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Full Length Research Paper

The influence of host tree morphology and stem size on epiphyte biomass distribution in Lusenga Plains National Park, Zambia

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The influence of host tree morphology and stem size on epiphyte biomass distribution in host trees was assessed in Lusenga Plains National Park, Zambia for the period 2004 to 2007. A total of 8 ha were sampled in bush land, woodland and riparian forest vegetation communities. Epiphytes were collected, dried and weighed to obtain biomass, which was apportioned between different host tree species, vertical and horizontal branches, crown and trunk, and small, medium, and large stems, as well as smooth and rough bole textured substrates. Horizontal branches had more epiphytes, 50% than vertical branches (17%). Tree canopies had more epiphyte biomass, 68% than trunks (32%). In riparian forests *Usnea articulata* and *Ramalina reticulata* were not selective. In Miombo woodlands, epiphytes and certain tree species with larger stems and rough bore texture were selected. Larger substrates dbh > 100 cm had higher epiphyte biomass (94.46%) followed by medium dbh 51 to 100 cm (5.29%) and the least was on small girth dbh ≥ 20 to 50 cm (0.25%). Rough substrates had 89% biomass and only 11% occurred on smooth bole substrates. It was concluded that tree crowns, horizontal stems and branches, large and rough bole textured tree substrates provided suitable habitat for epiphyte seed settling, germination and moisture retention, while exposure to sunlight supported germination and growth of epiphytes. Maintenance of mature Miombo woodlands was therefore found to be critical in maintaining epiphytes, while protection of preferred tree species would ensure their long-term survival and sustenance of hydrologic functions.

Key words: Epiphyte, host, pattern, biomass, crown, trunk, horizontal, vertical.

INTRODUCTION

Epiphytes are plants growing perched on other plants, which differ from parasitic plants in not deriving water or food directly from supporting plant and from lianas in not having soil connections (Daubenmire, 1970). Their roots cling to the surface of the support, or penetrate cracks in its bark. The support is strictly mechanical; and not nutritional apart from substances available as exudates from the supporting tree and decay of its outer layers (Lind and Morrison, 1974). Dutta (1989) also suggested that epiphytes derived their nutrient supply in part from rainwater, which always contains some dissolved substances, and in part from the accumulated wind-borne particles on the surface of the supporting plants. In the aerial habitat, where epiphytes are found, the most limiting factor is moisture. Therefore, epiphytes are most abundant where humidity is high and droughts not protracted. Lind and Morrison (1974) and Sanford (1968)

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described epiphytes as characteristic life form of wetter tropical forests. In cold or dry climates, epiphytes are few and consist chiefly of algae, lichens, liverworts and mosses. In warm climates, ferns and orchid families augment these groups. Epiphytes grow mostly on trees and shrubs but also on other physical structures such as on walls of buildings.

Regarding the distribution of epiphytes in host trees, Kelly (1985), Cornellissen and Ter-Steege (1989) and Eggling (1947) showed that certain species of epiphytes may be stratified within individual tree species, but they did not state their actual location on host trees in varying moisture regimes such as in Miombo woodlands, where water catchment functions are most critical. In such vegetation communities rainfall is only restricted to a certain part of the year while the rest of the year remains dry. In Zambia for instance, ground water recharge is important as it feeds into aquifers which release into rivers and streams during the dry season. Knowing the distribution and biomass of epiphytes is important as they play a very significant role in intercepting rain water and recharging aquifers.

Comparing the distribution of epiphytes on many tree species can be useful in revealing location preferences (Todzia, 1986) which can guide Zambia Wildlife Authority and the Forest Department in regulating harvesting of woody plants in areas which have epiphytes and which are also important water catchment areas. This is because epiphytes play an important role not only in intercepting rainfall but also in retaining atmospheric nutrients and pollutants as earlier reported by Nadkarni (1984). Therefore, knowing their distribution and abundance would not only be useful in forest conservation and maintenance of water catchment functions, but conservation of biodiversity, soil conservation and monitoring levels of air pollution.

In Zambia, no studies have been done on epiphyte species composition, distribution and abundance, yet all areas where epiphytes are found in Zambia are critical water catchment areas. Information on the abundance and distribution of epiphytes would help Zambia Wildlife Authority and the Department of Forestry to regulate harvesting of trees in a manner that would secure epiphytes while at the same time maintaining water catchment functions. Logging for timber and pollarding for *Chitemene* (slash and burn cultivation) for instance, would destroy the host tree substrates which are the most preferred habitats for epiphytes and should be discouraged.

This study was also found to be important in generating data on epiphyte abundance and distribution on host tree substrates, as a guide in securing species and tree locations found to be critical epiphyte habitats and water catchment functions. This paper specifically addressed the following:

1) Epiphyte biomass pattern of distribution within host tree species in Lusenga Plains National Park and the areas surrounding waterfalls,
2) Epiphyte host tree species preference,
3) Effect of substrate size on the abundance and distribution of epiphytes,
4) Effect of branch and stem morphology on epiphyte biomass, and
5) Effect of host tree bark texture on epiphyte biomass.

MATERIALS AND METHODS

Study area location and description

The study was conducted in Lusenga Plains National Park which is 880 km^2 in extent and is located in northern Zambia. It lies in Kawambwa District of Luapula Province between longitudes 28° 55' East and 29° 12' south latitudes (Figure 1).

Vegetation communities

The National Park is mainly covered by dense Miombo woodlands which is dominated by the genera *Brachystegia*, *Julbernadia* and *Isoberlinia* spp., interspaced with few small areas of *Pteleopsis anisoptera* on alluvial patches. Areas exposed to intense fires are covered mainly by bush land. The rivers and dambos are mainly covered by evergreen forests. The woodland was described as areas supporting trees up to 20 m high, with an open or continuous but not thickly interlaced canopy. Bush land was described as areas supporting an assemblage of trees and shrubs often dominated by plants with shrubby habit but with trees always conspicuous, with a single or layered canopy, usually not exceeding 10 m in height except for occasional emergents, and a total canopy cover of more than 20% (Pratt and Gwyne, 1978).

Climate

The Lusenga Plains National Park is located in a high rainfall agro-ecological zone III of Zambia receiving ≥ 1000 mm per annum. The area experiences three seasons; cool and dry from April to August, hot and dry from September to October and hot and rainy from November to March/April. Annual temperature ranges between 18 to 22°C. The monthly mean for June and July, which are the coldest months, is 15 to 17°C and 23 to 28°C for September and October (Anon, 2008).

Field methods

The study was conducted in Lusenga Plains National Park and adjoining water falls at Lumangwe, Kabwelume and Kundabwika waterfalls every September 2004 to 2007, during which time the National Park was dry and accessible by road. All woody vegetation communities in Lusenga National Park and riparian vegetation at the three waterfalls were sampled for epiphyte location/position on the host tree species.

Rainfall data

Rainfall data was collected from the metrological station based at Kawambwa town near the National Park (Figure 1). The data was used to verify whether the amount of rainfall received during the period 2004 to 2007 was lower or higher than the areas' recorded

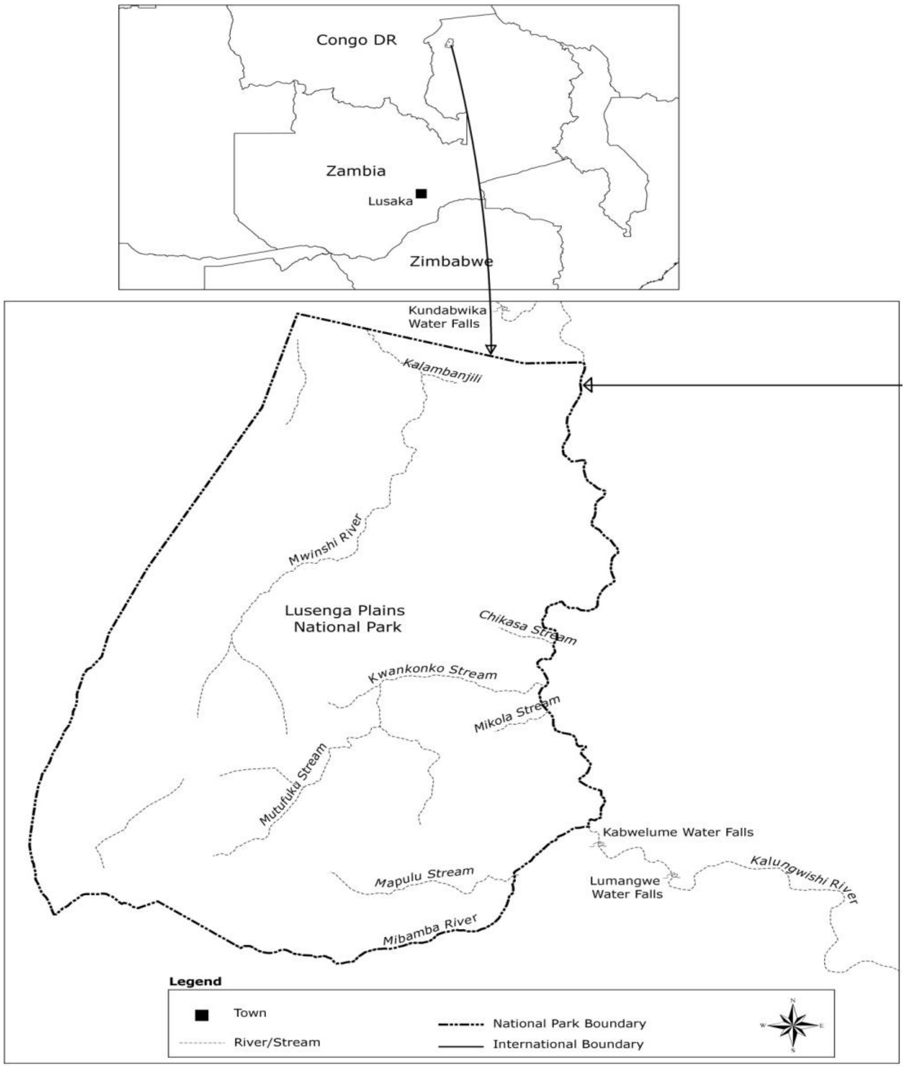

Figure 1. Location Lusenga Plains National Park, Zambia.

mean of 1,000 mm as lower rainfall would entail less humidity which is known to negatively affect epiphytes.

Assessing host tree floristic composition and distribution of epiphytes

Data on epiphyte host selection and pattern of distribution within host tree substrates and between vegetation communities were collected by surveying woody vegetation types inside the National Park and at the waterfalls. Vegetation communities were identified from a vegetation map of Lusenga Plains National Park (Anon, 2008). Based on the vegetation communities identified, a total of 8 ha were sampled; 2 ha in bush land, four in woodland and two in riparian forest. In each vegetation community, transects of 1 km long each were established. Along each transect, 20 × 20 m quadrats were located every 100 m. Transects were laid out in directions chosen to avoid trails and clearings but otherwise separated by a minimum distance of 50 m in the National Park.

At the waterfalls, transects were only up to 200 and 10 m apart, set to maximize vegetation exposed to the mist rising from falling water. In each quadrat, all woody plants were identified based on the field guide by Palgrave (2006) and Storrs (1995). Species that could not be identified in the field were taken to the herbarium at Mt' Makulu Chilanga for identification. For each woody plant, the following measurements were taken:

1. Diameter at 1.3 m above ground, using a linear caliper for trees ≥ 20 cm. This DBH is large enough to support the weight of a climber;
2. Crown cover, which was measured and calculated using the formula;

$$\frac{(D_1 + D_2)^2 \pi}{4}$$

Where D_1 is the first diameter measurement taken on the ground from one edge of the crown across the center of the tree to the other edge of the crown. D_2 taken more or less perpendicular to the first one (D_1). Substrate size was classified as follows: small substrate with diameter at breast height (dbh) 20 to 50 cm; medium substrate dbh 51 to 100 cm and larger substrate dbh > 100 cm. Name of the tree and bark texture of each host tree were recorded. Bark texture was determined by feel of the palm. Rough bole textures were those that felt rough and prickly in the palm while the smooth bole had a smooth feel in the palm.

To collect epiphytes from the host tree substrate, single rope and ordinary climbing techniques were used to climb tree canopies to collect crown epiphytes as described by Nadkarni (1984), Tucker and Powell (1991) and Gentry and Dobson (1987). All epiphytes found within the quadrat and their positions on the host tree were recorded. Position of epiphytes on the host tree species were assigned to one of the three categories; (i) on the trunk; thus epiphytes found on the bole alone excluding axils and branches. Trunks were further classified as horizontal and upright (ii) on the canopy; epiphytes found on branches including axils. Branches were further classified as horizontal and vertical. All epiphytes sampled were recorded under the respective categories.

Biomass

Removal of epiphytes from host tree was done by scrapping them off with a knife into prefabricated carton boxes which were taken to the base camp and dried at 70°C for a minimum of 2 days and weighed to obtain dry weight using a solar weighing scale calibrated to the nearest 0.5 g.

Statistical analysis

A parametric test One Way Anova (Fowler et al., 1998), was used to test the difference in epiphyte biomass between host tree substrate sizes. Non parametric Mann Whitney U test and Chi-square were used to test the difference in epiphyte biomass distribution between rough and smooth bole host tree substrates and canopy and trunk.

RESULTS

Mean annual rainfall received

The mean annual rainfall for the study area for the period 2004 to 2010 was high 1,298 mm which was higher than the areas' mean of 1000 mm by 298 mm (23%) (Anon, 2010). During the five year period of study, rainfall was highest in 2010 when 1,394 mm was received. In 2004, 1,355 mm was recorded, 1,518 mm in 2005; 1,175 mm in 2006; 1 324 mm in 2007; 1,065 mm in 2008 and 1 254 mm in 2009. With this above average rainfall, no negative impact on epiphyte abundance was expected.

Distribution of epiphyte biomass across vegetation communities

A total of three vegetation communities were surveyed; bush land, woodland and riparian forest. A total of 8 ha were sampled; four in woodland and two each in bush land and riparian forest. There were 950 trees of dbh ≥ 20 cm in bush land, 1, 575 in woodland and 2,300 in riparian forest. The canopy cover for bush land was 45%, woodland ≥ 70% and 100% for riparian forests within 100 m of the waterfalls. Thirty-seven host tree species were identified and recorded in the study area (Table 1). Of the 37 tree species identified, 21 species (57%) had epiphytes and 16 (43%) had no epiphytes (Table 1). The most important epiphyte host substrates were; *Vitex doniana, Isoberlinia angolensis, Brachystegia spiciformis, Parinari curatelifolia, and Brachystegia floribunda* (Figure 2).

Of all the 21 species with epiphytes, only four species in the woodland vegetation community had more than 10% of total epiphyte biomass and these were; *V. doniana* 378.5kg (17.85%), *I. angolensis* (13.34%), *B. spiciformis* (11.13%) and *P. curatellifolia (*10.74%). In the riparian vegetation community, epiphytes mainly *Usnea articulata* and *Ramalina reticulata,* were non selective of host tree species, though older substrates and areas within 50 m within the waterfalls area had more epiphytes with carpets of moss on stems.

Effect of substrate size on epiphyte biomass

Tree species recorded showed that larger substrates (dbh > 100 cm) which were also older tree substrates had the most biomass 2,002.2 kg (94.46%) (Figure 3). Medium sized substrates (dbh 51 to 100 cm) had 112.2 kg (5.29%) and small substrates (dbh 20 to 50 cm) had the least 5.5 kg (0.25%). Epiphytes recorded were *U. articulata*, *R. reticulata, Dendrobium* spp*., Rhipidoglossum* spp*.,* and a hemi epiphyte *Ficus* spp*.* These were restricted to woodlands and riparian forests only and were absent in bush land (Table 1).

The difference in epiphyte biomass between the observed host trees diameter classes, was significant One Factor Anova ($P<0.025$), implying that larger tree diameter substrates which were also older trees were the most important substrates.

Bark texture and epiphyte biomass

Rough bole texture tree species had significantly higher biomass (dry weight) 1,886.71 (89%), most important being; *P. curatelifolia, V. doniana, Brachystegia* spp*.,* and *Isoberlinia* spp*.* All these were in the undisturbed mature miombo woodlands. Smooth bole textured barks had lower biomass 233.19 kg (11%) (Figure 4). Mann Whitney U test showed a significant difference in epiphyte biomass in favour of rough bole substrates ($P < 0.001$).The smooth bole texture species were; *Ficus* spp*., Syzygium* spp*.,* and *Pericopsis angolensis* implying that rough barks provided better surface for anchorage of epiphytes. .

Effect of host morphology on abundance of epiphytes

A comparison of epiphyte biomass distribution between horizontal and vertical branches showed that horizontal branches had significantly higher biomass of 900 kg

Table 1. Epiphyte host tree species selection and biomass between host species and vegetation communities, Zambia 2004-2007

Code	Species name	Number of individuals	Vegetation community	Total epiphyte volume (cm^3)	Epiphyte Dry weight (kg)	Epiphyte recorded
1	*Ficus spp*	404	Moist evergreen/Riparian forest	206.00	19.50	Moss and lichens
2	*Diospyros spp*	1,807	Moist evergreen/Riparian forest	806.00	97.50	Moss and lichens
3	*Syzygiums spp*	1,099	Moist evergreen/Riparian forest	665.60	53.70	Moss and lichens
4	*Khaya anthotheca*	366	Moist evergreen/Riparian forest	475.00	51.60	Moss and lichens
5	*Xylopia aethiopica*	924	Moist evergreen/Riparian forest	715.70	67.30	Moss and lichens
6	*Vitex doniana*	245	Miombo Woodland	875.00	378.50	Moss, orchids, and hemi epiphyte (*Ficus* spp).
7	*Isoberlinia angolensis*	565	Miombo Woodland	417.00	283.00	Moss, orchid, and hemi epiphyte.
8	*Brachystegia spiciformis*	629	Miombo Woodland	317.00	236.00	Moss, orchid, and hemi epiphyte.
9	*Isoberlinia tomentosa*	561	Miombo Woodland	238.00	125.90	Moss, orchid, and hemi epiphyte.
10	*Parinari curatelifolia*	560	Dry Evergreen Forest/Miombo Woodland	714.00	227.70	Moss, orchid, and hemi epiphyte.
11	*Brachystegia floribunda*	475	Miombo Woodland	413.00	189.80	Moss, orchid, and hemi epiphyte.
12	*Brachystegia utilis*	498	Miombo Woodland	517,00	91.20	Moss, orchid, and hemi epiphyte.
13	*Burkea africana*	76	Miombo woodland	15.00	3.90	Moss, orchid, and hemi epiphyte.
14	*Pterocarpus angolensis*	295	Miombo woodland	9.00	5.00	Moss, orchid, and hemi epiphyte.
15	*Uapaca sp*	572	Miombo woodland	21.00	39.50	Moss and orchid
16	*Anisophyllea boehmii*	505	Miombo woodland ecotone	7.00	1.50	Moss
17	*Uapaca kirkiana*	428	Open woodland / ecotone	47.00	5.50	Moss and orchid
18	*Afzelia quanzensis*	215	Miombo woodland	315.00	120.70	Moss, orchid and hemi epiphyte.
19	*Pterocarpus angolensis*	445	Miombo woodland/	17.00	6.60	Moss and Orchid
20	*Pericopsis angolensis*	45	Miombo woodland/	11.00	2.00	Orchid
21	*Marquesia macroura*	431	Miombo woodland; Dry evergreen forest	129.00	113.50	Moss and orchid
22	*Hymenocardia acida*	278	Bushland			Absent
23	*Bauhunia peternesiana*	71	Bushland			Absent
24	*Berchemia discolour*	75	Bushland			Absent
25	*Diplorhynchus condylocarpon*	147	Bushland			Absent
26	*Cassia abbreviata*	16	Bushland			Absent
27	*Terminalia spp*	9	Bushland			Absent
28	*Combretum spp*	308	Bushland/ edge of dambo			Absent
29	*Ximenia spp*	126	Bushland			Absent
30	*Erithrina abyssinica*	72	Bush land			Absent
31	*Strychnos spinosa*	114	Bushland / open woodland			Absent
32	*Dalbergia spp*	69	Bushland			Absent

Table 1. Contd.

33	*Lannea stulmannii*	97	Bushland / openwoodland			Absent
34	*Swartia madagascariensis*	110	Bushland			Absent
35	*Strychnos cocculoides*	136	Bushland			Absent
36	*Pseudolachnostylis maprouneifolia*	201	Bushland			Absent
37	*Diospyros mespiliformis*	17	Open woodland on anthills			Absent
Total		12,800		6,331.30	2,119.90	

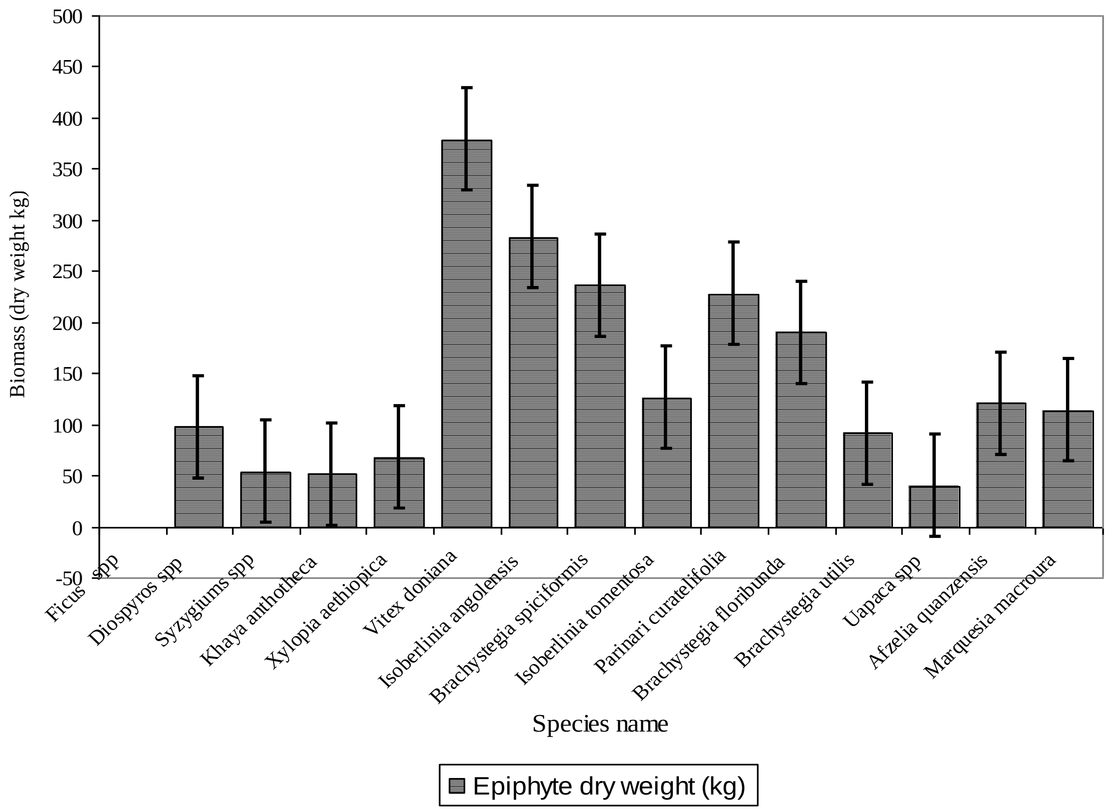

Figure 2. Number of epiphytes observed per host tree species and epiphyte biomass (dry weight kg) distribution per host tree species, Lusenga Plains National Park, Zambia, 2004-2007.

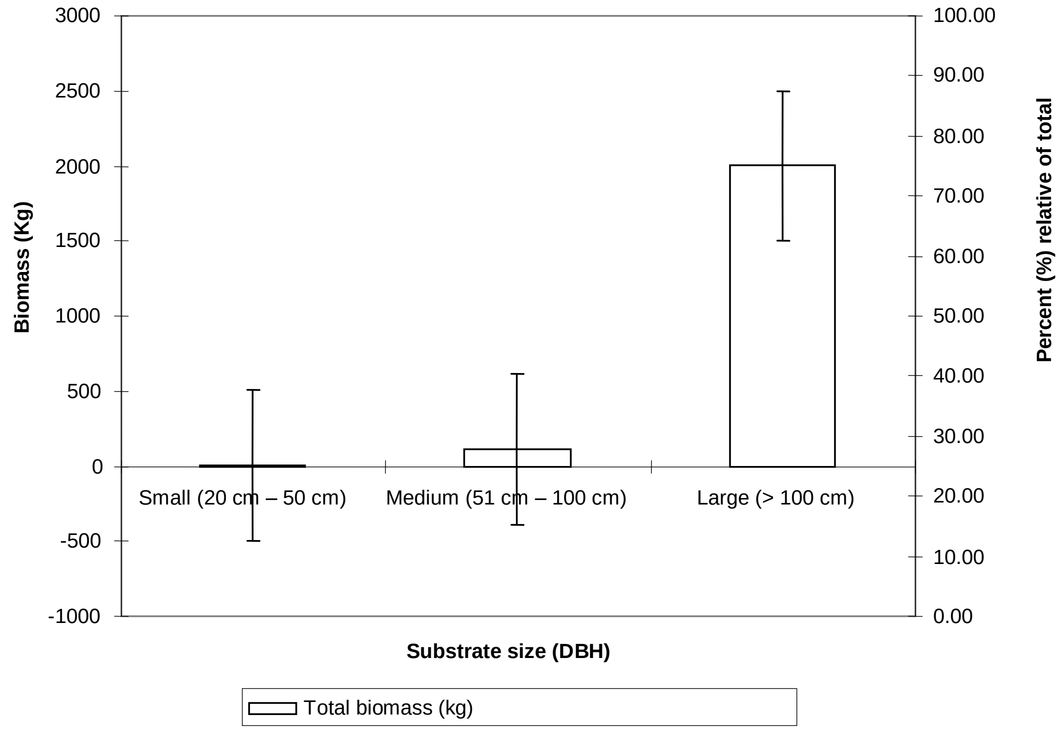

Figure 3. Distribution of epiphyte biomass among diameter categories of host tree species, Lusenga National Park, Zambia, 2004-2007.

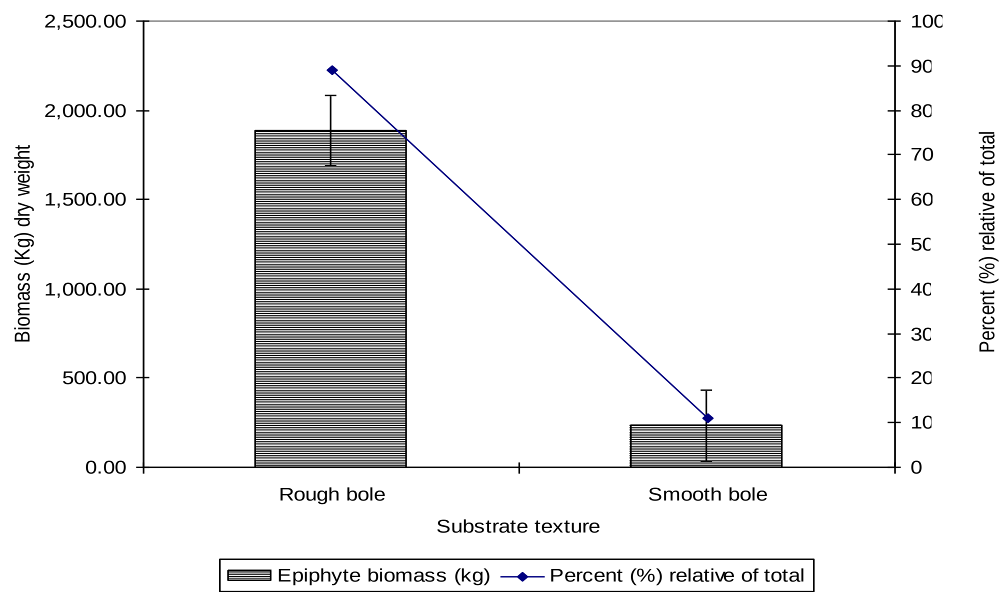

Figure 4. Epiphyte biomass on rough and smooth bole textures of substrates. Lusenga National Park, Zambia, 2004-2007.

(50%) and vertical branches had lower 320 kg (17%) Mann Whitney U Test (P < 0.05). Partitioning of biomass between crown (horizontal and vertical branches) and trunk (horizontal and upright stems) also showed that crowns had significantly higher biomass of 1,220 kg (68%) than trunk 585 kg (32) (Figure 5) (P < 0.005).

Overall, tree canopies were richer in epiphytes than trunks. Crowns had more epiphyte biomass, most of it being found on horizontal branches which was significantly higher than what was found on vertical branches

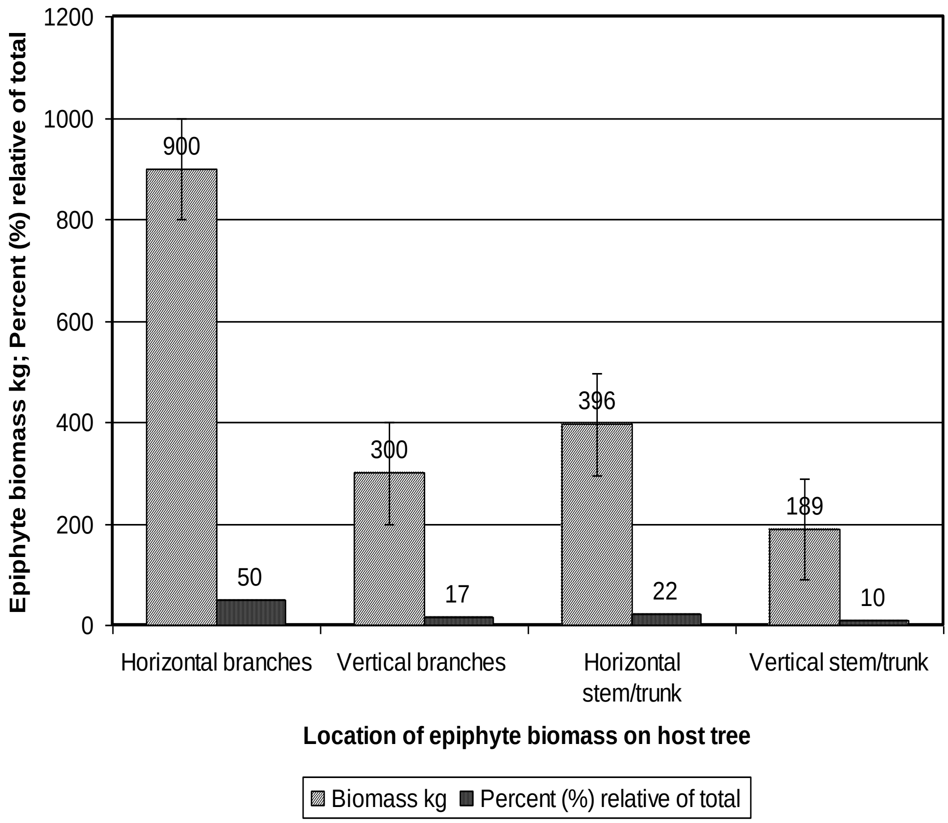

Figure 5. Epiphyte biomass pattern of distribution within host tree substrate, horizontal and vertical branches and horizontal and upright stems. Lusenga National Park, Zambia, 2004-2007.

and trunks.

DISCUSSION

Host tree preference

In this study, epiphyte biomass varied widely among vegetation communities and different species in the Miombo woodland except for lichens around the waterfalls. All epiphytes occurred in mature Miombo woodland and riparian vegetation around the waterfalls with canopy cover ≥ 70%. Factors characterising this distribution pattern were assumed to be humidity, bark texture of host trees, trunk physiognomy, and availability of minerals in the canopy of host trees. Causal agents for such difference in biomass between crown and trunk were assumed to be light and availability of minerals in the canopy of various host tree species. It was also possible to suggest reasons why the abundance of epiphytes was high or low in certain host tree species. For instance, huge trunk size, rough bark, horizontal branching and numerous invaginations on the stem may explain the high abundance of epiphytes on *V. doniana* (Figure 2).These physical attributes of a host tree facilitate epiphyte establishment (Mucunguzi, 2007; Yeaton and Gladdstone, 1982). Trees with deep irregular invaginations that accumulated detritus or retained enough moisture provided suitable substrate for establishment of epiphytes. Variations in the distribution of epiphytes on host tree species may also have reflected differences in establishment requirements, host tree microhabitats and dispersal agents. Vegetation communities where canopy cover was > 70% had high humidity were preferred to open canopy vegetation communities (Joseph, 2007) and these are the same vegetation commuities that were of commercial value to mainly illegal charcoal production, logging and *Chitemene* system of agriculture.

Effect of substrate size

In the present study, the relationship between species distribution pattern and tree diameter were based on the following assumptions: (i) trunk diameter indicated the approximate age of a plant, with lager diameter implying older trees, (ii) compared to older, rough, weathered exposures, the relative smooth surfaces of smaller trunks had little water retaining capacity and less capacity for absorbing and adsorbing leached nutrients and hence few or no epiphytes in the bush land vegetation community. Old larger trunks provided a more resource rich medium of rotten dead plant material and therefore better substrate for epiphyte colonization. It is for the same reasons that host tree species with dbh > 100 cm had 94.46% of the epiphyte biomass.

Effect of bark texture

Substratum properties, which facilitated epiphyte establishment, included; texture and porosity of bark, water interception and storage, grip of diasporas, pH and nutrient contents of the bark, toxins and bark turnover rate (Encyclopaedia Britannica, 2010; Feng and Yue, 2001). Rougher barks had space for holding water and seeds and hence being better and suitable substrate for epiphytes**.** It is for the same reason that in this study 1,886.71 kg (89%) of the epiphytes biomass was found on rough bole substrates and only 233.19 kg (11%) on smooth bole substrates. This is a disadvantage in that most of the timber yielding species such *Afzelia quanzensis* have rough bole textures.

Epiphyte biomass distribution between vegetation communities

The higher biomass for Miombo woodland than riparian was attributed to the large number of quadrats taken (4 ha) compared with 2 ha each for riparian and in bush land. Miombo woodland also had more orchids and hemi epiphytes, which despite the small volume weigh more than lichens and moss which were dominant in the riparian vegetation community.

Importance of epiphytes in Lusenga Plains National Park

Epiphytes were absent in bush land vegetation community but were most abundant around the waterfalls. The mist that rises after the water has fallen from the cliffs at the three waterfalls consists of water droplets. Such precipitated moisture may be absorbed directly by epiphytes. At the climax of the rainy season, water droplets fall copiously on foliage and later fall to the ground materially augmenting the supply of soil moisture. This ‘fog drip’ gives the character to the vegetation at the water falls and is important in determining epiphyte abundance at the waterfalls which also has a marked effect upon the wetness of host trees.

Distribution between branch angle classes

For all branch angle classes, 50% of the total crown biomass occurred on horizontal branches which is why virtually all epiphytes are associated with some form of humus. Dead organic matter easily settles on horizontal branches which is important to the survival of epiphytes as the presence of humus on horizontal branches improves water retention capacity that provides a more continuous moisture supply for epiphytes than the atmosphere of a vertical or bare bark (Benzing, 1981, 1990). In addition, nitrates from the atmosphere and mineralized dead organic matter was a source of nitrogen for epiphytes (Nadkarni, 1984) and is probably a more reliable source than from the atmosphere (Catling and Lefkovitch, 1989; Catling et al., 1986). A more inclined or vertical branch receives less wet season rainfall and experiences more rapid run off than a less inclined or horizontal branch. Gravity may also operate directly or indirectly to promote lower abundance of epiphytes on more vertical branches. Propagules and canopy litter are less likely to settle on a vertical branch and rapid runoff of moisture could accelerate leaching compared to conditions on horizontal surfaces.

The humus collecting on horizontal surfaces may also accelerate bark decay (Barkman, 1995; Michaloud, 1987) and improve physical anchorage of seeds, spores, and propagules. Likewise, interception of light and water increases as inclination decreases. Decreasing inclination enhances successful settling of seeds and spores and the accumulation of organic matter. All these conditions provided a suitable medium for epiphyte establishment. These properties favour horizontal branches to have more epiphytes than inclined or vertical branches. It is for this reason that in this study, the upper layers of horizontal branches, axils and invaginations in the host tree were the best sites for epiphyte establishment. The abundance of epiphytes between crown and trunk can also be explained by a number of factors. For instance, in each host tree, two major microhabitats were available, the crown and the trunk. In the crown, were forks and axils into which debris accumulated, as a result epiphytes found much mechanical support in the crown. Secondly, because epiphytes are light demanding, crowns were a better habitat due to their exposure to sunlight. Trunks were therefore, generally poor in epiphytes except where they had several crevices on the stem or where the bole was convoluted as to allow for accumulation of litter, otherwise stems were usually impoverished in epiphytes because they lacked suitable properties for epiphyte establishment and were often shaded by the crown preventing light from reaching them.

The need to conserve epiphytes

Epiphytes are crown plant community, which are important in the hydrological cycle of all water catchment forests and conservation of biodiversity. It is essential to ensure that Zambia Wildlife Authority and Forest

Department maintain woodland canopy cover of ≥ 70% in all mature Miombo and riparian forests to safeguard the habitat for epiphytes while maximizing water catchment functions. For instance, the estimated precipitation interception capacity of epiphytic moss cover was recorded by Poc's (1982, 1991) to be 400 to 500% of its dry weight in comparison to 60 to 175% of the dry weight for foliage. Poc's (1982, 1991) also found that the moss – lichen cover intercepted during one rain storm upwards of 50,000 L of rain water per hectare, and approximately 40% of annual precipitation. In comparison, the ordinary canopy foliage intercepted only 6,000 L/ha during a single rainstorm and only 18% of annual precipitation. With such an important function, epiphytes are essential in regulating water flow and reducing loss of water through evapouration. The water that is intercepted by epiphytes is released slowly ensuring a continuous supply of water to the watercourses. The highly interceptive epiphytes such as mosses and lichens are also important in preventing soil erosion. An additional advantage of epiphytic cover for the ecosystem is aerial humus. The litter accumulated by epiphytes including their own decaying organic matter is quickly converted into humus by fungi and micro fauna, contributing to the fertility of woodland and forest soils which support other soil microflora.

Due to small size and their inability to grow on their own, epiphytes can only be protected by protecting the entire habitat. Thus, mature Miombo woodland and riparian vegetation around the waterfalls which had the highest epiphyte biomass, require protection by Zambia Wildlife Authority, Forestry Department and the Local Community.

Conclusion

It would appear from this study that the colonization of wet Miombo woodlands by epiphytes occurs late in mature woodlands with canopy cover ≥ 70%. In Lusenga Plains National Park, the protection of epiphytes would also secure the catchment forests and assure a constant flow of water for animals and sustain agriculture in the surrounding local communities. The planned construction of a hydro power station at one of the three waterfalls would also benefit from a well-managed catchment forest for sustained supply of water to the dam. It is therefore important to protect mature woodland forest of canopy cover ≥ 70% to maximize water catchment functions.

It is concluded here that tree harvesting methods that target the crown would significantly alter epiphyte biomass and pattern of distribution. Such removal of tree crown as in *Chitemene* system of agriculture and harvesting of building poles would also impact on rain water retention capacity as epiphytes are known to be more efficient in intercepting rain water than ordinary foliage.

RECOMMENDATIONS

In view of the ecological importance of epiphytes in the wet Miombo woodland and riparian forest in Lusenga National Park, we suggest that Zambia Wildlife Authority should highlight the importance of lower plants in terms of their diversity, rarity, water interception values through National Park brochures and awareness campaigns in and around Lusenga National Park, particularly visitors to the waterfalls. Tree species which provide suitable substrates for epiphytes should be managed in a manner that encourages growth of epiphytes. In areas outside the National Park, local communities should be sensitized to carefully use fire and avoid *chitemene* system of agriculture which involves pollarding and at times felling the whole tree stem which in turn promotes secondary vegetation communities, which is not suitable for epiphytes.

In light of the current threats of deforestation, Zambia Wildlife Authority should consider implementing the following:

(i) Extending the National Park boundary for Lusenga Plains National Park to include all mature forests east of the Kalungwishi River in Mporokoso and Kaputa districts,
(ii) Control illegal logging to prevent opening up of thick mature Miombo forests,
(iii) Strictly regulate firewood collection which should, if any, be restricted to dead and fallen trees.
(iv) Prevent wild fires particularly late in the dry season as this may cause ground and crown fire which may burn aerial humus of dead epiphytes and cause loss of epiphytes,
(v) Include in the broader educational campaigns for visitors to the National Park and waterfalls, the importance of lower plants in water interception,
(vi) Ensure that opening up of roads for the development of tourism should consider and avoid unnecessary destruction of mature forests with high epiphyte biomass because these are critical water catchment areas, and
(vii) Ensure that construction of large tourist hotels in thick mature Miombo woodland and near water-falls should be preceded by a comprehensive environmental impact assessment, so as to safeguard the canopy cover of ≥ 70%.

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