The Effect of Bark Type, Canopy Architecture, and Tree Leaf Characteristics on Epiphyte Abundance and Diversity in Maliau Basin Conservation Area, Sabah, Malaysia

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ABSTRACT

As plants specially adapted to a non-soil substrate, epiphytes face unique challenges to successful growth and propagation. These challenges include balancing light, water, and mechanical stability needs, all of which are closely associated with the characteristics of the epiphyte's host tree. Therefore, we hypothesized that tree leaf type, leaf size, leaf arrangement, bark texture, and canopy branch density would exhibit non-random associations with the abundance and diversity of epiphytes associated with a given tree. We surveyed a 300 m transect of canopy walkway in Maliau Basin Conservation Area, recorded epiphyte counts and identification for 21 trees, and recorded the aforementioned characteristics of each tree. Using ANOVA analysis, we found a significant association between bark type and epiphyte abundance (Pr (>F)=**0.024**, F-value= **4.0543**) and epiphyte diversity (Pr (>F)=**0.036**, F-value= **3.5696**), with smooth bark hosting the greatest abundance and diversity of epiphytes. Furthermore, using generalized linear models, we observed a significant negative association between canopy branching density and epiphyte abundance (p-value= **2e-16**) and diversity (p-value= **0.000465**). Additional research based upon these highly significant results may indicate precise light, water, and mechanical support demands of epiphytes and may have the potential to further elucidate the effects of climate change and of deforestation on epiphyte abundance and diversity.

Key words: epiphyte, bark type, order of branching, leaf characteristics, abundance, diversity, Borneo

INTRODUCTION

As mechanically and often nutrient dependent tree-dwellers, epiphytes face distinct challenges to survival in a non-traditional plant habitat. Epiphyte survival strongly depends on overcoming inavailability of light beneath a thick rainforest canopy, water insecurity and inorganic nutrient scarcity in the absence of water- and nutrient-retaining soil, and diminished ability to anchor roots in elevated, non-soil media.

Light availability in an everwet rainforest depends on many factors, including tree height, leaf type (simple vs. compound), leaf size, and leaf arrangement. Epiphyte distribution and occurrence is impacted by the existence of a vertical gradient of light within the canopy; consequently, epiphytes growing on taller trees experience greater light incidence. In addition, simple leaves are thought to allow less penetration of light than compound leaves of similar size, and leaves of larger size have also been associated with lower light conditions. When tree height and order of branching are standardized, large leaves exhibit less flutter during wind, disallowing equivalent passage of light as compared to their smaller counterparts (Reyes-Garcia, et al. 2008). Leaf arrangement (alternate, opposite, or whorl) may also affect the passage of light from the upper canopy to epiphytes photosynthesizing below, with oppositely-spaced leaves providing maximum light penetration to the tree's lower branches. Therefore, we predict a greater abundance and diversity of epiphytes growing on trees with compound, small, alternately-arranged leaves due to light availability associated with these leaf characteristics.

Furthermore, water availability for the epiphyte at any stage of development not only depends on local rainfall and humidity, but also upon the bark type of the host tree. Seedlings growing on rough, porous, and/or water-retaining bark have greater drought resistance than seedlings growing on smooth bark unable to retain adequate surface moisture, and water scarcity continues as a threat for the mature epiphyte (Reyes-Garcia, et al. 2008). Previous studies have implicated the water-shedding effect of smooth bark in decreased drought resistance and consequently decreased moss abundance on smooth-barked trees (Forsyth and Miyata, 1984). In contrast, flaky bark has also been associated with increased water retention and consequently increased moss growth (Kim, et al. 1997). In addition to its role as a water sink for epiphytes, tree bark also provides the essential substrate to which epiphyte roots anchor far above the forest floor. Previous studies have shown that trees with rough bark are conducive to small vines that use tendrils to cling to crevasses (Forsyth and Miyata, 1984), but flaky bark tends to dislodge upon growth of heavier epiphytes (Kim, et al. 1997). For the majority of epiphytes, the trade-off between lower mechanical security high among the branches of the canopy and higher light levels at these riskier altitudes has been a major factor in epiphyte adaptation. Consequently, we predict a greater abundance and diversity of epiphyte communities situated on trees with rougher bark due to evidence of its provision of increased water availability and mechanical stability when compared to smoother barks.

Lastly, canopy density plays a major role in the distribution of epiphytes within the rainforest system. As previously mentioned, leaf characteristics may play a large role in determining light quantity filtering down from the upper canopy (Whitmore 1984). However, canopy branch architecture may also impact canopy density measurements, as some trees exhibit a greater branching order and/or total branch count within a given canopy area, therefore simultaneously providing numerous locations for epiphyte root adhesion and restricting light availability. As a result of this trade-off scenario, we predict that neither a wholly positive nor negative association between branch density and epiphyte abundance and diversity exists, and we endeavor to determine the nature of this association.

Our discussion examines the adaptations of tropical epiphytes to tree canopy niches and evaluates the potential impact that climate change and deforestation may have on tropical epiphyte communities. The goal of the present paper is to determine the effect of tree leaf characteristics, bark texture, and canopy branch density on the relative abundance and diversity of epiphyte communities.

METHODS

Data collection occurred in an unlogged area of Maliau Basin Conservation Area, . We surveyed every tree meeting specifications along a 300 meter transect of the rainforest canopy using the Maliau Skybridge, a canopy walkway ranging from 5-21 meters above ground level. Specifications for surveyed trees included diameter of 1.0-1.5 meters at canopy walkway level as well as absence of large lianas due to their interference with epiphyte growth and propagation. For each sample tree, we estimated **leaf size** (small leaves, length <10 cm; medium leaves, 10 cm< length < 20 cm; large leaves, length> 20 cm). We also recorded **leaf structure** (simple versus compound), **leaf arrangement** (alternate, opposite, or whorl), and **bark texture** (smooth and hooped, dippled, cracked, lenticellate, fissured, flaky, or scaly). A conical section of 7 meter radius within each tree's canopy architecture was examined using binoculars, and the number and species of present epiphytes was recorded. If species level identification proved difficult to attain, particularly for Orchiadaceae sp., family level identification was used. Furthermore, we recorded **order of branching** (secondary, tertiary, etc.) and **branch counts** for each sample tree within the 7 meter radius conical section. These values served as an indicator of complexity of canopy architecture. Lastly, we examined the association between epiphyte abundance and diversity and leaf size, leaf structure, leaf arrangement, bark texture, and canopy architecture using the software program R.

Our R analysis included various ANOVA analyses as well as linear and generalized linear models. The analysis of variance models tests whether more variation exists within a data set versus between sets of data. If more variation exists between data sets than within, the probability of obtaining that variance value (as quantified by probability of obtaining that ANOVA f-statistic) is very low, indicating a non-random association between two variables. We performed an ANOVA analysis to test for non-random association between total counts of each species or family of epiphyte and tree bark type. Next, we calculated a Shannon index to quantify epiphyte species richness. After renaming the Shannon index matrix, we tested for its non-random association with bark type using ANOVA.

Furthermore, we summed counts of primary, secondary, tertiary, and quaternary branchings within our sample cone of 7 m radius to obtain total branch count per tree. We compared this total to the total epiphyte count per tree using linear and generalized linear models The p-value based on a linear model comparing total branch count to epiphyte abundance was 0.089 (R^2=0.1048), indicating lack of statistical significance. Due to the preponderance of "0" count values in our data, a generalized linear model using the Poisson distribution was instead used to analyze this association. Lastly, we used a generalized linear model based on the Gaussian distribution to examine the association between epiphyte species richness values and total branch counts.

RESULTS

TABLE 1: Total Epiphyte Counts and Average Number of Epiphytes per Tree for Each Bark Type

Bark Type	Number of Trees	Total Epiphyte Counts								Total Count for All Epiphyte Species	Average Number of Epiphytes Per Tree
		Aroid	Fern	*Pandanus*	Orchid-aceae	*Asplenium nidus* (Bird's nest fern)	*Platycerium coronarium* (Stag's horn fern)	*Pyrrosia piloselloides*	*Pyrrosia lanceolata*		
Cracked	2	1	1	0	1	1	0	6	0	10	5.0
Dippled	2	0	1	0	0	2	0	0	0	3	1.5
Fissured	14	3	13	0	10	5	0	38	1	70	5.0
Smooth & hooped	3	4	18	3	4	2	1	9	0	41	13.4
Column Totals	21	8	33	3	15	10	1	53	1	124	N/A

During data collection from the 300 meter transect, we obtained the above data for epiphyte counts for each of four observed tree bark types. Our ANOVA analysis for epiphyte abundance and bark type indicated a statistically significant association, with **Pr (>F)= 0.024 (F-value=4.0543)**. ANOVA analysis also indicated a non-random association between epiphyte richness and tree bark type, with **Pr (>F)=0.036 (F-value= 3.5696)**. Furthermore, we examined the association between total canopy branch count and epiphyte abundance and diversity using generalized linear models (see Figure 1). Fitting to the Poisson distribution indicated a very strong, negative, non-linear association between branch density and epiphyte abundance, with a highly significant p-value = **2e-16**. Modeling based on the Gaussian distribution indicated a strong negative correlation between epiphyte species diversity and canopy branch density, with p-value= **0.000465**.

Lastly, with reference to other defined variables (branching order, leaf size, leaf type, and leaf arrangement), we obtained no significant result for association with either epiphyte abundance or diversity.

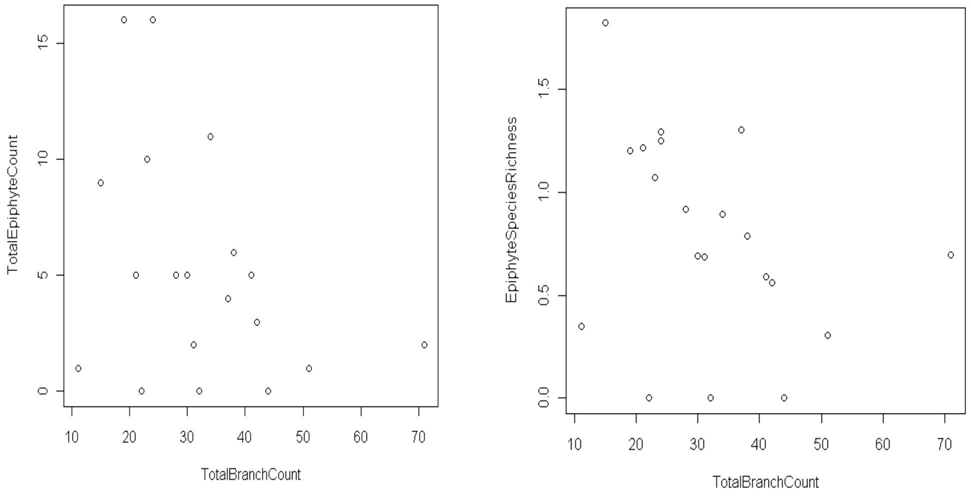

FIGURE 1: Total Epiphyte Count and Epiphyte Species Richness Versus Total Branch Count

DISCUSSION

We may conclude that bark texture exhibits a highly significant association with both epiphyte abundance and diversity as tested using ANOVA (abundance Pr (>F)= 0.024, F-value=4.0543; diversity Pr (>F)=0.036, F-value= 3.5696). Smooth bark exhibited the highest abundance and diversity of epiphytes, followed by cracked and fissured, with dippled bark exhibiting the lowest epiphyte abundance and diversity. This result contrasted with our prediction, indicating that perhaps water availability and/or mechanical stability may not be primary factors determining epiphyte survival in Malaysian everwet rainforest. Furthermore, canopy branch density exhibited a strong negative association with epiphyte abundance and a similarly negative association with epiphyte diversity (abundance p-value = 2e-16; diversity p-value= 0.000465). However, neither of the models (Poisson, Gaussian) utilized to elucidate these associations are linear, suggesting that association between canopy density and epiphyte abundance and diversity may tend slightly towards normality. In addition, we conclude that tree leaf size has no association with epiphyte abundance or diversity. Tree leaf arrangement may have an association with epiphyte abundance and/or diversity, but our sample size for compound leaves was too minimal (1/21 samples) to determine any relationship. Tree leaf arrangement (alternate, opposite, or whorl) exhibited a weak association with epiphyte abundance (ANOVA Pr (>F) = 0.137, F-value= 2.4136) and a moderate association with epiphyte diversity (ANOVA Pr (>F)= 0.061, F-value= 3.9576), but a more conclusive result necessitates further study. Lastly, minimal variation in branching order was observed within the 7 m radius, disallowing analysis.

During sampling, we noted certain methodological difficulties that impacted data collection and that should be addressed during future studies. Our sighting range was limited by the power of our binoculars, and consequently, we experienced difficulty quantifying number of individuals when epiphytes of the same species were clumped. In addition, our data collection serves only as a pilot study to explore the associations between various factors and epiphyte abundance and diversity; a large sample size during future studies may further untangle these complex relationships. Lastly, our data collection technique purposely restricted sampling to the actual canopy of the trees. Although we employed this technique in order to standardize our sampling area in light of various tree canopy sizes, we only observed abundance and diversity of canopy-dwelling epiphytes during our study. Additional studies may sample both in the canopy and closer to the rainforest floor to understand the associations between our study's target factors and epiphytes with differing light, water, inorganic nutrient, and mechanical support demands.

The results of our study have many crucial implications regarding the vulnerability of epiphytes to drastic changes in light or water availability as well as the unique associations between specific epiphyte and tree pairings. The significant associations between bark type and epiphyte abundance and diversity as observed during our study point to the importance of bark water regulation and bark-provided mechanical support in determining epiphyte survival. However, rapidly changing rainfall patterns due to global climate change threaten to undermine the fragile hydraulic relationship between epiphytes and host trees. Furthermore, the negative association between canopy density and epiphyte abundance and diversity indicates an already pressing problem associated with unsustainable logging. Removal of large rainforest trees increases the size of gaps, which effectively decreases canopy density. As a result, epiphytes and lianas grow uncontrollably and choke the already pulverized rainforest habitat. Our study's observation of this phenomenon in miniature may solidify understanding of its occurrence even in unlogged forest. Lastly, we recommend further study regarding the most precise model for the association between canopy branch density and epiphyte abundance and diversity. Since the strongest association did not follow a linear model, the data indicates the trade-off between epiphyte ability to anchor in elevated, non-soil substrate and light availability. A non-linear, normally modeled distribution perhaps indicates an “ideal” canopy branch density for maximum abundance and diversity of epiphytes, a density at which sufficient light and anchoring locations perfect the light versus canopy density trade-off. Further study regarding the balance of these two factors is highly recommended.

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