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Descriptive Analysis of Tree Composition and Diversity in a Coastal Tropical Lowland Moist Secondary Forest in Puerto Rico

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ABSTRACT

This analysis describes the tree composition and diversity of two forest plots in the Northeastern Ecological Corridor of the island of Puerto Rico. These 50mx20m plots were formed in May of 2013 on both the west- and east-facing slopes of a hill in this tropical secondary forest as a basis for a long-term ecological study to identify the growth and change in the plots over time. This area has been affected by environmental and anthropological distress, making it important to study its reforestation. In order to do so, this study tagged and identified 1,526 trees within the two plots and measured their DBH (diameter at breast height) in May 2013 and January 2014 as an initial record of tree composition and diversity. Species richness and diversity tests were done to assess community similarity between the east and west plots. Overall, 42 species of trees have been identified, but the east plot had greater species richness and diversity with 35 species compared to the 22 species found in the west plot. We performed t-tests were to assess any significant difference in the basal area of a species in both areas. There were 12 species that could be tested and four of them showed a significant difference. These four species were also the most specious in the plots, suggesting that the sensitivity of the t-tests may have been greater in those cases. These data will be used to compare future forest growth and work as a reference point for species composition in later years.

Keywords: *Northeastern Ecological Corridor, Puerto Rico, tree species diversity, forest composition, coastal tropical lowland moist secondary forest*

INTRODUCTION

Puerto Rico, the smallest of the Greater Antilles, is located in the tropics with respective sides facing both the Atlantic Ocean and the Caribbean Sea. The wide range of environments found on the island that is approximately the size of Connecticut (Miller and Lugo 2009) can be attributed to the trade winds that interact with the sea and mountains to distribute rainfall in various patterns across the island. Mountains in the northeastern portions of the island capture the moisture-laden air and as it cools, large amounts of precipitation fall. Subsequently, the air "passes over the mountains and the amount of rain decreases resulting in the south coast being much dryer" (Miller and Lugo 2009).

The Northeastern Ecological Corridor (NEC) is the northeastern tip of Puerto Rico. The NEC is approximately 1,200 ha situated between Luquillo and Fajardo (Frye 2013). The area had previously been threatened by development. The corridor was then established as a nature reserve in order to preserve the area, as it is now "considered the longest stretch of coastal land without urban development on the island" (Frye 2013). It has a range of habitats that include forests, wetlands, beaches, coral communities, and a bioluminescent lagoon.

Due to the geographic position, hurricanes and other tropical storms are a major disturbance to the area and can cause long-term alterations in the ecosystems of the island (Miller and Lugo 2009). These environmental events cause "catastrophic high winds and waves [and] large amounts of rain" that result in enormous changes to natural ecosystems" (Miller and Lugo 2009). Deforestation is a major repercussion from these events. Branches are broken, trees are uprooted, and soils are eroded, disturbing the composition of the forests. Other changes that hurricanes can cause include: "elimination of reproduction for some individuals, vastly altered amounts of light throughout the forest, landslides, and alteration of succession patterns and forest regeneration" (Miller and Lugo 2009). This suggests that there would be a difference in the species and age distributions in forests across the island, depending on which sides of the mountains they are located.

Another force that contributes to the forest composition and tree diversity is the amount of nonnative plants that were introduced to the island in the last several centuries due to trade and colonization. This makes it difficult to study the percentages of native plants to foreign species and estimate what the species diversity will look like in upcoming centuries. Also, deforestation for farming in the early 19th century has had an impact on this area and though much work has been done to reforest the land, there may now be a large difference in how these forests grow after this disturbance.

This research focused on these differences by collecting data from plots of forest located on both the east and west sides of a hill within the NEC. It is one portion of a long-term ecological study to describe vegetation and biodiversity in this coastal lowland moist forest (Frye 2013). Similar to a study published in 2009 concerning Las Cabezas de San Juan Natural Reserve, the data will be collected to "summarize information on forest structure, species composition, and tree increment with similar sites" (Weaver and Rodriguez 2009).

MATERIALS AND METHODS

In May 2013, two 50m by 20m plots were established on either side of the slope of a hill located at 18° 21′ 30″ North latitude, 65° 38′ 30″ West longitude. All free-standing woody stems with a diameter greater than 1 cm and a height greater than 130 cm were tagged, measured, and identified (Frye 2013). This occurred during the island's wet season, when it gets a much larger amount of precipitation.

In January 2014, (the dry season) the next step of the experiment included measuring the DBH (diameter at breast height ≈ 1.4 m) of approximately 1600 trees in these predetermined plots, located on both the east and west sides of the hill. We used calipers for trees measuring less than 5 cm in diameter and a DBH tape for any tree larger than 5 cm. As this is a long-term study, the group also collected samples of unknown trees, identified trees that had been labelled unknown, and tagged new stems that were over 1 cm in diameter within the grids. The task of this project was to perform statistical analysis of the growth and species composition on either side of the hill. These data will be used to compare similar regions within Puerto Rico and other parts of the globe.

The data collection that occurred in the NEC was done using the verified citizen science method, ensuring that the entirety of the data were collected in the short amount of time allotted to do so. There were 13 students from the University of Puerto Rico and three students from McPherson College who were taught to make the measurements accurately so that the data was comparable and consistent. Using a clipboard and measuring device, students paired up to collect information within the plots that had been formed in May 2013.

Those data were entered alongside the information collected eight months prior and analyzed looking at specific criteria. The issue with only studying change in DBH of any given tree species is that it doesn't necessarily account for actual added mass. When looking at DBH alone, it appears as if the smaller trees are growing much faster. However, when DBH is converted to basal area, (a cross-sectional area of the tree) it is a much more accurate representation of growth. To convert the data, the following formula was used:

$$BA = (\pi \div 4) \times DBH^2$$

The calculations include average basal area per species for each side of the hill and T-test statistics to analyze any correlation that may have been present between the East and West plots. Calculations were also done to describe species richness and diversity, including Simpson's Index and Jaccard's Coefficient of Community Similarity. Simpson's Index (D) indicates both species richness and evenness by the summation of the number of individuals in each species (n_i) to the total number of individuals in the community across all species (N) as such:

$$D = \sum(\frac{n_i}{N})^2$$

The results range from 0-1, with the smaller number equaling a higher biodiversity. The following equation is Jaccard's Coefficient (CC_j):

$$CC_j = \frac{C}{S}$$

C represents the number of species two areas have in common and *S* represents the total number of species in both areas. Also, the number of each species that made up the plots in both grids were recalculated from the January 2014 data, given that many of the unknown species were identified.

RESULTS

There have been 42 species identified from both plots out of the 1,526 individual trees that were tagged. This number, (along with the Simpson's Index and Jaccard's Coefficient) excludes the unknown species. The east plot showed greater species richness with 35 known species, while 22 known species were observed in the west plot. Similarly, the east plot proved to have a higher biodiversity with a Simpson's Index of 0.0961. The west plot had a much lower diversity with a Simpson's Index of only 0.3371. There were 16 out of the 42 species located on both sides. The east plot was dominated by Eugenia pseudosidium, with 200 individuals observed out of the 746 trees in that plot. Tetragastris balsamifera made up a majority of the 780 trees in the west plot with 434 individuals observed.

Table 1 shows the average basal area per species, (including standard error) and the number of individuals within each species that we found. Two-sample T-tests were performed in order to show significance between the same species on opposite sides of the hill. Out of the 12 tests that were performed, only four showed *P* values of less than 0.05. Bursera simaruba, Eugenia monticola, Myrciaria floribunda, and Savia sessiliflora proved to have an extremely high probability of significant differences with $P<0.00$. However, the other eight.

Table 1. Average Basal Area per species and number of individuals per species for the east and west plots. P values for t-test results. P<0.05 means a significant difference is present. Species that were tested had *P* values between 0.435-0.839, suggesting little to no correlation in the difference between samples.

Species	East		West		P(T<=t) two-tail
	Avg. Basal Area (cm^2) ±Standard Error	# of Individuals	Avg. Basal Area (cm^2) ±Standard Error	# of Individuals	
Amiris emilifera	7.07 ± 4.77	5	--	0	n/a
Boraginaceae	66.01 ± 52.81	2	--	0	n/a
Bursera simaruba	1054.65 ± 192.59	5	120.38 ± 34.56	13	0.009
Casearia guianensis	13.27	1	--	0	n/a
Chrysophyllum argenteum	8.51 ± 4.53	5	--	0	n/a
Coccoloba diversifolia	41.28 ± 18.51	4	7.60	1	n/a
Coccoloba rugosa	--	0	1.77 ± 0.40	2	n/a
Cordia alliodora	142.5 ± 141.33	2	--	0	n/a
Cynaphallo hastada	48.21 ± 10.29	16	--	0	n/a
Erythroxylum areolatum	6.61	1	--	0	n/a
Erythroxylum rufum	9.95	1	--	0	n/a
Erythroxylum spp	8.04	1	--	0	n/a
Eugenia ligustrina	7.64 ± 1.07	37	5.27 ± 2.56	13	0.435
Eugenia monticola	20.97 ± 3.88	22	2.35 ± 1.11	2	0.000
Eugenia pseudosidium	5.09 ± 0.75	200	4.80 ± 1.22	58	0.839
Faramea occidentalis	--	0	4.74 ± 0.54	70	n/a
Guapira fragance	60.00 ± 11.81	32	44.78 ± 34.32	3	0.716
Hymenaea algarrobo	--	0	177.32 ± 128.39	3	n/a
Hymenaea courbaril	330.74 ± 84.16	10	373.80 ± 74.25	62	0.704
Krugeodendrum ferrum	--	0	5.46 ± 0.97	2	n/a
M239	--	0	1.76 ± 0.51	2	n/a
M517	--	0	4.85 ± 1.16	4	n/a
M584	--	0	12.68 ± 5.68	4	n/a
M994	23.10 ± 21.10	2	--	0	n/a
M1696	110.34 ± 35.86	6	--	0	n/a
Maytenus domingensis	15.04 ± 2.79	43	10.55 ± 5.28	16	0.459
Myrciaria floribunda	2.14 ± 0.13	2	6.16 ± 1.00	61	0.000
Nectandra coriacea	3.79 ± 1.41	2	--	0	n/a
Neea buxifolia	1.98 ± 0.36	5	2.93	1	n/a
Ocotea coriacea	42.07 ± 7.97	46	56.07 ± 29.38	2	0.726
Ocotea spp	42.40 ± 15.08	11	--	0	n/a
Ouratea litoralis	7.19 ± 4.77	4	--	0	n/a
Quadrella indica	2.04	1	--	0	n/a
Quadrella synophallophora	3.80	1	--	0	n/a
Quizás Solanum	4.91	1	--	0	n/a
Randia aculeata	3.05 ± 0.46	3	0.79	1	n/a
Samyda dodecandra	4.32 ± 0.84	10	1.73	1	n/a
Savia sessiliflora	12.01 ± 1.96	73	2.41 ± 0.85	3	0.000
Schoepfia spp	4.19 ± 0.73	2	--	0	n/a
Senegalia muricata	164.21 ± 21.54	22	--	0	n/a
Tetragastris balsamifera	75.43 ± 58.78	6	21.36 ± 2.28	434	0.400
Trichilla pallida	9.74 ± 1.49	9	6.67 ± 4.33	12	0.514

When observing the overall growth of the forest from May 2013 to January 2014, the average change in basal area in the east plot was 1.10 cm^2. Conversely, the west plot actually showed a negative average change in basal area of -0.12cm^2.

DISCUSSION

The greater species richness and diversity found in the east plot could be attributed to the increased amount of sunlight and precipitation that occurs on the east side of the hill due to the direction it faces and tradewinds that bring in moisture-laden air. An interesting correlation can be found in the results of the t-tests. The species that proved to have a significant difference in basal area were also the most specious groups that were observed in both plots. The t-tests are far more sensitive and representative when the number of individuals being compared is greater. This suggests that if the plots may have been larger and a bigger group of trees were studied, the P values for various species may have differed. Since these plots have been set up already, however, it is possible for future research in this area to focus on these few species for an accurate description of tree growth. The other species will be useful in describing species composition within the plots. Also, this set of data can be used to acknowledge appearance or loss of species that may occur in later years.

When discussing the error that may have been involved in data collection, it is necessary to note the difficulty in measuring the DBH at the exact same height and with the exact same methodology, depending on the person taking the readings. We had a standard breast height of 1.4 meters, however, the markings which noted this location on many of the trees was rubbed off or very difficult to see. It was necessary to use our best judgment and try to make the measurements as consistent as possible, but there were other factors that made that difficult. Some stems had growths, or protrusions, at exactly 1.4 meters which would have been an inaccurate representation of the tree's actual mass. Also, depending on how an individual used the DBH tape, the data might have been slightly skewed.

Another important factor to note is the time of year in which these measurements were made. Out in the field and at first glance, we had been confused by the data when noting that on average the diameter was smaller than it had been previously. After a discussion with Dr. Ariel Lugo, an ecologist and Director of the International Institute of Tropical Forestry, we discovered that the diameter of a tree can change drastically depending on the amount of water it is uptaking. Since the plots had been previously measured during the island's wet season and we took our data during the dry season, it is reasonable that our data shows a decrease in both DBH and basal area within some species.

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