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ABSTRACT

The purpose of this study was to determine if and how much forest canopy density affects the richness and composition of epiphytic lichen communities in Tropical Premontane Moist Forest. Lichen communities on the trunk and in the canopy on nine *Ficus* trees were examined. Friedman's test was used to assess differences in lichen richness along a vertical gradient on trees, and Spearman rank test was used to look for a correlation between canopy density and lichen richness. Average habitat breadth between zones and between trees was also calculated. The results showed that there are significant differences in lichen richness across zones (Freidman test, P = 0.01, N = 7), but no significant correlations were found between canopy density and any individual zone or canopy density and total lichen richness on trees. Lichens were found to have similar average habitat breadth within (average habitat breadth = 2.24) and between trees (average habitat breadth = 2.42).

RESUMEN

El propósito de este estudio fue determinar si la densidad del dosel del bosque affecta la riqueza y la composición de las comunidades epifíticas de líquenes en el bosque húmedo tropical premontano. Se examinaron las comunidades de líquenes en el tronco y en el dosel de nueve árboles de *Ficus*. La prueba de Friedman fue utilizada para determinar diferencias en riqueza de líquenes en un gradiente vertical en los árboles y la prueba de rangos de Spearman fue utilizada para buscar una correlación entre la densidad del dosel y la riqueza de líquenes. La anchura media del hábitat entre las zonas verticals y entre los árboles también fue calculada. Los resultados mostraron que había diferencias significativas en la riqueza de líquenes entre de zonas (Prueba de Friedman, P = 0.01, N = 7), pero no se encontró ninguna correlacion significativa entre la densidad del dosel y cualquier densidad individual de la zona, o entre la densidad del dosel y la riqueza total en árboles. Se determinó que los líquenes tienen una anchura promedio de hábitat similar en el mismo árbol (Anchura promedio del hábitat = 2.24) y entre árboles (Anchura promedio del hábitat = 2.42).

INTRODUCTION

Lichens are an association between fungi (usually of the Division Ascomycota, but occasionally Basidiomycota) and a photosynthetic partner, or "photobiont" (green algae or cyanobacteria). They are generally considered a symbiotic relationship in which the photobiont provides food for the fungi via photosynthesis, and the fungus provides a "home" for the algae. Some lichenologists disagree with this, and claim that lichens are and example of controlled parasitism, in which the fungus "enslaves" the photobiont as a food source, but the photobiont grows faster than the fungus can eat it. Be they symbiotic, or parasitic, lichens can grow in areas where neither partner could grow alone. With the exception of some highly polluted areas, lichens grow nearly everywhere in the world, but most prefer areas with lots of light and moisture. Some lichens are extremophiles are and resistant to very harsh conditions, including extreme temperatures (some can photosynthesize at – 4 °C), high salt concentrations, very high levels of solar radiation, and prolonged desiccation. Although lichens as a group thrive over a large range of conditions, individual lichen species tend to be very sensitive to slight changes in environmental conditions (Purvis, 2000). For this reason, lichens are used as a means of assessing pollution in some parts of the world, and have shown a strong potential as a bio-indicator of the effects of forest fragmentation in primary temperate forests (Essens and Renhorn, 1998; Sillett, 1995). The main factors that affect lichen growth are light availability and air purity, but texture and chemistry of the lichen's substrate also affect growth; some lichens are extremely substrate-specific. Lichen richness can be especially high in old growth tropical forests. In Costa Rica, leaves of the tree *Ocotea atirrensis* (Lauraceae) have been found to support up to 80 species of lichens on a single leaf (Purvis, 2000).

Abiotic factors such as wind, light, temperature and humidity create a vertical gradient of microclimates in trees in closed forests. Five distinct zones are recognized, each with distinctive microclimates (Johannson, 1975; Fig. 1). While little is known about microclimates in tropical canopies, a few general trends have been observed in the vertical gradient from canopy to understory. The amount of wind, light and solar radiation decrease drastically with distance from the canopy. Maxima, means and ranges of temperature also decrease with distance from the canopy, although there is little difference in minimum temperatures across zones. Carbon dioxide concentrations and humidity decrease with distance from the forest floor, and evapotranspiration potential is greatest in the canopy (Walsh, 1996). Forest interiors and edges differ in a number of factors that affect lichen growth, and the differences between canopy and understory microclimates in primary forest become less pronounced near forest edges (Balsberg-Pahlsson and Bergkvist, 1995). A study in Sweden found that windier conditions near forest edges caused large differences in lichen abundance between forest edge and forest interor (Essens and Renhorn, 1998). This shows that lichens can be sensitive to wind, which is important because wind is stronger in the canopies of trees than in the understory.

The purpose of this study was two-fold: to determine if and how much forest canopy cover affects the composition and richness of epiphytic lichen communities, and to examine how habitat specific lichens are to both the region of the tree and the area of the forest. Epiphytic lichens were studied along a vertical gradient on trees in a forest with varying levels of canopy density. I predicted that the greatest lichen richness would be found in the canopies of trees and that there would be different lichen richness in different tree zones. I also predicted that canopy density would have a more significant impact on lichen richness in Zone One and Zone Two, and less impact in Zones Three and Four.

MATERIAL AND METHODS

STUDY SITES

This study was conducted on the property of the Ecolodge, in San Luis, Costa Rica, a Tropical Premontane Moist, as classified by Holdridge Life Zone (Hayes & Laval, 1989). Elevation at the Ecolodge is about 1,100 m. Data collection took place from October 24, 2004 to November 14, 2004.

METHODS

The forest is mainly secondary growth, but there are some very large trees that are clearly much older than the surrounding forest. Nine large, emergent *Ficus* tree along the Camino Real trail were surveyed for epiphytic lichens. Seven trees were surveyed in Zones One through Zone Four, and two trees were surveyed in Zones One through Zone Three. Zone Five was not studied because it is very difficult to safely sample and doing so is destructive to the tree.

Two transects (100 cm x 20 cm each) were made in each of the surveyed zones. All transects were on the southeast side of the tree, and went up the trunk or along a branch. Lichen richness for each zone of each tree was measured as the total number of different morpho-species present in at least one of the two transects in each zone. Transects from Zones One and Two were taken from approximately the middle of their respective zones, but the exact location (bottom, middle, or top of zone) of the transects in zones three and four was not consistent due to differences in accessibility between trees. Transects within a zone were always with in 3 m of each other. The canopy was accessed using the single rope technique (Perry, 1978). Canopy density was measured with a densitometer, and the average of the south and east facing readings was used as the percentage of canopy cover over each tree.

A Friedman's Test was used to determine whether lichen richness differed between zones. A Spearman Rank Test assessed whether a correlation exists between canopy density and lichen richness in any given zone, and canopy density and lichen richness on the entire tree. Beta diversity between trees and between zones was computed and average habitat breadth was found by taking the inverse of beta diversity. Sorrenson's qualitative index was used to find similarity between zones. A species area curve was used to see if exhaustive sampling had taken place.

RESULTS

A total of 45 morpho-species were found on nine trees. Densitometer readings for all but one tree were similar (ranging from 89.6% to 92.7%). The outlier tree had a canopy density of 82.3%. This tree, "Tree One", appeared to have partially fallen due to erosion and was growing out of the ground at a 45º angle, but its roots were still in the ground and the tree appeared healthy. The tree fall caused a gap in the canopy, and the trunk of this tree was exposed to high amounts of light, perhaps more light than in zones three and four. Four species of lichens found were observed on only this tree. Zone One richness

(N = 8) was the highest found on any tree, and zone four richness (N = 7) was the lowest found on any tree (Table 1).

In Zone One, 15 morpho-species were found, 23 morpho-species were found in Zone Two, 32 morpho–species were found in Zone Three, and 31 morpho-species were found in Zone Four. Figure 1 shows the average lichen species richness in each zone and the total the entire tree. Two averages are given for each tree, one of which does not include Tree One, which was exposed to unnaturally high levels of light at the lower zones. Averages for Zone One, Zone Two, Zone Three and total on entire tree is based on nine trees, the average for Zone Four is based on seven trees.

A Friedman's Test shows significant differences in lichen species richness between zones, with the greatest richness being found in Zone Four, followed by Zone Three, then Zone Two, and Zone One has the lowest species richness (Table 1). A Spearman Rank Test shows no significant correlation between canopy density and lichen species richness in any of the Zones One through Four or total tree (Fig. 2). This analysis includes only the seven trees for which Zone Four data was available.

Of the 45 morpho-species of lichens found, 22 (49%) were only seen on one tree, and only 14 (31%) species were seen on more than two trees. Only three (7%) species of lichens were found on all nine trees. Figure 3 shows the frequency of the occurrences of lichen species in each zone; figure 4 plots the frequency of tree specific lichens to each of the nine trees. β diversity between trees = 0.413 (α = 15.54, γ = 45, n = 7). Average habitat breadth between trees (1/β) = 2.42.

Seventeen (38%) morpho-species were seen in only one zone, but all of these species were rare, being found fewer than three times over the course of this study. Figure 5 shows the frequency of the occurrences of lichen species in each zone; figure 6 plots the frequency of lichens specific to a single zone to each zone. β diversity between zones = 0.446 (α = 25.25, γ = 45, n = 4). Average habitat breadth between zones (1/β) = 2.24.

Sorrenson's quantitative index was applied to find similarity between zones, and Table 2 shows the results of this. The highest similarity was found between Zones Two and Four and Zones Three and Four. Zone 1-3 and Zone 1-4 similarity were very low, and nearly identical. The least similarity was found between Zones One and Three and Zones One and Four,

Of the 18 lichen species (43%) seen at least three times over the course of this survey, only one was limited to a single tree, and none were limited to a single zone. All common lichens where widely spread over a multiple zones and trees. Many rare species, but few common species, were found, this signifies that insufficient sampling has taken place. A species area curve shows that this is most likely true (Fig. 7).

Discussion

As I predicted, there are significant differences in lichen richness in different zones of trees, with the greatest richness being found in Zone Four. Data did not support my hypothesis that lichen richness in Zone One and Zone Two would be disproportionately affected by canopy density. While there is a significant difference in lichen species richness across zones of trees, most individual lichens species do not appear to be limited to any certain zone and they do they appear to show preferences for trees in areas of forest with specific canopy cover, as is displayed by the fact that all common lichens are widely distributed over multiple zones and trees. Relatively high homogeneity of lichen species composition was found between zones and trees, and the average habitat breadth for trees and zones was very similar.

Canopy density was not found to affect the richness of lichen species growing on trees. This may be because the canopy densities of all but one tree were very similar, and lichens may not be sensitive enough to such slight changes in light. Also, as this was a secondary forest, there was no place with a very dense canopy. It is possible that the changes in microclimatic conditions caused by increased light become less pronounced in areas of lower canopy density. In other words, a change from 98% to 96% canopy density may be more profound than a change from 94% to 92% canopy density. Future studies should survey more trees, in order to get an accurate representation of the lichens present, and it should study primary forests with a very dense canopy.

One reason for studying vertical gradients in forests is because it may provide some insight into forest edge effect. Forest canopies differ from forest understories in many of the same ways that forest edges differ from forest interiors, such as more light, more wind, greater temperature fluctuation, less humidity near edges and in canopies. This study found significant differences in lichen communities between zones of trees, and it is likely that similar changes in lichen communities will be observed along transects moving away from forest edges. Forest canopies are a poorly studied and poorly understood subject, but probably contain significant amounts of the world's biodiversity. If an understanding of communities along a vertical gradient can improve our understanding communities near disturbances in closes forest, then this area of study may be very important for conservation. A better understanding of the effects of forest fragmentation on community structure, richness and diversity of all taxa becomes increasingly important as more pristine forest is lost every year. It is possible that with more knowledge of tropical lichens and their habitats, they will prove to be an accurate, easy, and inexpensive means of quantifying the extent of damage done by forest fragmentation in tropical forests.

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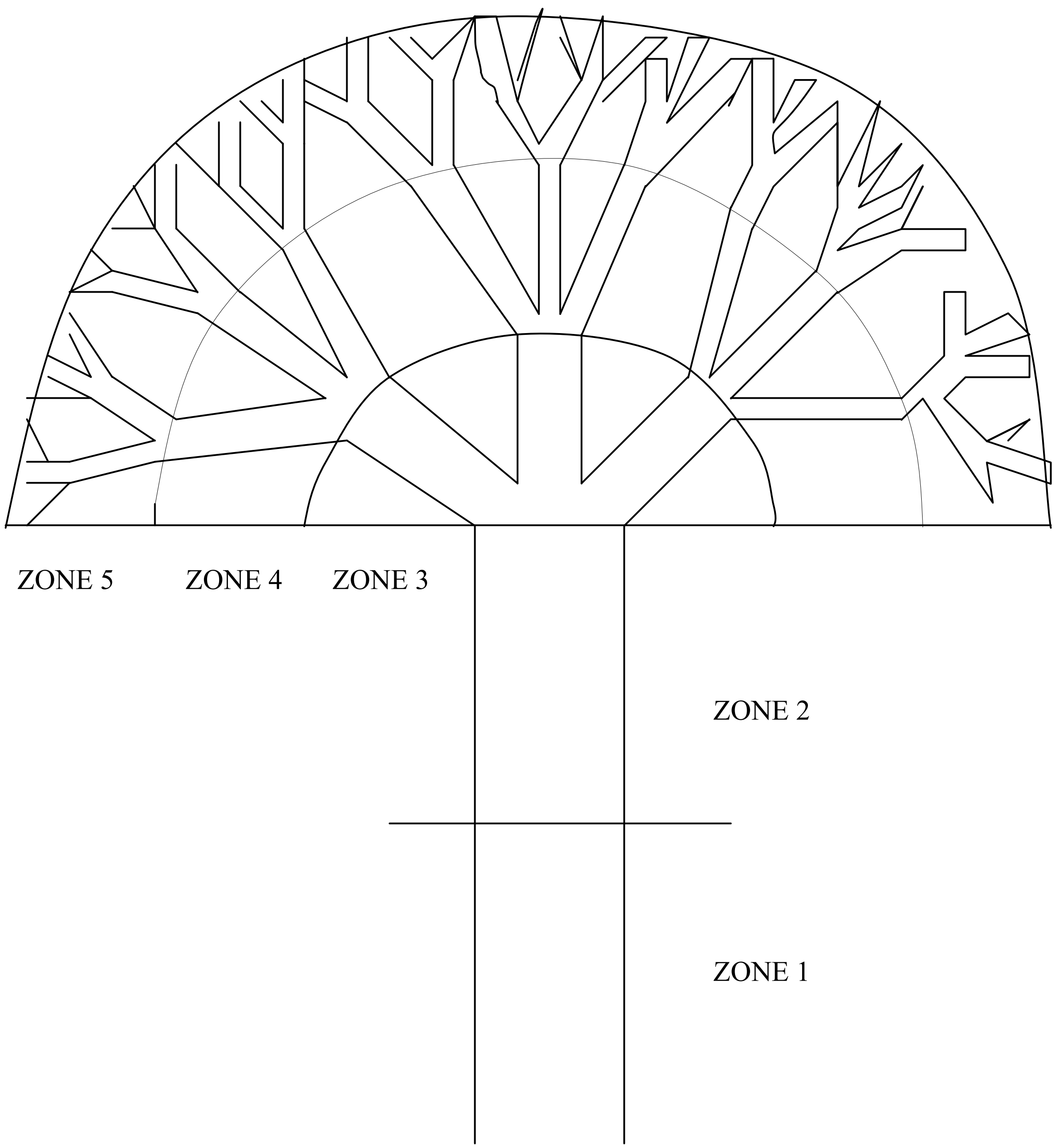

FIG. 1. Diagram of tree zones. Zone One is the lower half of the trunk and Zone Two is the upper half of the trunk. Zone Three starts where the first branch meets the trunk and extends up until the second bifurcation. Zone Four extends from the end of zone three to the third bifurcation. Zone Five consists of all remaining branches (Johansson, 1975).

Fig. 2. *Average lichen species richness in each zone and total tree richness. values which exclude the fallen tree are shown because that tree may have artificially high richness in some zones.*

Table 1. *Lichen species richness by tree zone and tree. Friedman's Test results show that Zone 4 has significantly more species than any other zone, followed by Zone 3, then Zone 2, and Zone 1 has the least amount of species when only the seven trees with data for all four zones are included ($F = 9.682$, $p = 0.0215$, $n = 7$). When only zones 1-3 are analyzed on all nine trees, the order of zones from greatest to least number of species is Zone 3, Zone 2, Zone 1 ($F = 10.800$, $p = 0.0052$, $n = 9$).*

	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5	Tree 6	Tree 7	Tree 8	Tree 9
Zone 1	8	2	4	5	5	3	3	3	3
Zone 2	10	8	7	5	8	9	4	7	4
Zone 3	6	9	9	10	7	10	9	8	6
Zone 4	7	9	9	9	8	11	10	N/d	N/d

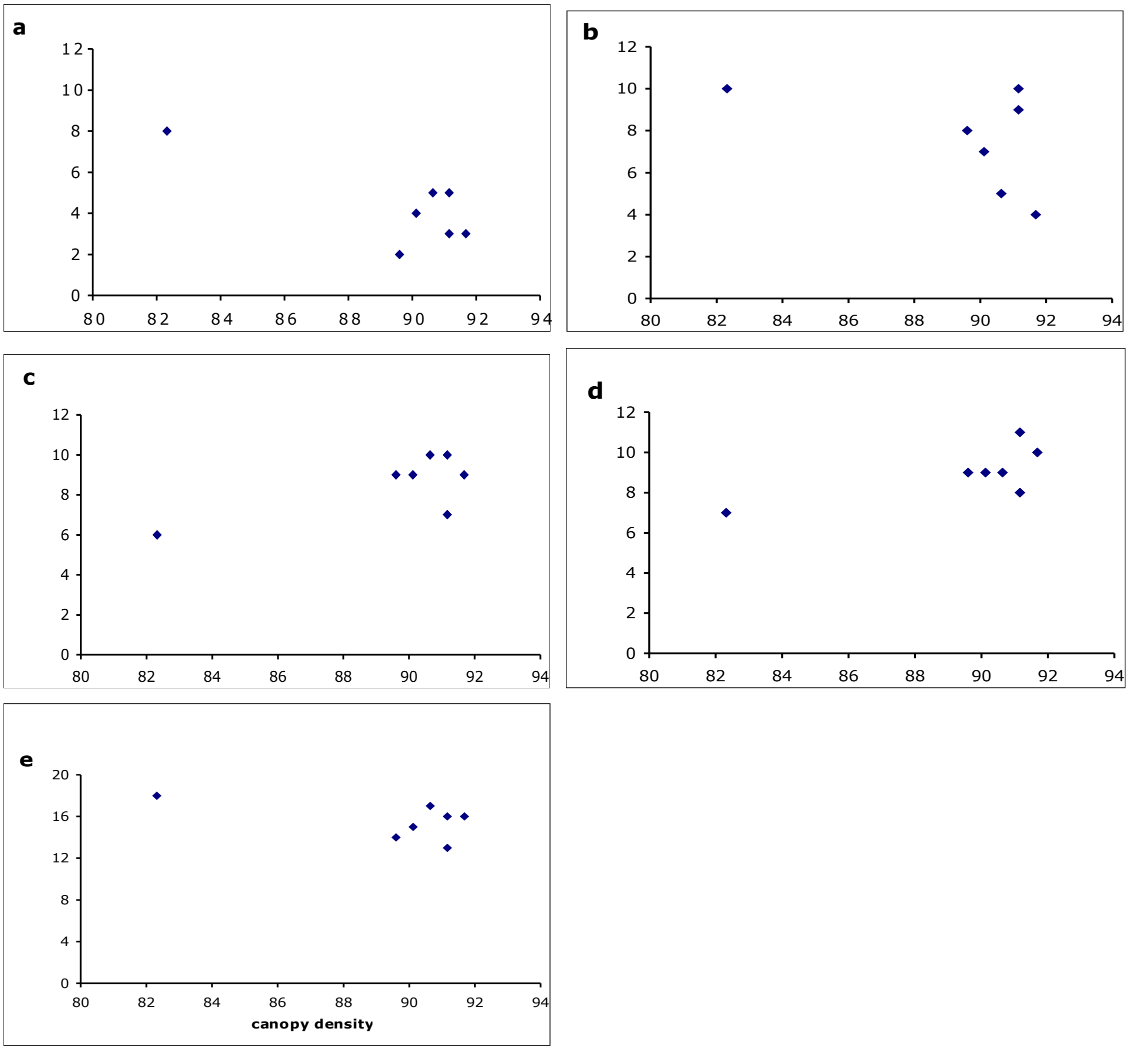

Fig. 3. *Lichen species richness in relation to percent canopy density, for lichens in (a) Zone 1; (b) Zone 2; (c) Zone 3; (d) Zone 4; and (e) overall for all trees for which Zones 1-4 were surveyed (n = 7). Spearman rank correlation results: (a) r = -0.28, p = 0.55, n = 7; (b) r = -0.52, p = 0.23, n = 7; (c) r = 0.37, p = 0.42, n = 7; (d) r = 0.62, p = 0.14, n = 7; (e) r = -0.19, p = 0.68, n = 7.*

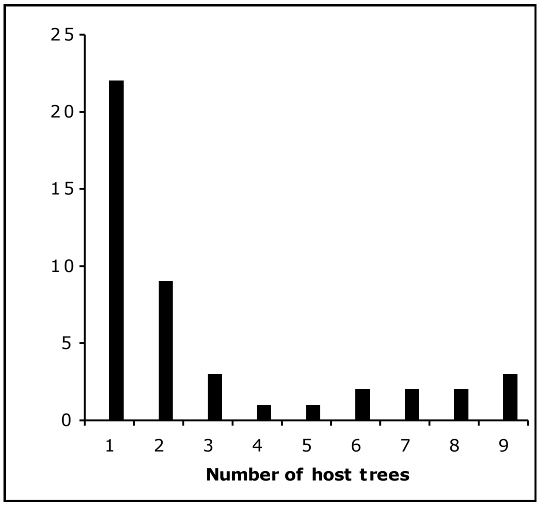

Fig. 4. *Frequency of occurrence of lichen species on host trees. Of 45 lichen species total, 22 were found on only one host tree.*

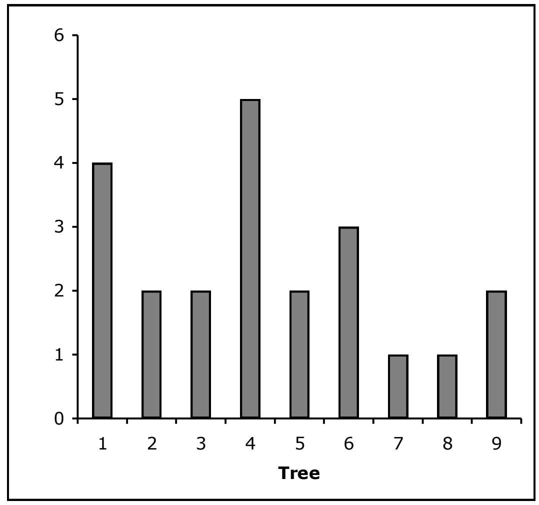

Fig 5. *The frequency of tree specific lichens. Four lichen species were found only on Tree 1, two species were found only on Tree 2, etc.*

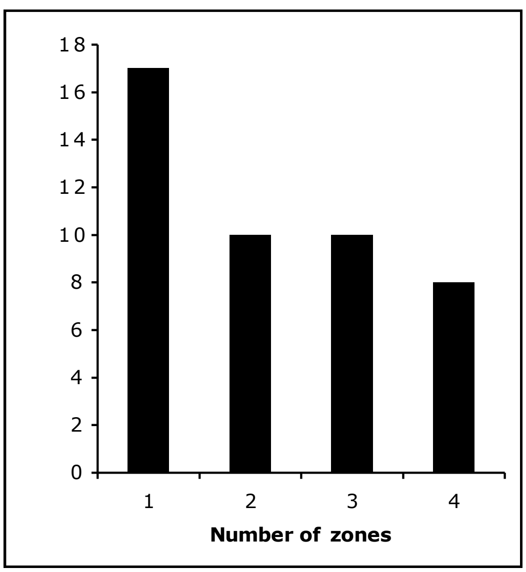

Fig. 6. *The frequency of the occurrence of lichen species across zones, 17 lichen species were found in only one zone, 10 species occurred in two zones, 10 species occurred in three zones, and eight species occurred in all four zones.*

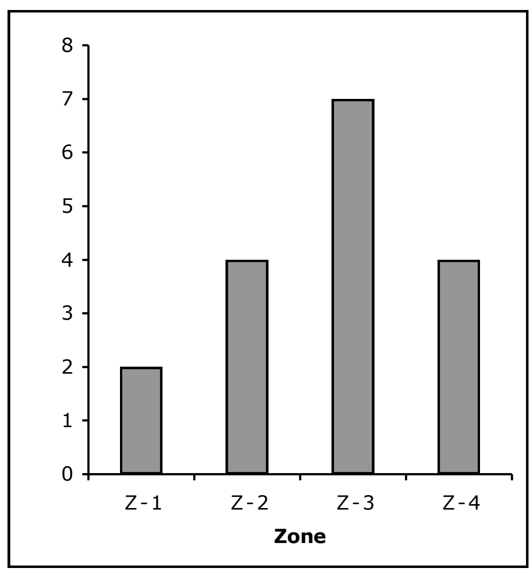

Fig. 7. *The frequency of zone specific lichens in Zones 1, 2, 3 and 4. Two species were found only in Zone 1, four species occurred only in Zone 2, seven species were found only in Zone 3, and four species were found only in Zone 4.*

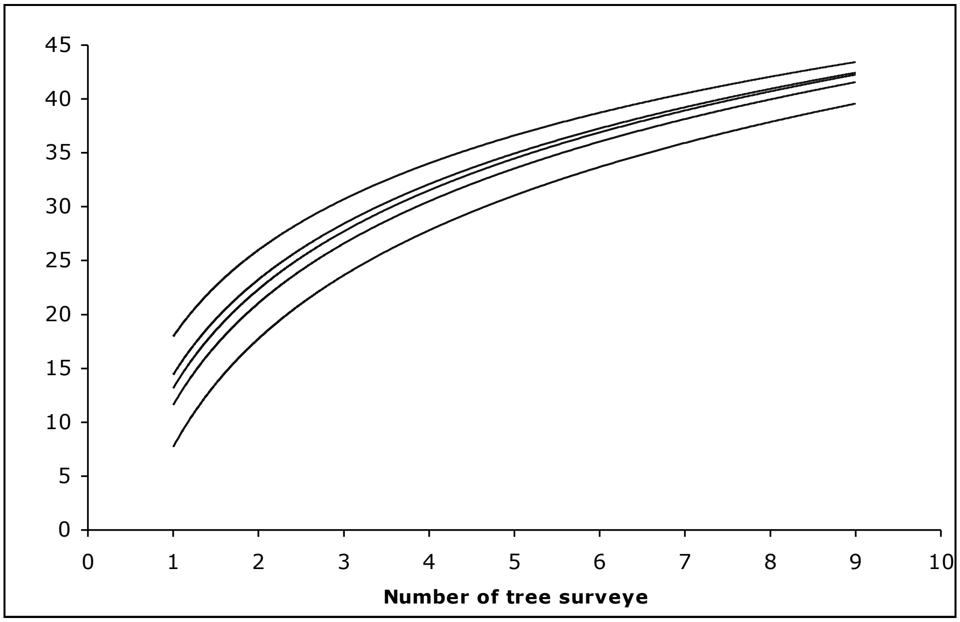

Fig. 8. Species area curve of the number of lichen morpho-species found is plotted against the number of trees (of nine total) surveyed. Random number generation was used to place tree in order, and was repeated five times. No asymptote was reached, which shows that epiphytic lichens in the study area were not exhaustively sampled.

Table 2. Sorrenson's Qualitative Index (C_N) Similarity between each zone

Zones being compared	C_N
1-2	0.28
1-3	0.21
1-4	0.22
2-3	0.35
2-4	0.38
3-4	0.38