Diversity and abundance of macrophytes of streams under different anthropogenic influences in the Buea municipality, southwestern Cameroon

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Abstract

Macrophytes can occur as submerged, floating or emergent. They provide not only important structural supports in streams and river habitats, but also absorb and sequester pollutants, provide primary food production, nutrients and habitats to a wide range of macro and micro-organisms living in and around lotic sites. Their existence is however threatened by both anthropogenic and natural stresses. This study aimed to document macrophyte diversity and abundance in streams under different anthropogenic influences in Buea, southwestern Cameroon. Floristic surveys were carried out using 500 m long transects laid along the different streams. Plants encountered were identified and confirmed at the Limbe Botanic Garden Herbarium. One hundred and ten species belonging to 38 families and 83 genera were recorded. There were no floating species and only one stream had submerged species (Vallisneria spiralis L and Crinum calamistratum Bogner & Heine). The highest number of families (26), genera (58) and species (70) were obtained in Ndongo while the least of these taxa were obtained in Bulu (16, 35 and 39, respectively). Overall, Asteraceae and Poaceae were the most abundant, suggesting anemophilic dispersals. However, individual species abundances varied with streams. The highest diversity index (0.945) was in Wongangjio while the least (0.760) was in Nange, suggesting that waste discharge from car wash might influence species diversity negatively. The macrophyte composition was made up of obligate and non-obligate species as a consequence of anthropogenic influences. These results constitute baseline data for the area that can be exploited for further research and monitoring.

Keywords: Macrophyte; Streams; Anthropogenic influence; Buea Municipality

1. Introduction

Aquatic ecosystems usually contain macrophytes which may be submerged, floating or emergent. The plants are very important in the structure and function of the aquatic system in that they absorb and sequester pollutants, reduce erosion by damping wave action and stabilize shorelines and river bottoms [1, 2, 3]. Additionally, macrophytes provide primary food production, nutrients and habitat for a wide range of macro and micro-organisms living in and around lotic sites [4]. The effectiveness of their functioning depends, amongst other factors, on their diversity and abundance [5].

Studies on macrophyte abundance and diversity in Cameroon are rare [1, 6, 7]. Other studies involving macrophytes in other areas of the country, focus on their use in wastewater treatment [8, 9, 10]. Little or no such data exist for the Southwest Region and Buea in particular.

Buea lies between 3°57’N – 4°27’N and 8°58’ – 9°25’E on the eastern flank of mount Cameroon. The mean annual precipitation and temperature stand at 3000 mm and 28 °C, respectively. The mean relative humidity is 86% and...
sunshine ranges from 900 to 1200 hrs per annum [11]. The climate is equatorial, with two seasons: a dry season from November to February and a rainy season from March to October. The municipality has a rich hydrological network. The absence of conscious efforts to protect water catchments, haphazard waste disposal especially in water ways, deforestation motivated by agriculture, timber for local consumption, fuel wood and bush fires (natural and hunting fires) have all contributed to degrade the aquatic ecosystem within the municipality.

This work had as objective to assess the diversity and abundance of macrophytes from five streams with different anthropogenic influences in the Buea municipality. This baseline data will complement data from other areas which can be exploited for further research and by aquatic ecosystem protection services of the municipality.

2. Material and methods

2.1. Sampled streams and their characteristics

Five streams subjected to different anthropogenic influences were selected. Farming as an activity cuts across the different streams.

Nange water: This is a stream located far from habitation but with characteristic that cars are driven into it and washed. In this stream, there are two car wash points.

2) Stream at Mile 17 Hill (M17): The catchment area of this stream was used as dumping ground for municipal waste before the arrival of the waste collection company in 2010. In this stream, cars are washed by the banks, with effluents discharged into it. It also receives storm drainage from Molyko, a residential neighbourhood with dense population.

3) Ndongo: It is exposed to waste from various anthropogenic (waste disposal, bathing and laundry) activities as it flows from lower Bokoko to Mile 16, passing through Molyko, with dense population. Despite the presence of the waste collection company, municipal waste are deposited at various points along the course of the stream. Bathing and laundry, in addition to farming, are other activities along the stream course.

4) Bulu water: It originates from Lower Bunduma and flows down to Bulu Native, with storm drainage as well as municipal wastes from Upper Bunduma and Great Soppo getting into it at various points along the course.

5) Wonganjio: It is a stream located far from habitation with no waste dump and no washing of cars.

2.2. Data collection

Floristic inventory was carried out along 500 m long transects laid along the different streams (Figure 1). The transect for Nange originated 10 m before the first car wash point and extended downstream beyond the second car wash point. In the stream at Mile 17 Hill, the transect originated from the catchment and extended downstream beyond the car wash area. The transects for Ndongo and Wonganjio originated 10 m from the catchment. For Bulu, the transect was laid 10 m after the observed point of water emergence along the course.

Ten plots were laid per transect. The plots began 10 m from transect origin and were interspaced by a distance of 42 m. Within each plot, sampling units of 1mx1m were mapped out by dividing it into strips of (1 x 1) m and numbering. Ballots were then drawn to select sampling units such that 1/3 of them were on each of the right and left bank and within the stream. A total of twelve sampling units were randomly selected within each plot. A frame measuring (1 x 1 m, in-to-in) was placed at the selected number of the strip and the vegetation within it censured.

Plants were identified in the field. Unidentified species were photographed, voucher specimens collected and identified using illustrations and photographs in manuals and later confirmed at the Limbe Botanic Garden Herbarium (SCA).
The frequency of occurrence and abundance of each species were recorded. Creeping species were evaluated by percent cover and later converted to count using Braun Blanquet scale index [12].

### 2.3. Data analysis

Species composition for the streams were determined through Simpson’s diversity indices. Simpson’s diversity index = 1 – \( D \)

\[
D = \sum \left( \frac{n_i}{N} \right)^2
\]

Where:

- \( n_i \) = number of individuals of species \( i \)
- \( N \) = Total number of individuals of all species

Species richness was determined using the Menhinicks index (\( D \))

\[
D = \frac{S}{\sqrt{N}}
\]

Where

- \( S \) = number of different species in the sample
- \( N \) = total number of individual organisms in the sample

Species similarity between steams was determined using Sörensen similarity coefficient (\( S_s \)).

\[
S_s = \frac{2a}{2a + b + c}
\]

Where \( S_s \) = Sorenson similarity coefficient
3. Results and discussion

The study revealed a total of 108 emergent and two submerged (Vallisneria spiralis L. and Crinum calamistratum Bogner & Heine, unique to Nange) species from the five streams. These species belong to 83 genera in 38 families (Table 1; Plates 1, A-F). No floating species was found in any of the streams. The absence of floating species is due to the sloppy nature of the streams since such species are characteristic of stagnant and slow-flowing waters. However, the peculiarity of Nange with regard to submerged species is probably due to the fact that it is the only stream in the list with gentle slope and wide area (40 m stream breadth). These characteristics give it the ability to accumulate sediments and nutrients thus allowing shallow pools of water which favour the establishment of submerged species.

The occurrence and abundance of the different taxa varied among streams (Fig 2). In Nange, there were a total of forty eight species. Asteraceae and Poaceae had the highest number of genera with six each while those with one genus included; Amaryllidaceae, Arecaceae, Brassicaceae, Commelinaceae, Crassulaceae, Lamiaceae and Tiliaceae. Vallisneria spiralis had the highest (40.98) relative abundance while species with the least (0.01) were; Asystasia gangetica, Raphia farinifera, Conyza boriensis, Vernonia amygdalina and Plectranthus monostachyus.

In the stream at M17 hill with forty eight species, the Asteraceae had the highest number of genera (6) while Commelinaceae, Costaceae, Cyperaceae, Heliconiaceae, Malvaceae, Mimosaceae and Piperaceae were among the list of families represented by single genus. The species with the highest (31.06) relative abundance was Echinochloa pyramidalis while the least (0.04) included Anubias barteri, V. amygdalina and Abelmoschus esculentus

Ndongo had seventy species. Poaceae had the highest genera (11) while families with single genus were many and included Asparagaceae, Cannaceae, Costaceae and Sellaginellaceae. Pennsetum purpureum had the highest (17.24) relative abundance while the least (0.03) were species such as Axonopus compressus, Colocasia esculenta and Diplocyclos palmatus.

In Bulu, there were a total of thirty nine species and the families with the highest genera (6) were Poaceae and Asteraceae while those with the least (1) included Costaceae, Dryopteridaceae, Fabaceae, Oxalidaceae, Piperaceae and Solanaceae. P. purpureum had the highest (10.66) relative abundance while the least (0.08) was Oxalis simplex.

In Wongangjio with a total of forty six species, Asteraceae had the highest (7) genera while the least were families such as Araceae, Brassicaceae, Blechnaceae, Costaceae, Lamiaceae and Tiliaceae with one genus each. A. barteri had the highest (12.89) relative abundance while the least (0.05) were Vernonia hyminolepis, Luffa aegyptiaca and Dryopteris felixmas.
Table 1 Macrophtes of different streams in Buea

| Species*                     | Nange Freq | Rel Abun | Mile 17 Freq | Rel Abun | Ndongo Freq | Rel Abun | Bulu Freq | Rel Abun | Wongangjio Freq | Rel Abun |
|------------------------------|------------|----------|--------------|----------|-------------|----------|-----------|----------|-----------------|----------|
| Acanthaceae                  |            |          |              |          |             |          |           |          |                 |          |
| *Asystasia gangetica* (L.) T. Anderson | 1.00       | 0.01     | 12.00        | 0.66     | 19.00       | 2.27     | 34.00     | 6.65     | 39.00           | 3.32     |
| *Asystasia intrusa* Nees     | 12.00      | 4.48     | 19.00        | 10.45    | 2.00        | 0.05     | 0.00      | 0.00     | 0.00            | 0.00     |
| *Brillantaisia nitens* Lindau| 0.00       | 0.00     | 0.00         | 0.00     | 17.00       | 2.62     | 2.00      | 0.16     | 3.00            | 0.28     |
| *Eremomastax speciosa* (Hochst.) Cufod | 0.00       | 0.00     | 4.00         | 0.35     | 1.00        | 0.27     | 0.00      | 0.00     | 4.00            | 0.75     |
| *Justicia carnea* Lindl.     | 0.00       | 0.00     | 0.00         | 0.00     | 1.00        | 0.70     | 0.00      | 0.00     | 0.00            | 0.00     |
| *Ruellia strepens* Lindl.    | 0.00       | 0.00     | 0.00         | 0.00     | 5.00        | 0.27     | 6.00      | 3.37     | 9.00            | 2.99     |
| *Ruellia prostrata* Poir.    | 0.00       | 0.00     | 0.00         | 0.00     | 0.00        | 0.00     | 0.00      | 0.00     | 1.00            | 2.99     |
| *Strobilanthes heyneanus* Nees| 0.00       | 0.00     | 0.00         | 0.00     | 0.00        | 0.00     | 0.00      | 0.00     | 4.00            | 3.50     |
| Amaranthaceae                |            |          |              |          |             |          |           |          |                 |          |
| *Achyranthes aspera* L.      | 2.00       | 0.72     | 1.00         | 0.14     | 9.00        | 0.72     | 0.00      | 0.00     | 7.00            | 0.98     |
| *Alternanthera sessilis* (L.) R.Br. ex DC | 0.00       | 0.00     | 0.00         | 0.00     | 20.00       | 3.82     | 6.00      | 2.16     | 0.00            | 0.00     |
| *Amaranthus blitum* L.       | 0.00       | 0.00     | 2.00         | 0.24     | 7.00        | 0.96     | 12.00     | 4.81     | 2.00            | 0.31     |
| *Amaranthus hybridus* L.     | 0.00       | 0.00     | 1.00         | 0.04     | 1.00        | 0.03     | 0.00      | 0.00     | 0.00            | 0.00     |
| *Amaranthus spinosa* L.      | 0.00       | 0.00     | 0.00         | 0.00     | 2.00        | 0.05     | 0.00      | 0.00     | 0.00            | 0.00     |
| Amaryllidaceae               |            |          |              |          |             |          |           |          |                 |          |
| *Crinum calamistratum* Bogner & Heine | 2.00       | 0.07     | 0.00         | 0.00     | 0.00        | 0.00     | 0.00      | 0.00     | 0.00            | 0.00     |
| Araceae                      |            |          |              |          |             |          |           |          |                 |          |
| *Alocasia cucullata* (Lour.) Schott | 0.00       | 0.00     | 0.00         | 0.00     | 1.00        | 0.03     | 0.00      | 0.00     | 0.00            | 0.00     |
| *Alocasia macrorrhizos* (L.) G.Don | 0.00       | 0.00     | 2.00         | 0.69     | 2.00        | 0.11     | 4.00      | 0.48     | 0.00            | 0.00     |
| *Anubias barteri* Schott.    | 9.00       | 6.96     | 1.00         | 0.04     | 0.00        | 0.00     | 0.00      | 0.00     | 13.00           | 12.89    |
| *Colocasia esculenta* (L.) Schott | 3.00       | 0.06     | 5.00         | 0.45     | 1.00        | 0.03     | 2.00      | 0.56     | 0.00            | 0.00     |
| Species* | Nange | Mile 17 | Ndongo | Bulu | Wongangjio |
|----------|--------|---------|--------|------|------------|
|          | Freq   | Rel Abun| Freq   | Rel Abun| Freq | Rel Abun| Freq | Rel Abun| Freq | Rel Abun | Freq | Rel Abun |
| Dieffenbachia picta Schott | 0.00 | 0.00 | 1.00 | 0.04 | 1.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 |
| Xanthosoma sagittifolium (L.) Schott | 0.00 | 0.00 | 3.00 | 0.28 | 6.00 | 0.67 | 9.00 | 0.72 | 0.00 | 0.00 |
| Areceaeae | Raphia farinifera (Gaertn.) Hyl. | 1.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Asparagaceae | Dracaena sp | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.03 | 0.00 | 0.00 | 0.00 |
| Asteraceae | Ageratina adenophora (Spreng.) King & H.Rob. | 8.00 | 2.47 | 13.00 | 1.90 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Ageratum conyzoides L. | 9.00 | 2.31 | 34.00 | 10.41 | 17.00 | 5.29 | 11.00 | 5.13 | 18.00 | 9.48 |
| | Bidens pilosa L. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Chromolaena odorata (L.) King & H.E. Robins | 11.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.09 |
| | Conyza boriensis (L.) Cronq. | 1.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Crassocephalum crepidioides (Benth.) S.Moore | 0.00 | 0.00 | 2.00 | 0.48 | 4.00 | 0.37 | 1.00 | 0.16 | 4.00 | 0.19 |
| | Emilia coccinea (Sims) G. Don | 1.00 | 0.10 | 5.00 | 0.17 | 1.00 | 0.11 | 2.00 | 0.40 | 2.00 | 0.09 |
| | Galinsoga quadriradiata Ruiz & Pav | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.40 | 5.00 | 2.08 | 0.00 | 0.00 |
| | Synedrella nodiflora (L.) Gaertn | 0.00 | 0.00 | 2.00 | 0.24 | 15.00 | 2.97 | 8.00 | 4.09 | 2.00 | 0.09 |
| | Tithonia diversifolia (Hems!.) A.Gray | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 22.00 | 10.24 | 0.00 | 0.00 |
| | Vernonia amygdalina Delile | 1.00 | 0.01 | 1.00 | 0.04 | 1.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Vernonia hyninolespis A. Rich. | 0.00 | 0.00 | 1.00 | 0.04 | 3.00 | 0.13 | 0.00 | 0.00 | 1.00 | 0.05 |
| Athyriaceae | Diplazium proliferum (Lam) Thouars. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.09 |
| Blechnaceae | Woodwardia fimbriata Sm. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.09 |
| Species*              | Nange Freq | Nange Rel Abun | Mile 17 Freq | Mile 17 Rel Abun | Ndongo Freq | Ndongo Rel Abun | Bulu Freq | Bulu Rel Abun | Wongangjio Freq | Wongangjio Rel Abun |
|----------------------|------------|----------------|--------------|-----------------|-------------|-----------------|-----------|---------------|-----------------|---------------------|
| Brassicaceae         |            |                |              |                 |             |                 |           |               |                 |                     |
| Rorippa nasturtium- aquaticum R.Br. | 13.00      | 24.05          | 0.00         | 0.00            | 0.00        | 0.00            | 0.00      | 0.00          | 5.00             | 5.37                |
| Cannaceae            |            |                |              |                 |             |                 |           |               |                 |                     |
| Canna. indica L.     | 0.00       | 0.00           | 0.00         | 0.00            | 1.00        | 0.53            | 0.00      | 0.00          | 0.00             | 0.00                |
| Commelinaceae        |            |                |              |                 |             |                 |           |               |                 |                     |
| Aneilema umbrosum (Vahl) Kunth | 0.00       | 0.00           | 0.00         | 0.00            | 11.00       | 2.86            | 1.00      | 0.16          | 5.00             | 0.42                |
| Commelina benghalensis L. | 43.00     | 1.06           | 42.00        | 2.15            | 45.00       | 5.13            | 41.00     | 8.57          | 39.00            | 3.36                |
| Convolvulaceae       |            |                |              |                 |             |                 |           |               |                 |                     |
| Ipomoea alba L.      | 0.00       | 0.00           | 0.00         | 0.00            | 0.00        | 0.00            | 8.00      | 1.76          | 0.00             | 0.00                |
| Ipomoea batatas (L.) Lam. | 0.00       | 0.00           | 17.00        | 0.93            | 21.00       | 2.06            | 23.00     | 4.09          | 0.00             | 0.00                |
| Ipomoea muricata (L.) Jacq. | 0.00       | 0.00           | 0.00         | 0.00            | 13.00       | 1.76            | 26.00     | 7.13          | 36.00            | 6.02                |
| Ipomoea purpurea (L.) Roth | 10.00      | 0.30           | 0.00         | 0.00            | 11.00       | 0.67            | 0.00      | 0.00          | 21.00            | 6.16                |
| Ipomoea tiliacea (Wild.) Choisy | 0.00       | 0.00           | 54.00        | 2.80            | 3.00        | 0.32            | 0.00      | 0.00          | 0.00             | 0.00                |
| Costaceae            |            |                |              |                 |             |                 |           |               |                 |                     |
| Costus scaber Ruiz & Pav. | 6.00       | 1.20           | 2.00         | 0.62            | 14.00       | 2.54            | 4.00      | 0.72          | 8.00             | 2.05                |
| Crassulaceae         |            |                |              |                 |             |                 |           |               |                 |                     |
| Bryophyllum pinnatum (Lam.) Oken | 1.00       | 0.09           | 0.00         | 0.00            | 0.00        | 0.00            | 0.00      | 0.00          | 0.00             | 0.00                |
| Cucurbitaceae        |            |                |              |                 |             |                 |           |               |                 |                     |
| Diplocyclos palmatus (L.) C.Jeffrey | 7.00       | 0.15           | 1.00         | 0.04            | 1.00        | 0.03            | 8.00      | 0.96          | 8.00             | 0.79                |
| Coccinea grandis (L.) Voigt | 0.00       | 0.00           | 0.00         | 0.00            | 2.00        | 0.45            | 0.00      | 0.00          | 0.00             | 0.00                |
| Luffa acutangula (L.) Roxb. | 0.00       | 0.00           | 0.00         | 0.00            | 4.00        | 0.32            | 0.00      | 0.00          | 10.00            | 0.98                |
| Luffa aegyptiaca Mill. | 0.00       | 0.00           | 0.00         | 0.00            | 0.00        | 0.00            | 0.00      | 0.00          | 1.00             | 0.05                |
| Momordica dioica Roxb. ex Willd | 0.00       | 0.00           | 0.00         | 0.00            | 15.00       | 1.26            | 0.00      | 0.00          | 13.00            | 1.82                |
| Species*                        | Nange       | Mile 17     | Ndongo      | Bulu       | Wongangjio  |
|--------------------------------|-------------|-------------|-------------|------------|-------------|
|                                | Freq | Rel Abun | Freq | Rel Abun | Freq | Rel Abun | Freq | Rel Abun | Freq | Rel Abun | Freq | Rel Abun |
| Momordica foetida Schumach.    | 5.00 | 0.16     | 26   | 1.49     | 18.00 | 1.12     | 12.00 | 3.00     | 14.00 | 1.82     |
| Sicyos angulatus L.            | 0.00 | 0.00     | 13.00 | 0.66     | 8.00  | 0.35     | 0.00  | 0.00     | 0.00  | 0.00     |
| Cyperaceae                     |          |           |       |           |       |           |       |           |       |           |
| Cyperus erythrorhizos Muhl.    | 5.00 | 0.46     | 7.00  | 3.84     | 1.00  | 0.05     | 0.00  | 0.00     | 2.00  | 0.37     |
| Cyperus oxylepis Nees ex Steud | 1.00 | 0.04     | 0.00  | 0.00     | 0.00  | 0.00     | 0.00  | 0.00     | 0.00  | 0.00     |
| Kyllinga gracillima Miq.       | 1.00 | 0.07     | 0.00  | 0.00     | 2.00  | 0.21     | 0.00  | 0.00     | 1.00  | 0.47     |
| Dryopteridaceae                |          |           |       |           |       |           |       |           |       |           |
| Dryopteris cochleata (D. Don)  | 0.00 | 0.00     | 0.00  | 0.00     | 0.00  | 0.00     | 0.00  | 0.00     | 8.00  | 1.17     |
| C. Chr.                        |          |           |       |           |       |           |       |           |       |           |
| Dryopteris cycadina (Franch. & Sav.) C. Chr. | 3.00 | 0.12     | 0.00  | 0.00     | 0.00  | 0.00     | 3.00  | 0.64     | 12.00 | 1.20     |
| Dryopteris felixmas (L.) Schott| 2.00 | 0.04     | 0.00  | 0.00     | 1.00  | 0.11     | 0.00  | 0.00     | 1.00  | 0.05     |
| Euphorbiaceae                  |          |           |       |           |       |           |       |           |       |           |
| Euphorbia dentata Michx        | 0.00 | 0.00     | 0.00  | 0.00     | 2.00  | 0.05     | 0.00  | 0.00     | 0.00  | 0.00     |
| Fabaceae                       |          |           |       |           |       |           |       |           |       |           |
| Puereria phaseoloides (Roxb.) Benth. | 6.00 | 0.20     | 14.00 | 0.90     | 8.00  | 0.40     | 4.00  | 0.64     | 0.00  | 0.00     |
| Vigna radiata (L.) R. Wilczek   | 5.00 | 0.12     | 2.00  | 0.07     | 4.00  | 0.96     | 0.00  | 0.00     | 0.00  | 0.00     |
| Heliconiaceae                  |          |           |       |           |       |           |       |           |       |           |
| Heliconia marginata (Greigg) Pittier | 0.00 | 0.00     | 1.00  | 0.04     | 0.00  | 0.00     | 0.00  | 0.00     | 0.00  | 0.00     |
| Hydrocharitaceae               |          |           |       |           |       |           |       |           |       |           |
| Vallisneria spiralis L.        | 18.00 | 40.98    | 0.00  | 0.00     | 0.00  | 0.00     | 0.00  | 0.00     | 0.00  | 0.00     |
| Lamiaceae                      |          |           |       |           |       |           |       |           |       |           |
| Plectranthus aboinicus (Lour.) Spreng | 0.00 | 0.00     | 0.00  | 0.00     | 0.00  | 0.00     | 0.00  | 0.00     | 3.00  | 1.54     |
| Plectranthus monostachyus (P.Beauv.) B.J.Pollard | 1.00 | 0.02     | 1.00  | 0.14     | 1.00  | 0.03     | 0.00  | 0.00     | 0.00  | 0.00     |
| Malvaceae                      |          |           |       |           |       |           |       |           |       |           |
| Abelmoschus esculentus (L).Moench | 0.00 | 0.00     | 1.00  | 0.04     | 0.00  | 0.00     | 0.00  | 0.00     | 0.00  | 0.00     |
| Species*          | Nange |        | Mile 17 |        | Ndongo |        | Bulu |        | Wongangjio |
|------------------|-------|--------|---------|--------|--------|--------|------|--------|------------|
|                  | Freq  | Rel Abun | Freq  | Rel Abun | Freq  | Rel Abun | Freq  | Rel Abun | Freq  | Rel Abun |
| Melastomataceae  |       |         |        |         |       |         |       |         |       |         |
| *Tristemma mauritianum* J.F. Gmel. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.19 |
| Mimosaceae       |       |         |        |         |       |         |       |         |       |         |
| *Mimosa pudica* L. | 0.00 | 0.00 | 4.00 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Musaceae         |       |         |        |         |       |         |       |         |       |         |
| *Ensete ventricosum* (Welw.) Cheesman | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Musa* paradisiaca* L. | 0.00 | 0.00 | 1.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Nephrolepidaceae |       |         |        |         |       |         |       |         |       |         |
| *Nephrolepis biserrata* (Sw.) Schott | 8.00 | 0.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.09 |
| *Nephrolepis cordifolia* (L.) K. Presl | 1.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Onagraceae       |       |         |        |         |       |         |       |         |       |         |
| *Ludwigia adscendens* (L.) H.Hara | 2.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ludwigia alternifolia* L. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.24 | 0.00 | 0.00 |
| *Ludwigia longifolia* (DC.) H. Hara | 1.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ludwigia peruviana* (L.) H. Hara | 10.00 | 0.41 | 17.00 | 1.83 | 2.00 | 1.26 | 1.00 | 0.32 | 0.00 | 0.00 |
| *Ludwigia stolonifera* (Guillemin & al.) P. H. Raven | 11.00 | 0.59 | 3.00 | 0.623 | 2.00 | 0.48 | 1.00 | 0.24 | 0.00 | 0.00 |
| Oxalidaceae      |       |         |        |         |       |         |       |         |       |         |
| *Oxalis simplex* Salter | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.08 | 1.00 | 0.08 | 0.00 | 0.00 |
| Piperaceae       |       |         |        |         |       |         |       |         |       |         |
| *Peperomia pellucida* Kunth | 0.00 | 0.00 | 1.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Piper umbellatum* L. | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.83 | 1.00 | 0.41 | 26.00 | 3.74 |
| Poaceae          |       |         |        |         |       |         |       |         |       |         |
| *Axonopus compressus* (Sw.) P.Beauv | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.027 | 0.00 | 0.00 | 0.00 | 0.00 |
| Species*                              | Nange | Mile 17 | Ndongo | Bulu | Wongangjio | Nange | Mile 17 | Ndongo | Bulu | Wongangjio |
|---------------------------------------|-------|---------|--------|------|------------|-------|---------|--------|------|------------|
|                                       | Freq  | Rel Abun| Freq   | Rel Abun| Freq   | Rel Abun| Freq   | Rel Abun| Freq   | Rel Abun|
| Coix lacryma-jobi L.                  | 0.00  | 0.00    | 0.00   | 0.00  | 1.00    | 0.08   | 0.00   | 0.00    | 0.00  | 0.00      |
| Dactyoctenium aegyptium (L.) Beauv.   | 11.00 | 0.38    | 0.00   | 0.00  | 4.00    | 0.51   | 0.00   | 0.00    | 0.00  | 0.00      |
| Echinochloa cruss-galli (L.) Beauv     | 0.00  | 0.00    | 0.00   | 0.00  | 4.00    | 0.67   | 0.00   | 0.00    | 0.00  | 0.00      |
| Echinochloa pyramidalis (Lam.) Hitchc. & Chase | 1.00  | 0.12    | 52.00  | 31.06 | 3.00    | 13.20  | 0.00   | 0.00    | 0.00  | 0.00      |
| Eleusine indica (L.) Gaertn           | 0.00  | 0.00    | 0.00   | 0.00  | 4.00    | 0.67   | 0.00   | 0.00    | 0.00  | 0.00      |
| Microstegium vinineum (Trin.) A. Camus| 0.00  | 0.00    | 0.00   | 0.00  | 4.00    | 0.72   | 0.00   | 0.00    | 0.00  | 0.00      |
| Panicum maximum Jacq.                 | 0.00  | 0.00    | 0.00   | 0.00  | 4.00    | 0.86   | 1.00   | 0.16    | 0.00  | 0.00      |
| Panicum sellowii Nees                | 2.00  | 0.07    | 0.00   | 0.00  | 1.00    | 0.03   | 0.00   | 0.00    | 13.00 | 1.31      |
| Paspalum fimbriatum Kunth             | 2.00  | 0.10    | 1.00   | 0.24  | 6.00    | 0.96   | 4.00   | 5.13    | 9.00  | 3.74      |
| Pennesetum purpureum Schumach        | 15.00 | 1.36    | 45.00  | 17.12 | 22.00   | 17.24  | 14.00  | 10.66   | 6.00  | 1.59      |
| Sacharrum officinalis L.              | 0.00  | 0.00    | 1.00   | 0.04  | 0.00    | 0.00   | 3.00   | 0.64    | 0.00  | 0.00      |
| Zea mays L.                           | 0.00  | 0.00    | 3.00   | 0.17  | 0.00    | 0.00   | 0.00   | 0.00    | 0.00  | 0.00      |
| Polygonaceae                          |       |         |        |       |          |        |        |         |       |           |
| Polygonum hydropiper L.               | 0.00  | 0.00    | 0.00   | 0.00  | 4.00    | 0.96   | 0.00   | 0.00    | 0.00  | 0.00      |
| Polygonum hydropiperoides Michx.      | 7.00  | 0.38    | 1.00   | 0.17  | 0.00    | 0.00   | 0.00   | 0.00    | 0.00  | 0.00      |
| Polygonum persicaria L.               | 22.00 | 7.46    | 1.00   | 0.14  | 0.00    | 0.00   | 0.00   | 0.00    | 0.00  | 0.00      |
| Portulacaceae                         |       |         |        |       |          |        |        |         |       |           |
| Talinum triangulare (Jacq.) Willd     | 0.00  | 0.00    | 2.00   | 0.83  | 1.00    | 0.24   | 0.00   | 0.00    | 0.00  | 0.00      |
| Sellaginellaceae                      |       |         |        |       |          |        |        |         |       |           |
| Sellaginella kraussiana (Kunze) A. Braun| 0.00  | 0.00    | 0.00   | 0.00  | 2.00    | 0.08   | 0.00   | 0.00    | 0.00  | 0.00      |
| Solanaceae                            |       |         |        |       |          |        |        |         |       |           |
| Brugmansia arbora (L.) Sweet          | 4.00  | 0.29    | 1.00   | 0.07  | 19.00   | 2.97   | 11.00  | 2.72    | 15.00 | 3.27      |
| Solanum carolinense L.                | 0.00  | 0.00    | 0.00   | 0.00  | 0.00    | 0.00   | 0.00   | 0.00    | 1.00  | 0.05      |
| Solanum nigrum L.                     | 0.00  | 0.00    | 5.00   | 3.22  | 2.00    | 0.11   | 0.00   | 0.00    | 0.00  | 0.00      |
| Species* | Nange | Mile 17 | Ndongo | Bulu | Wongangjio |
|----------|-------|---------|--------|------|------------|
|          | Freq  | Rel Abun| Freq   | Rel Abun| Freq   | Rel Abun| Freq | Rel Abun| Freq | Rel Abun| |
| Tiliaceae |       |         |        |       |           |         |       |       |       |           |         |       |       |       |
| *Triumphetta cordifolia A. Rich.* | 1.00  | 0.04    | 4.00   | 0.73  | 3.00     | 1.23    | 0.00  | 0.00  | 26.00 | 5.79    |
| Urticaceae |       |         |        |       |           |         |       |       |       |           |         |       |       |       |
| *Boehmeria cylindrica (L.) Swartz* | 6.00  | 0.30    | 0.00   | 0.00  | 0.00     | 0.00    | 2.00  | 0.24  | 2.00  | 6.68    |
| *Fleurya aestuans (L.) Gaudich*   | 5.00  | 0.39    | 22.00  | 3.18  | 32.00    | 11.57   | 19.00 | 8.01  | 30.00 | 0.28    |
| *Parietaria officinalis L.*        | 0.00  | 0.00    | 0.00   | 0.00  | 5.00     | 0.35    | 3.00  | 1.60  | 0.00  | 0.00    |
| *Pilea pumila (L.) A. Gray*       | 0.00  | 0.00    | 0.00   | 0.00  | 0.00     | 2.38    | 0.00  | 0.00  | 0.00  | 0.00    |
| *Urera hypselodendron (Hochst. ex A. Rich.) Wedd.* | 6.00  | 0.22    | 0.00   | 0.00  | 0.00     | 0.00    | 0.00  | 0.00  | 10.00 | 1.26    |

Note: *Frequency of occurrence (Freq) was calculated as the number of times a species was encountered in the stream. Relative abundance (Rel Abun) was calculated as the percentage of individuals of a particular species over the total number of individuals of all species.
Overall, Poaceae and Asteraceae were the most abundant in the different streams. Plants in these families have tiny feathery/light seeds which are easily dispersed by wind and insects. The variability in the relative abundances of the different macrophytes for the different streams could be associated to the fact that some species such as *P. purpureum* are able to survive under both wetland and dry land conditions.

The highest number of families (26), genera (58) and species (70) were obtained in Ndongo while the least of these taxa were obtained in Bulu (16, 35 and 39, respectively) (Figure 2).

![Figure 2](image1.png)

**Figure 2** Macrophyte occurrence in different streams in Buea

Fourteen families, 28 genera and 44 species were specific to particular streams (Figure 3). Nange and Ndongo had the highest number (4) of unique families while Bulu had none. Across the unique genera and species, Ndongo had the highest number (10 and 13 respectively) while the least were in Bulu (1 and 3 respectively). The high number of unique species in Ndongo is accounted for by the presence of species which are not obligate macrophytes, brought about by anthropogenic impacts, in line with the findings of Fonkou *et al.* [6] in Yaounde and Tita [13] in Foumbot, other areas in Cameroon.

![Figure 3](image2.png)

**Figure 3** Unique macrophytes in different streams in Buea

The highest diversity index (0.945) was in Wongangjio while the least (0.760) was in Nange (Table 2), suggesting that waste discharge from car wash might influence species diversity negatively. The highest species richness index (1.144) was in Ndongo while the least (0.577) was in Nange.
### Table 2 Diversity and species richness indices of macrophytes in different streams in Buea

| Stream     | Simpson’s diversity index | Species richness index (D) |
|------------|----------------------------|----------------------------|
| Nange      | 0.760                      | 0.577                      |
| M17        | 0.846                      | 0.893                      |
| Ndongo     | 0.925                      | 1.144                      |
| Bulu       | 0.939                      | 1.104                      |
| Wongangjio | 0.945                      | 1.016                      |

The highest Sorensen similarity index (0.606) was between Ndongo and Bulu while the least (0.391) was between Nange and Bulu (Table 3) possible because the two streams Ndongo and Bulu have similar anthropogenic influence.

### Table 3 Macrophyte Sorensen similarity indices of different streams in Buea

|        | Nange | M17 | Ndongo | Bulu | Wongangjio |
|--------|-------|-----|--------|------|------------|
| M17    | 0.563 | 1.00|        |      |            |
| Ndongo | 0.458 | 0.593| 1.000  |      |            |
| Bulu   | 0.391 | 0.506| 0.606  | 1.000|            |
| Wongangjio | 0.532 | 0.426| 0.5    | 0.471| 1.000      |

The impact of agricultural activities on the natural environment includes the creation of new habitats, which is brought about by clearing and cultivation of plant species at the expense of others [14, 15, 16]. This is probably the reason for the high diversity indices encountered in the different streams except Nange. The presence of edible species such as *Vernonia hyninolepis*, *Abelmoschus esculentus* and *Colocasia esculenta* among the list further constitutes anthropogenic impact on vegetation structure along stream courses.

The spatial differences in species composition, diversity and richness of macrophytes observed are in conformity with the findings of Bini *et al.* [17], Thomaz *et al.* [18] and Ruto *et al.* [19], and could also be accounted for by differences in physico-chemical properties [20] of both water and sediments of the streams.

### 4. Conclusion

Macrophyte diversity and abundance in Buea is high, composed of both submerged (unique to Nange) and emergent plants. The composition is made up of both obligate and non-obligate species as a consequence of anthropogenic impact along the stream belts. The abundance of the macrophytes varied with streams. Overall, Poaceae and Asteraceae were the most abundant due to anemophilic dispersal mechanisms. These results constitute baseline data for the area that can be exploited for further research and monitoring.
Plate 1 Submerged and Emergent macrophytes of streams in Buea Municipality, Cameroon

Compliance with ethical standards

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Disclosure of conflict of interest
The authors do not disclose any conflict of interest.

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