Al Tamaki, A. N. A., & Al Obeidi, N. A. (2023). Use of Epiphytic Diatoms in Cyperus Papyrus L. As Bioindicators in the Assessment of the Health of the Upper Euphrates River Between the Haditha Dam and Al-Baghdadi, Iraq. *IOP Conference Series: Earth and Environmental Science*, *1222*(1), 12020.
11. Arsad, S., Putra, K. T., Latifah, N., Kadim, M. K., & Musa, M. (2021). Epiphytic microalgae community as aquatic bioindicator in Brantas River, East Java, Indonesia. *Biodiversitas Journal of Biological Diversity*, *22*(7).
12. Razli, S. A., Abas, A., Ismail, A., Othman, M., Mohtar, A. A. A., Baharudin, N. H., Aiyub, K., & Latif, M. T. (2022). Epiphytic microalgae as biological indicators for carbon monoxide concentrations in different areas of Peninsular Malaysia. *Environmental Forensics*, *23*(3–4), 314–323.
13. Saraphol, S., Rindi, F., & Sanevas, N. (2024). Diversity of Epiphytic Subaerial Algal Communities in Bangkok,

Thailand, and Their Potential Bioindicator with Air Pollution. *Diversity*, *16*(1), 55.
14. Das, S. K., & Singh, D. (2021). Epiphytic algae on the bryophytes of Larsemann Hills, East Antarctica. *National Academy Science Letters*, *44*(2), 161–165.
15. Inman-Carter, K. (2022). *An overview of the current research on epiphyte ecology*.
16. Riato, L., & Leira, M. (2020). Heterogeneity of epiphytic diatoms in shallow lakes: Implications for lake monitoring. *Ecological Indicators*, *111*, 105988.
17. Sahu, S. K., Ingle, K. N., & Mantri, V. A. (2020). Epiphytism in seaweed farming: Causes, status, and implications. *Environmental Biotechnology Vol. 1*, 227–242.
18. Zhang, Z., Yu, R., Xia, X., Li, J., Sun, H., Cao, Z., Qi, Z., Lu, C., & Lu, X. (2022). Significant diurnal variation of CO2 flux from a shallow eutrophic lake: effects of submerged aquatic vegetation and algae bloom. *Aquatic Sciences*, *84*(4), 62
19. Zhang, Y., Guo, X., & Zhu, X. (2023). Strong diurnal variability of carbon dioxide flux over algae-shellfish aquaculture ponds revealed by eddy covariance measurements. *Agriculture, Ecosystems & Environment*, *348*, 108426.
20. Nakamaya et al 2014
21. Moncreiff, C. A., Sullivan, M. J., & Daehnick, A. E. (1992). Primary production dynamics in seagrass beds of Mississippi Sound: the contributions of seagrass, epiphytic algae, sand microflora, and phytoplankton. *Marine Ecology-Progress Series*, *87*, 161.
22. Qui-Minet, Z. N., Davoult, D., Grall, J., & Martin, S. (2022). The relative contribution of fleshy epiphytic macroalgae to the production of temperate maerl (rhodolith) beds. *Marine Ecology Progress Series*, *693*, 69–82.
23. Lv, T., Fan, S., Wang, H., Li, D., Wang, Q., Lei, X., Liu, C., & Yu, D. (2022). Invasion of water hyacinth and water lettuce inhibits the abundance of epiphytic algae. *Diversity and Distributions*, *28*(8), 1650–1662.
24. Nelson, W. G. (2017). Development of an epiphyte indicator of nutrient enrichment: a critical evaluation of observational and experimental studies. *Ecological Indicators*, *79*, 207–227.
25. Chen, C., Yin, D., Yu, B., & Zhu, H. (2007). Effect of epiphytic algae on photosynthetic function of Potamogeton crispus. *Journal of Freshwater Ecology*, *22*(3), 411–420.
26. Jones, E., & Thornber, C. S. (2010). Effects of habitat-modifying invasive macroalgae on epiphytic algal communities. *Marine Ecology Progress Series*, *400*, 87–100.
27. Levin, P. S., & Mathieson, A. C. (1991). Variation in a host-epiphyte relationship along a wave exposure gradient. *Marine Ecology Progress Series*, 271–278.
28. Awo, M.S. Tabot, P.T., Daniel Kenko, & Fonge B. A(2023). Occurrence and Nutrient concentration of aquatic macrophytes in roadside streams in the Mount Cameroon region *GSC Biological and Pharmaceutical Sciences* 22 (01)25-37.
29. Akoachere, R. A., Etone, E. N., Mbua, R. L., Ngassam, M. P., Longonje, S. N., Oben, P. M., & Engome, R. W. (2019). Trace metals in groundwater of the south eastern piedmont region of Mount Cameroon: quantification and health risk assessment. *Open Access Library Journal*, *6*(4), 1–22.
30. Kenko, D. B. N., Maffo, F. M., Kenfack, A. D., Amougou, C. A., & Ngameni, N. T. (2023). Limnology of the Ndongo stream (South-West Cameroon): wastes management, water physicochemical quality and phytoplankton species richness. *GSC Biological and Pharmaceutical Sciences*, *24*(1), 72–86.
31. Anyinkeng, N., Neba, G. A., Mih, A. M., & Tening, A. S. (2020). Phytoremediation Potential of Some Macrophytes from a Car Wash Stream in Buea, South Western Cameroon. *Journal of Environmental Protection*, *11*(12), 1052.
32. Fai, P. B. A., Kenko, D. B. N., Tchamadeu, N. N., Mbida, M., Korejs, K., & Riegert, J. (2023). Use of multivariate analysis to identify phytoplankton bioindicators of stream water quality in the monomodal equatorial agroecological zone of Cameroon. *Environmental Monitoring and Assessment*, *195*(6), 788.
33. Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*, *11*(5), 1633–1644.
34. APHA (2005). Standard Methods, 21st Edition. 19th Edition/Ed. Washington, D.C.: American Public Health Association.
35. Awo, M. E., Fonge, B. A., Tabot, P. T., & Akoachere, J. T. K. (2020). Water quality of the volcanic crater lake, Lake Barombi Kotto, in Cameroon. *African Journal of Aquatic Science*, *45*(4), 401–411.
36. Arguelles, E. D., & Monsalud, R. G. (2021). Taxonomy and Species Composition of Epiphytic Algae in Sta. Cruz River, Laguna (Philippines). *Journal of Microbiology, Biotechnology and Food Sciences*, *11*(3), 1–8. https://doi.org/10.15414/JMBFS.2039
37. Bellinger, E. G., & Sigee, D. C. (2015). *Freshwater algae: identification, enumeration and use as bioindicators*. John Wiley & Sons.
38. Brierley, B., Carvalho, L., Davies, S., & Krokowski, J. (2007). *Guidance on the quantitative analysis of phytoplankton in Freshwater Samples. Report to SNIFFER (Project WFD80), Edinburgh, December 2007*.
39. ALGAEBASE.ORG
40. van Vuuren, S. J., Taylor, J., & van Ginkel, C. (2006). *Freshwater algae*. School of Environmental Sciences and

Development: Botany.
41. WHO,2017