To the Graduate Council:

I am submitting herewith a thesis written by Keith Walter Dyer entitled "Community Change Two Decades Following a Catastrophic Ice Storm in the Marshall Forest of Northwest Georgia." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ecology.

J. Franklin McCormick
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Major Professor

We have read this thesis and recommend its acceptance:

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Vice Chancellor
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COMMUNITY CHANGE TWO DECADES FOLLOWING A CATASTROPHIC ICE STORM IN THE MARSHALL FOREST OF NORTHWEST GEORGIA

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Keith Walter Dyer

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ABSTRACT

A disclimax pine-oak hickory forest was examined in the 180-acre Marshall Forest in the Piedmont of Northwest Georgia. The Marshall Forest has a record of cyclic catastrophic ice storms and a history of frequent fires. Ice storms and fire are thought to be responsible for the maintenance of the pine-oak disclimax. Results of this study are compared to results of a similar study twenty years earlier in order to determine changes in forest composition and dominants.

Dominant oak and hickory species increased in importance while pine species decreased during the period 1961-1981. Increased importance of dominant hardwood species is a response to canopy openings created by ice damage to pine. Subcanopy species also increased in importance as a consequence of ice damage to pines in the canopy. Decreased importance of pine species is a consequence of ice damage to canopy individuals and the effects of fire suppression upon regeneration. If current trends continue an oak-hickory or mixed oak forest will dominate this site. A relatively greater increase in the importance of oak species favors the latter.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

INTRODUCTION

This is the second study of the Marshall Forest in Floyd County, of northwest Georgia. The original investigation was initiated in 1961 and completed in 1966 by Dr. E. Lewis Lipps. The original study produced an annotated list of flora of the forest (Lipps and DeSelm, 1969) and related height and diameter of pine species to age. Lipps also examined original Georgia 1832 Land Survey Records of the forest and surrounding area (as well as local references to the research site) for historical records of forest composition, distribution and disturbance (Lipps, 1966).

The forest community is one which is prone to extensive catastrophic damage by frequent (ca. 30 yrs.) ice storms. One such storm occurred in March 1960 just prior to the study by Lipps. Lipps proposed a Clementsian (Clements, 1916) definition for the forest believing it is a "Catastrophy-caused subclimax." Disclimax may be a more applicable descriptor. Disclimax implies a relatively stable ecological community that displaces a climax community because of disturbance.

Lipps reported that three distinct forest communities were represented in the 40 1/10 acre study plots. They are the Pine-Oak, Mixed Forest and Chestnut-Oak communities. The Pine-Oak community was chosen for this study because of its larger area and greater number of plots.

Objectives of this study are: (1) to determine changes in composition which have ensued since the catastrophic ice storm of March 1960; (2) to evaluate the role of catastrophy in the Marshall Forest; (3) to interpret the influence of fire protection placed in the forest since the original investigation; and (4) to examine the apparent codominance of pine and hardwoods within the study site.

CHAPTER 2

THE STUDY AREA

Location

The Marshall Forest is located near Rome, Floyd County, in northwest Georgia. Its geographic location is within 34° 14' to 34° 15' 30" north latitude; 85° 10' 30" to 85° 12' 30" west longitude. The 180 acre Marshall Forest tract (hereafter referred to as the Forest) is composed of 100 acres of old growth primeval forest and 80 acres of continually grazed pasture land. The boundary between the two communities is delimited (north to south-southwesterly) by a county roadway, Horseleg Creek Road. The altitude in the Forest ranges from 575 to 1000 feet above mean sea level. The area is mapped on the Rome North and Rome South 7.5 minute topographic quadrangle maps of the U.S. Geological Survey.

Lipps (1966) established 35 permanent 1/10 acre research plots along a north-south reference line traversing all common types of topography. Five additional plots were established at right angles to the reference line bringing the total sample area to 40 plots or 4 acres.

Climate

The climate of Floyd County is much like that of lower elevations of the Great Smoky Mountains. Floyd Co. has a "humid mesothermal climate [$B_2B_2^1rb_4^1$] and experiences little or no water deficiency in any season" (Thornwaite, 1948). As a result of its proximity to Gulf and Atlantic waters the climate of northwest Georgia is warm with humid summers and short, mild winters (Carter, 1959).

Precipitation is heavy and evenly distributed throughout the year. Summer precipitation occurs primarily as thunderstorms. Thunderstorms occur approximately 61 times a year with 80 percent of them taking place during the summer months. Winter precipitation is frequently rain or occasional snow with little accumulation except at the highest elevations. In 23 percent of the winters no measurable snowfall occurs and in 64 percent the total recorded accumulation is less than two inches.

Total annual precipitation is approximately 132.4 cm (52.14 inches). Of this total, 48 percent (63.2 cm, 24.87 inches) usually falls during the six month period of April to September. The frost-free growing season is approximately 217 days long and extends from April 1 to November 3.

Average summer temperature is 25°C (77°F) with an average daily maximum of 31.8°C (89.3°F). The absolute highest temperature recorded was 41.1°C (106°F) on July 29, 1952. Average winter temperature is 5.5°C (41.9°F) with an average daily minimum of -0.8°C (30.5°F). The absolute lowest temperature recorded was -10.5°C (-5°F) on January 24, 1963.

Since 1902 fourteen glaze or ice storms have been recorded. The most destructive occurring in the years 1901, 1932, 1935, and 1960. This suggests a thirty year periodicity of catastrophic ice storms, a contention supported by observations of local foresters who regard the area as having a 25-year cycle of catastrophy (personal communication, F. Hubbard, 1981).

Substrate

The landscape of northwest Georgia is characterized by a succession of ridges and valleys. These form the Armuchee Ridges (Fenneman, 1938) and are bound to the east by the Cohutta Mountains of Georgia and to the northwest by the eastern escarpment of the Cumberland Plateau. Few ridges in this region exceed 1500 feet.

Many surface drainages dissect the ridges and mountains. Slopes generally are strongly sloping to very steep on ridges and gently sloping in the valleys. The area has been subjected to geologic erosion with some partial weathering of underlying igneous and metamorphic rocks.

The physiographic history, lithology and soils of this region have been described in great detail by Lipps (1966). The following descriptions are included for the purpose of revision and amplification of earlier reports. Inclusions are from the Soil Survey of Chattooga, Floyd and Polk Counties, Georgia, a publication issued November 8, 1978, by the United States Department of Agriculture, Soil Conservation Service and Forest Service.

In the Forest, eight different soil series classification units have been described. Five of the eight are represented in the Pine-Oak Community. They are:

1. Holston Series of Plots 1-5, and 36. This series consists of deep, well drained, gently sloping to steep soils that occupy foot

slopes at the base of mountains. They formed in colluvium that originated from material weathered from sandstone, siltstone, and shale.

The Holston series has moderate natural fertility and is low in organic matter content. The permeability is moderate and available water capacity is medium. The effective rooting zone is thick, and tilth is good. These soils are strongly acid to very strongly acid throughout. The solum ranges from slightly less than 60 inches to 80 or more inches in thickness.

2. Wax Series of Plots 6-8. They are moderately well drained, nearly level to gently sloping soils. These soils occupy long, narrow, low stream terraces, toe slopes and drainage ways. They formed in alluvium from material weathered from cherty limestone or shale.

The Wax series soils are moderately low in natural fertility and in organic matter content. Permeability is slow and available water capacity is medium. Tilth is good in these soils and they are very strongly acid to strongly acid throughout. The solum ranges from 40 to 72 inches in thickness.

3. Allen Series of Plots 14, and 37. These are deep, well drained, gently sloping to steep soils. They occupy foot slopes, low hills and ridges adjacent to mountains. The soils of this series formed in colluvial material weathered from sandstone, shale, and in places, from cherty limestone.

They have moderate natural fertility and low organic matter content. Available water capacity is medium, and permeability is moderate. The effective rooting zone is thick and tilth is good. These soils are strongly acid to very strongly acid throughout. The solum ranges from 60 to 80 inches or more in thickness.

4. Decatur Series of Plots 9-13, and 15-21. This series occupies the largest area in the Forest. They are well drained, gently sloping to steep soils. These soils occupy upland ridgetops and side slopes. They formed in residuum weathered from noncherty dolomitic limestone and from old valley fill material.

They have moderately high natural fertility and low organic matter content. Permeability is moderate with a medium available water capacity. Tilth is generally good but is fair on eroded soils. These soils are strongly acid or very strongly acid throughout. The solum ranges from 72 to 80 inches or more in thickness.

5. Fullerton Series of Plots 29-35. This series consists of deep, well drained gently sloping to very steep cherty soils that occupy the tops and sides of mountains. These soils formed in residuum from cherty limestone.

Fullerton soils are low in natural fertility and organic matter content. Available water capacity is medium and permeability is moderate. Tilth is fair. These soils are strongly acid or very strongly acid. The solum ranges from 60 to 80 inches or more in thickness.

In summary the soils of the Pine-Oak community of the Forest are generally deep and well drained. They are formed from material weathered from sandstone, siltstone, shale, cherty limestone and/or noncherty dolomitic limestone.

These soils range from low to moderately high in natural fertility and are generally low in organic matter content. Tilth is generally good. They average strongly acid to very strongly acid throughout, from 4.0 to 6.8 with a median pH of 4.8. The soil solum ranges from 40 to 80 or more inches in thickness with a median thickness of 68.4 inches.

Vegetation

In the physiographic-floristic map of Tennessee (Shanks, 1958), Floyd County is recognized as part of a southwesterly continuation of the area designated as the Pine-Oak Section of the Appalachian Valley Floristic Region. Two other regions are designated within a few miles of Floyd County: the Unaka Floristic Region to the northeast and the Cumberland Plateau Floristic Region to the northwest.

Braun (1950) viewed the area as a "transitional belt where the ranges of trees of the central hardwood forest and of the evergreen forest of the Southeast overlap." Bailey (1978) delimited major ecologic communities of the country by integrating accepted biotic and abiotic land classification systems. In this holistic synthesis Northwest Georgia is in the Humid Temperate; Subtropical; Southeastern Mixed Forest Ecoregion [#2320] (Bailey, 1978).

The Forest lies on the northern end of Horseleg Mountain. The "pine-oak" community occupies most of the uplands except on north-facing slopes. The Forest is most closely related to the Society of American Foresters Type 75 (shortleaf pine) designation (Soc. of Am. Foresters, 1961 and Eyre, 1960). According to Lipps canopy dominates are shortleaf pine (Pinus echinata Miller) and black oak (Quercus velutina Lam.). Shrub and vine dominates are muscadine (Vitis rotundifolia Michaux), greenbrier (Smilax rotundifolia L.), gooseberry (Vaccinium stamineum L.), sparkleberry (Vaccinium vacillans Torrey), and poison oak (Rhus toxicodendron L.). Herbaceous cover is dominated by Coreopsis major (Walter), Goat's Rue (Tephrosia virginiana L.), spotted wintergreen (Chimaphila maculata L.), Solomon's seal (Polygonatum biflorum Walter), Wood sorrel (Oxalis stricta L.), Panicum ashei (Pearson), and the Christmas fern (Polystichum acrostichoides Michaux).

Lipps (1966) further categorized the Pine-Oak forest into three divisions of dominants by slope position: (1) the shortleaf pine, southern red oak and dogwoods of the lower slope, (2) a shortleaf pine, mixed oak species and sand hickory complex occupying the midslope positions, and (3) the upperslope where loblolly pine (Pinus taeda L.) exceeded shortleaf, with mockernut hickory (Carya tomentosa Poiret) and chestnut oak (Quercus prinus L.).

CHAPTER 3

METHODS

Field Data Collection

Lipps (1966) established thirty permanent tenth acre (1/10) plots in the pine-oak forest of the Marshall Forest, the plant community with the largest cover area. In 1981 plots #1-21, 29-35, and 37 (Lipps, 1966) were relocated, their boundaries marked with wire, and each 1/10 acre plot divided into quarters (1/40 acre). All original pine-oak community plots were relocated except #36.

Field work for this study was conducted from July 1981 through May 1982. Sampling procedures followed those of Lipps (1966). Tree seedlings (those less than 5 feet tall) were recorded by presence. Tree saplings [5 feet tall to 1 inch dbh (diameter at breast height)] were recorded by presence and number. Trees (those greater than 1 inch) were recorded by number and dbh class (to the nearest 1/10 inch). Percent of canopy cover was estimated to the nearest 10 percent.

Taxonomic identification was performed in the field when possible. Unrecognized species were collected and their identification checked against herbarium samples placed in The University of Tennessee Herbarium by Lipps (1966). Taxonomic treatment follows that of Radford et al. (1968).

Slope aspect was measured from each plot center using a hand held Silva compass. Using a hand held Suunto Clinometer, slope angle was measured for the upper and lower center of each plot, then averaged for the plots center.

Data Analysis

Computer assisted data analysis was performed at The University of Tennessee Computing Center employing the IBM 360/370 computers and the DECsystem-10 Operating System. Original plot data supplied by Lipps (1966) were utilized to generate statistics reported in this study for 1961. All data were submitted to a program prepared by the Uplands Field Research Laboratory of the Great Smoky Mountains National Park. The program was modified for analysis of 1/10 acre plots. The program generates statistics for absolute and relative densities, basal area, relative basal area and importance values [IV = (RD + RBA)/2] for all species by plot. Descriptive statistics and comparisons between the data periods (1961 and 1981) for the Forest as a whole were generated using the means program of the Statistical Analysis System (SAS Institute 1981). The data sets, 1961 and 1981, were compared to determine change in species composition during the last twenty years. Relative density, relative basal area, importance value, and frequency were utilized to measure change. Species composition for three topographic classifications were examined to detect changes relative to slope position.

CHAPTER 4

RESULTS

Canopy cover varied from fairly closed on lower slope positions to open on the middle and upper slopes. Storm damage such as wind throws, topped boles and broken branches was more pronounced on the upper slope topographic positions.

Shrub and woody vine taxa were moderate to abundant in most plots. Little change in frequency was recognized between sample periods (Table 1). Vaccinium arboreum (Marshall) and Vitis rotundifolia were present at both sample periods with 100 percent frequency. Other shrub and woody vine taxa frequently recorded were Smilax rotundifolia, Vaccinium stamineum, Vaccinium vacillans, Rhus radicans (L.), Rhus toxicodendron, and Parthenocissus quinquefolia (L.).

Of the thirty-three taxa recorded in 1961 five were not represented in 1981. They are Diospyros virginiana (L.)., Corylus americana (Walter), Morus rubra (L.), Quercus falcata var. pagodifolia (Ell.), and Quercus michauxii (Nuttall). None of these five species represented greater than a 3 percent (1 plot) frequency for the 1961 study.

Three taxa were recorded in this study that were not recorded in 1961. They are Ulmus rubra (Muhl.), Carya laciniosa (Michaux) and Carya cordiformis (Wang.). Frequencies for these species are 3 percent. This represents a frequency of occurrence in only 1 plot. A total of thirty-six tree taxa were recorded for both sample periods (Table 2).

Table 1

Dominant Shrub and Woody Vine Taxa Frequency (%)
of All Plots (N = 29)

Taxa	1961	1981
Vaccinium arboreum	100	100
Vitis rotundifolia	100	100
Smilax rotundifolia	90	93
Vaccinium stamineum	83	86
Vaccinium vacillans	76	76
Rhus radicans	63	52
Rhus toxicodendron	47	38
Parthenocissus quinquefolia	37	34

Table 2

Tree Taxa Frequency (%) of All Plots (N = 29)

Taxa (Total = 36)	1961	1981
Pinus echinata	100	90
Quercus stellata	100	66
Quercus velutina	93	93
Carya tomentosa	83	90
Carya pallida	76	66
Quercus marilandica	72	28
Cornus florida	69	86
Prunus serotina	66	80
Quercus prinus	62	59
Carya glabra	59	61
Carya ovata	59	31
Quercus falcata	55	31
Pinus taeda	45	41
Nyssa sylvatica	45	21
Oxydendrum arboreum	41	72
Quercus rubra	41	28
Sassafras albidum	34	55
Quercus alba	31	59
Acer rubrum	24	48
Ulmus alata	21	21
Crataegus spp.	14	0
Quercus nigra	14	3
Liquidambar styraciflua	7	14
Liriodendron tulipifera	7	7
Pinus palustris	7	3
Diospyros virginiana	3	--
Castanea dentata	3	3
Corylus americana	3	--
Juniperus virginiana	3	7
Morus rubra	3	--
Quercus falcata var. pagodifolia	3	--
Quercus bicolor	3	3
Quercus michauxii	3	--
Ulmus rubra	--	7
Carya laciniosa	--	3
Carya cordiformis	--	3
Total taxa recorded/year	33	31

Individual species composition data for each sample plot were averaged to obtain overall forest composition for each sample period. To be consistent with Lipps, species with 10 percent or greater relative density or basal area are considered dominants. Importance values for these dominant species were used to identify change over the twenty year period.

The Forest in 1961 was dominated by Pinus echinata (IV = 30.3), Quercus prinus (11.4), Quercus velutina (10.9), Oxydendrum arboreum (L.) (10.0), Pinus taeda (8.9), and Carya tomentosa (8.1). Other dominant species with less than 10 percent mean relative density or basal area were Quercus stellata (Wang.) (IV = 8.6), Quercus falcata (Michaux) (5.2), Quercus marilandica (Muenchh.) (5.1), and Quercus alba (L.) (4.3) Table 3).

The Forest in 1981 was dominated by Pinus echinata (IV = 28.9), Quercus velutina (12.4), Quercus prinus (12.4), Oxydendrum arboreum (11.3), Quercus stellata (8.7), Carya tomentosa (8.6), and Carya pallida (8.5). Other dominant species with less than 10 percent mean relative density or basal area were Quercus marilandica (IV = 7.4), Pinus taeda (6.5), Cornus florida (L.) (6.4), Quercus alba (5.7), and Quercus falcata (4.7) (Table 4).

In the sapling category for 1961 the most abundant species with the possibilities of reaching the canopy were Carya pallida (Ashe) (Rel. den. = 25.4), Carya ovata (Miller) (11.9), Oxydendrum arboreum (10.6), and Carya tomentosa (10.4) (Table 5). Pine saplings were found to have a low mean relative density compared to hardwood sapling species.

Table 3

Forest Composition in 1961 (N = 29)[a]

Taxa	Trees[b] Imp. Values	Relative Basal Area	Relative Density
Pinus echinata	30.3	48.1 ± 4.6[c]	12.4 ± 0.5[c]
Quercus prinus	11.4	12.1 ± 3.9	10.7 ± 3.6
Quercus velutina	10.9	7.1 ± 1.7	12.9 ± 1.5
Oxydendrum arboreum	10.0	6.0 ± 1.0	15.7 ± 3.1
Pinus taeda	8.9	10.2 ± 3.4	7.5 ± 1.5
Quercus stellata	8.6	7.6 ± 1.9	9.6 ± 1.4
Carya tomentosa	8.1	6.1 ± 1.8	10.1 ± 2.0
Carya pallida	7.0	5.9 ± 2.5	8.0 ± 2.0
Quercus falcata	5.2	2.1 ± 0.4	8.2 ± 2.0
Quercus marilandica	5.1	3.4 ± 1.2	6.7 ± 1.3
Cornus florida	4.6	1.6 ± 0.3	6.7 ± 1.2
Quercus alba	4.3	2.8 ± 1.2	5.7 ± 2.3
Prunus serotina	3.9	2.4 ± 0.9	5.3 ± 1.1
Nyssa sylvatica	3.4	3.5 ± 2.2	3.3 ± 0.8
Acer rubrum	3.2	1.3 ± 0.6	5.0 ± 1.8
Carya ovata	2.8	1.3 ± 0.4	4.2 ± 0.8
Sassafras albidum	2.8	0.9 ± 0.4	4.6 ± 1.3
Quercus rubra	2.7	1.7 ± 0.5	3.7 ± 0.7
Carya glabra	2.6	1.4 ± 0.7	3.8 ± 0.8
Ulmus alata	2.3	0.4 ± 0.1	4.1 ± 1.4
Liquidambar styraciflua	1.7	1.2 ± 1.2	2.2 ± 1.0
Pinus palustris	P	P	P
Quercus nigra	P	P	P
Crataegus spp.	P	P	P
Castanea dentata	P	P	P
Quercus falcata var. pagodifolia	P	P	P
Liriodendron tulipifera	P	P	1.1 ± 0.3
Quercus bicolor	P	P	P
Quercus michauxii	P	P	P
Corylus americana	P	P	P
Diospyros virginiana	P	P	P
Juniperus virginiana	P	P	P
Morus rubra	P	P	P

[a]Species which reached more than 1 percent in any reported parameter. Data are mean values.

[b]Stems greater than 1" dbh.

[c]Standard error.

P = Present but less than 1 percent.

Table 4

Forest Composition in 1981 (N = 29)[a]

Taxa	Trees[b] Imp. Values	Relative Basal Area	Relative Density
Pinus echinata	28.9	46.7 ± 4.1[c]	11.1 ± 1.5[c]
Quercus velutina	12.4	10.8 ± 1.8	14.0 ± 1.5
Quercus prinus	12.4	12.8 ± 4.4	12.0 ± 3.2
Oxydendrum arboreum	11.3	8.4 ± 2.8	14.1 ± 2.5
Quercus stellata	8.7	10.2 ± 2.9	7.1 ± 1.4
Carya tomentosa	8.6	5.1 ± 1.3	12.8 ± 2.3
Carya pallida	8.5	6.8 ± 3.0	10.2 ± 1.8
Quercus marilandica	7.4	2.5 ± 0.6	4.9 ± 1.3
Pinus taeda	6.5	9.4 ± 3.1	3.5 ± 0.8
Cornus florida	6.4	2.2 ± 0.3	10.5 ± 1.5
Quercus alba	5.7	4.5 ± 1.4	6.9 ± 1.6
Quercus falcata	4.7	4.2 ± 1.4	5.2 ± 0.9
Carya glabra	4.4	2.6 ± 1.3	6.2 ± 1.5
Prunus serotina	4.1	2.5 ± 0.7	5.6 ± 1.0
Acer rubrum	3.6	1.2 ± 0.5	5.9 ± 1.6
Ulmus alata	3.5	0.5 ± 0.1	6.4 ± 2.6
Carya ovata	3.3	1.4 ± 0.5	5.0 ± 0.9
Nyssa sylvatica	2.8	2.9 ± 1.3	2.7 ± 0.8
Sassafras albidum	2.5	0.6 ± 0.1	4.4 ± 0.6
Quercus rubra	2.4	2.9 ± 1.3	1.9 ± 0.2
Liquidambar styraciflua	2.1	1.7 ± 1.4	2.4 ± 0.5
Ulmus rubra	1.4	0.8 ± 0.0	4.8 ± 3.2
Liriodendron tulipifera	P	P	2.0 ± 0.6
Juniperus virginiana	P	P	1.7 ± 0.2
Pinus palustris	P	P	P
Carya cordiformis	P	P	P
Quercus bicolor	P	P	P
Quercus nigra	P	P	P
Carya laciniosa	P	P	P
Castanea dentata	P	P	P

[a]Species which reached more than 1 percent in any reported parameter. Data are mean values.

[b]Stems greater than 1" dbh.

[c]Standard error.

P = Present but less than 1 percent.

Table 5

Relative Density of Sapling[a] Taxa for 1961 (N = 29)[b]

Taxa	Relative Density
Carya pallida	25.4
Carya ovata	11.9
Oxydendrum arboreum	10.6
Carya tomentosa	10.4
Carya glabra	8.8
Nyssa sylvatica	8.4
Diospyros virginiana	8.3
Quercus prinus	7.8
Acer rubrum	7.4
Quercus velutina	7.2
Cornus florida	7.0
Ulmus alata	5.8
Pinus echinata	5.1
Sassafras albidum	4.5
Prunus serotina	4.3
Quercus marilandica	4.2
Quercus falcata	3.9
Quercus alba	3.7
Liquidambar styraciflua	3.6
Quercus stellata	3.6
Quercus rubra	2.9
Crataegus spp.	2.5
Pinus taeda	2.4
Liriodendron tulipifera	1.1
Quercus nigra	P

[a]Stems less than 1" dbh and greater than 5' tall.

[b]Species which reached more than 1 percent. Data are mean values.

P = Present but less than 1 percent.

In the sapling category for 1981 the most abundant species with the possibilities of reaching the canopy were Carya pallida (Rel. den. = 20.6), Carya tomentosa (19.2), Acer rubrum (L.) (18.3), Carya glabra (Miller) (14.0), Sassafras albidum (Nuttall) (13.6) and Ulmus alata (Michaux) (13.4) (Table 6). Pine saplings again have a low mean relative density compared to hardwood sapling species.

Comparing species importance value for the two sample years some change was observed. Longleaf pine (Pinus palustris Miller) was represented by two individuals in 1961. In the 1981 study only one individual remains in the forest. Shortleaf and loblolly pine showed a decrease in importance value for canopy taxa (Table 7). Oaks and hickories predominantly increased in importance between the data periods (Table 7).

Effects of catastrophic disturbance in the Forest are born out by the increase in importance of subcanopy species (Table 7). These include sourwood (Oxydendrum arboreum), flowering dogwood (Cornus florida), black cherry (Prunus serotina Ehrhart), red maple (Acer rubrum) and winged elm (Ulmus alata). Each of these species increased in importance value. Pine is not included among pioneer species because in this disclimax forest pine is codominant with oaks.

Tree taxa frequencies by slope position were examined for evidence of change in relation to topographic position (Tables 8, 9, 10). Frequency values for shortleaf pine and loblolly pine did not change in either the lower slope nor middle slope topographic positions. Upper slope frequencies for shortleaf pine and loblolly pine decreased. This

Table 6

Relative Density of Sapling[a] Taxa for 1981 (N = 29)[b]

Taxa	Relative Density
Cornus florida	26.5
Carya pallida	20.6
Carya tomentosa	19.2
Acer rubrum	18.3
Carya glabra	14.0
Sassafras albidum	13.6
Ulmus alata	13.4
Quercus velutina	9.8
Carya ovata	7.7
Oxydendrum arboreum	7.7
Quercus prinus	7.1
Quercus alba	6.9
Quercus marilandica	6.4
Prunus serotina	5.6
Quercus falcata	4.9
Quercus stellata	4.8
Pinus echinata	4.6
Nyssa sylvatica	2.4
Pinus taeda	2.3

[a]Stems less than 1" dbh and greater than 5' tall.

[b]Species which reached more than 1 percent. Data are mean values.

Table 7

Importance Values for Selected Species, 1961 and 1981

	1961	1981
Pine Species		
Pinus echinata	30.3	28.9
Pinus taeda	8.9	6.5
Oak-Hickory Species		
Quercus prinus	11.4	12.4
Quercus velutina	10.9	12.4
Quercus stellata	8.6	8.7
Carya tomentosa	8.1	8.6
Carya pallida	7.0	8.5
Quercus falcata	5.2	4.7
Quercus marilandica	5.1	7.4
Quercus alba	4.3	5.7
Carya ovata	2.8	3.3
Quercus rubra	2.7	2.4
Carya glabra	2.6	4.4
Subcanopy Species		
Oxydendrum arboreum	10.0	11.3
Cornus florida	4.6	6.4
Prunus serotina	3.9	4.1
Acer rubrum	3.2	3.6
Ulmus alata	2.3	3.5

Table 8

Frequency (%) of Tree Taxa by Slope Position:
Lower Slope Plots (N = 7)

Taxa	1961	1981
Carya tomentosa	100	100
Pinus echinata	100	100
Prunus serotina	100	100
Quercus alba	100	100
Quercus falcata	100	71
Quercus stellata	100	43
Quercus velutina	100	71
Cornus florida	86	86
Nyssa sylvatica	86	29
Carya glabra	71	86
Carya ovata	71	14
Carya pallida	71	29
Quercus rubra	71	71
Sassafras albidum	57	57
Oxydendrum arboreum	43	43
Acer rubrum	29	86
Pinus taeda	29	29
Quercus marilandica	29	0
Quercus nigra	29	14
Quercus prinus	29	29
Ulmus alata	29	14
Corylus americana	14	--
Crataegus spp.	14	--
Diospyros virginiana	14	--
Liquidambar styraciflua	14	14
Quercus bicolor	14	14
Carya cordiformis	--	14
Carya laciniosa	--	14
Ulmus rubra	--	29

Table 9

Frequency (%) of Tree Taxa by Slope Position:
Middle Slope Plots (N = 15)

Taxa	1961	1981
Pinus echinata	100	100
Quercus stellata	100	73
Quercus marilandica	93	47
Quercus velutina	93	100
Carya pallida	80	80
Carya tomentosa	67	80
Quercus prinus	67	60
Carya glabra	60	60
Cornus florida	60	80
Prunus serotina	40	73
Quercus falcata	40	20
Carya ovata	33	13
Oxydendrum arboreum	33	73
Quercus rubra	33	13
Nyssa sylvatica	20	13
Pinus taeda	20	20
Acer rubrum	13	20
Pinus palustris	13	7
Quercus alba	13	53
Sassafras albidum	13	53
Ulmus alata	13	13
Castanea dentata	7	0
Crataegus spp.	7	0
Liriodendron tulipifera	7	0
Quercus falcata var. pagodifolia	7	0
Quercus michauxii	7	0
Juniperus virginiana	0	7
Liquidambar styraciflua	0	7

Table 10

Frequency (%) of Tree Taxa by Slope Position:
Upper Slope Plots (N = 7)

Taxa	1961	1981
Carya ovata	100	86
Carya tomentosa	100	100
Pinus echinata	100	57
Pinus taeda	100	86
Quercus stellata	100	71
Quercus velutina	86	100
Quercus prinus	86	86
Prunus serotina	71	86
Carya pallida	71	71
Cornus florida	71	100
Quercus marilandica	71	14
Nyssa sylvatica	57	29
Oxydendrum arboreum	57	100
Sassafras albidum	57	57
Acer rubrum	43	71
Carya glabra	43	43
Quercus falcata	43	14
Crataegus spp.	29	0
Quercus nigra	29	0
Quercus rubra	29	14
Ulmus alata	29	43
Juniperus virginiana	14	14
Liquidambar styraciflua	14	29
Liriodendron tulipifera	14	29
Morus rubra	14	0
Castanea dentata	0	14
Quercus alba	0	29

area appeared to sustain greater disturbance than the other slope positions. Downed and decomposing pine boles were numerous and frequent. Other subcanopy species slightly increased in plot frequencies or did not change on all slope positions. Dominant oak and hickory species exhibited little change in frequency. *Quercus velutina* slightly increased in frequency while *Quercus stellata* slightly decreased.

CHAPTER 5

DISCUSSION

Storm damage is more pronounced on the upper slope position than at the lower and middle slope positions. Enhanced storm damage on the upper slope position may be related to differences in forest composition, rocky substrate, slope position, and clay content of the A and B horizons. Canopy openings on the upper slope position were caused by the loss of many large shortleaf and loblolly pines. Oak and hickory species are slightly increasing in importance value at this time. Introduced openings due to windthrow in a forest canopy have been shown to increase air and substrate temperatures, increase light intensity and decrease humidity resulting in an increasingly xeric microenvironment (McCormick, 1970). These conditions should favor the growth of oaks and hickories.

Canopy closure on lower slopes may be related to a cantilevered edge effect maintained by a county roadway and/or the establishment of nature trails in close proximity (Ranney, 1977, 1978). These factors can appreciably modify wind and solar radiation inputs (Burgess and Sharpe, 1981). Wind batters edge trees (Moen, 1974), enhances seed dispersal, alters temperature fields (Crockett, 1971), and increases evapotranspiration which alters soil moisture regimes. Edge aspect controls solar radiation (Wales, 1967, 1972; Swift and Knoerr, 1973). Increased light intensity by a newly created edge effects shade tolerant and intolerant species differently (Smith, 1962). This effect is reversed as an edge matures to a canopy (Wales, 1972).

Barden and Woods (1976) proposed that fire was a major factor in the establishment of pine species in the Great Smoky Mountains National Park. They showed that fire in mixed stands shifted composition in favor of pine species. The history of fire has been documented in the Marshall Forest. The last fire occurred in 1939 (Lipps, 1966). Introduction of fire suppression in the Forest may favor deciduous hardwoods. This could, in time, alter the composition of the present pine-oak disclimax forest. However, insufficient time has passed to be certain of the effect of fire protection on species composition in the Forest.

The loss of Diospyros virginiana, Corylus americana, Morus rubra, Quercus falcata var. pagodifolia, and Quercus michauxii is of interest. Their absence in 1981 can be due to a combination of many factors. It could be that: (1) they were only temporary invader species; (2) they were not successful in reaching stand maturity during the interval between sampling periods; (3) they were excluded along a plot boundary wire and/or (4) microclimatic or edaphic conditions were altered by windthrows or ice storm damage.

The introduction of the three new species Ulmus rubra, Carya laciniosa and Carya cordiformis is indicative of new species immigrating onto available sites. Their occurrence in close proximity to the study area probably accounts for their introduction. Site condition or site stability may be a factor influencing the later arrival or loss of the above species. All of the newly introduced species arrived on the lower slope plots.

Pine species decreased slightly in every measured parameter. This shows that pine species are not being replaced at levels proposed by the earlier investigator. Lipps (1966) proposed ice storms were a factor for the maintenance of pine in the Forest. Ice storms create canopy openings through wind throws, possibly taking other trees down as they fall.

> In such openings, seedlings may be expected to have good survival rates and become well established. (Lipps, 1966)

Why pines did not respond to the canopy openings is purely conjectural. The ice storm of 1960 was responsible for extensive damage in the Forest (Lipps, 1966). High basal area and density of *Pinus echinata* and *Pinus taeda* should have ensured an adequate seed source for regeneration. Seed crop in *P. taeda* fluctuates from negligible amounts in some years to about a million seed per acre in other years (Fowells, 1965). A 70-year old stand in the North Carolina Piedmont varied from 18,000 to nearly 300,000 seed per acre during 13 years from 1936 to 1948 (Pomeroy and Korstian, 1949). With a suitable seed stock these pines should have been represented by higher densities if ice storms are influencing their establishment. Perhaps increasingly xeric microenvironments of canopy openings are, in part, responsible.

Longleaf pine (*Pinus palustris*) decreased from two individuals to one tree remaining in the Forest. No reproduction was observed on either of the plots where longleaf pine were earlier recorded. The remaining individual appeared healthy but storm damage was evidenced by broken limbs and bent bole. This pine increased in diameter from 18.5 inches (47 cm) in 1961 to 20.9 inches (53.0 cm) in 1981. An increase in dbh of 2.4 inches (6.0 cm). Longleaf pine is at the extreme northern edge of its range in this region (Fowells, 1964; Lipps, 1966). The northern limit of longleaf is believed to be controlled by snowfall but reproduction potentials were believed by Chapman (1948) to be a function of site preparation, control of brown spot needle disease, and control of herb and woody competitors by periodic ground fire (Wahlenberg, 1946). Having longer needles makes it more susceptible to damage by snow and ice (Wahlenberg, 1946). In competition with loblolly, or shortleaf pine, longleaf pine is usually overtopped before it begins height growth. After it has reached the sapling stage longleaf grows at about the same rate as the other southern pines (U.S. Forest Service, 1929).

The creation of canopy openings enabled opportunistic or pioneering species to become established and predictably enhanced the growth potential of already existing subcanopy individuals. Flowering dogwood (Cornus florida), sourwood (Oxydendrum arboreum) and winged elm (Ulmus alata) represented the greatest change in importance value. Although this change is slight it is believed to be a result of ice storm damage to the canopy.

Oosting (1942) monographed the dynamics of plant succession on the Piedmont of North Carolina. He proposed an oak-hickory climax for this region stating that hardwoods would become the dominant or climax with a few scattered relic pines. Hardwood, but not conifer, reproduction would be taking place. This view was also shared by Clements (1916) and Wells (1928, 1932). They agree the climatic climax for this region is oak-hickory forest and that pines were anthropogenic and would be replaced by hardwoods.

Braun (1956) addressed the occurrence of pine species in this region. Her statement regarding the oak-pine region in general is warranted in the Forest:

> The characteristic appearance of this region, brought about by the dominance of oaks and pines over much of the area, is responsible for the name "Oak-Pine." However, except on poorer soils and in drier sites, pines are more or less temporary and are ultimately replaced by deciduous species. (Braun, 1950)

Relatively poor soils and drier sites do occur on the upper slopes of the Forest.

McCormick and Platt (1980) examined the role of oak and hickory species replacement on oak-chestnut forests in the Appalachians. Most Chestnut (Castanea dentata Marshall) trees were killed by the chestnut blight Endothia parasitica (Murr.). In their study, canopy openings created by the loss of chestnut were partially filled by the growth of persistent oak species after twenty five years. During the subsequent twenty five year period rapid growth of understory hickory populations enabled hickory to become a codominant species with oak. After this half century of succession an oak-hickory association was formed. At this time, oak and some hickory species are increasing slightly in importance in the Forest while pines are decreasing. If these trends continue an oak-hickory or mixed oak association will be the ultimate climax. Relatively greater increases in the importance of oak species favors the latter.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Major objectives of this study were to determine changes in species composition which have ensued two decades following a catastrophic ice storm; to evaluate the role of catastrophy in the Marshall Forest; to interpret the role of fire protection in the Forest since the original investigation and to reevaluate the apparent codominance of pine and hardwoods within the study site.

Dominant deciduous species were shown to have increased in importance values while pine species have decreased. Pine species sustained extensive damage in the ice storm of March 1960 resulting in tipups, windthrows, and twisted or broken boles. Canopy openings were partially filled by persistent oak species. Resultant canopy codominance was shared by *Pinus echinata*, *Quercus velutina* and *Quercus prinus*.

Pine species are not persisting. Site disturbance and site condition may be responsible for the apparent lack of pine regeneration. Fire suppression is proposed as the major factor responsible for the lack of pine regeneration.

With a high incidence of storm damage and the subsequent lack of regeneration pine species are being replaced by deciduous species. If cyclic catastrophic ice storms continue and fire continues to be suppressed, a mixed oak association is most likely to replace the pine-oak codominants that are present today.

The twenty year period between studies may not have been sufficient time for all potential changes to take place. The role of fire protection and ice storm damage can be further determined by a study of this Forest in the future.

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VITA

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In September 1975 he entered Shorter College, Rome, Georgia. While studying, he worked as teaching assistant in the Biology Department and student ranger of the Marshall Forest during 1978-1980. In May 1980 he received a Bachelor of Science degree in natural science with a major in biology and botany.

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He is engaged to be married to Laura K. McCormick from Chapel Hill, North Carolina, in June 1983. His future plans and goals in life include earning a Ph.D. degree in ecology.