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Abstract

In April 1974, a tornado crossed Monte Sano Mountain, North Alabama, inflicting considerable damage on a mature stand of deciduous hardwood forest in Monte Sano State Park. The purpose of this study is to determine if significant differences are present between the forest structures of undisturbed hardwood forest and the tornado-damaged stand. The tornado-damaged stand occupies a south-southeast facing slope on a steep ridge descending into Mackay Hollow. Since the damaged occurred, the area has remained generally untouched and thus has been allowed to recover naturally. On this site, ten parallel plots of 100 m in length were selected from within the damage boundaries. The undisturbed area consisted of a plot 200 x 60 m in the City of Huntsville's Cold Springs Natural Area. The two sites are approximately 400 m apart and exist in the same stratographic setting at an elevation of 480 m. The information recorded included the diameter at breast height (dbh) and the specie of the individual. Only individuals over 10 cm dbh were included.

Introduction

A stand of mature deciduous hardwood forest in Monte Sano State Park sustained considerable damage in April 1974 when a tornado crossed Monte Sano Mountain. It is important to consider the period of recovery for a damaged forest so that management officials can make informed decisions as to the best course of action for the forest when similar disasters occur. The question addressed here is; does the regenerating forest twenty-five years after the tornado damage resemble the pre-disturbed forest? The present forest composition fulfills expectations as "hardwood stands occur at higher altitudes and on steeper slopes than other forest types" (Foster and Boose 1992). This study set out to determine if significant differences are present in the forest structure in both the size and species distribution of the individual trees. If these differences do in fact exist, what are the new characteristics of the forest, and what implications does this have?

Methods

The tornado-damaged stand examined was on a south-southeast facing upper slope of a steep ridge descending south onto the upper gorge of Mackay Hollow. Since the destruction, the area has remained generally untouched by park services, except to remove trees impeding trails, which now only skirt the area of interest, and thus has been allowed to recover naturally. The tornado-damaged site was located using 1:12000 aerial photographs, taken a few weeks after the tornado outbreak of April 1974, of Monte Sano State Park and the surrounding areas. The photo detail is fine enough to reveal individually downed trees and the paths running through the park. Using this, along with topographical maps and compass, the site area was located and marked. From the entire tornado track, ten parallel plots of 100 m in length were selected from within its boundaries, talking care to avoid recent landslide activity that would alter the composition. The beginning points of these transects were selected at random (outside of the experimental requirements) to avoid any sample bias. Beginning at one end of the 100-m plot, all trees within five meters on each side were recorded. The information recorded included diameter at breast height (dbh – approximately 137 cm from the ground) and specie of the individual. Only individuals over 10 cm dbh were included. Once recorded, the frequency per species and frequency per diameter size class, along with other statistical analyses, including the Kolmogrov-Smirnov X^2 test, were performed.

Since no recordings were made of the forest composition before the tornado damage occurred, a second area on an adjacent ridge to the tornado-damaged site was selected for comparison. The two sites are similar in elevation, water availability, and slope alignment in order to approximate what the study area would most likely have looked like. The two sites are approximately 400 m apart and exist in the same stratographic setting. The tornado-damaged plot was compared to data in the undisturbed plot, which had been previously collected by Dr. Jim Daniels and Dr. Robert Lawton in 1995. The area was a plot 200 x 60 m, consisting of 30 adjoining 20 x 20 m quadrats in the City of Huntsville's Cold Springs Natural Area on Monte Sano at an elevation of 480 m. A permanent spring runs through the area, which is situated in a north-facing hollow.

Results

Tornado-damaged plot

The tornado-damaged plot, 1 ha, contained a total basal area of 17.35 m^2 of wood from the measured stems. This included 338 individuals. The individuals counted that contained one or more stems due to branching, were counted only once for the individual categories, but each stem over 10 cm at dbh was measured and recorded distinctly for the basal area measurement. For cases such as *Tilia heterophylla*, for which closely located individuals are most often from the same beginning individual, the stems were treated as all other individuals, if from above ground, stems seemed to be separate individuals, they were treated as such, despite their genetic composition. Any other determination would have entailed excavation and parentage determination. The average diameter for this plot was 20.3 cm. From this, trees that were of a size that would have been adult at the time of the disturbance, yet survived, were calculated to have attributed to a 36.6% survival rate for the forest as a whole. The rest of the individuals were either juveniles at the time or have grown up in the time since the disturbance. Living trees only were recorded; no dead or fallen trees found at the site were recorded, whether or not they had been a part of the forest community since the disturbance.

Undisturbed Plot

The undisturbed plot was taken over 1.2 ha, and then the data was normalized to present the statistics on a per-hectare basis. The frequency was found to be 303 stems/ha. This was likewise representative of entire trees, not branching stems as individuals. The basal area was 24.19 m^2 and the average stem diameter was 26.8 cm. All of the trees recorded were living and standing. Broken trees, if living, were included, while standing dead individuals were not.

Statistical Analyses

The Kolmogrov-Smirnov X^2 test was completed on the groups both in whole and by species, where practicable. The species that consisted of large enough numbers of individuals in both plots were the *Quercus alba*, *T. heterophylla*, *Robinia pseudoacacia*, and *Ulmus rubra*, which contained at least 20-30 individuals. The diameter distributions were the subject of inquiry in this comparison and the range of X^2 was great. All of the categories tested contained statistically significant differences, the overall survey being the largest. It showed a X^2 of 54.8. Next, the *Q. alba* had a X^2 of 15.65 and the *R. pseudoacacia* a X^2 of 14.2. The other two species had X^2 under 6, with *U. rubra* at 5.93 and *T. heterophylla* showing the smallest X^2 of 5.76.

Diameter Distribution Analysis

The frequency distributions (Figure 1) by species showed that each population had a distinct curve between the tornado-damaged and undisturbed plots. The overall frequency distribution by species showed two great spikes at *R. pseudoacacia* and *U. rubra* for the tornado-damaged plot, while the undisturbed plot showed level frequency distribution with co-dominance of six or seven species. This attests to the reduced diversity of the tornado-damaged plot. The undisturbed plot contains a greater number of species, and so the number of each is relatively lower than seen in the tornado-damaged plot.

Likewise, the basal area (Figure 2) showed differences with the tornado-damaged plot having the greatest spikes. The area per species per hectare was fairly moderate, with the tornado-damaged *T. heterophylla* the highest overall producer. Looking at the information distributed by percentage composition rather than overall area, the tornado-damaged plot shows that a small number of species make up most of the wood volume while the undisturbed plot is much more evenly distributed. This shows the relative abundance of the wood taking into account the size of the tree, and therefore the amount of wood produced by each specie, not solely the number of individuals. The

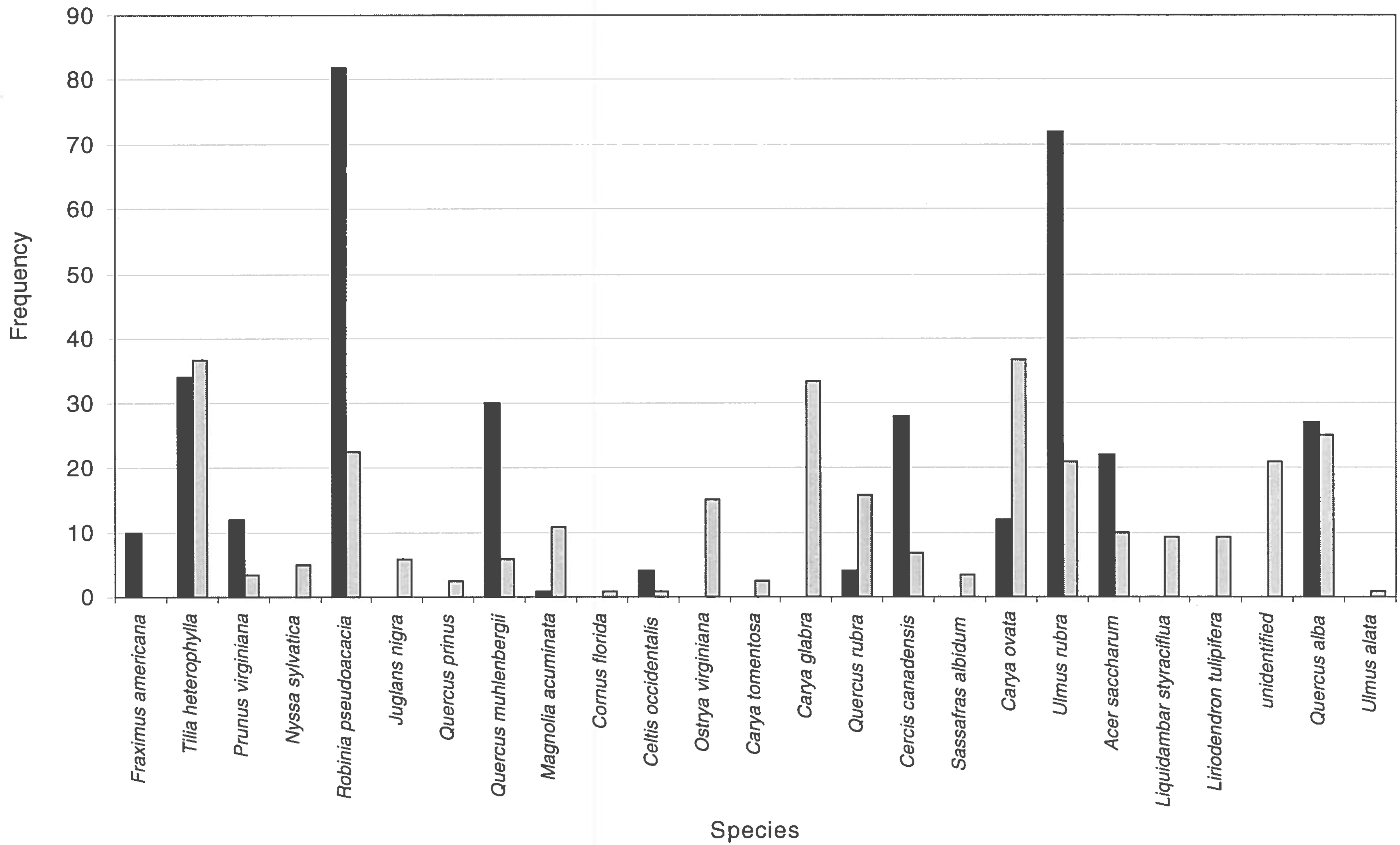

Figure 1. Frequency distribution by species (trees >10 cm dbh) of undisturbed mixed hardwood forest (grey) and tornado-disturbed stands (black) on southeast facing upper slopes of Monte Sano Mountain, North Alabama.

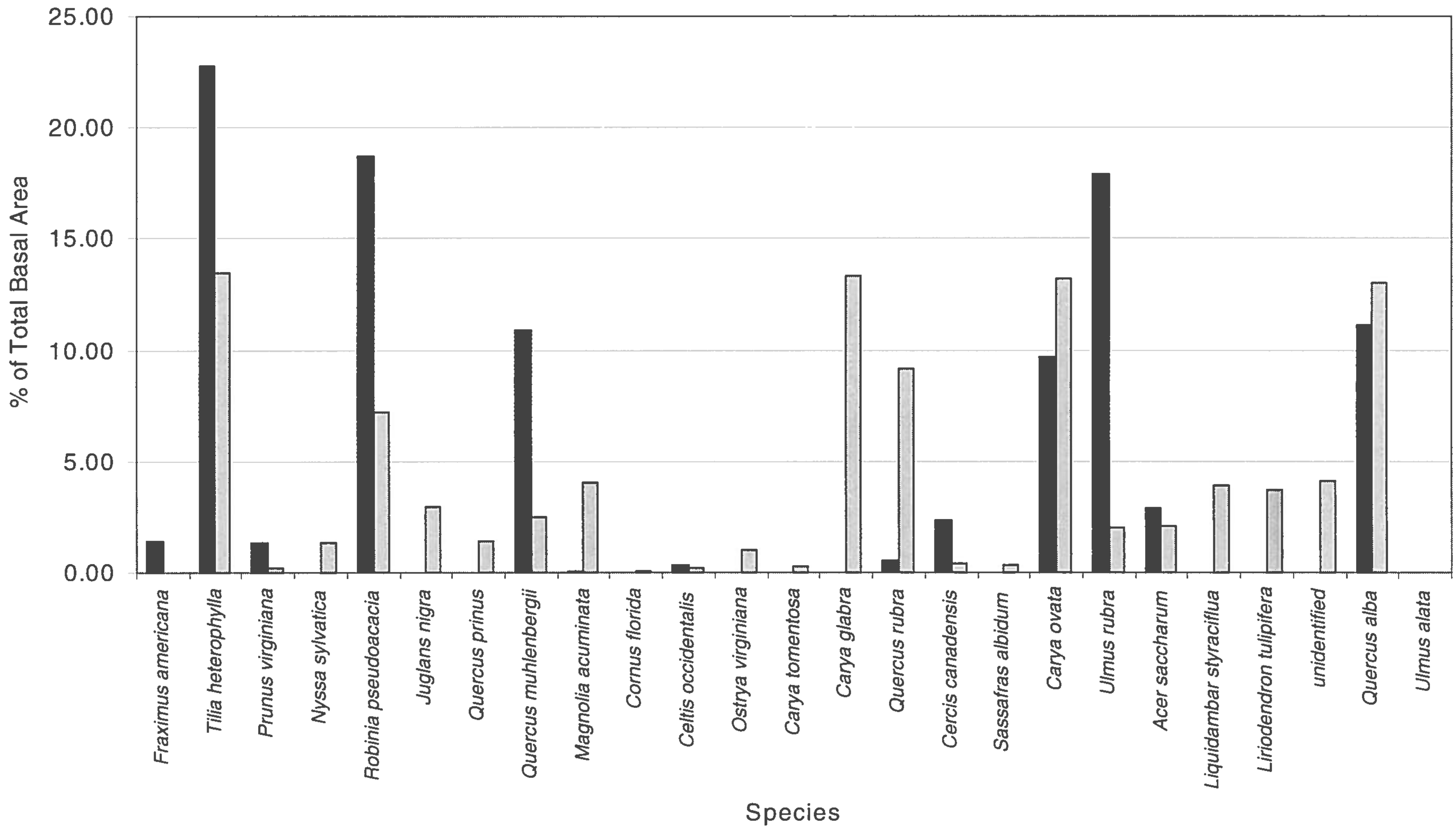

Figure 2. Basal area by species (per hectare) as a function of percent total basal area by species (trees >10 cm dbh) of undisturbed mixed hardwood forest (grey) and tornado-disturbed (black) stands on southeast facing upper slopes of Monte Sano Mountain, North Alabama.

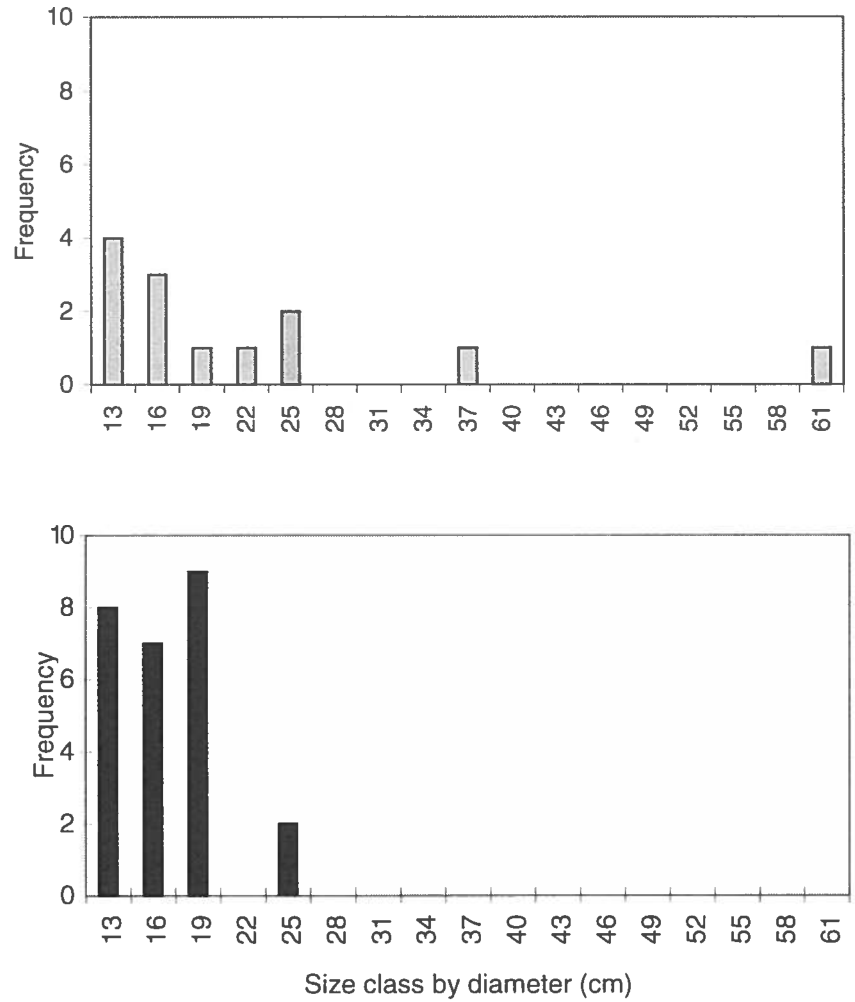

Figure 3. *Acer saccharum* distribution (trees >10 cm dbh) of undisturbed mixed hardwood forest (grey) and tornado-disturbed (black) stands on southeast facing upper slopes of Monte Sano Mountain, North Alabama.

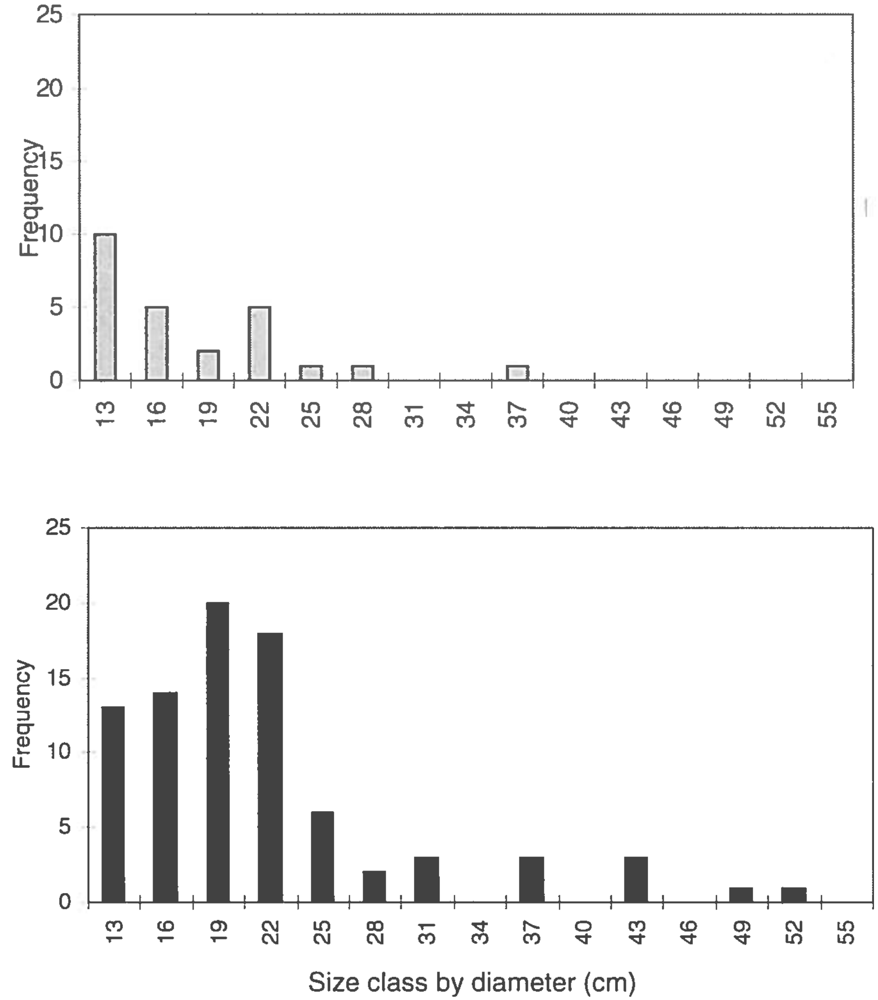

Figure 4. *Ulmus rubra* distribution (trees >10 cm dbh) of undisturbed mixed hardwood forest (grey) and tornado-disturbed (black) stands on southeast facing upper slopes of Monte Sano Mountain, North Alabama.

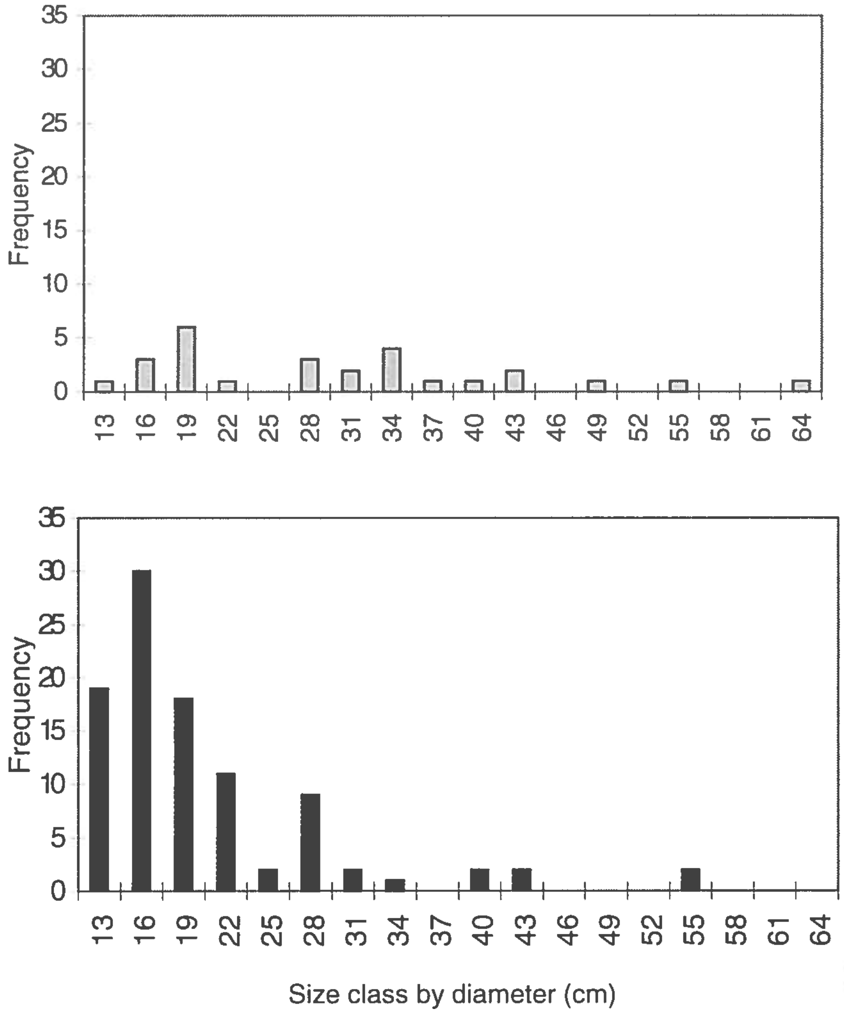

Figure 5. *Robinia pseudoacacia* distribution (trees >10 cm dbh) of undisturbed mixed hardwood forest (grey) and tornado-disturbed (black) stands on southeast facing upper slopes of Monte Sano Mountain, North Alabama.

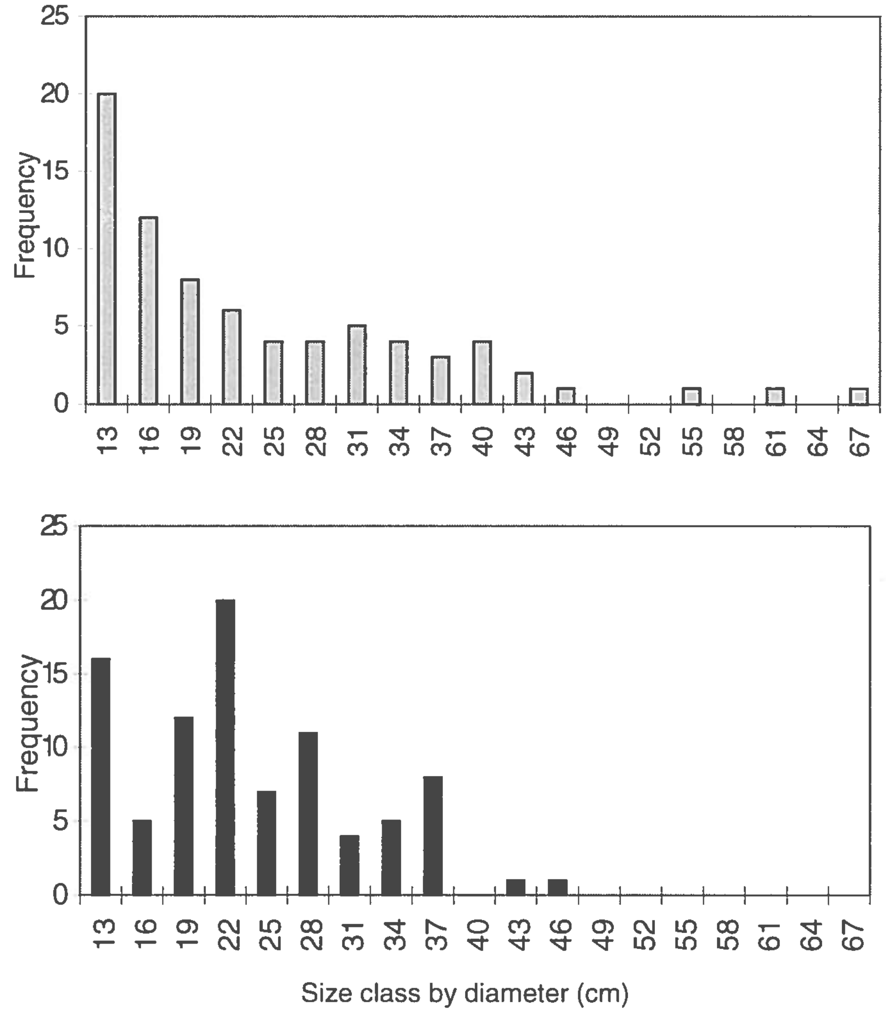

Figure 6. *Tilia heterophylla* distribution (trees >10 cm dbh) of undisturbed mixed hardwood forest (grey) and tornado-disturbed (black) stands on southeast facing upper slopes of Monte Sano Mountain, North Alabama.

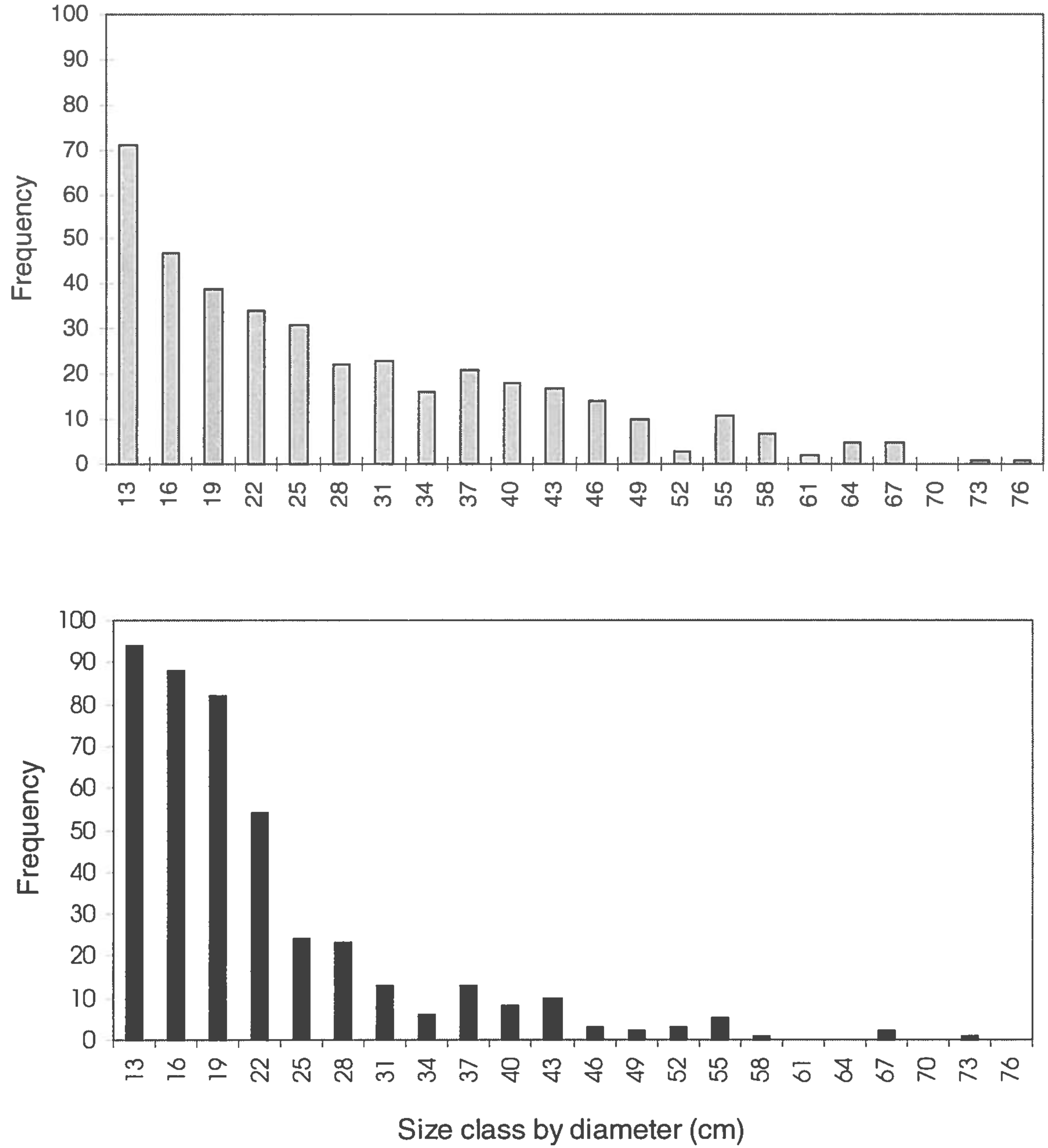

Figure 7. Distribution by diameter of all individuals (trees >10 cm dbh) of undisturbed mixed hardwood forest (grey) and tornado-disturbed (black) stands on southeast facing upper slopes of Monte Sano Mountain, North Alabama.

tornado-damaged plot has the greatest spikes of the two plots, and these come with the faster-growing woods, *T. heterophylla*, *R. pseudoacacia*, and *U. rubra*. The undisturbed plot has four peaks that stand out higher than the rest, but unlike the other plot, they are representatives of harder, slower-growing woods. *T. heterophylla* is included in the highest categories of both, attesting to its lasting effect upon forest communities and to the similarity of the sites. The tornado-damaged *T. heterophylla*, *R. pseudoacacia*, and *U. rubra* hovered around 20.0% each of the total basal area; however, no species comprised 25.0% of the forest.

The comparison of *Acer saccharum* distribution (Figure 3) in the two plots shows that, though both contain mostly small individuals, the tornado-damaged plot contains no individuals above the 25-cm dbh. These would be considered survivors from the disturbance, and thus no adults survived from that time.

The tornado-damaged plot contains a much greater number of *U. rubra* (Figure 4) than the undisturbed plot. The individuals of the undisturbed plot all tended to stay smaller in response to the lessened sunlight, while the individuals in the tornado-damaged plot were able to take advantage of the open canopy after the disturbance and establish themselves as a dominant specie.

The major difference between the *R. pseudoacacia* (Figure 5) in the undisturbed and tornado-damaged plots is the greater abundance of the specie in the tornado-damaged plot. The distributions are similarly shaped for the young individuals, until the spike in the undisturbed plot at the 34 cm class. There are also a greater number of large, mature individuals in the undisturbed plot. The abundance of the younger individuals can be due to the opening up of space in the canopy to provide the light needed for the saplings of this shade intolerant tree to establish themselves.

The overall abundance of *T. heterophylla* individuals (Figure 6) is similar between both plots, but the shape of the distribution shows a dramatic population structure difference. The undisturbed plot shows an expectedly normal curve, while the tornado-damaged plot shows the greatest number of individuals of the size that would have just been saplings as the disturbance occurred. There are no extremely large individuals as seen in the undisturbed plot, but the middle range population seems stable in numbers, ranging from 5-20 individuals, and not dropping off significantly until reaching greater than 37 cm in diameter.

The shape of the distribution curves (by diameter of all individuals) differs greatest in the smaller individuals (Figure 7). The undisturbed plot shows a smooth curve while the tornado-damaged plot has a convex curve and then drops sharply after the 22 cm size class. The distributions look fairly similar after that point. This increased number of smaller individuals in the tornado-damaged plot indicates the rapid growth right after the disturbance, and the absence of larger individuals is due to blow-down.

Species Composition

The species composition was fairly common to both plots, but each contained elements that the other did not. The species list (Table 1) included 24 different species. The undisturbed plot contained all but one, while the tornado-damaged plot contained only thirteen. Of these, six were shade tolerant varieties, six were moderately tolerant of shade, and twelve were considered to be species intolerant of shade (Parks Department, *Silvics of North American Forest Trees*).

Discussion

From the results, the plots clearly differed, and there are a variety of ways of determining this. Looking at the total basal area, the undisturbed plot exceeded the tornado-damaged plot by nearly 6.00 m^2. This is better explained when considering also the average diameter and number of individuals. The average diameter of the undisturbed plot was 132% that of the tornado-damaged plot. The number of individuals was higher in the tornado-damaged plot, but that is easily reconcilable with the fact that those trees were of smaller diameter and thus contributed less to the total basal area. The 36.6% survival rate, since it is a relatively small part of the current composition, in being so low could have allowed for the shift in species diversity seen. The undisturbed plot contained twice as many shade tolerant species as did the tornado-damaged plot. This can be expected, as the under-story of the more densely populated undisturbed plot is more shaded than the tornado-damaged plot. The same was the case with the moderately tolerant species, though here is contained the one specie which did not occur in the undisturbed plot, *Fraximus americanus.* In the tornado-damaged plot, it was found infrequently (only 10 individuals), and by a trickling stream (<50 cm width, no measurable depth). All of the species determined to be intolerant of shade were found in the undisturbed plot, and seven of the twelve were found in the tornado-damaged plot. The lower species diversity of the tornado-damaged plot can be evidence of the healthy post-disaster start of certain shade intolerant or weedy trees, such as *T. heterophylla*, *R.. pseudoacacia*, and *U. rubra.* These trees, likewise, made up the greatest part of the frequency distribution by species and the basal area of the tornado-damaged plot.

Conclusion

The balance seen in the undisturbed plot is evidence of a stable forest community, while the greater abundance of certain fast-growing shade intolerant trees in the tornado-damaged plot suggests that it has not yet become a stable forest community. So while the composition is significantly different at the present, it may not remain so. As the rest of the forest grows up around the shade intolerant species and those older trees die out, they will be replaced with more shade tolerant saplings, as the canopy will be fuller than it was after the tornado disturbance. The forest, then, could eventually return to a similar composition to that of the undisturbed plot, but it may never gain the greater species diversity of the undisturbed plot.

Acknowledgment

Thanks to Dr. Robert Lawton, my advisor and greatest resource for the project. Thanks also to Dr. Jim Daniels for, along with Dr. Lawton, allowing me to use their data as undisturbed plot data with which to compare mine. Thanks also to the Alabama Honors Conference Spring 2001 who gave me the opportunity to present my findings to the public for the first time, and thanks to all of my family and friends who were of great assistance and support.

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Table 1. Forest composition (trees >10 cm dbh) of undisturbed mixed hardwood forest and tornado-disturbed stands on southeast-facing upper slopes of Monte Sano Mountain, North Alabama.

	Undisturbed Stand		Tornado-damaged Stand		
Species	No. trees/ha	Basal area/ha (cm^2)	No. trees/ha	Basal area/ha (cm^2)	Shade Tolerance Rating
Fraximus americana	0.0	0.0	10.0	2468.2	Moderately Tolerant
Tilia heterophylla	36.7	32587.6	34.0	39510.3	Intolerant
Prunus virginiana	3.3	421.8	12.0	2318.3	Intolerant
Nyssa sylvatica	5.0	3267.5	0.0	0.0	Moderately Tolerant
Robinia pseudoacacia	22.5	17461.0	82.0	32458.4	Intolerant
Juglans nigra	5.8	7196.3	0.0	0.0	Intolerant
Quercus prinus	2.5	3453.6	0.0	0.0	Moderately Tolerant
Quercus muhlenbergii	5.8	6051.9	30.0	18885.3	Moderately Tolerant
Magnolia acuminata	10.8	9769.8	1.0	78.5	Intolerant
Cornus florida	0.8	100.7	0.0	0.0	Tolerant
Celtis occidentalis	0.8	435.7	4.0	582.4	Intolerant
Ostrya virginiana	15.0	2476.7	0.0	0.0	Intolerant
Carya tomentosa	2.5	661.3	0.0	0.0	Tolerant
Carya glabra	33.3	32399.6	0.0	0.0	Tolerant
Quercus rubra	15.8	22202.6	4.0	887.6	Moderately Tolerant
Cercis canadensis	6.7	1025.3	28.0	4142.8	Intolerant
Sassafras albidum	3.3	762.7	0.0	0.0	Intolerant
Carya ovata	36.7	31993.8	12.0	16784.7	Tolerant
Ulmus rubra	20.8	4968.8	72.0	31136.1	Intolerant
Acer saccharum	10.0	5068.2	22.0	4972.3	Tolerant
Liquidambar styraciflua	9.2	9437.3	0.0	0.0	Intolerant
Liriodendron tulipifera	9.2	8958.2	0.0	0.0	Intolerant
unidentified	20.8	9962.7	0.0	0.0	N/A
Quercus alba	25.0	31531.6	27.0	19232.8	Tolerant
Ulmus alata	0.8	76.3	0.0	0.0	Moderately Tolerant