EPIPHYTE DISTRIBUTION WITH RESPECT TO MICROHABITATS IN MO'OREA, FRENCH POLYNESIA

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Abstract. Epiphytes contribute significantly to the biomass of forest canopies; however, in the tropics, epiphytes have been greatly understudied. This study seeks to better understand the effects of forest edge on the distribution of epiphytes as well as describe general characteristics of epiphytic communities on *Inocarpus fagifer* in Mo'orea, French Polynesia. It was found that species richness was relatively similar throughout the study site. While there was no significant difference between locality on buttress root or trunk of the host tree, moss communities in particular were significantly affected by distance from forest edge and proximity to perennial streams. Ferns were found to be somewhat correlated with their proximity to streams while liverworts and lichens were not greatly affected. Overall, location of epiphyte communities relative to edge or at different heights on the host tree did not play a large role in the establishment of epiphytes.

Key words. epiphyte communities; edge effects; microhabitats; *Inocarpus fagifer*; Mo'orea, French Polynesia

INTRODUCTION

Vascular and non-vascular epiphytes are essential contributors to the biomass of tropical and neotropical forest canopies (Nadkarni 1984). True epiphytes are autotrophic, and thus must absorb atmospheric moisture (Hietz 1998). In particular, vascular macroepiphytes, such as orchids and bromeliads, are often very different from microepiphytes such as bryophytes (Gradstein and Pocs 1989). Non-vascular microepiphytes, such as lichens, lack mechanisms for the regulation of water, making them more susceptible to abiotic stress (Renhorn 1998). However, non-vascular epiphytes tend to out-compete their vascular counterparts in wetter and cooler environments (Benzing 1998).

While much research has investigated forest fragmentation in temperate zones (Kivisto and Kuusinen 2000, Lindlar and Frahm 2002, Znotina 2003, Baldwin and Bradfield 2007, Echeverria *et al*. 2007), tropical zones have not been thoroughly studied (Nadkarni 1984, Frahm and Gradstein 1991). Fragmentation and agricultural management has been shown to negatively affect epiphytic communities in Brazilian forests (Pereira-Alvarenga and Porto 2007) but the effects of fragmentation and management have yet to be examined in many other tropical areas. Fragmentation creates microclimates because wind speed, solar radiation, air temperature, and relative humidity are often modified at forest edges (Chen *et al*. 1993, Esseen and Renhorn 1998). These edge habitats tend to discourage certain epiphyte growth as wetter, more suitable epiphyte habitats can often be found within a forest stand away from a clearing (Ghuman and Lal 1987).

In addition, the management of forest stands lead to lower species diversity and abundance of macrolichens and bryophytes (Andersson and Gradstein 2005). While most results are species specific, epiphytes respond negatively to habitat modification

and disturbance (Benavides *et al*. 2006). Because tropical rain forests are home to nearly 30% of the world's non-vascular epiphytes (Gradstein and Pocs 1989), examining growth patterns of epiphytes can help us understand how habitats altered by forest fragmentation and management affect this important portion of the community. Understanding growth conditions is necessary to restore species diversity and abundance in epiphyte communities following disturbance. Additionally, investigating colonization processes can help us understand natural changes in communities and monitor epiphyte response to fragmentation.

In Mo'orea, French Polynesia, several species of epiphytes grow on *Inocarpus fagifer*, also known as the Tahitian Chestnut or *mape* (De Sloover 1994, d'Artenay *et al.* 2006). Previous studies of epiphyte growth on Mo'orea have measured factors including canopy cover, aspect, host tree diameter, and height of trunk growth *Metrosideros collina* (Cushing 2002, Dobbs 2006). Finding abundance correlated with canopy cover, size of tree and trunk height.

This study seeks to describe general characteristics of epiphyte growth on *Inocarpus fagifer*. It examines how epiphyte communities are affected by forest edge, locality and distribution on trees. Because little is known about *I. fagifer* and its associated epiphytes, this study also examines two aspects of epiphyte communities: ecological succession and growth conditions. While effects are species specific (Hilmo and Holien 2002), I hypothesize that communities further from the edge and closest to running water are characterized by greater growth rates and species richness. In contrast, host trees closer to the edge of the stand have slower epiphyte growth and lower species richness. I also predict that epiphyte communities growing at different trunk heights on *I. fagifer* would be composed of different dominant species.

METHODS

Study organism and site

All field work was conducted between 8 October 2007 and 16 November 2007. Work was completed near the Tetiiroa Marae immediately below the Belvedere in Mo'orea, French Polynesia (UTM coordinates X199566 Y8058975). The marae was amid mid elevation cloud forest, dominated by *mape*, a Polynesian introduction to Mo'orea (Lepofsky 1994). *Mape* was planted extensively in the mid-1900s to prevent erosion in mid and high elevations (Jennifer Kahn, personal communication). Unique climates associated with high net precipitation characterize these cloud forests and contribute to moisture gradients within the stand.

Sampling design

Transects were established that sampled a range of distances from forest edge and streams. Three linear transects of 75m were established that started at the parking lot at the edge of the stand and ended past a stream in the middle of the stand. A fourth transect of 75m was sampled along the lower reach of stream. Epiphytes were sampled every 10m along transects, on trees within a 5m radius of the transect point. Because species associations between *Inocarpus* tree size and epiphyte diversity was not known, samples were limited to trees with buttressing 2m high with circumferences no larger than 150cm at height 1.5m. I recorded species present along a circumferential transect at height 1.5m and along transects on the two largest buttresses at height 0.75m. Epiphyte species present were recorded every 2cm along the top of the measuring tape. I estimated the aspect of epiphyte growth around the trunk, and noted the aspect of the buttress face.

Experimental design

In order to test the effects of microclimates, an edge-interior transplant was performed, following a technique modified from Renhorn *et al*. (1997) after initial sampling. I removed 9cm diameter circles of bark from trees on the edge of the stand and transplanted them on Petri dishes to the interior of the stand, and vice versa. One sample from the four cardinal directions was transplanted from each location in addition to four control samples that were transplanted to trees within the same location. Species were collected, cleaned of debris, weighed individually, and the species present were identified for individual samples. Samples were then mounted to Petri dishes with botany paste and reattached to trees using fishing line and nails on in late October. After twenty three days, samples were brought back to the lab for weighing and assessment of growth.

A second experiment was conducted to examine influential factors on epiphyte colonization. Colonization experiments were completed at both the interior and exterior of the forest stand. Epiphytes were removed from the tree while the bark remained intact. I cleared a 9cm diameter circle from four trees on the exterior of the stand and from four trees on the interior of the stand, one at each cardinal direction, respectively. Epiphytes present were catalogued before clearing and after twenty three days, any epiphyte growth was also noted.

Organisms were identified with keys by Gradstein (1989), D'Artenay *et al*. (in press), Murdock and Hinkle (1999), and De Sloover (1994). Mosses and ferns were identified to species level. Lichens, liverworts, and algae were identified to the genera level. Voucher specimens of all epiphytes were submitted to the University of California and Jepson Herbaria. Fern specimens were also submitted to the Herbarium of Tahiti.

Statistical analysis

Species diversity along each transect was calculated using the Shannon Diversity Index. Because my response variables were percent values, I used an arcsine transformation to convert the data. Additionally, I used a Bonferonni correction to adjust my p-value. With four responses tested separately, my significant p-value was 0.0125. I performed t-tests between buttressing and trunk height to test for differences in species richness on *I. fagifer.* Because some of my data could not be normalized, I used Wilcoxon tests between buttressing and trunk height. I also performed a two-way ANOVA test to examine the effects of edge and colonization height on microhabitats. All statistical tests were completed using JMP 5.1 (©2004).

RESULTS

A total of eleven epiphyte species were sampled more than once, consisting of three lichens, four ferns, two mosses, two liverworts, and one alga (Appendix A). On average, lichens were most abundant,

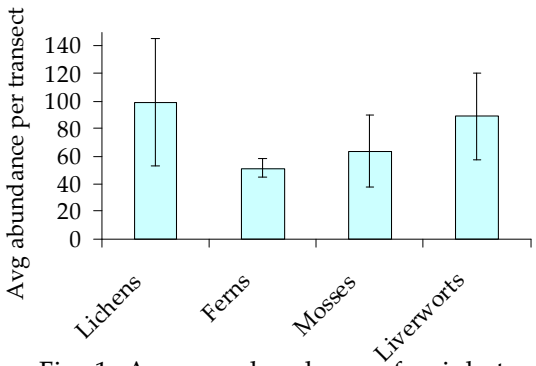

Fig. 1. Average abundance of epiphytes between transects was greatest for lichens, but lichens also had the most variance. Ferns were least abundant between transects and had lowest variance.

followed closely by liverworts (Fig. 1). Lichens had the greatest variance between transects while ferns had little variation (Fig.

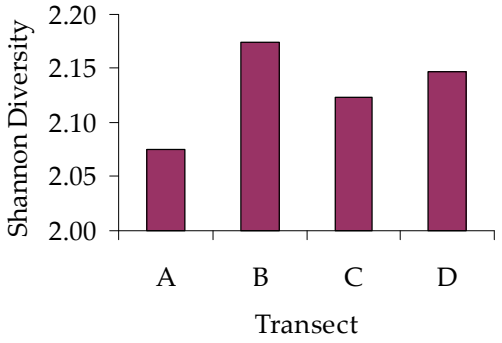

Fig. 2. Transect B had greatest diversity while Transect A had lowest diversity value. There was no significant variance between transects.

1). Mosses and liverworts varied about the same between each transect (Fig.1).

Looking at species richness, transect B showed the greatest diversity with a Shannon Diversity Index of 2.17 and transect A had the lowest diversity of 2.07 (Fig. 2). Transect C had a diversity of 2.12 and transect D had a diversity of 2.14 (Fig. 2). There was no variance between transects.

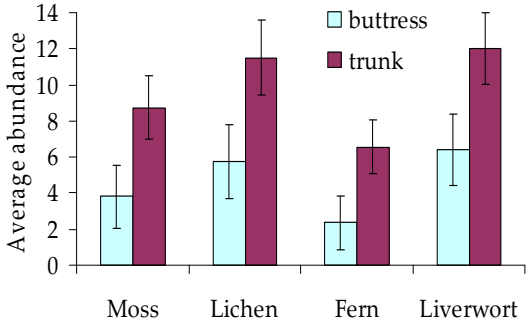

Fig. 3. Average abundance of epiphytes was twice as great on trunks than on buttresses. Liverworts had greatest abundance, followed by lichens, mosses, and ferns.

Results of a t-test to examine species richness showed that it was not significantly different in epiphytes at trunk or buttressing height for liverworts (p=0.7672) or lichens (p=0.8168, Fig. 3). Similarly, results of a Wilcoxon test found non-significant differences in fern richness (p=0.2566) and moss richness (p=0.6524, Fig 3). All calculated p-values were less than the critical value (p-value$\leq$0.0125), thus the null hypothesis could not be rejected.

By a two way ANOVA, there was no significant difference between buttressing and trunk height on lichen (p=0.5166), fern (p=0.3823), moss (p=0.5495), or liverwort (p=0.7248) coverage (Fig. 4). Distance from a stream or edge had no significant effect on lichen growth (p=0.6353), or liverwort growth (p=0.1766, Fig. 4). As communities were sampled closer to a stream, there was a significantly positive effect on mosses (p=0.0033) and a positive loose correlation with ferns (p=0.0631, Fig. 4). The cross-factor between the trunk height and location showed no significant effect on coverage of lichens (p=0.8826), ferns (p=0.8461), mosses (p=0.9861), or liverworts (p=0.6560, Fig. 4).

Most experimental transplants decreased in weight by the end of the study, whether control or experimental plate. The internal East control plate was the only plate to increase in weight, gaining 1.9g. Exterior control plates decreased by 0.9g on average compared interior control plates which decreased by 2.3g on average (Fig. 5). Exterior plates transplanted to the interior location decreased by 2.4g on average, and interior plates transplanted to the exterior location decreased the most on average by 2.6g (Fig. 5).

There was no growth due to colonization after twenty three days, on any of the eight cleared areas.

DISCUSSION

Overall, I did not expect great differences in species composition or

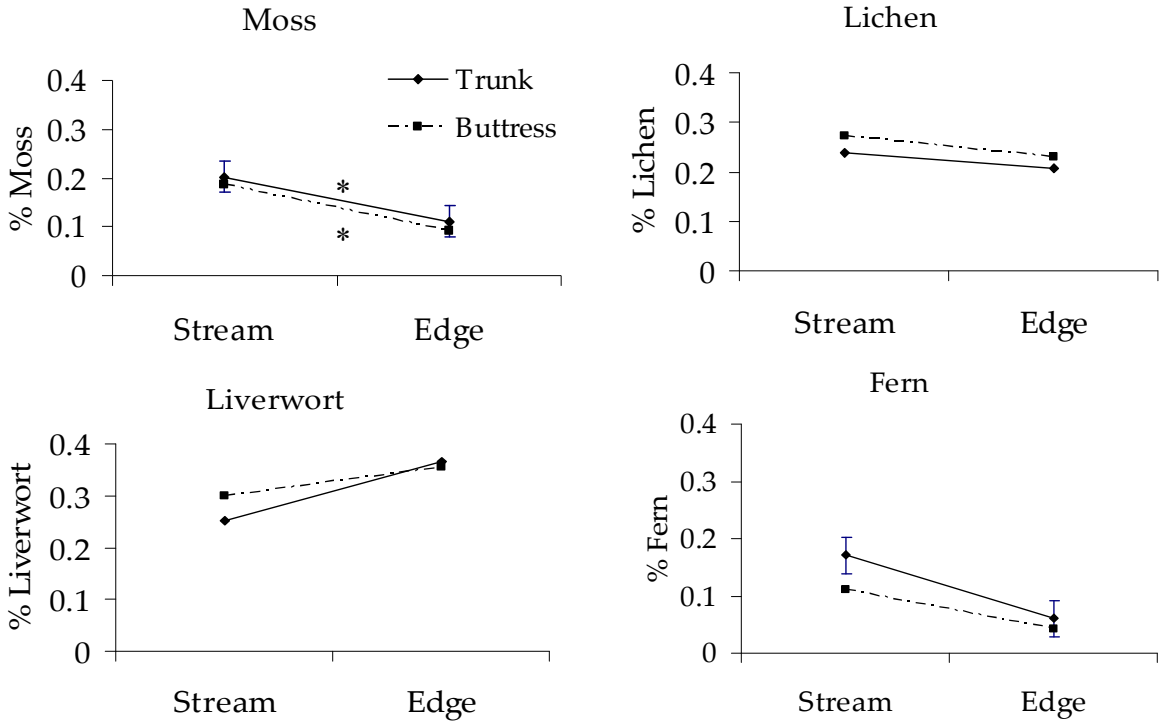

Fig. 4. Percent coverage by epiphyte species as a response to habitat (stream vs. edge) and tree position (trunk vs. buttress). Error bars represent ± 1 standard error. Vertical bars indicate lack of significance between position; asterisks indicate significant difference between habitat.

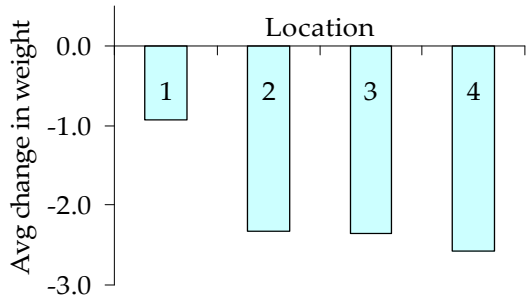

Fig. 5. Average change in weight by location for control and experimental transplants. 1=external control, 2=internal control, 3=external transplant, 4=internal transplant

diversity as all transect sampling was completed in the same area. However, I noticed that edge microhabitats had greater lichen richness which quickly disappeared as sampling continued along transects. These edge environments had the greatest constant light exposure and typically had the least canopy cover which may explain the surge in lichen richness.

In regards to total epiphyte abundance, the patterns in variance between transects support the idea that microhabitats are conducive to growth of specific epiphytes. Lichens seem to tolerate the greatest range of habitats, while ferns are less tolerant of certain microhabitats. Mosses and liverworts seem to be somewhat generalists in their ability to flourish in varying habitats.

I predicted that microhabitats on tree buttresses would differ from that of tree trunks because of the amount of light, canopy cover, and moisture. However, the species richness was not significantly

different between the two heights. This may be due to a variety of factors including host preference, or it may be that the two heights were not far enough apart for comparison. There may be a greater difference in richness between epiphyte communities in the under-story as compared to epiphytes 40m high in the *I. fagifer* canopy.

Although there was similar richness, I found that the average abundance of epiphytes at trunk height was twice as great as buttressing height. This could be attributed to age of communities on the host tree. It would be interesting to see if this trend continued at greater heights on the trunk.

Statistically, only mosses were significantly affected by the distance from the stream. This was surprising because mosses are typically more tolerant to desiccation. Although ferns are the most susceptible to desiccation, there was only a loose correlation between fern growth coverage and stream distance. I expected more of a correlation between fern growth coverage and stream distance. Perhaps a larger sample size is needed to examine this correlation more thoroughly. It is possible that certain species of mosses and ferns are more or less affected by distances from streams, an aspect that this study did not examine. Liverwort and lichen coverage was not significantly affected by distance from the stream. Other than considerable lichen richness at the edge, I did not notice any other trends in liverwort or lichen growth as I sampled along transects. Based on these results, there is not enough evidence to support the idea that variation in stream proximity plays a significant role on epiphyte growth.

Decreased average weight in the transplant experiment was likely due to overall water loss by epiphytic individuals. As mentioned above, the internal East control plate, transplanted from one tree to another in the same location, was the only one to increase in weight. The composition of this plate was 90% lichen coverage with some liverwort and algal growth. This was the only transplant that increased in weight. It is difficult to determine whether this increase was due to productivity, water retention, species present, or other factors, as there was no defining element that differentiated this plate from the other control and experimental plates.

In addition, most specimens, despite full exposure to outdoor elements, had mold growth at the end of the transplant period. This may be due to a contamination introduced during the transplant or in the materials. However, it is worth noting that two transplant plates that only contained *Coenogium* lichen had no mold growth. It may be that this particular genus interacts differently with the environment as compared to other epiphytes on the transplant plates.

There was no epiphyte colonization on any of the cleared areas. Colonization often depends on fertilization cycles and environmental factors, among others, thus it is understandable that growth did not occur. If conditions were favorable, it is possible there may have been some epiphyte growth noted in the short time that this study was conducted. However, most colonization experiments, including Cobb *et al*. (2001), occur over greater lengths of time with estimations of biomass increase noted annually.

CONCLUSIONS

Overall, stream proximity primarily affected moss coverage in epiphyte communities on *Inocarpus fagifer*, while forest edge environments were favorable for lichen abundance. The distribution of epiphyte communities at varying tree heights was not correlated with richness but rather abundance. Because there are many environmental factors that affect epiphyte growth, more specific measurements of abiotic conditions such as relative humidity

could lead to a more detailed understanding of growth patterns. Also, canopy access would allow for a broader look at the range of epiphytic communities on *I. fagifer* as light, humidity, and temperature differ at the canopy level. Future studies could investigate seasonal effects on epiphyte and bryophyte communities in tropical habitats because it has not been well studied. Seasonal differences in rainfall may contribute to the success of vascular and nonvascular plant communities. In addition, the life cycles epiphyte communities have not been well documented as reproductive structures are often elusive to the naked eye. As *I. fagifer* is considered a Polynesian introduction, a comparison of epiphytes on *I. fagifer* between islands in French Polynesia would be an interesting study to examine the possibility of speciation.

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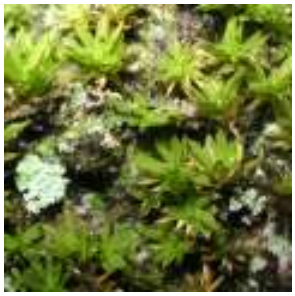
APPENDIX A

Epiphytes found on *Inocarpus fagifer* in Mo'orea, French Polynesia



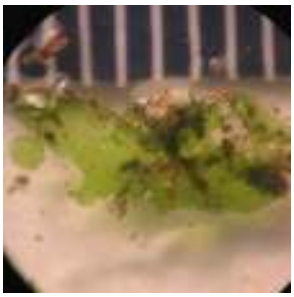
Vesicularia aperta/calodictyon

Orthorrhynchium cylindrium

Trentepohlia sp.

Plagiochila sp.

Rectolejeunea sp.



Fern gametophyte

Trichomanes tahitense

Crepidomanes humile

Crepidomanese bipunctatum

Lepraria sp.

Coenogium sp.

Lichen H