Sampling and identification of the flora of a cloud forest reserve in Costa Rica

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Abstract

The Cloudbridge Nature Reserve lies in a Costa Rican cloud forest where conservation initiatives are underway to preserve the remaining forest fragments and to reforest previously cleared logging and pasture lands. 112 unknown plant species were collected in the reserve to identify to scientific family, genus, and species. The work was done to acquire new herbarium specimens as well as to contribute to two ongoing bio-monitoring studies at the reserve, where floristic inventory data is certainly necessary and largely incomplete. Plant samples were extracted, pressed, and sent for drying to the National Museum of Costa Rica, while digital photos and scans, along with plant descriptions, were sent electronically to professional sources for identification. 48 identifications have been acquired so far, and more are in progress. General trends show high genetic diversity and richness, confirming the forest area as a high priority conservation spot. Further investigation is necessary to come to more definite conclusions on the structure and composition of the forest area.

Introduction

It is no news that the world's cloud forests are threatened by increasingly alarming deforestation rates caused by man's destructive influence over the past few decades (Denslow, 1987; Oosterhoorn & Kappelle, 2000). Logging, cattle grazing, and urbanization in general have wiped out much of the Earth's forest cover. The problem is severe especially in a country such as Costa Rica, which has had one of the highest tropical deforestation rates in the world (Sánchez-Azofeifa et al., 2003). From the Spanish conquest and into the 1960s, thousands of hectares of Costa Rican forest were converted into cropland and pasture, and in the 1970s, the deforestation rate averaged about 3.7% before dropping to less than 1.5% at the end of the twentieth century (Sánchez-Azofeifa et al., 2001 and 2003). The deforestation trends have given rise to landscape mosaics composed of patches of primary and secondary forests, pastures, tree plantations, croplands, and shrublands, evident on the Costa Rican Cordillera de Talamanca mountain range (Oosterhoorn & Kappelle, 2000). Moreover, numerous studies have emphasized the strong negative impact that forest fragmentation has on the biodiversity of species, particularly tree species (Alvarez-Buylla et al., 1996; Cayuela et al., 2006).

The degradation of forest land is presumed to be the primary driving force of biodiversity loss worldwide, an issue that is particularly relevant in tropical forests, famous for holding the highest and richest levels of diversity than any other ecosystems on Earth (Sánchez-Azofeifa et al., 2003; Cardelús et al., 2006; Gordon & Newton, 2006). Diversity of plants in particular is of special note, as studies suggest that some tropical rainforests have more plant species in small areas of a few hectares than any other kind of vegetation in the world, with up to 473 tree and liana species in a single hectare (Givnish, 1999; Whitmore et al., 1985; Wills et al., 1997). Cloud forests are quickly drawing the attention of scientists and conservationists worldwide as they rush to discover the mysteries of the forests' overwhelming diversity, at least 80% of which has not yet been catalogued, before they disappear (Roach, 2001). It has become clear that in-situ biodiversity conservation initiatives are now more urgent than ever, especially with the realization that a very long recovery time is needed to re-establish deforested microhabitats and community structures (Holz & Gradstein, 2005; Langholz et al., 1999). This is all the more pertinent considering the many endemic species found in their unique cloud forest niches- and no where else.

Fortunately, Costa Rica has taken significant conservation initiatives, and although about 75% of its forest lands have already been cleared, the remaining 25% is currently protected, in part by private refuges or reserves such as the Cloudbridge Nature Reserve. It is in this reserve that the investigation at hand takes place, inspired by the need to identify the plant species of a forest area where very few prior studies have been conducted.

Cataloguing the species that compose the rapidly fading cloud forests seems to be the logical first step in understanding and conserving them (Gentry, 1991), but plant identification is important for many other reasons. It is essential in the area of resource management, as man's most basic and frequent needs are fulfilled by the utilization of plants (as a food source, as useable for product materials, clothing materials such as silk or cotton, wood, paper, rubber, drugs, medicines, etc.). Identifying plants is the first step in knowing more about them and about their uses, values, and properties. It is applicable to the ranching industry, horticultural industry, herbal industry, and in fields of ecological consulting or environmental law. One primary purpose in this case, however, is to advance future botanical research. With an inventory of plants in a given area, ecosystem productivity can be assessed, comparative biogeographic or regional studies can be conducted, patterns of ecosystem response to variation in plant diversity over time can be observed, and conservation priorities can be more accurately identified. Furthermore, floristic data can be used as a foundation for studies of biodiversity, distribution, endemism, exotic species, immigrant species, and restoration (Makings, 2003).

Identifying unknown plant species in pre-determined study sites of the Cloudbridge reserve is the primary objective for this project. Other objectives include: 1) collecting samples of all plant specimens with several duplicates to preserve in the herbariums of the National Museum of Costa Rica, Arizona State University, and other herbariums of specialists around the United States who may have helped in their identification; 2) compiling an archive of plant photos and descriptions to add to botanical databases such as the BIOMON database (a bio-monitoring software developed by the Smithsonian Institution); and 3) constructing plant species reference pages for ongoing and future Bio-monitoring studies at the Cloudbridge reserve.

Materials and Methods

Study Site

The project was conducted over a four month period from June – October 2007 in the Cloudbridge Nature Reserve in South-Central Costa Rica. The private reserve is situated within the remote cloud forests of the Cordillera de Talamanca, the country's highest mountain chain. Cloudbridge currently covers about 700 acres and lies at an altitude between 1,500 and 2,600 meters. Its primary goal is "to preserve and reforest an important gap in the cloud forest adjoining the Chirripó Pacifico river on the slopes of Mt. Chirripó, the highest mountain in Costa Rica" (Giddy, 2007). In addition, the reserve is active in ongoing scientific investigations with experts and volunteers, and is open for public recreation without charge.

I collected plant samples throughout the reserve, particularly within several pre-determined sites where research investigations were already taking place. The investigations are the Cloudbridge Bio-Monitoring Study and the Smithsonian Institution Monitoring and Assessment of Biodiversity Program (here on after referred to as SI/MAB). Both projects require extensive botanical inventory data as the great majority of plants within these sites remained unidentified. My aim was to identify as many unknown plants as I could in order to contribute to the understanding of the species composition of the area and to further the current biodiversity research initiatives that only partially complete. This plant identification project is valuable to the progress of these investigations as botanical inventory is a crucial preliminary step in any bio-monitoring, plant community, or diversity investigation (Chazdon et al., 1998; Nadkarni et al., 1995).

Cloudbridge Bio-monitoring Research

The Bio-monitoring research at Cloudbridge was established to study the recovery and biodiversity of the cloud forest in areas of deliberate reforestation as well as areas of natural forest recovery. There are 7 sites, including 3 plantations and 4 naturally recovering forest fragments. Each site is characterized by a central marker, and within a 20 meter radius from this point lie smaller 2x2 meter bio-monitoring quadrants. The plants in these quadrants are documented with notes and photographs in the Cloudbridge Bio-monitoring field book, but their names and values are unknown. Using the field book images and descriptions as reference, I collected unidentified samples within the 20 meter radius plots. Because the bio-monitoring study is concerned with regeneration in secondary or recovering forests, the plants collected from these areas were mainly ferns, grasses, shrubs, vines, and low trees.

Smithsonian Institution Hectare

In contrast, the SI/MAB program involves a one-hectare primary forest plot where mainly tree samples were collected. All trees in the plot with a breast height diameter of 10 centimeters or more were tagged and numbered. There are 712 total marked trees, all of which must be identified to family, genus and species. I worked to collect samples from the unknown trees in order to identify them and to contribute to a growing compilation of data, hoping to further the progress of the Smithsonian Institution project and mission.

The SI/MAB mission to promote biodiversity conservation has been at work since 1986, cooperating with governments, academia, local communities, non-governmental organizations and others to assess and monitor the diversity within distinct regions across the globe. At the Cloudbridge Reserve the project has three goals: 1) to collect extensive biodiversity and tree community data to compare to other sites and to guide the restoration efforts of the reserve; 2) to become a part of the Smithsonian Institution Network of Biodiversity Monitoring sites, which assesses and monitors the dynamics of over 300 sites around the world; and 3) to establish a framework or base for future diversity and ecological studies in the one-hectare study site.

Identifying all the trees in the site, which have been tagged and mapped, as well as processing the collected data using the BIOMON database system developed by SI/MAB, is only the first stage in the project. Once all the trees are identified and data entered, the second stage engages biodiversity studies of various organisms within the plot.

Materials

Field:

- Cloudbridge Bio-monitoring field book
- Cloudbridge Smithsonian Institution hectare field book
- Personal field notebook for collection information
- GPS
- Digital camera, at least 4 megapixels
- Ruler for scale
- Paperboard for picture background
- Plant shears
- Gallon size plastic bags
- Notepad paper
- Magnifying lens
- Binoculars
- Big Shot sling shot, bucket with attached cord, weighted sandbag, and extra line and sandbags
- Gloves

Office:

- Scanner, ruler, and paperboard
- Computer, internet access
- Plant press materials
- Newspaper
- Alcohol spray bottle
- Plastic trash bags
- Masking tape
- Tropical plant guide books for reference

I chose specimens to collect based on priority of identification (Smithsonian Hectare trees, then Bio-monitoring plants, then others) and potential for becoming exemplary herbarium specimens (plant in good, undamaged or minimally damaged condition, ideally with fruits or flowers). For the plant identifications needed in the simultaneous biodiversity projects, I was able to detect the Cloudbridge Bio-monitoring Research plants using the field book images as a guide, and I recognized the trees in the Smithsonian Hectare by aluminum tags with a specific tree code on each one.

Once I chose a specimen that needed to be identified, I recorded the coordinates, elevation, and location of the plant based on previously acquired data in the study sites, or by using a GPS for subjects outside of the study areas. In addition, I recorded more detailed descriptions of the specific plant characteristics such as morphology, aroma, texture, and presence or absence of latex within the stem. I then took multiple digital photographs of the entire plant, its stem or trunk, leaves, fruits, and flowers (if present). In each picture I included a ruler for scale, and I also used blue paperboard as a backdrop for clearer images of close-up plant parts. Using a pair of shears, I cut samples of the plant organs and placed them carefully in large, clear plastic bags along with post-it notes marked with the specific plant collection number. If at all possible, I collected roots as well.

When collecting from tall trees in the Smithsonian Hectare, an oversized sling shot (appropriately called the Big Shot) was used in order to take down branch samples from the canopy. The sling shot was utilized by placing a sand bag attached to a long cord of about 30 meters long into the band. The cord was also kept in and tied to a bucket on the other end to transport the cord as well as to prevent the researcher from losing it in the field when projected. When the shot was fired, the sand bag would fly up into the air trailing the cord behind it and catch onto a branch. The branch would be broken down and then recovered on the ground. The same procedure for cutting and storing leaf and fruit or flower parts in marked plastic bags would then be applied.

Figure 1:
Big Shot Sling Shot

The samples were then taken out of the forest to be scanned and pressed. Although it is best to press plants immediately after acquisition, the bulky size of the plant press made it very difficult to carry into the study sites, which oftentimes required hikes of over an hour long from the reserve on difficult terrain and through dense vegetation. Furthermore, the plant press was very limiting in the field because at least three duplicates of each plant specimen were sought, and each duplicate occupied too much space in the plant press. To be able to take back more than three sets of specimens at a time, I had to use plastic bags to temporarily store the plants and carry them carefully back to the reserve.

After returning from the field, I removed the plants from the bags, cleaned them when necessary, and laid them out onto a sheet of posterboard, sometimes taking more pictures if doing so in the field had proven too difficult. I then scanned a sample of each of the species, making sure to include a ruler for scale and blue paperboard as a backdrop for clarity and consistency, as done with the photographs. Included in the scans were both the adaxial and abaxial leaf surfaces of the specimen, as well as fruits and/or flowers when present.

These digital camera and scanned images were sent by electronic mail to Arizona State University where they were identified to family by Herbarium Curator Dr. Leslie R. Landrum. Dr. Landrum then sent the images to cooperating specialists within the plant families who were able to identify them to genus and species. The information was relayed back to me and I, in turn, entered these new IDs into the Cloudbridge Bio-monitoring database. When possible, I also referenced some literary botanical sources to try to confirm some identifications on my own. For a list of utilized books, see *Appendix 1*.

As for the physical plant materials, these were treated thoroughly with alcohol to prevent mold growth before being labeled, pressed and sealed tightly in a trash bag, further reinforced by masking tape. New plant press materials, such as newspaper and sheets of cardboard between which plants are placed, as well as cord to tie the press shut, were constantly replenished as a new plant press was made and sealed every day with the samples collected. Each set was labeled with typed field notes printed on a single sheet of paper attached to the bag before they were brought to the National Museum in San José, Costa Rica. There, the specimens were received by the herbarium to be dried. The National Museum plans to keep a duplicate of each species and send the rest off by mail to Arizona State University. From there the remaining duplicates will be distributed between ASU and the specialists who helped in their identification.

Finally, written and visual data for each plant collected were organized on the computer for the Cloudbridge database. I typed out all my field notes, revised and labeled all pictures, and wrote herbarium descriptions of each specimen in Spanish for the National Museum. Moreover, I revised and created several reference pages of photos and descriptions of the species identified to add to the Cloudbridge Bio-Monitoring field book, which can be used by future researchers at the reserve. Lastly, I calculated the preliminary data acquired in the Smithsonian Institution primary forest hectare to calculate relative density, relative dominance, diversity, and equitability trends using the following ecological formulas and variables:

Variables

n = the number of individuals of a particular species

N = the total number of individuals

Basal area (b.a) = area occupied at breast height

S = total number of species

Formulas

1) Relative density = n/N * 100
2) Relative dominance = combined b.a. of a species/total b.a. of all species * 100
3) Shannon-Wiener Diversity (H')
   $H' = -\Sigma [(n/N) * \ln (n/N)]$
4) Equitability (E)
   $E = H'/\ln S$
5) Simpson's Index (λ)
   $\lambda = \Sigma\, n(n-1)/ N(N-1)$
6) Simpson's Index of Diversity
   $= 1- \lambda$
7) Simpson's Reciprocal Index
   $= 1/ \lambda$

Results

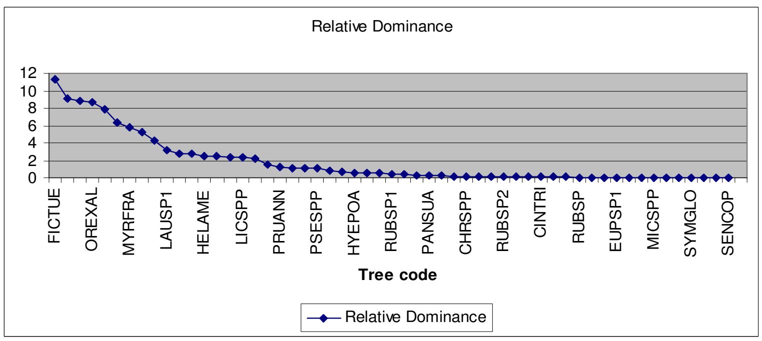
I collected samples from 112 individuals: 58 from the Smithsonian Institution hectare and 54 from Bio-monitoring sites and along Cloudbridge Reserve trails. Currently, 48 have been positively identified and remaining identifications are in progress. For a complete spreadsheet of species data, see *Appendix 2*. Some samples have been identified to only genus or family, and those that are blank have not yet been identified at this point. Most of the achieved identifications were for ferns and flowering shrubs, while there has been little success in distinguishing the trees, which were largely infertile.

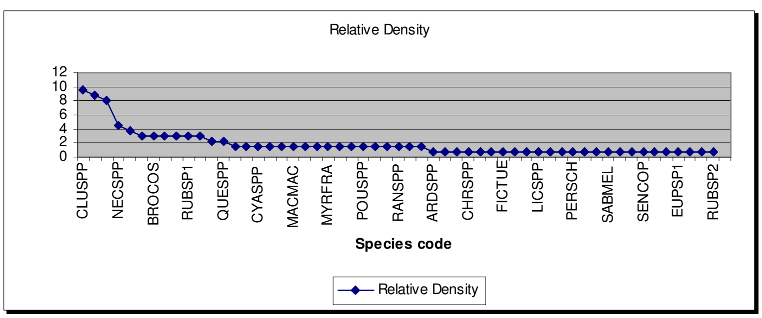
The data for the samples taken outside of the Smithsonian hectare is widespread and still insufficient to make ecological calculations; therefore, formulas will not be applied to them to try to determine biological trends. However, because the plants in the Smithsonian project were collected in one defined area, the preliminary data we have is enough to begin initial, though limited, ecological analysis.

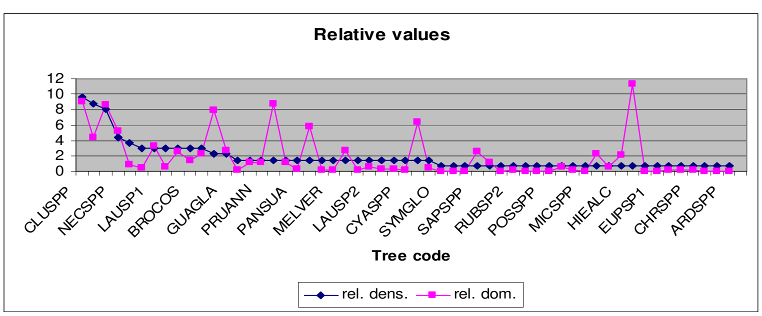
There are a total of 712 trees with a breast height diameter of 10 centimeters or more that are marked in the hectare plot. A modest 136 of them, or approximately 19.1%, have been identified thus far. Three of them were found to be dead. Although I could not identify many trees myself, I can begin to analyze the preliminary data that was already acquired as the project started before my arrival. I accomplished this by importing lists of recorded text data to Excel spreadsheets to interpret the results.

The 136 trees belonged to 55 different species, 48 genera, and 24 families. For a spreadsheet of data in this hectare plot, consult *Appendix 3.* The data displayed includes a specific tree code assigned to each species found, the family, genus, and species names, the number of individuals belonging to that species, the combined breast height diameter, basal area, relative density, and relative dominance for each species.

The three most dominant trees and their dominance values were Ficus tuerckheimii (11.27), Clusia sp. (9.08), and Pouteria sp. (8.78). The three most relatively dense, or abundant tree species were Clusia sp. (9.56), Posoqueria latifolia (8.82), and Oreopanax xalapensis (8.09). Tree dominance and density did not necessarily coincide, although Clusia is a significant genus in that it appeared in the top three lists of both dominance and density.







The overall total number of species, or species richness, was 55. The Shannon-Weiner Diversity Index yielded a diversity value of 3.65 while the Simpson Index yielded a value of 0.97, both very high indicators of diversity in the area. Equitability, or evenness, measured at 0.91.

Summary Table of Ecological Calculations

Species richness	55
Shannon-Weiner Diversity	H'=3.65
Equitability	E=0.91
Simpson's Index	λ=0.03
Simpson's Index of Diversity	1-λ=0.97
Simpson's Reciprocal Index	1/λ=33.33

Discussion

In the Smithsonian (SI/MAB) hectare, it is difficult to say with certainty whether or not species dominance occurs in the plot. Even though I was able to find the three most relatively dense and dominant tree species, their total number of individuals are only 11, 12, and 13 (other species normally have less than five). I may discover, however, that the Clusia species will be the most abundant or dominant tree once more data is collected.

Clusia species is a key player because it was the species with the most individuals and the second highest measure of dominance. Dominance, which is a measure corresponding to basal area, was headed by the Ficus tuerckheimii. Ficus dominates because it is a gigantic strangler fig tree with an enormous basal area; however, still only one individual was identified in this species. This is to say that within the sampled trees, one Ficus had a larger basal area than the combined basal area of any other species.

It is important to realize that there are limitations to this data, the primary one being that there is still not enough of it. These calculations are based on less than

20% of all the trees in the hectare, and I expect them to change once all data is collected. Even then, the preliminary data and ecological calculations can still provide some clues as to the ultimate outcomes and conclusions.

For one, Clusia is likely to be the most abundant species or one of the most abundant. Two, gigantic trees like Ficus tuerckheimii can show very high dominance even though few individuals are found, a factor which must be considered when interpreting the final data. Three, ecological calculations show the plot to be extremely equitable and diverse thus far.

Equitability, a measure of evenness of the abundance of species, is at 0.91, which confirms that there is no clear domination trend and that most species populations are roughly even in abundance. The indication is that the plot is very rich, with 55 total species out of 136 trees. Diversity, as calculated by the Shannon-Weiner equation, is significantly high. The formula produces a value between 0 and 5, usually ranging from 1.5-3.5. The calculation of 3.65 is an indicator of great diversity indeed. Similarly, the Simpson's Index of Diversity yields a high score, demonstrating a 97% probability that any two trees selected at random from the plot would belong to different species. The Simpson's Reciprocal Index, which must yield a value between 1 and 55, shows high diversity as well.

Once again, these figures are likely to change once all data is collected. A species-area curve for this site would surely show that this investigation is on the steep, rising part of the curve, meaning that the sample is still too small and not an accurate indicator of the species composition of the area. Yet the high equitability and diversity of this part of the primary forest cannot be overlooked. The results are consistent with previous studies showing that tropical rain forest trees possess high levels of genetic diversity (Alvarez-Buylla et al., 1996; Givnish, 1999). The danger, then, is that the impact of forest fragmentation is a larger threat in tree species due to the high genetic load carried in tree community populations (Alvarez-Buylla et al., 1996). Experts agree that the few remaining areas of intact native forests should be considered a high conservation priority, "regardless of size and connectivity" (Cayuela et al., 2006), and especially genera and species exclusive to primary forests are important as indicator taxa and targets for conservation (Holz & Gradstein, 2004).

For these reasons, it is clear that reserves and refuges such as Cloudbridge play a significant and even crucial role in the conservation movement. This is particularly relevant in lower-income countries such as Costa Rica where a disproportionately high number of the world's most diverse ecosystems are found, but lack of resources and technical capacities to conduct floristic inventories is a restraint (Gordon & Newton, 2006).

It is necessary, therefore, to continue to the best of our abilities the tree inventory work in the ongoing SI/MAB project, where relatively few trees have been identified up to this point. Composed of sessile and long-lived autotrophic organisms, tree communities are a fundamental forest component whose structures and compositions must be understood to make wise conservation decisions, comparative studies, and future bio-monitoring work (Gentry, 1992). It would be truly beneficial to conduct more studies at the Cloudbridge Reserve to assess floristic composition and structure.

As for the present Plant Sampling and Identification investigation, the study accomplished its objectives of making collections, identifying species, creating images and descriptions to add to databases, and updating and creating plant reference pages for the Cloudbridge Bio-Monitoring field book. Yet it is also important to realize the limitations and challenges of inventory research at the reserve. Far be it from me to say that the present study was without errors, but it was a significant learning experience. My hope is that future volunteers can learn a great deal from the struggles I faced in the field to be able to improve efficiency of their own plant-related projects, especially within the Smithsonian Hectare.

First, it must be mentioned that a scientific passport must be obtained if a researcher seeks to remove plants from the country. This passport must be obtained through the Environment and Energy Ministry (MINAE) in Costa Rica and in cooperation with the National Museum in San José, and filling out paperwork and requirements is a long process.

Once field work begins, one limitation is collecting enough plant material for herbariums and specialists who sometimes request duplicates of plant specimens they help identify. The problem is that a researcher may want to collect a certain plant, but its leaves may not be in the best condition to preserve, or there may not be enough flowers to make more than one duplicate. The absence of fruits or flowers, the reproductive parts of plants that are crucial in identifying species, is often the greatest obstacle. Many experts also require roots for identification, and these may be hard to come by as well (not to mention hard to clean if they *are* successfully pulled). One improvement for future plant sampling work would be to include a small shovel in the list of materials to bring out in the field for extracting roots.

Once the plants are collected and placed in the plastic bags (or sometimes carried by hand when they are too large for the bags), it becomes problematic to maintain them while hiking back out of the forest, as some specimens are too delicate to withstand the trip. On several occasions I would arrive at the office and take out my collections, just to realize that all the flowers had broken, rendering the sample practically useless for herbarium purposes.

There are also many other challenges that were unique to collecting in the Smithsonian Hectare primary forest plot. First, to collect a sample, I had to use an enormous sling shot that requires a great deal of practice to master. One must first find a somewhat level spot in the jagged and steeply inclined terrain to set the sling shot, aim through a carefully selected forest clearing, and fire, which can be very dangerous in itself if not done properly. Then one can only hope that the projectile brings down a decent branch sample without merely slipping through the leaves or branches, and without getting caught and permanently stuck in the crook of another branch or tree on the way up or down. Aiming for a specific branch with fruit or flowers presents an even greater challenge. Additionally, the forest canopy is so dense and layered with mid-story plants, vines, and epiphytes, that it is difficult to even see which branches are coming from which trees, or if the branch is actually an epiphytic or parasitic extension of the tree. These trees are also up to 40 meters in height, while the Big Shot Sling Shot has a range of approximately 30 meters, making some collections nearly impossible.

Furthermore, the method for projecting a bean bag tied to a long cord in a bucket leaves room for improvement. The inefficiency of taking the time to detangle long lines of rope was experienced daily. This problem can be fixed in the future by employing a reeling mechanism. If sufficient funds are available, there are also specialized crossbows with reels and tools resembling fishing poles that are produced for tree sampling (http://www.newtribe.com/technical-new.html).

When a sample was successfully lowered from a tree, which also required focus, precision, and sometimes luck in recovering falling leaves on their way down in the midst of numerous obstructions, it was, unfortunately, of poor quality. In trees that are thousands of years old, one cannot expect the canopy leaves to be clean and free of holes. On the contrary, all samples taken down were greatly damaged by sun, insects, and mosses. These samples could not be accepted in herbariums, but moreover, they could not be identified because they were infertile.

In the months that I conducted research, the trees were not fruiting or flowering. Even experts in plant families cannot distinguish them; in fact, classifying them just to families is challenging. Identifying plants without reproductive organs is no doubt difficult, but identification in general can prove troublesome too.

Using plant keys can be deceiving, especially for the non-expert. They can be very ambiguous, and such drastic variations can exist within species that pinpointing their characteristics is no easy task. For instance, I unknowingly made several collections of the same species because the leaves were polymorphic: they simply looked different. The same plant can also look very different during separate growth stages in life. On the other hand, two species often appear to be exactly the same species when they are actually distinct. To top it all off, scientific names are commonly changing as taxonomists find more accurate ways to group taxa. For these reasons, I relied heavily on specialists and experts rather than my own ability to distinguish plant species. For these reasons it is also recommended to have at least two people working in the field: an expert and an assistant.

The original methodology for the SI/MAB project called for a staff of 1 project leader/field investigator, 2-3 volunteer field investigators, and 1 Costa Rican botanist. A full staff would make the project much more efficient, especially with the expertise of the Costa Rican botanist.

It is not advisable to take on the job alone considering the challenges that the rich rain forest ecosystem represents. As Alwyn Gentry of the Missouri Botanical Garden puts it, "To a biologist this concentration of diversity is exciting and challenging; but it is also a kind of scientific millstone around his neck because…our level of taxonomic knowledge is inadequate to cope with such overwhelming diversity. The world's tropical forests are disappearing at alarming rates, yet the cataloguing of their constituent species…is made impossible by the dearth of taxonomic expertise" (1992).

Finally, a future improvement to this investigation would be simply more time. Similar past studies have required field work in the duration of 18 months to be able to return to collect from plants when they were in flower (Hamann et al., 1998). One exemplary study in the Monteverde cloud forest in the northern region of Costa Rica conducted over 4 years of field work between 1987 to 1991 for a floristic composition investigation (Nadkarni et al., 1995). Time was definitely a limiting factor, and future studies in this SI/MAB hectare should be conducted when the trees are flowering.

Despite these limitations and challenges, the present project was mostly successful. Although many samples did not make it to herbariums because they were damaged, some ferns and other sturdier shrubs did survive and will serve as reference specimens to be preserved in herbariums for many years. All data in the form of images and descriptions are still intact, and with the help of Dr. Landrum as well as other specialists, we were successful in identifying various unknown plant species.

This is of special significance because we believe this may be one of the first times that a scientist working in the field may communicate so directly with experts in other parts of the world to determine an unidentified species. The field scientist can consult professional organizations by sending plant images and scans, and receive almost immediate feedback from the experts. Taking advantage of new technology is a unique methodology in this field, but it has its drawbacks as well. One of the biggest challenges out of the field was scarcely having access to a reliable internet source in the remote rain forest reserve. Cloudbridge has one communal computer and wireless internet, but by modern standards it is slow, unreliable, and often non-functional, especially during the frequent heavy rains and blackouts. In the relatively close-by village community of San Gerardo, internet access was also limiting and expensive. Yet despite the challenges, the new methodology showed results.

Looking at the general results, having 48 confirmed identifications out of 112 collections may seem unimpressive, to say the least, but finding identifications takes time and can be a long process. When diversity is as high as it is in this Costa Rican cloud forest reserve, experts must be sought out to help. Unfortunately, however, the 58 collections made in the SI/MAB hectare may never be identified for lack of fruits or flowers.

Finally, the project was significant because we were able to identify a unique acanth- the Pseuderanthemum. According to Lucinda McDade, one of the authors of the Manual of the Flora of Costa Rica, this is one of the toughest genera in the country and is rarely collected.

Floristic inventory and identification studies are valuable to the Cloudbridge Reserve's continuing restoration efforts. As a relatively new reserve, few studies of the area have been conducted thus far, but we hope that this investigation can be used as a base or springboard to encourage further plant identification studies with future implications on biodiversity and community structure research. With a better understanding of the forest area, comparative investigations can take place and the SI/MAB hectare can become part of the Smithsonian Institution's network of over 300 sites around the world, thus contributing to ecological research on a global scale.

Acknowledgements

I would like to thank first of all my supportive thesis director and mentor, Dr. Les Landrum, for his reliable and constant guidance, valuable teachings, much needed help, numerous recommendation letters, and above all, genuine interest and involvement in the undertaking of this project. Without him, none of this would have been possible. I thank my thesis committee, Dr. Nash and Dr. Maienshein, for their support, input, and presence throughout my study, albeit only through cyberspace in the form of emails. I am indebted to the College of Liberal Arts and Sciences at ASU, having granted me the Dean's Circle Scholarship and the CLAS International Scholarship for Travel and Study Abroad. The Barrett Honors College at ASU aided me financially as well, and these three scholarships were truly needed and appreciated.

To Dr. Ian and Genevieve Giddy, owners of Cloudbridge, I extend deep thanks for allowing me this opportunity to conduct my research on their beautiful reserve. Thank you also to on-site Cloudbridge directors Eric Kang and Tom and Amy Gode for moral support and supervision, and to volunteer James Macpherson for assistance in the field in the Smithsonian Hectare. Thank you to Dr. Armando Estrada of the National Museum in Costa Rica, for exceptional kindness and assistance with herbarium samples; to Adrian Arias, who presented me with my scientific passport, and to the Environment and Energy Ministry of Costa Rica as a whole, who opened their doors for me and provided a setting for which to present my lecture. I must also express thanks to Robbin Moran and other botany specialists who helped in identifying specimens. Last but not least, special appreciation is given to my host family in the San Gerardo village: Ulises and Iris Arias, who provided encouragement, an ample work space, and anything I ever needed during my stay, and Diego Vallejos, who willingly gave up hours of his time in the afternoons to help me scan and press plants when I came back tired from a day's work of collecting in the field. To all of my supporters in the Cloudbridge Reserve, the San Gerardo village, and Arizona, I express heart-felt thanks and appreciation for everything I have been given to make this project possible.

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Appendix 1: Costa Rican Botanical Reference Books.

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Appendix 2: Collector's Data

Collector name: Jacqueline Z. Medrano PH=photomonitoring site

Collection #	Date	Location	Longitude	Latitude	Elev.	Family	Genus	Species
JM001	27-Jun-07	SI Hectare, B5	09°27'58" N	83°34'14" W	2000m	MALVACEAE	Pavonia	pendulifora
JM002	4-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	GESNERIACEAE	Moussonia	deppeana
JM003	4-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	ORCHIDACEAE	Epidendrum	radicans
JM004	4-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	LYCOPODIACEAE	Lycopodium	clavatum L.
JM005	4-Jul-07	Ridge Trail gate	09°28'25" N	83°34'06" W	1762m	ASTERACEAE	Acmella	sp.
JM006	5-Jul-07	PH7	09°28'25" N	83°34'17" W	1637m	ASTERACEAE	Senecio	sens. lat.
JM007	5-Jul-07	PH7	09°28'25" N	83°34'17" W	1637m			
JM008	5-Jul-07	PH7	09°28'25" N	83°34'17" W	1637m			
JM009	5-Jul-07	PH7	09°28'25" N	83°34'17" W	1637m	CYATHEAECEAE	Cyathea	sp.
JM010	5-Jul-07	PH7	09°28'25" N	83°34'17" W	1637m	ROSACEAE	Rubus	sp.
JM011	6-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	PASSIFLORACEAE	Passiflora	sp.
JM012	6-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	DENNSTAEDTIACEAE	Pteridium	pseudocaudatum
JM013	6-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	GLEICHENIAECEAE	Sticherus	bifidus
JM014	6-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	DENNSTAEDTIACEAE	Pteridium	arachnoideum
JM015	6-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	PTERIDACEAE	Pityrogramma	ebenea
JM016	6-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	PTERIDACEAE	Pityrogramma	ebenea
JM017	6-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	DENNSTAEDTIACEAE	Pteridium	arachnoideum
JM018	10-Jul-07	Jilguero	09°28'14" N	83°34'45" W	1642m			
JM019	12-Jul-07	PH2	09°28'23" N	83°34'15" W	1704m	ORCHIDACEAE		
JM020	12-Jul-07	PH2	09°28'23" N	83°34'15" W	1704m	PIPERACEAE		
JM021	12-Jul-07	PH2	09°28'23" N	83°34'15" W	1704m			
JM022	12-Jul-07	PH2	09°28'23" N	83°34'15" W	1704m			
JM023	13-Jul-07	Vivero	09°28'25" N	83°34'10" W	1736m			
JM024	16-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	LYCOPODIACEAE	Lycopodium	clavatum L.
JM025	16-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	GLEICHENIAECEAE	Sticherus	bifidus
JM026	16-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	DENNSTAEDTIACEAE	Pteridium	arachnoideum
JM027	16-Jul-07	PH4	09°28'25" N	83°34'06" W	1767m	PTERIDACEAE	Pityrogramma	ebenea
JM028	30-Jul-07	PH3	09°28'25" N	83°34'16" W	1665m	POLYPODIACEAE	Phlebodium	pseudoaureum
JM029	31-Jul-07	PH6	09°28'46" N	83°34'04" W	1749m	THELYPTERIDACEAE	Thelypteris	sp.
JM030	31-Jul-07	PH6	09°28'46" N	83°34'04" W	1749m	DRYOPTERIDACEAE	Polystichum	sp.
JM031	31-Jul-07	PH6	09°28'46" N	83°34'04" W	1749m	POLYPODIACEAE	Phlebodium	pseudoaureum
JM032	1-Aug-07	PH1	09°28'26" N	83°34'12" W	1684m			

JM033	1-Aug-07	PH1	09°28’26” N	83°34’12” W	1684m	THELYPTERIDACEAE	Thelypteris	dentata
JM034si	2-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m	CLUSIACEAE	Clusia	sp.
JM035si	2-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m	ARALIACEAE	Oreopanax	xalapensis
JM036si	2-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m			
JM037si	2-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m			
JM038si	2-Aug-07	SI Hectare	09°27’60” N	83°34’17” W	1978m			
JM039si	3-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m			
JM040si	3-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m			
JM041si	3-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m			
JM042si	3-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m			
JM043si	3-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m			
JM044si	7-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m			
JM045si	7-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m			
JM046si	8-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM047si	8-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m	RUBIACEAE	Randia	sp.
JM048si	8-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM049	8-Aug-07	SI Hectare, Q20	09°27’59” N	83°34’16” W	1989m			
JM050si	8-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m			
JM051si	9-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m			
JM052si	9-Aug-07	SI Hectare	09°27’59” N	83°34’15” W	1997m	RUBIACEAE	Randia	sp.
JM053	9-Aug-07	SI Hectare, Q15	09°27’59” N	83°34’16” W	1989m	ACANTHACEAE	Pseuderanthen	sp.
JM054si	10-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m			
JM055si	10-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m			
JM056si	13-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m	MELASTOMATACEAE		
JM057si	13-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM058si	13-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM059si	13-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m		Clusia?	
JM060si	13-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m		Clusia?	
JM061si	14-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m			
JM062si	16-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM063si	16-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM064si	16-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1983m			
JM065si	17-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM066si	17-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM067si	17-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM068si	17-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM069si	17-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			

JM070	17-Aug-07	SI Hectare, Q20	09°27’59” N	83°34’16” W	1989m	PHYTOLACCACEAE		
JM071si	21-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m			
JM072si	21-Aug-07	SI Hectare	09°27’60” N	83°34’17” W	1980m		Clusia?	
JM073si	21-Aug-07	SI Hectare	09°27’60” N	83°34’17” W	1980m			
JM074si	21-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m			
JM075si	21-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM076si	21-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m			
JM077si	22-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m	TILIACEAE	Heliocarpus	americanus
JM078si	22-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m			
JM079si	22-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1982m			
JM080si	24-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m		Clusia?	
JM081si	24-Aug-07	SI Hectare	09°27’59” N	83°34’16” W	1989m			
JM082si	24-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m		Clusia?	
JM083si	24-Aug-07	SI Hectare	09°27’59” N	83°34’17” W	1989m			
JM084si	28-Aug-07	SI Hectare	09°27’58” N	83°34’14” W	2003m	LAURACEAE		
JM085si	28-Aug-07	SI Hectare	09°27’59” N	83°34’15” W	2003m			
JM086si	28-Aug-07	SI Hectare	09°27’59” N	83°34’15” W	2003m		Clusia?	
JM087si	28-Aug-07	SI Hectare	09°27’59” N	83°34’15” W	2003m	RUBIACEAE		
JM088si	29-Aug-07	SI Hectare	09°27’59” N	83°34’15” W	1997m	CLUSIACEAE	Clusia	
JM089	25-Sep-07	PH5	09°28’46” N	83°34’04” W	1749m	ASTERACEAE		
JM090	25-Sep-07	PH5	09°28’46” N	83°34’04” W	1749m	RUBIACEAE		
JM091	25-Sep-07	PH5	09°28’46” N	83°34’04” W	1749m	APIACEAE		
JM092	25-Sep-07	PH2	09°28’23” N	83°34’15” W	1704m	ASTERACEAE		
JM093	25-Sep-07	PH2	09°28’23” N	83°34’15” W	1704m			
JM094	25-Sep-07	PH2	09°28’23” N	83°34’15” W	1704m			
JM095	26-Sep-07	Casita	09°28’20” N	83°34’40” W	1551m	ACANTHACEAE		
JM096	26-Sep-07	Casita	09°28’23” N	83°34’40” W	1551m	PHYTOLACCACEAE		
JM097	26-Sep-07	along road	09°28’13” N	83°35’12” W	1466m	MELASTOMATACEAE		
JM098	26-Sep-07	along road	09°28’13” N	83°35’12” W	1466m	ACANTHACEAE		
JM099	26-Sep-07	along road	09°28’13” N	83°35’12” W	1466m	ORCHIDACEAE	Epidendrum	radicans
JM100	27-Sep-07	PH1	09°28’26” N	83°34’12” W	1684m			
JM101	27-Sep-07	PH1	09°28’26” N	83°34’12” W	1684m			
JM102	27-Sep-07	PH1	09°28’26” N	83°34’12” W	1684m			
JM103	27-Sep-07	PH1	09°28’26” N	83°34’12” W	1684m			
JM104	27-Sep-07	PH3	09°28’25” N	83°34’16” W	1665m			
JM105	27-Sep-07	PH3	09°28’25” N	83°34’16” W	1665m	SOLANACEAE	Solanum	torvum?
JM106	27-Sep-07	PH3	09°28’25” N	83°34’16” W	1665m			

JM107	27-Sep-07	PH3	09°28’25” N	83°34’16” W	1665m			
JM108	27-Sep-07	river trail	09°28’21” N	83°34’21” W	1460m			
JM109	27-Sep-07	river trail	09°28’21” N	83°34’21” W	1460m			
JM110	2-Oct-07	SI hectare, Q5	09°27'59" N	83°34'15" W	2003m	ACANTHACEAE		
JM111	2-Oct-07	Gavilan/Jilguero	09°28'12"N	83°34'20" W	1858m	SCROPHULARIACEAE	Calceolaria	tripartita
JM112	2-Oct-07	Gavilan casa	09°28'15" N	83°34'22" W	1802m	LILIACEAE		

Appendix 3: SI/MAB Data

Sp. #	code	family	genus	species	n	Σ dbh	Σ b.a.	rel. dens.	rel. dom.
1	AIOCOS	LAURACEAE	Aioueae	costaricensis	2	50.9	2033.79	1.47	0.45
2	ARDSPP	MYRSINACEAE	Ardisia	sp.	1	15.4	186.17	0.74	0.04
3	BILHIP	HIPPOCASTANACEAE	Billia	hippocastanum	4	116.3	10617.67	2.94	2.33
4	BROCOS	MORACEAE	Brosimum	costaricense	4	91.9	6629.80	2.94	1.45
5	BROSPP	MORACEAE	Brosimum	sp.	1	11	94.99	0.74	0.02
6	CEDTON	MELIACEAE	Cedrela	tonduzii	2	192	28938.24	1.47	6.34
7	CHISYL	RUBIACEAE	Chione	sylvicola	1	14.1	156.07	0.74	0.03
8	CHRSPP	CLUSIACEAE	Chrysoclamys	sp.	1	29.9	701.80	0.74	0.15
9	CINTRI	LAURACEAE	Cinnamomum	triplinerve	1	23	415.27	0.74	0.09
10	CITCOS	ICACINACEAE	Citronella	costaricensis	1	24.8	482.81	0.74	0.11
11	CLUSPP	CLUSIACEAE	Clusia	sp.	13	229.8	41454.31	9.56	9.08
12	CYASPP	CYATHEACEAE	Cyathea	sp.	2	22.9	411.66	1.47	0.09
13	DENARB	ARALIACEAE	Dendropanax	arborens	2	37.2	1086.31	1.47	0.24
14	ELAAUR	RUBIACEAE	Elaeagia	auriculata	2	36	1017.36	1.47	0.22
15	EUPSP1				1	14.4	162.78	0.74	0.04
16	FERN				1	10.3	83.28	0.74	0.02
17	FICTUE	MORACEAE	Ficus	tuerckheimii	1	256	51445.76	0.74	11.27
18	GUAGLA	MELIACEAE	Guarea	glabra	3	126.2	12502.26	2.21	2.74
19	HELAME	TILIACEAE	Heliocarpus	americanus	4	121.3	11550.25	2.94	2.53
20	HIEALC	EUPHORBIACEAE	Hyeronima	alchornioides	1	112.5	9935.16	0.74	2.18
21	HYEPOA	EUPHORBIACEAE	Hyeronima	poasana	1	57.7	2613.49	0.74	0.57
22	INGSPP	FABACEAE-MIMOSOIDE	Inga	sp.	4	60.2	2844.87	2.94	0.62
23	LAUSP1				4	136.3	14583.49	2.94	3.19
24	LAUSP2				2	57.5	2595.41	1.47	0.57
25	LAUSPP				2	26	530.66	1.47	0.12
26	LICSPP	CHRYSOBALANACEAE	Licania	sp.	1	116	10562.96	0.74	2.31
27	MACMAC	FLACOURTIACEAE	Macrohasseltia	macroterantha	2	125.5	12363.95	1.47	2.71
28	MELVER	SABIACEAE	Meliosma	vernicosa	2	33.4	875.71	1.47	0.19
29	MICSPP	MELASTOMATACEAE	Miconia	sp.	1	12.4	120.70	0.74	0.03
30	MOLSPP	MONIMIACEAE	Mollinedia	sp.	5	68.5	3683.42	3.68	0.81
31	MORANI	TILIACEAE	Mortoniodendrum	anisophylum	2	29.25	671.62	1.47	0.15
32	MYRFRA	MYRISTICACEAE	Myristica	fragrans	2	183.7	26490.37	1.47	5.80
33	NECSPP	LAURACEAE	Nectandra	sp.	6	173.9	23739.35	4.41	5.20
34	OREXAL	ARALIACEAE	Oreopanax	xalopansis	11	224.7	39634.72	8.09	8.68

35	PANSUA	PROTEACEAE	Panopsis	suaveolens	2	36.4	1040.09	1.47	0.23
36	PERAME	LAURACEAE	Persea	americana	1	22	379.94	0.74	0.08
37	PERSCH	LAURACEAE	Persea	schiedeana	1	55	2374.63	0.74	0.52
38	POSLAT	RUBIACEAE	Posoqueria	latifolia	12	158.5	19720.97	8.82	4.32
39	POSSPP	RUBIACEAE	Posoqueria	sp.	1	11.8	109.30	0.74	0.02
40	POUSP2	SAPOTACEAE	Pouteria	sp.	2	80.7	5112.30	1.47	1.12
41	POUSPP	SAPOTACEAE	Pouteria	sp.	2	226	40094.66	1.47	8.78
42	PRUANN	ROSACEAE	Prunus	annularis	2	83	5407.87	1.47	1.18
43	PSESPP	MORACEAE	Pseudolmedia	sp.	2	78.8	4874.41	1.47	1.07
44	QUESPP	FAGACEAE	Quercus	sp.	3	213.6	35815.59	2.21	7.84
45	RANSPP	RUBIACEAE	Randia	sp.	2	27.6	597.98	1.47	0.13
46	RONAMO	RUBIACEAE	Rondeletia	amoena	1	11.4	102.02	0.74	0.02
47	RUBSP				1	19.2	289.38	0.74	0.06
48	RUBSP1		Randia	sp.	4	52.7	2180.17	2.94	0.48
49	RUBSP2				1	26.3	542.98	0.74	0.12
50	SABMEL	SABIACEAE	Sabia	melliosma	1	16.9	224.20	0.74	0.05
51	SAPGLA	EUPHORBIACEAE	Sapium	glandulosum	1	79	4899.19	0.74	1.07
52	SAPSPP	EUPHORBIACEAE	Sapium	sp.	1	120.1	11322.85	0.74	2.48
53	SENCOP	ASTERACEAE	Senecio	copeyensis	1	10	78.50	0.74	0.02
54	SLOAMP	ELAEOCARPACEAE	Sloanea	ampla	1	13.3	138.86	0.74	0.03
55	SYMGLO	CLUSIACEAE	Symphonia	globulifera	1	11.4	102.02	0.74	0.02
					136		456624.33		