DYNAMICS AND SPATIAL PATTERN OF A VIRGIN OLD-GROWTH HARDWOOD-PINE FOREST IN THE OUACHITA MOUNTAINS, OKLAHOMA, FROM 1896 TO 1994

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CHAPTER I

INTRODUCTION

This thesis is composed of 2 distinct manuscripts formatted for submission to the Journal of Ecological Applications. Each manuscript is complete as written and requires no additional material for support. Manuscripts are arranged in the order of text, literature cited, tables, and figures. Appendixes follow the manuscripts.

CHAPTER II

DYNAMICS OF A VIRGIN, OLD-GROWTH, HARDWOOD-PINE FOREST FROM 1896 TO 1994

Abstract. The presettlement landscape of the McCurtain County Wilderness Area (MCWA) of the Ouachita Mountain region is described using General Land Office (GLO) land survey field notes of 1896. General Land Office survey points were resurveyed in 1994 in order to quantify temporal landscape and vegetation change. Presettlement vegetation was described by GLO surveyors as primarily pine, oak, and hickory; or oak, pine, and hickory. Analysis of GLO survey points showed significant increase ($P = 0.0001$) in stand density (70 trees/ha, 1896; 615 trees/ha, 1994), and a decrease in mean diameter at breast height (29 cm, 1896; 22 cm, 1994). Analysis using a geographic information system (GIS) showed change in species location relative to topography. Carya spp., Quercus rubra, Q. stellata, and Q. velutina all were found more frequently than expected on relatively steep south slopes in 1994. Pinus echinata was found more often than expected on east slopes and on gentle south slopes in 1994. P. echinata was found more often than expected on steep south slopes in 1896. The increase in midstory hardwood stem density may be a probable cause for red-cockaded woodpecker decline known to have occurred from 1977 to 1991.

Key Words: landscape change; fire suppression; Ouachita Mountains; GIS; landscape restoration.

INTRODUCTION

The alteration of North American landscapes following Euro-American settlement (18th to mid-19th century) is well known (Cottam 1949, Stearns1949, Curtis 1956, Forman and Godron 1986). Much of our natural vegetation has been removed for agricultural and urban development, resulting in fragmented landscapes composed of managed systems with altered structure (Forman and Godron 1986). Undeveloped areas, such as federal and state owned forests, wilderness areas, parks, and game preserves, have been altered by active suppression of natural disturbance regimes such as fire (Garren 1943, Christensen 1978, Buckner 1989, Clark 1988, Baker 1992, Masters et. al. 1994). During the past several decades, efforts have been made to reconstruct general characteristics of the landscape mosaic found by early explorers and settlers. Efforts to restore presettlement landscapes require a greater knowledge of landscape characteristics at the time. Although studies have shown that fire was the key mechanism that maintained open woodland ecosystems of the southeastern United States (Christensen 1978, Buckner 1989, Masters et. al. 1994), many still believe there is insufficient evidence of landscape change over the last century.

Historical literature suggests that the Ouachita Mountain landscape was once an open-aspect, mixed shortleaf pine (Pinus echinata) and oak dominated forest with a ground cover of bluestems, other grasses, and woody sprouts (Foti and Glen 1991, Masters et. al. 1994). Over the past several decades, fire suppression has led to the development of dense hardwood midstories and, in some instances, replacement of predominantly pine forests with hardwood forests (Bruner 1931, Guldin 1986, Cain 1987).

Historically, the focus of ecological research has been on successional development of equilibrium communities. This approach has generated a vast knowledge of the composition and function of ecosystems. Recently, however, many researchers have begun to focus on processes of disturbance and the evolutionary significance of such events (Pickett and White 1985). Landscapes subject to natural disturbances have a patchy structure that is important to ecological processes of that landscape. This structure may be altered when the disturbance regime is modified by climatic change or human influence (e.g., fire suppression). Yet, little is known about how different components of this structure will change or how temporal changes in the landscape structure can be detected. Effects of settlement and fire suppression, however, can be directly studied if historical data is available, and if human influence periods can be dated (Hunsaker et al. 1990, Baker 1992, Baker 1993).

A knowledge of vegetation patterns at the time of settlement is essential to appropriate management of old-growth forests,. This knowledge provides a baseline for monitoring temporal landscape change, which can aid in evaluating effects of long-term management techniques and natural disturbance processes. Description of presettlement landscape structure provides baseline conditions for setting ecosystem restoration goals. A given landscape is a result of centuries of land use patterns, and the temporal development of that landscape is one of the most illustrative factors in characterizing species distribution (Sheail 1986, Semotanova 1988, Kienast 1993). Thus, historical land use records have become an important source of information for studies in landscape restoration (Iverson and Risser 1987, Iverson 1988). General Land Office (GLO) survey notes have been used successfully to describe presettlement landscapes (Lutz 1930, Fassett 1944, Cottam 1949, Stearns 1949, Blewett and Potzger 1950, Lorimer 1980, Foti and Glenn 1990). Public land surveyors were required to refer to the landscape in several capacities. First, the species, diameter, distance, and azmuth for two bearing trees were to be recorded at each quarter-section corner, as well as for four bearing trees at section corners. In addition, descriptions of timber types were recorded in the order in which they predominated, as well as some description of understory species. General descriptions of topology, minerals, soils, and economic values were also given (Breed and Hosmer 1908, Lutz 1930).

Data provided by this study supply qualitative and quantitative measures of landscape change for the McCurtain County Wilderness Area (MCWA) of the Ouachita Highlands of southeast Oklahoma. The primary objectives of this study are to describe components of the original plant community mosaic of MCWA, and to determine the degree of landscape change over the last century. Historical documents were used to record vegetative structure at the time of settlement. Field notes from the GLO original land surveys of 1896 were analyzed within a geographic information system to characterize distribution of dominant species in relation to topography.

STUDY AREA

Ouachita Mountains

The Ouachita Mountain region of western Arkansas and southeastern Oklahoma covers an area approximately 380 km east to west by 100 km north to south (Croneis 1930). Ridges typically run east-west, having long north-facing and south-facing slopes. Elevations range from 100 m to 900 m. Complex folding and faulting have resulted in thin, rocky soils composed of shale, slate, sandstone, novaculite, limestone, and quartzite (Croneis 1930, Nelson and Zillgett 1969). South-facing slopes are much drier and are more sparsely vegetated than north-facing slopes because of higher insolation. Ridge tops are exposed to high winds and colder winter temperatures, and valleys are subjected to cold air drainage (Palmer 1924, Foti and Glenn 1991).

The Ouachita Mountains support mixed stands of shortleaf pine and hardwood tree species with a higher frequency of shortleaf pine on south-facing slopes. Because of extreme variation in slope, aspect, and elevation, species composition tends to change with topography (Johnson 1986). Shortleaf pine, hickory (Carya spp.), post oak (Quercus stellata), and blackjack oak (Q. marilandica) dominate the upper slopes while lower slopes support maple (Acer spp.), blue beech (Carpinus caroliniana), hop hornbeam (Ostrya virginiana), and white oak (Q. alba) (Masters et al. 1989). The oak-pine forest of the Ouachitas is the largest timber type in the southeastern United States (Lotan et al. 1978).

MCWA

The 5,701 ha McCurtain County Wilderness Area (MCWA), located in the Kiamichi Mountain Range of the Ouachita Highlands of southeast Oklahoma (Figure 1), is divided into two parts by Broken Bow Reservoir (Mountain Fork River), with most of the area (5215 ha) east of the reservoir. The area is characterized by steep and narrow ridges bearing east-west, with occasional rock outcrops. Elevation varies from 183 m to 415 m. The MCWA is forested with virgin old-growth pine - hardwood forest and is the largest representative tract of its kind (Stahle et al. 1985). Five perennial streams dissect the area, and the largest are North and South Linson Creeks. Annual rainfall averages 121 cm and temperatures range from 34 °C in July to -2°C in January (Masters et al. 1989). Evidence of some timber theft is apparent near area boundaries.

The area has been owned by the Oklahoma Department of Wildlife Conservation (ODWC) since 1918 and has been designated as a state wilderness area since 1951. The MCWA contains all but one of the last known red-cockaded woodpecker (RCW) populations in Oklahoma. Red-cockaded woodpecker populations on MCWA have declined precipitously during the last seventeen years (Masters et al. 1989, Kelly 1993, Masters et al. 1994). With the development of Broken Bow Reservoir in mid-1960's, the Corps of Engineers acquired ownership of adjacent shoreline within MCWA. Thus, the entire study area encompasses approximately 6000 ha. Limited habitat management surrounding red-cockaded woodpecker clusters has occurred on the area. Besides the reintroduction of fire in two areas, all other fire events have been suppressed since the mid-1920's (Masters et al. 1994).

METHODS

General Land Office (GLO) 1896 survey notes from the original land survey of MCWA were obtained from Oklahoma Department of Libraries. Bearing tree data from the GLO notes were extracted for all 97 quarter-section corners on and within the boundaries of MCWA. All 97 points were relocated in summer 1993 and 1994 by use of a compass and hip chain. Attempts to use a global positioning system (GPS) for point locations failed because dense canopy cover and mountainous terrain blocked satellite signals.

Tree density was sampled at GLO points during the summers of 1993 and 1994 using the point-centered quarter sampling method (Cottam and Curtis 1956). At each GLO point the distance to the nearest tree greater than 11.4 cm in diameter, diameter at breast height (dbh), azmuth, and species was measured in each of four quarters. Additional calculations for average stem density were performed using data collected with the variable radius plot sampling method (Grosenbaugh 1952). The variable radius plot method was used as a test for the validity of the point-centered quarter sampling method.

Data Analysis

Mean tree distance and dbh can be used to determine density and basal area. Mean distance, diameter, and density were calculated for 1994 for all 97 sites sampled, and for all interior (non-edge) and undisturbed points. General Land Office surveyors generally recorded 2 trees at each quarter section corner, and 4 trees at each mile section corner. In 1994, 4 trees were recorded at each sample point. Thus, a total of 260 and 384 trees were analyzed for 1896 and 1994, respectively. One point was covered by water in 1994 and was not relocated. Data from 1896 and 1994 were treated as point-centered quarter samples and were used to calculate average distance to nearest tree, stem density, diameter distribution, and basal area for all trees as well as for individual species. Mean diameters and frequency of occurrance were calculated for each species. Student's t (Steel and Torrie 1980) was used to assess differences between years in average distance to nearest tree, tree diameters, and basal area. Because disturbance from timber theft was observed on some parts of MCWA, analyses were also performed for interior (non-edge) and undisturbed points.

Detailed digital elevation data for MCWA made possible more extensive GIS analysis of species distribution by physiographic position. Physiographic position was determined for all tree species using GRASS Geographic Information System (GIS) (U.S. Army Construction Engineers Research Laboratory, Champaign, Illinois). Bearing trees were digitized by calculating north and east adjustments for the Universal Transverse Mercator (UTM) coordinate value of each survey point. Trees were sorted by topographic category (slope and aspect) using data layers derived from USGS 1:24000 scale digital elevation models (DEM). A chi-square analysis was performed to test for significant deviations from random species distributions across each topographic category. From the chi-square, positive and negative associations were assigned for species distribution relative to slope and aspect. Significant assocations ($\underline{P} > 0.01$) were sorted into groups according to the percent difference (D) between observed and expected values. Associations were grouped as follows: FF = far fewer trees than expected (D > -300% difference); F = fewer trees than expected (D $\leq$ -300% difference); M = more trees than expected (D $\leq$ 300% difference); MM = many more trees than expected (D > 300% difference).

RESULTS

Qualitative Land Survey Descriptions

General Land Office survey notes provide both qualitative and quantitative descriptions of the presettlement landscape. General descriptions given for each township provide numerous references to the landscape:

> "The surface of this township is mountainous, the mountains and hills ranging from 50 to 600 feet high and are covered with broken stone. The soil of same being classed as 4th rate. Mountain Fork River runs through the central portion of the township. It is a very rapid stream and contains a number of large boulders. In some places there are narrow bottoms, but in the majority of instances the bluffs extend down to the water's edge. The timber that predominates is pine, oak, elm, ash, hickory, and gum. Sandstone, quartz, and limestone are found on ridges. There are no towns or villages and no farms where noted. December 10th, 1896. J.E. Joy and J. Scott Harrison - U.S. Surveyors."

Additional references were given at each quarter-section corner:

> "Set a sandstone 18 x 6 x 6 inches in the ground for corner of sections 5, 6, 7, and 8. Marked with 5 notches on the south and east edges. From which: A white oak 6 inches diameter bears N 35 E, 65 links distance marked T3S R25E S5 B.T. A post oak 6 inches diameter bears S34 E, 65 links distance marked T3S R25E S8 B.T. A post oak 6 inches diameter bears S49 W, 66 links distance marked T3S R25E S7 B.T. A white oak 6 inches diameter bears N42 W, 18 links distance marked T3S R25E S6 B.T. Land broken and mountainous, soil 4th. rate. Timber pine, oak, and undergrowth."

Three surveyors were responsible for the original survey of MCWA. Two of the surveyors invariably noted predominant timber as "pine, oak, and hickory" or "pine and oak". The third surveyor deviated from this trend and noted predominant species as "oak, pine, and hickory", or "oak and pine". Thus, approximately one-third of the mile summaries catalogue oak as the dominant species, whereas two-thirds of the summaries catalogue pine as dominant. Several areas were described as "pine and undergrowth" and one area was described as "pine, oak, and cedar". Pine was listed first for over 90 percent of the mile summaries given by two of the three surveyors, indicating pine as the dominant species. However, one surveyor consistently listed oak as dominant.

Forest Community

Of the 96 points revisited, 47 of the original corner stones were located in place with legible etchings. Corner stones were often covered over with litter, broken into several pieces, or were lying loose on the surface. Average distance to corner stones from our points of measurement was 12.0 m. Thus, measurements taken at corners where the rock was unable to be found were considered relatively accurate. Of 266 witness trees surveyed in 1896, only 6 of a possible 124 trees (at points where corner stones were located in 1994) were found still standing in 1994, 2 of these were no longer living. Evidence of other witness trees sampled in 1896 remained as large depressions or mounds of soil at the exact distance and azmuth where the witness tree once stood. Comparison of point-centered quarter data for both years show that species composition was similar, with a few additional species encountered in 1994 (Table 1).

General field observations in 1994 showed little or no shortleaf pine recruitment on MCWA. Shortleaf pine seedlings were found only on disturbed sites such as roadsides and blow downs, and were often dense in these areas. Grassy undergrowth was seldom encountered and was found only on a few remnant glades on south-facing slopes. Ground cover on most sites was composed of a thick layer of leaf litter, and scattered shrubs, vines, or sparse herbaceous vegetation. Evidence of fire was observed in the form of fire scars and cat faces on living trees, and charred downed pine knots at 95 of the 96 sample points.

Stem Density and Diameter Comparisons

Individual corner data provides a simple means of quantifying temporal change in landscape structure. In 1896 and 1994, the average distance from a corner point to the nearest tree was 11.2 m and 4.0 m, respectively. Mean distance to the nearest tree, DBH, and basal area were found to be significantly different ($P = 0.0001$) between 1896 and 1994 (Table 2). A near 10-fold difference in average stem density was found for 1896 (70.8 stems/ha) (Table 3) compared to 1994 (615.6 stems/ha) (Table 4). When all 1994 edge and disturbed sites were excluded from the analysis, average stem density was less than when these areas were included (Table 5). Basal area and diameter for Carya spp. and Quercus spp. were different ($P = 0.05$) with all edge and disturbed sites removed (Table 6). Data from the variable radius plot samples without edge and disturbed plots removed (Table 7) and with edge and disturbed plots removed (Table 8) gave similar results for stem density in 1994.

Average diameter for all trees was 28.9 cm for 1896 and 22.0 cm for 1994. When all 1994 edge and disturbed sites excluded, average diameter was 23.33 cm. Species for both years were grouped into four categories: P. echinata, Quercus spp., Carya spp., and other. Size classes differed between 1896 and 1994 (Figure 2). P. echinata in 1994 occurred with a larger frequency of smaller trees (Figure 2a). Carya spp. in 1896 had a slightly larger average diameter than in 1994 (Figure 2b). Quercus spp. diameters in 1994 were much smaller than those observed in 1896. Diameters in 1896 had a much wider range than in 1994 (Figure 2c). Other species in 1994 were slightly smaller than those found in 1896 (Figure 2d). When diameter distributions were summarized with disturbed and edge plots removed, only minor differences were noted (Figure 3a,b,c,d).

GIS Analysis of Species Distribution

More P. echinata ($P > 0.05$) were found on south-facing slopes and on 19°-27° slopes in 1896 than if the species were distributed at random. P. echinata in 1994 occurred less frequently than expected on south and northwest-facing slopes. No relationships between slope angle alone and P. echinata in 1994 were signicicant. Many more P. echinata ($P > 0.05$) than expected occurred in 1896 on south and southeast-facing aspects with 19°- 27° slope (Figure 4). In 1994, many more P. echinata ($P > 0.01$) than expected occurred on 0°-9° south-facing slopes, fewer trees ($P > 0.05$) than expected on 0°- 9° northwest-facing slopes, and fewer than expected ($P > 0.01$) on 19°-27° east-facing slopes (Figure 4).

In 1896, more Carya spp. ($P > 0.05$) than expected occurred on 10°-18° south-facing slopes, and many more trees ($P > 0.01$) than expected on 19°-27° east-facing slopes (Figure 5). Carya in 1994 were distributed with far fewer trees ($P > 0.05$) than expected on 0°-9° southwest-facing slopes, more than expected ($P > 0.01$) on 19°-27° south-facing slopes, and many more than expected on 28°-36° south and southwest-facing slopes (Figure 5).

In 1994, Quercus were found less frequently ($P > 0.05$) than expected on 0°-9° slopes and more than expected occurred on 19°-27° slopes. More Quercus than expected occurred on 0°-9° north slopes and 10°-18° northeast slopes in 1896. Quercus species in 1994 occurred with more trees than expected on 10°-18° east-facing slopes, 19°-27° north-facing slopes, and 19°-27° southeast-facing slopes (Figure 6).

Quercus alba were found to occur more frequently ($P > 0.05$) in 1896 on northwest-facing slopes. No significant occurrences were found in 1994 over slope angle or aspect. When slope angle and aspect were considered simultaneously for 1896, more Q. alba occurred on 10°-18° northeast-facing slopes and 19°-27° northwest-facing slopes

(Figure 7). When considered for 1994, more than expected occurred on 0°-9° slopes with southwest-facing slopes (Figure 7).

Quercus rubra had far fewer trees ($P > 0.05$) than expected in 1994 on 0°-9° slopes and more than expected on 19°-27° slopes. Distribution over aspect showed more trees than expected on north and east-facing slopes. No significant differences were observed over individual layers of slope angle or aspect for 1896. When analyzed over slope angle and aspect combined, 1896 Q. rubra was found more frequently than expected on 10°-18° west-facing slopes (Figure 8). Q. rubra in 1994 was found much more frequently than expected on 10°-18° east-facing slopes, and on 19°-27° north and southeast-facing slopes (Figure 8).

Quercus stellata in 1896 were found to have far fewer trees ($P > 0.05$) than expected on northwest-facing slopes. Q. stellata in 1994 were found more frequently than expected on southwest-facing slopes. Many more ($P > 0.01$) trees than expected occurred on 19°- 27° east and southwest-facing slopes, and many more than expected on 28°- 36° southwest-facing slopes in 1994 (Figure 9).

Distribution of Quercus velutina in 1896 over individual layers of slope and aspect were found more often than expected on east-facing slopes, and much more often than expected on areas with no aspect ($P>0.05$). Distribution in 1994 was found with more trees than expected on 19°-27° slopes and more than expected on northeast-facing slopes ($P>0.05$). Over slope angle and aspect simultaneously, 1896 Q. velutina was found much more frequently ($P>0.01$) than expected on flat areas and more frequently ($P>0.01$) than expected on 0°-9° north and east aspects (Figure 10). In 1994, Q.velutina was distributed much more frequently ($P>0.01$) than expected on 0°-9° and 10°-18° northeast-facing slopes, and much more frequently ($P>0.01$) than expected on 19°-27° north and southeast-facing slopes (Figure 10).

DISCUSSION

In a review of the General Land Office survey and its use in quantitative studies of presettlement landscapes, Bourdo (1956) identified potential sources of bias in the original notes. Surveyor instructions specified that witness trees must be "of the most durable wood of the forest at hand" (Bourdo 1956), suggesting bias in selection of witness trees. Thus, in the survey of the Ouachita Mountain region, Quercus spp. may have been chosen over shortleaf pine. This would explain why pines were recorded as the predominant species in many of the GLO mile summaries, but were rarely used as witness trees. Additional potential for bias is error in species identification during winter surveys, because the absence of leaves made species identification difficult. Of the six witness trees relocated in 1994, one was misidentified. Other sources of bias include estimation of distances and diameters, and accidental or fraudulent location of section corners (Cottam 1949, Bourdo 1956).

Although the 1896 data may potentially be biased, it still provides useful information when the source of bias is identified or accounted for and other independent means of verification provide similar colaborative evidence. General Land Office survey notes and data from points we revisited demonstrate that the vegetation structure of MCWA has undergone change in several capacities over the last century. Although species types supported by the area appear relatively unchanged, stand density and microsite distribution of dominant species have been modified over time.

Species composition and stem density

Total number of individuals, including P. echinata, increased for nearly all dominant species. Others have demonstrated that hardwood encroachment over several decades resultes in a decrease in P. echinata in the absence of fire (e.g., Cain 1987). However, an independent study that utilized aerial photography for random sampling, showed an increase in dominant and codominant shortleaf pine from 73 stems/ha in 1955 to 93 stems/ha in 1990 (Kreiter 1995). This is important because P. echinata recruitment was low in 1994. This suggests that shortleaf pine populations on MCWA have reached a critical successional stage, where most of the population is made up of intermediate and dominant individuals. Although a shortleaf pine component may generally exist on MCWA, development towards a more even-aged population may result in a decrease in total numbers as older members die and are replaced by more shade tolerant hardwood species. This situation may be exacerbated by outbreak of southern pine beetle on the area (Masters et al. 1989).

Equally as interesting was the observation that very few trees surveyed in 1896 were still in place in 1994. This contrasts with the presumption that surveyors bias witness tree selection, where young, and perhaps more distant trees that were more likely to survive were selected. This also suggests a relatively high turnover rate, where old-growth stands may be less common than previously suspected. Additionally, increment cores of large shortleaf pines near several of the sample points showed that none of these potential witness trees were alive at the time of the survey, thus discounting surveyor bias in witness tree selection.

Trees in 1896 generally had a larger range of diameters than those found in 1994. Particularly interesting was the large range of Pinus and Quercus diameters, each of which ranged from 13cm - 75cm diameters. This suggests that MCWA landscape in 1896 was composed of a more uneven aged structure than that found in 1994. A high frequency of smaller trees, the majority of which had diameters ranging from 13cm - 23cm were present in 1994. The large number of smaller hardwoods supports the hypothesis that decreased fire frequency may have contributed to an increased hardwood development in the midstory and intermediate canopy classes.

Species distribution

Species in 1896 tended to follow the expected trends in microsite distribution. P. echinata was found most frequently on moderately steep south-facing slopes, Q. alba was found on moderately steep northeast and northwest-facing slopes, Q. stellata was found on steep north-facing slopes, and Carya was found on moderately steep north-facing slopes. However, several species deviated from expected trends. Q. velutina, was expected to occur most often on west-facing slopes, but was distributed on gentle or flat east and north-facing slopes in 1896. Q. rubra, usually found on north-facing slopes, was found on moderately steep west-facing slopes in 1896.

Perhaps the most intriguing change in overall species distribution was the increased frequency of hardwoods on relatively steep (19°-36°) south-facing slopes by 1994. Carya spp., Q. rubra, Q. stellata, and Q. velutina were all found more frequently than expected on relatively steep south slopes in 1994. This trend suggests that decreased fire frequency has allowed these less fire tolerant species to expand into much more xeric, fire prone areas. Pinus was found more frequently than expected on relatively steep south slopes in 1896, but not in 1994. This is consistent with the observation that present day pine recruitment is virtually non-existent, suggesting that the increased number of hardwoods on south-facing slopes has created an unsuitable growing environment for less shade tolerant pine seedlings.

Management implications

In landscape restoration it is important to understand landscape structure at the time of settlement, as well as relative species composition. This study demonstrates that the total number of individuals has increased since settlement for all dominant tree species. Equally important, however, distribution of size classes and species relative position on the landscape have also changed since settlement. Although MCWA still supports a similar species complement compared to that in 1896, these species are arranged in a way that is different from the open, park-like woodland of the Ouachitas referred to in historic literature (e.g., Nuttal 1980, Foti and Glen 1991). Examination of such change in vegetation pattern can allow for assessment of risk to wildlife that may be sensitive to habitat fragmentation (Jurgensen 1993). Rare and sensitive species will likely be susceptible to fragmentation by loss of habitat, as well as from isolation of constituents of the population when habitats become fragmented (Lehmkuhl et al. 1993). Replacement of early successional species such as shortleaf pine, with more shade tolerant species such as white oak (Quercus alba) and mockernut hickory (Carya tomentosa) may affect species such as the red-cockaded woodpecker, which is associated with open pine habitats.

Change detected over a short term indicates that forests may experience rapid change. Stahle et al. (1985) suggested that climate had not changed recently on the MCWA. However, results found in previous studies (e.g., Foti and Glenn 1991, Masters et al. 1994, Kreiter 1995), strongly support the presumption that rapid change may result from fire exclusion.

Restoration of MCWA presettlement landscape should focus on reconstruction of original landscape components found at the time of settlement. This could best be accomplished by reintroduction of the fire regime known to be present before active suppression. Reintroduction of fire would likely decrease stand density, thus allowing natural succession of native species to take place. To be most effective, land managers should consider topographic differences in restoring open forest types along xeric ridges and south-facing slopes, where the effects of hardwood encroachment have had the most impact. This will allow drainages, bottoms, and north-facing slopes to remain as hardwood-dominated forest types. Efforts should be made to study how the use of growing season fires and large-scale burns could be initiated to better mimic the anthropogenic and lightning-caused fire events that historically shaped the system.

Landscape managers must continue to develop plans to approximate natural processes. Based on previous studies (Masters et al. 1994, Wilson 1994) fire intensity and frequency should likely be increased in order to mimic the anthropogenic and lightning-caused fire regime that historically shaped the system. More importantly, however, managers must become more knowledgeable of the ecological effects of natural disturbances such as fire. This study is one of the first attempts at such an assessment and it describes the potential for rapid change in forest landscape pattern when fire is removed. Future research needs to be done to assess different landscape management configurations and desired future conditions for MCWA. Additional research also should be done to determine how changes in landscape pattern have affected the potential spread of fire, insects, and disease across the system.

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Table 1. Species recorded in McCurtain County Wilderness Area, Oklahoma. Vernacular names used by surveryors, with probable scientific names.

Vernacular name	Scientific name	1896	1994
Shortleaf pine	(Pinus echinata)	X	X
Hickory	(Carya spp.)	X	X
Northern red oak	(Quercus rubra)	X	X
Post oak	(Q. stellata)	X	X
Black oak	(Q. velutina)	X	X
White oak	(Q. alba)	X	X
Blackjack oak	(Q. marilandica)	X	X
Southern red oak	(Q. falcata)	X	X
Cherry	(Prunus serotina)	X	X
Sweetgum	(Liquidumbar styraciflua)	X	X
Maple	(Acer spp.)	X	X
Black gum	(Nyssa sylvatica)	X	X
Flowering dogwood	(Cornus florida)		X
Ash	(Fraxinus americana)		X
Serviceberry	(Amelanchier arborea)		X
American elm	(Ulmus alata)		X
Eastern red cedar	(Juniperus virginiana)	X	

Table 2. Comparison of 1896 and 1994 mean tree basal area (BA), diameter breast height (DBH), and mean distance (DIST) to the nearest tree at 97 General Land Office Survey points on McCurtain County Wilderness Area, Oklahoma.[a]

	Year					
	1896		1994			
Parameter	Mean	SE	Mean	SE	T	P
BA (m^2/ha)	0.07A	0.00	0.05B	0.00	5.58	0.0001
DBH (cm)	28.94A	0.74	22.02B	0.58	7.24	0.0001
DIST (m)	11.22A	0.55	4.03B	0.13	13.35	0.0001

[a] Row means followed by different letters were significantly different.

Table 3. Frequency (Freq), diameter at breast height (DBH), standard error diameter at breast height SED, basal area (BA), standard error basal area (SEB), density by species, absolute frequency (ABS), and dominance ranking (DR) for McCurtain County Wilderness Area, Oklahoma, Fall 1896. Results from General Land Office corner data.

Species	Freq	DBH(cm)	SED	BA(m^2)	SEB	Trees/ha	ABS	DR
Acer spp.[a]	2	17.8	0.0	> 0.0	0.0	0.5	1.0	11
Carya spp.[a]	7	24.0	2.0	0.1	0.0	1.9	7.2	7
Liquidambar styraciflua	1	35.6	.	> 0.0	.	0.3	1.0	12
Nyssa sylvatica	1	20.3	.	> 0.0	.	0.3	1.0	9
Pinus echinata	17	32.0	3.2	0.4	0.0	4.5	14.4	5
Prunus serotina	1	15.2	.	> 0.0	.	0.3	1.0	13
Quercus alba	58	29.8	1.4	1.2	0.0	15.4	33.0	2
Quercus marilandica	7	21.4	2.8	0.1	0.0	1.9	5.2	8
Quercus rubra	41	28.4	1.4	0.8	0.0	10.9	33.0	3
Quercus stellata	38	26.7	1.4	0.6	0.0	10.1	25.8	4
Quercus velutina	23	27.5	1.8	0.4	0.0	6.1	14.4	6
Quercus spp.[a]	67	32.3	1.2	1.6	0.0	17.8	27.8	1
Ulmus spp.[a]	3	17.8	2.5	> 0.0	0.0	0.8	3.1	10
TOTAL	266			5.2		70.8	167.9	

[a] Individual species names were frequently not given in original land survey notes.

Table 4. Frequency (Freq), diameter at breast height (DBH), basal area (BA), density by species, absolute frequency (ABS), and dominance ranking (DR) for McCurtain County Wilderness Area, Oklahoma, Summer 1994. Results from point-centered quarter sampling method.

Species	Freq	DBH(cm)	BA(m^2)	Trees/ha	ABS	DR
Acer rubrum	2	14.8	0.1	3.2	2.1	16
Acer saccharum	1	18.9	>0.0	1.6	1.0	17
Amelanchier arborea	1	21.3	0.1	1.6	1.0	15
Carya texana	3	14.8	0.1	4.8	1.0	13
Carya tomentosa	58	18.0	2.6	93.0	34.4	3
Cornus florida	1	12.6	>0.0	1.6	1.0	19
Fraxinus americana	3	20.5	0.2	4.8	3.1	11
Juniperus virginiana	3	19.6	0.2	4.8	3.1	10
Liquidambar styraciflua	2	12.5	>0.0	3.2	2.1	18
Nyssa sylvatica	9	19.0	0.5	14.4	7.3	8
Pinus echinata	149	27.0	15.9	238.9	70.8	1
Prunus serotina	9	21.0	0.5	14.4	9.4	7
Quercus alba	48	21.1	3.1	77.0	33.3	2
Quercus falcata	8	19.3	0.4	12.8	5.2	9
Quercus marilandica	3	15.2	0.1	4.8	2.1	12
Quercus rubra	36	20.3	2.1	57.7	20.8	4
Quercus stellata	24	17.1	1.0	38.5	18.8	5
Quercus velutina	22	17.0	0.9	35.3	13.5	6
Ulmus alata	2	16.3	0.1	3.2	2.1	14
TOTAL	384		27.9	615.6	232.1	

Table 5. Frequency (Freq), diameter at breast height (DBH), standard error diameter at breast height (SED), basal area (BA), standard error basal area (SEB), density by species, absolute frequency (ABS) and dominance ranking (DR) for McCurtain County Wilderness Area, Oklahoma, Summer 1994. Results from point-centered quarter sampling method with edge and disturbed plots removed.

Species	Freq	DBH(cm)	SED	BA(m^2)	SEB	Trees/ha	ABS	DR
Acer rubrum	2	14.8	2.7	0.1	0.0	5.8	3.9	13
Acer saccharum	1	18.9	.	0.1	.	2.9	2.0	14
Carya texana	3	14.8	0.9	0.1	0.0	8.7	2.0	11
Carya tomentosa	39	17.9	0.8	3.1	0.0	112.7	41.2	3
Fraxinus americana	2	17.3	1.5	0.1	0.0	5.8	3.9	12
Juniperus virginiana	1	30.8	.	0.2	.	2.9	2.0	10
Nyssa sylvatica	4	14.9	2.6	0.2	0.0	11.6	5.9	9
Pinus echinata	78	29.6	1.4	18.1	0.0	225.5	72.5	1
Prunus serotina	4	18.2	1.2	0.3	0.0	11.6	7.8	8
Quercus alba	27	23.3	1.8	3.8	0.0	78.0	35.3	2
Quercus falcata	6	19.8	1.6	0.6	0.0	17.3	7.8	7
Quercus marilandica	1	17.0	.	0.1	.	2.9	2.0	15
Quercus rubra	8	24.2	3.5	1.2	0.0	23.1	11.8	5
Quercus stellata	9	17.4	1.6	0.7	0.0	26.0	11.8	6
Quercus velutina	18	16.9	1.7	1.4	0.0	52.0	17.6	4
Ulmus alata	1	12.1	.	>0.0	.	2.9	2.0	16
TOTAL	204			30.1		589.7	229.5	

Table 6. Comparison of 1896 and 1994 (with edge and disturbed points removed) mean tree basal area (BA) and diameter breast height (DBH) at General Land Office Survey points on McCurtain County Wilderness Area, Oklahoma.[a]

	Variable							
	DBH (cm)				BA (m^2)			
	1896		1994		1896		1994	
Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Acer spp.	17.8	0.0	16.2	2.1	0.02	0.00	0.02	0.00
Carya spp.	23.9A	2.0	17.7B	0.8	0.05A	0.01	0.03B	0.00
Nyssa sylvatica	20.3	0.0	14.9	2.6	0.03	0.00	0.02	0.01
Pinus echinata	32.0	3.2	29.6	1.4	0.09	0.02	0.08	0.01
Prunus serotina	15.2	0.0	18.2	1.2	0.02	0.00	0.03	0.00
Quercus spp.	29.3A	0.63	20.6B	1.0	0.07A	0.00	0.04B	0.00
Ulmus spp.	17.8	2.5	12.1	0.0	0.03	0.01	0.01	0.00

[a] Row means followed by the same letters or without letters were not significantly different ($P > 0.05$).

Table 7. Frequency, density (trees/ha), basal area (BA), and totals in 1994 by species for McCurtain County Wilderness Area, Oklahoma. Results from variable radius plot sampling method.

Species	Freq	Trees/ha	BA(m^2)
Acer rubrum	6	9.8	0.1
Acer saccharum	1	0.9	> 0.0
Amelanchier arborea	1	0.7	> 0.0
Carya cordiformis	1	1.4	> 0.0
Carya texana	7	5.2	0.2
Carya tomentosa	82	84.2	2.0
Cornus florida	1	2.0	> 0.0
Fraxinus americana	3	2.5	0.1
Juniperus virginiana	3	1.2	0.1
Liquidambar styraciflua	3	5.4	0.1
Nyssa sylvatica	11	13.4	0.3
Pinus echinata	437	222.4	10.5
Prunus serotina	15	10.3	0.4
Quercus alba	87	71.1	2.1
Quercus falcata	13	9.3	0.3
Quercus marilandica	12	11.2	0.3
Quercus rubra	71	60.0	1.7
Quercus stellata	40	30.6	1.0
Quercus velutina	40	39.0	1.0
Ulmus alata	7	5.6	0.2
TOTAL	841	586.2	20.4

Table 8. Frequency, density (trees/ha), basal area (BA), and totals in 1994 by species for McCurtain County Wilderness Area, Oklahoma. Results from variable radius plot sampling method with disturbed and edge plots removed.

Species	Freq	Trees/ha	BA(m^2)
Acer rubrum	6	18.5	0.3
Acer saccharum	1	1.6	0.5
Carya texana	6	8.5	0.3
Carya tomentosa	52	98.6	2.3
Fraxinus americana	2	3.9	0.1
Juniperus virginiana	2	1.1	0.1
Nyssa sylvatica	7	19.5	0.3
Pinus echinata	231	178.4	10.4
Prunus serotina	9	12.3	0.4
Quercus alba	53	70.6	2.4
Quercus falcata	9	11.7	0.4
Quercus marilandica	4	6.3	0.2
Quercus rubra	15	15.4	0.7
Quercus stellata	17	19.4	0.8
Quercus velutina	35	67.9	1.6
Ulmus alata	2	4.4	0.1
TOTAL	451	538.1	20.9

Figure 1. McCurtain County Wilderness Area, Oklahoma study area and 1896 General Land Office survey points.

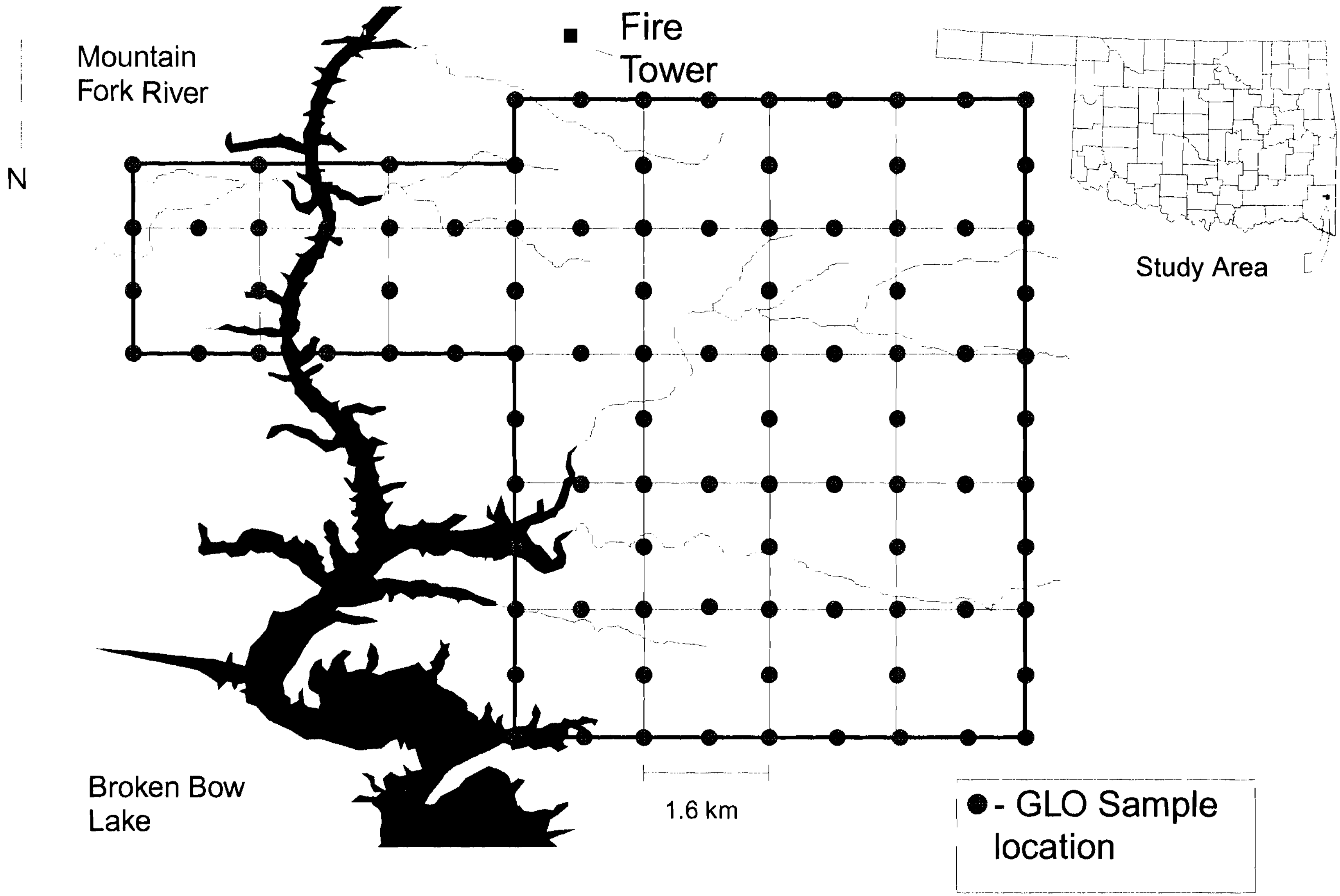
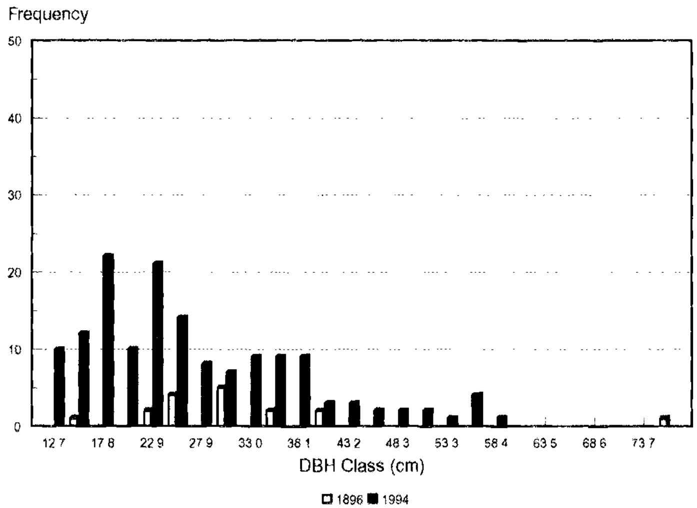
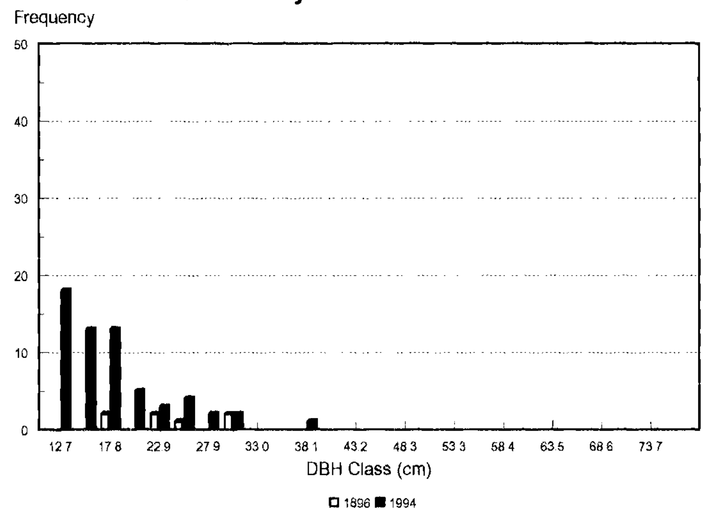

N
Mountain Fork River
Fire Tower
Study Area
Broken Bow Lake
1.6 km
- GLO Sample location

Figure 2. Diameter distributions in 1896 and 1994 for dominant tree species ≥ 11.4 cm at General Land Office survey points on the McCurtain County Wilderness Area, Oklahoma.

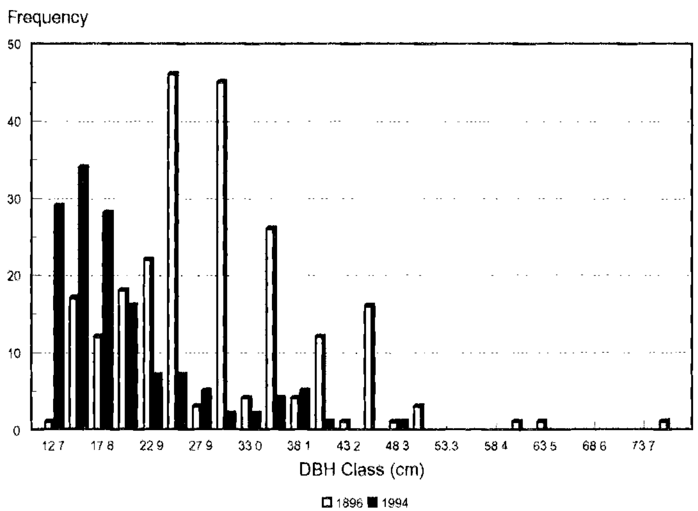
a. Shortleaf Pine Diameter Distribution



b. Hickory Diameter Distribution



c. Oak Diameter Distribution



d. Other Species Diameter Distribution

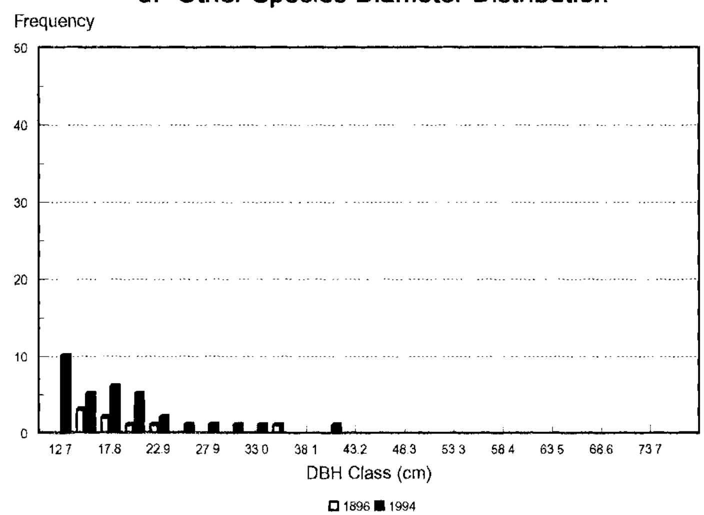
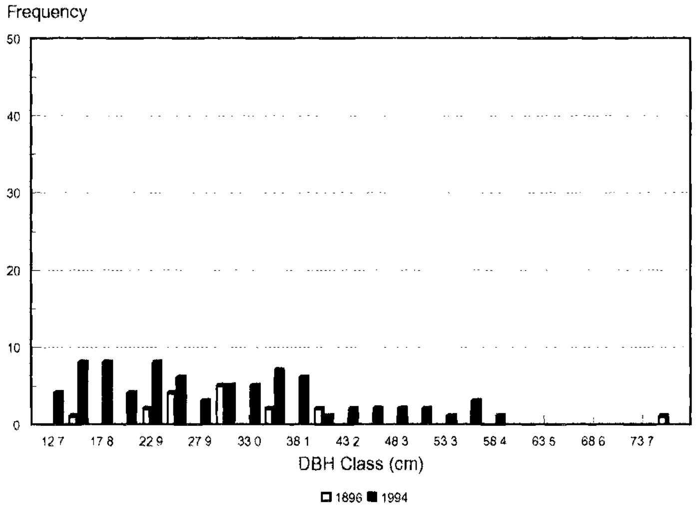
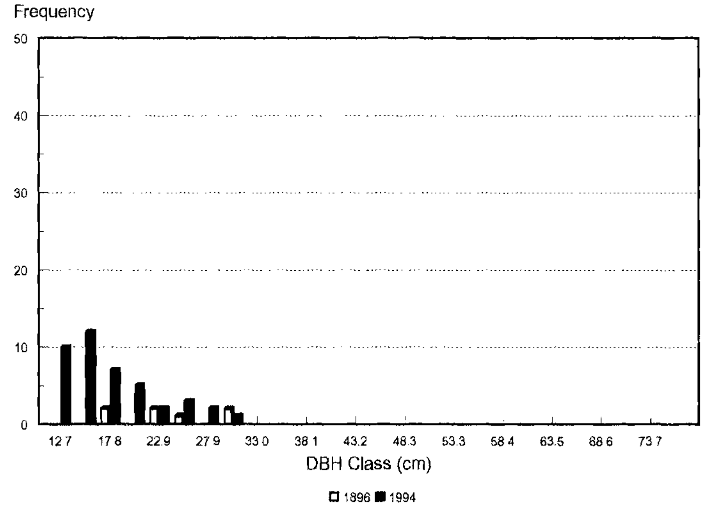


Figure 3. Diameter distributions in 1896 and 1994 for dominant tree species $\geq$ 11.4 cm at General Land Office survey points on the McCurtain County Wilderness Area, Oklahoma. Edge and disturbed plots have been removed.

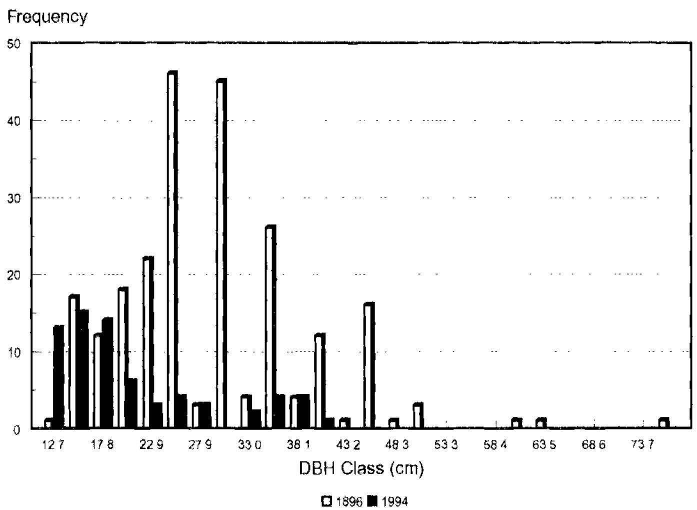
a. Shortleaf Pine Diameter Distribution



b. Hickory Diameter Distribution



c. Oak Diameter Distribution



d. Other Species Diameter Distribution

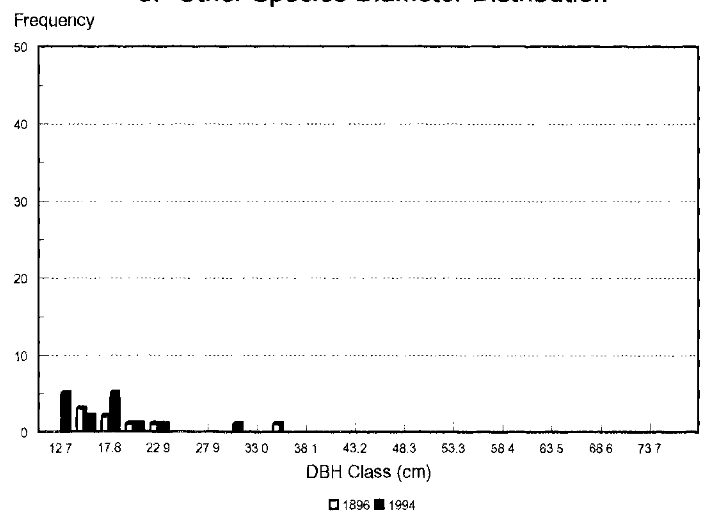
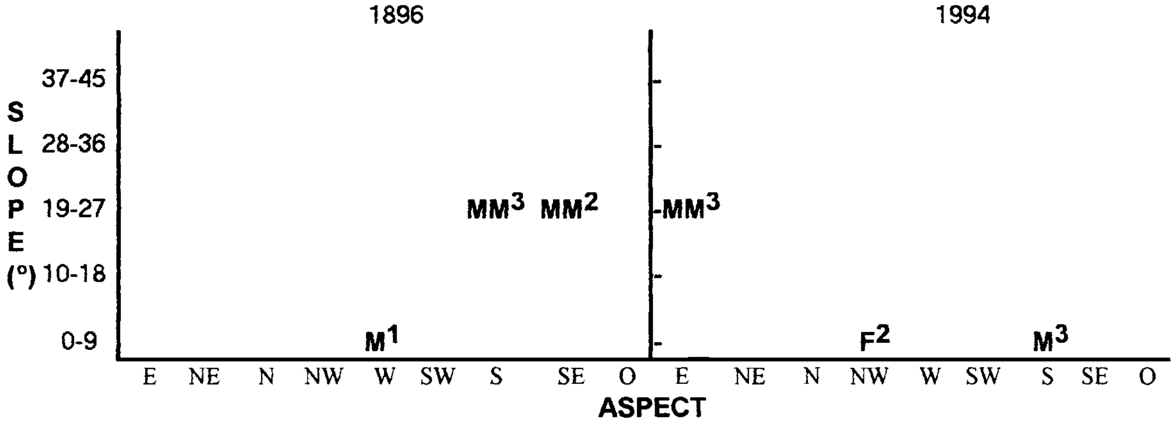


Figure 4. Pinus echinata distribution by slope angle and aspect in 1896 and 1994 based on measurements at 97 General Land Office survey points on McCurtain County Wilderness Area, Oklahoma. Slope angle and aspect data were derived from 30 m USGS digital elevation models. Significant assocations ($\underline{P} > 0.01$) were sorted into groups according to the percent difference (D) between observed and expected values. Associations were grouped as follows: FF = far fewer trees than expected (D > -300% difference); F = fewer trees than expected (D ≤ -300% difference); M = more trees than expected (D ≤ 300% difference); MM = many more trees than expected (D > 300% difference).



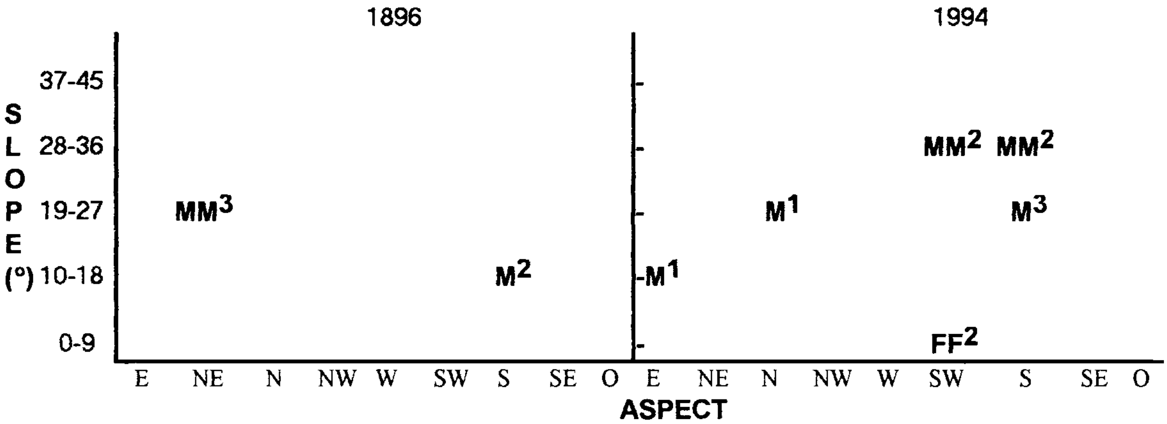
Legend:

1 $\underline{P} = 0.05 - 0.10$

2 $\underline{P} = 0.01 - 0.05$

3 $\underline{P} < 0.01$

Figure 5. Carya spp. distribution by slope angle and aspect in 1896 and 1994 based on measurements at 97 General Land Office survey points on McCurtain County Wilderness Area, Oklahoma. Slope angle and aspect data were derived from 30 m USGS digital elevation models. Significant assocations ($\underline{P} > 0.01$) were sorted into groups according to the percent difference (D) between observed and expected values. Associations were grouped as follows: FF = far fewer trees than expected (D > -300% difference); F = fewer trees than expected (D ≤ -300% difference); M = more trees than expected (D ≤ 300% difference); MM = many more trees than expected (D > 300% difference).



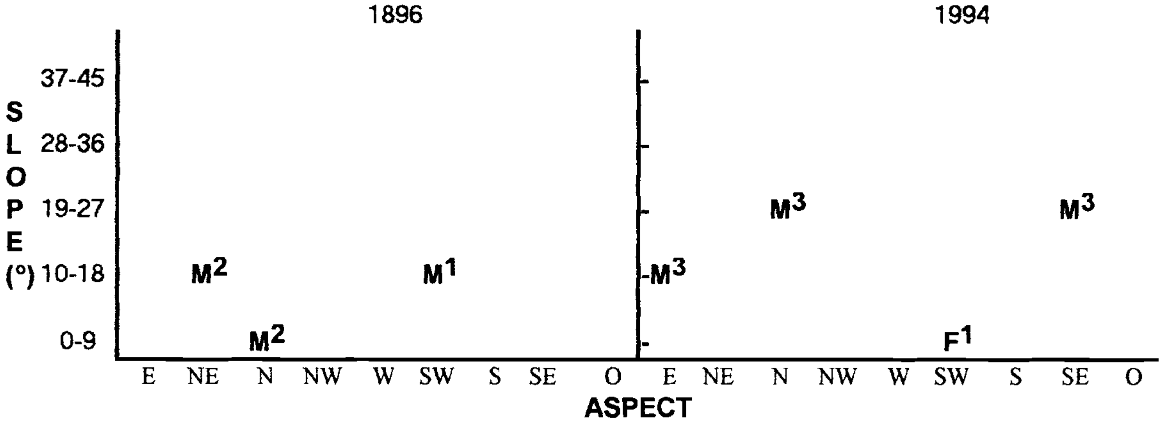
Legend:

1 P = 0.05 - 0.10

2 P = 0.01 - 0.05

3 P < 0.01

Figure 6. Quercus spp. distribution by slope angle and aspect in 1896 and 1994 based on measurements at 97 General Land Office survey points on McCurtain County Wilderness Area, Oklahoma. Slope angle and aspect data were derived from 30 m USGS digital elevation models. Significant assocations ($\underline{P} > 0.01$) were sorted into groups according to the percent difference (D) between observed and expected values. Associations were grouped as follows: FF = far fewer trees than expected (D > -300% difference); F = fewer trees than expected (D ≤ -300% difference); M = more trees than expected (D ≤ 300% difference); MM = many more trees than expected (D > 300% difference).



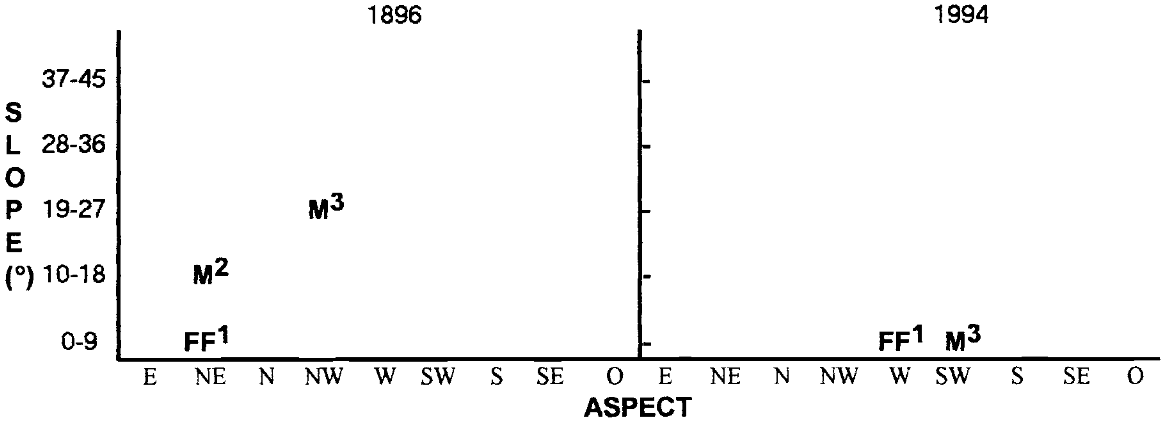
Legend:

1 $\underline{P} = 0.05 - 0.10$

2 $\underline{P} = 0.01 - 0.05$

3 $\underline{P} < 0.01$

Figure 7. Quercus alba distribution by slope angle and aspect in 1896 and 1994 based on measurements at 97 General Land Office survey points on McCurtain County Wilderness Area, Oklahoma. Slope angle and aspect data were derived from 30 m USGS digital elevation models. Significant assocations ($P > 0.01$) were sorted into groups according to the percent difference (D) between observed and expected values. Associations were grouped as follows: FF = far fewer trees than expected ($D > -300\%$ difference); F = fewer trees than expected ($D \leq -300\%$ difference); M = more trees than expected ($D \leq 300\%$ difference); MM = many more trees than expected ($D > 300\%$ difference).



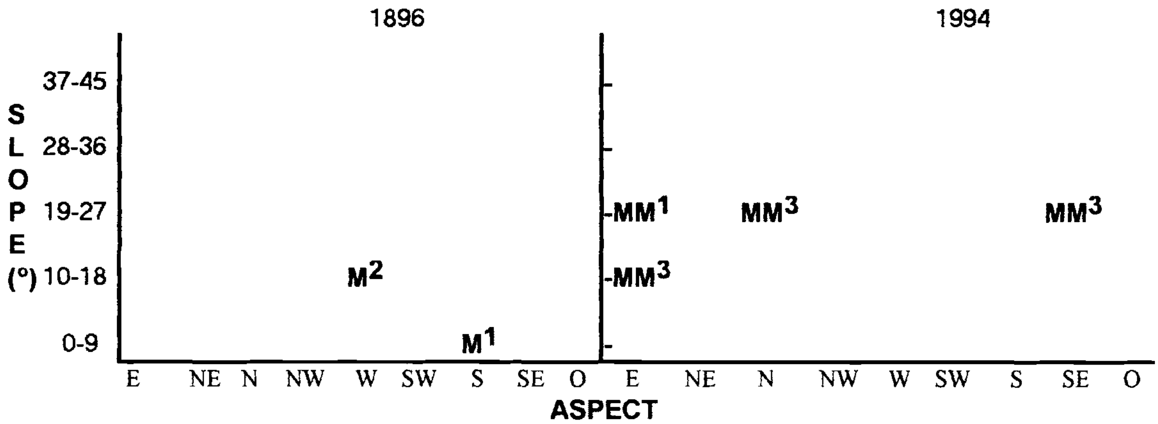
Legend:

1 $\underline{P} = 0.05 - 0.10$

2 $\underline{P} = 0.01 - 0.05$

3 $\underline{P} < 0.01$

Figure 8. Quercus rubra distribution by slope angle and aspect in 1896 and 1994 based on measurements at 97 General Land Office survey points on McCurtain County Wilderness Area, Oklahoma. Slope angle and aspect data were derived from 30 m USGS digital elevation models. Significant assocations ($\underline{P} > 0.01$) were sorted into groups according to the percent difference (D) between observed and expected values. Associations were grouped as follows: FF = far fewer trees than expected (D > -300% difference); F = fewer trees than expected (D ≤ -300% difference); M = more trees than expected (D ≤ 300% difference); MM = many more trees than expected (D > 300% difference).



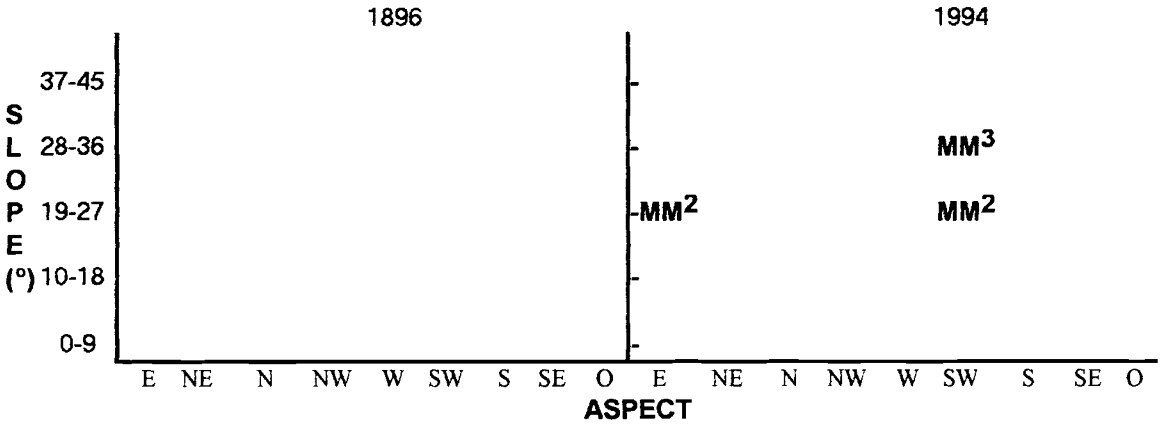
Legend:

1 P = 0.05 - 0.10

2 P = 0.01 - 0.05

3 P < 0.01

Figure 9. Quercus stellata distribution by slope angle and aspect in 1896 and 1994 based on measurements at 97 General Land Office survey points on McCurtain County Wilderness Area, Oklahoma. Slope angle and aspect data were derived from 30 m USGS digital elevation models. Significant assocations ($\underline{P} > 0.01$) were sorted into groups according to the percent difference (D) between observed and expected values. Associations were grouped as follows: FF = far fewer trees than expected (D > -300% difference); F = fewer trees than expected (D ≤ -300% difference); M = more trees than expected (D ≤ 300% difference); MM = many more trees than expected (D > 300% difference).



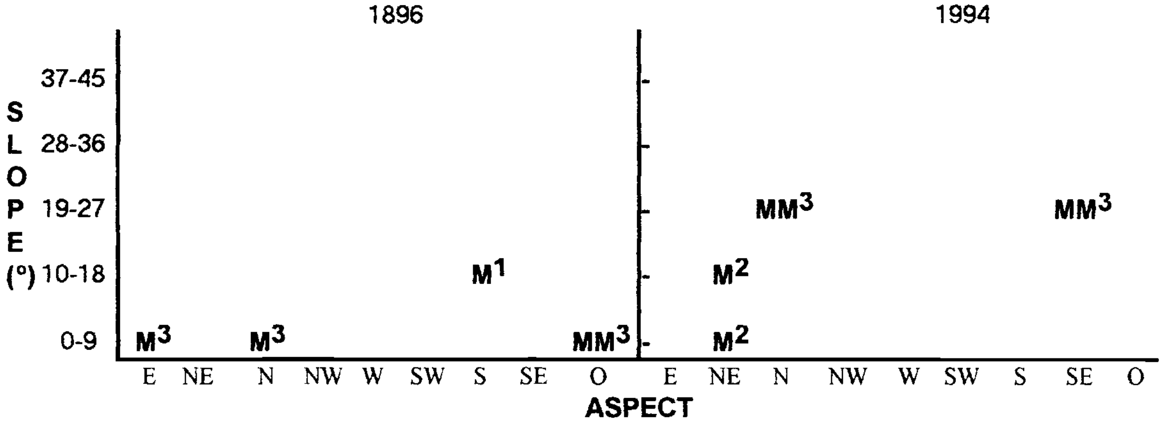
Legend:

1 $P = 0.05 - 0.10$

2 $P = 0.01 - 0.05$

3 $P < 0.01$

Figure 10. Quercus velutina distribution by slope angle and aspect in 1896 and 1994 based on measurements at 97 General Land Office survey points on McCurtain County Wilderness Area, Oklahoma. Slope angle and aspect data were derived from 30 m USGS digital elevation models. Significant assocations ($P > 0.01$) were sorted into groups according to the percent difference (D) between observed and expected values. Associations were grouped as follows: FF = far fewer trees than expected (D > -300% difference); F = fewer trees than expected (D ≤ -300% difference); M = more trees than expected (D ≤ 300% difference); MM = many more trees than expected (D > 300% difference).



Legend:

1 P = 0.05 - 0.10

2 P = 0.01 - 0.05

3 P < 0.01

CHAPTER III

LANDSCAPE CHANGE ON A VIRGIN OLD-GROWTH HARDWOOD-PINE LANDSCAPE FROM 1955 TO 1990

Abstract. Overstory vegetation on the McCurtain County Wilderness Area (MCWA), a virgin old-growth area of the Ouachita Highlands in southeast Oklahoma, was mapped in a geographic information system (GIS) for the years 1955 and 1990. Landscape analysis was performed on 5,500 ha of the area using GIS landscape analysis programs. Results indicate that MCWA is becoming a less diverse and more homogeneous landscape. Mean patch shape for pure pine and pure hardwood stands decreased by 25 percent and 34 percent, respectively, between 1955 and 1990. Fractal dimension for the entire area decreased by 9 percent. Mean patch size for the entire landscape increased by 46 percent. Diversity measures, such as richness and Shannon's diversity index, decreased by 22 percent and 23 percent for the entire study area, respectively. Contagion increased for the entire study area by 8 percent. Species composition of stands have largely shifted to a pine and hardwood mixture, whereas stands of pure pine and pure hardwood have diminished. Open hardwood woodlands observed on 1955 photography had completely disappeared by 1990. Dominant and codominant shortleaf pine (Pinus echinata) increased ($P = 0.0001$) from 70 stems/ha to 90 stems/ha for 1955 and 1990, respectively.
Key Words: landscape change; fire suppression; Ouachita Mountains; GIS; landscape restoration, fragmentation.

INTRODUCTION

North American landscapes were markedly altered following Euro-American settlement (18th to mid-19th century) (Cottam 1949, Stearns 1949, Curtis 1956, Forman and Godron 1986). Much of the natural vegetation was removed for agricultural and urban development, resulting in fragmented landscapes composed of managed systems with altered structure (Forman and Godron 1986). Undeveloped areas such as wilderness, state parks, and national forests, have been altered by active suppression of natural disturbance regimes such as fire (Garren 1943, Christensen 1978, Buckner 1989, Clark 1988, Baker 1992, Masters et. al. 1994). During the past several decades, efforts have been made to reconstruct general characteristics of the landscape mosaic found by early explorers and settlers. Reconstructed landscapes give indication of presettlement conditions and can be used as guidelines for ecosystem restoration (Wilson 1994, Wilson et al. 1995). Although fire was the key mechanism that maintained open woodland ecosystems of the southeast United States (Christensen 1978, Buckner 1989, Masters et. al. 1994), quantitative evidence illustrating the degree of landscape change over the last century is lacking.

Historical literature suggests that the Ouachita Mountain landscape was once composed of open park-like woodlands. Shortleaf pine (Pinus echinata), dominated stands with a ground cover of bluestems, various other grasses, and woody resprouts were interspersed in a mosaic of hardwood dominated and mixed pine-hardwood or hardwood-pine forests (Foti and Glen 1991, Kreiter 1995). Hardwoods dominated on north slopes, along drainages and on other mesic sites (Wilson et al. 1995). Over the past several decades, fire suppression has led to the development of dense midstories in formerly open park-like woodlands (Kreiter 1995, Masters et al. 1994) and, in some instances, replacement of predominantly pine forests with hardwood forests (Bruner 1931, Guldin 1986, Cain 1987). Stem density of overstory trees has increased by almost 10 times in the last century (Kreiter 1995).

Efforts to restore presettlement landscapes of the Ouachita Mountain region require a greater knowledge of landscape characteristics at the time. Landscapes subject to natural disturbance have a patchy structure that changes when the natural disturbance regime is altered (Pickett and White 1985, Baker 1992). The structure of a heterogeneous landscape is important in the processes of many ecological and environmental phenomena (Krummel et al. 1987, Foreman and Godron 1986, Burgess and Sharpe 1981). Yet, relatively little is known about how components of landscape change over time (Baker 1992).

In this study, a GIS was used with historic aerial photography to assess landscape change on the McCurtain County Wilderness Area (MCWA) (Figure 1) of the Ouachita Highlands of southeast Oklahoma over a 30 year period. Fire frequency and aerial extent of fire had significantly declined by 1956 (Masters et al. 1994). The working hypotheses were that landscape patterns have changed, and that those observed changes will be characteristic of a landscape with an altered natural disturbance regime. Data provided by this study supply quantitative measures of landscape structure for MCWA at two points in time. The primary objectives of this study were to describe the plant community mosaic before successful fire suppression activities, and to characterize the degree of landscape change over a 35 year interval.

Density and distribution of tree species on MCWA has changed significantly over the last 100 years although composition has not (Kreiter 1995). This study builds on information from the previous study, and will characterize landscape dynamics on MCWA. Landscape analysis will allow managers to increase their knowledge of directional changes and characterize the rate of change that may be taking place over time.

STUDY AREA

The Ouachita Mountain region of western Arkansas and southeastern Oklahoma covers an area approximately 380 km east to west by 100 km north to south (Croneis

1930). Ridges typically run east-west, having long north-facing and south-facing slopes. Elevations range from 100 m to 900 m. Complex folding and faulting have resulted in thin, rocky soils composed of shale, slate, sandstone, novaculite, limestone, and quartzite (Croneis 1930, Nelson and Zillgett 1969). South aspects are much drier and are more sparsely vegetated than north aspects because of higher insolation. Ridge tops are exposed to harsh weather conditions such as high winds and cold winter temperatures (Palmer 1924, Foti and Glenn 1991).

The Ouachita Mountains support mixed stands of shortleaf pine and hardwood tree species with a higher frequency of shortleaf pine on south-facing slopes. Because of extreme variation in slope, aspect, and elevation, species composition tends to change with topography (Johnson 1986). Shortleaf pine, hickory (Carya spp.), post oak (Quercus stellata), and blackjack oak (Q. marilandica) dominate the upper slopes while lower slopes support maple (Acer spp.), blue beech (Carpinus caroliniana), hop hornbeam (Ostrya virginaiana), and white oak (Q. alba) (Masters et al. 1989). The oak-shortleaf pine forest is the largest forest cover type in the southeastern United States (Lotan et al. 1978).

The 5,701 ha McCurtain County Wilderness Area (MCWA) is located in the Kiamichi Mountain Range of the Ouachita Highlands of southeast Oklahoma (Figure 1). It is divided into two parts by Broken Bow Reservoir (Mountain Fork River) with most of the area (5,215 ha) on the east side. The area is characterized by steep, narrow ridges generally bearing east to west, with occasional rock outcrops. Elevation varies from 183 m to 415 m. The MCWA is forested with virgin old-growth pine - hardwood forest and is the largest representative tract of its kind (Stahle et al. 1985). Five perennial streams dissect the area, with the largest being North and South Linson Creeks. Annual rainfall averages 121 cm and temperatures range from 34 °C in July to -2 °C in January (Masters et al. 1989).

The MCWA, owned by the Oklahoma Department of Wildlife Conservation (ODWC) since 1918, has been designated as a state wilderness area since 1951. The MCWA contains nearly all of the remaining red-cockaded woodpecker (RCW) populations in Oklahoma. Red-cockaded woodpecker populations have declined precipitously during the last seventeen years (Wood 1977, Masters et al. 1989, Kelly 1993, Masters et al. 1994). Only limited habitat management surrounding red-cockaded woodpecker clusters has occurred on the area and fire has been suppressed (Masters et al. 1994). Fire has been reintroduced in two areas and evidence of some timber theft is apparent near area boundaries.

METHODS

Black and white aerial photographs were obtained from the Unites States Department of Agriculture Aerial Photography Field Office, Salt Lake City, Utah. Photographs were acquired for April, 1955 at a scale of 1:7,920, and for December, 1990 at a scale of 1:3,960. Aerial photographs for both years included all portions of MCWA. Because of inconsistencies in 1955 flight dates, the western portion of MCWA was excluded from the analysis. Regrowth of hardwood foliage made it difficult to distinguish between pines and hardwoods on photos taken in May, 1955 for the portion of the area west of Broken Bow Reservoir, were not interpretable at an equal level of confidence as those taken in April, 1955 for the eastern portion of MCWA. Thus, only the eastern 5200 ha of MCWA were included for analysis (Figure 1).

Vegetation was mapped for both years by placing clear acetate on each photograph and marking boundaries around each cover type. Cover types included the following categories: pine (80 - 100 % pine dominated), hardwood (80-100% hardwood dominated), pine - hardwood (60 - 80% pine dominated), hardwood - pine (60 - 80% hardwood dominated), pine - hardwood, low to medium density (60 - 80% pine dominated, land surface visible), hardwood woodlands (80 - 100% hardwood, low density), glade (80 - 100% grassland), water, and developed/disturbed.

Completed maps were digitized using a digital scanner. Scanned images were edited, rectified, and imported into the GIS GRASS (Geographic Resource Analysis Support System) (Shapiro et al. 1992). Vector maps were then patched together to form complete vegetation layers at a resolution of 8 meters for 1955 and 5 meters for 1990. Limited ground truthing was performed for the 1990 layer using permanent plot data (Masters, unpublished data) at 77 points.

Aerial photography for both years was sampled using 0.18 ha circular plots scaled to each set of photographs to estimate stem density for codominant and dominant shortleaf pine (Pinus echinata). Three north-south transects were placed in each mile section of the area at a random distance from the east section line. Thirty circular samples per 1.6 km^2 (i.e., per section) (600 samples for the entire study area) were taken by four different observers and averaged for each sample. Dominant and codominant shortleaf pine stem density from variable radius plots collected in 1994 were also calculated for comparison with stem density estimated from aerial photos.

Data analysis

Forest landscape analysis was performed using the raster landscape ecological (r.le) spatial analysis package within GRASS (Baker and Cai 1992), which was developed for quantitative analysis of landscape structure. The r.le programs were used to generate landscape measures of patch shape, size, and fractal dimension; diversity measures such as richness, dominance, and Shannon diversity; and texture measures such as contagion and angular second moment.

Patch shape (D) is an index that is used to determine boundary complexity. The smallest possible value for shape is equal to 1 for a perfectly circular patch. The higher the value for patch shape, the more complex the patch boundary. Shape was calculated in the r.le programs with the corrected perimeter area rather than the perimeter/area method. The perimeter/area method for shape is calculated by dividing the length of the patch perimeter by the total patch area. A problem with the ratio of perimeter/area as a shape index is that it varies with the size of the patch. The corrected perimeter area method uses the formula:

$$(0.282 * \text{perimeter}) / \text{area}^{1/2}$$

This index corrects for the size problem presented by the uncorrected perimeter/area method (Baker 1994). Values for patch shape were projected into the past (1920) and into the future (2025) in order to estimate change over a greater time period. Projected values were determined by extrapolating the increment of change between 1955 and 1990 to each value, respectively.

In landscape ecological research, patch shapes are frequently characterized by fractal dimension (Krummel et al. 1987, Milne 1988, Iverson 1989). Fractal dimension (F) was calculated for the entire landscape using the perimeter-area relationship:

$$F = 2 * s$$

where s is the slope of the regression of the patch perimeter versus the log of patch area. The perimeter area method quantifies the degree of complexity of planar shapes. Values for fractal dimension range from 1 to 2, where F = 1 for simple Euclidean shapes (circles and rectangles), and F approaches 2 as polygons become more complex and the patch perimeter becomes increasingly plane filling (Krummel et al. 1987).

Four measures of diversity of patch attributes were calculated for MCWA. Diversity measures included richness, dominance, Shannon's diversity index, inverse Simpson's index (Table 5). Richness is the number of different patch attributes present in the sampling area. Landscape dominance (D) measures cover type dominance or the tendency for one or a few cover types to comprise the majority of the landscape (O'Niell et al. 1988). This index is related to Shannon's index, but emphasizes the deviation from evenness. Large values of D indicate a landscape that is dominated by one or a few cover types represented in approximately equal proportions. Low values of D indicate a landscape that has many cover types represented in approximately equal proportions. Shannon's diversity index (H) combines richness and evenness, where richness refers to the number of patch attributes present in the sampling area, and evenness refers to the distribution of area among different patch types. Richness and evenness are generally referred to as the compositional and structural components of diversity, respectively (McGarigal and Marks 1994). The formula for Shannon's diversity index is:

$$H = \sum_{i=1}^{n} P_i \ln P_i$$

where n is the number of land types or vegetation types observed in the landscape, and P_i is the proportion of a landscape in land use (or vegetation type). The larger the value of H, the more diverse the landscape (O'Neill et al. 1988). Simpson's index, a combination of richness and evenness, is a measure of the probability of encountering two pixels with the same attribute when taking a random sample of two pixels. Specifically, this index represents the probability that any two cover types selected at random would be different types. Thus, the higher the value the greater the likelihood that any two randomly drawn patches would be different patch types (i.e., greater diversity) (McGarigal and Marks 1994).

Two texture measures, contagion and angular second moment, were calculated for MCWA for 1955 and 1896. Texture measures quantify the adjacency of similar patch types. Contagion (C) quantifies the extent to which landscape elements are clumped or aggregated. A landscape in which the patch types are well interspersed will have a lower contagion than a landscape in which cover types are poorly interspersed (McGarigal and Marks 1994). Angular second moment is a measure of homogeneity in the landscape. Larger values for angular second moment indicate more homogeneity (McGarigal and Marks 1994). The r.le programs allow for seven different methods for calculating texture, where each method is defined by the relationship or location of the neighboring pixels. Choices for texture methods include four methods for two neighbor analysis, two methods for four neighbor analysis, and one method for eight neighbor analysis. Each method is useful for different research applications. For this study, all methods were used to calculate contagion and angular second moment, where all seven resulting values were averaged into one final value for the entire area.

Dominant and codominant shortleaf pine samples from aerial photographs were compared for 1955 and 1990. Sample means for stem density of shortleaf pine were compared using a t-test at the 0.05 confidence level to determine if there were differences in dominant and codominant shortleaf pine density between 1955 and 1990. Data were also compared to stem density values derived from variable radius plots sampled in 1994.

RESULTS

Forest cover types were strongly associated with topographic features in both years with pine and pine-hardwood stands on south-facing aspects and hardwood and hardwood-pine stands on north-facing aspects and drainages (Figures 2 and 3). Total area for all cover types changed between 1955 and 1990 (Table 1). Change was greatest for hardwood woodlands and developed/disturbed areas, neither of which were observed on the 1990 photography. Total area for pure hardwood stands increased nearly nine-fold, and mixed hardwood-pine stands increased by over two times its total area in 1955. Considerable change was also observed for pure pine, which decreased in total area by 52 percent, and for medium density pine-hardwood stands, which increased by 38 percent. Mixed pine-hardwood stands decreased by 28 percent.

Patch Attributes

Mean patch shape for the entire MCWA decreased by nearly 6 percent between 1955 and 1990 (Table 2). Of the cover types sampled for MCWA in 1955 and 1990, the most complex shapes, or patches with highest shape value (D), were cover types classified as water, where D = 14.62 and 14.00 respectively. For vegetative patches, the highest values for D were those found for hardwood woodlands in 1955 and for open pine-hardwood stands in 1990 (Table 2). The lowest values for D, or the most circular cover types, were those found for glades in 1955 and pine in 1990.

Between 1955 and 1990, several cover types showed considerable change in patch shape. Hardwood woodlands and developed/disturbed cover types were not observed in the analysis region in 1990, thus resulting in a value of 0 for those cover types. Many cover types such as roads and fire guards were not observed on the 1990 photographs because many of these areas had regrown or were obscured by tree canopy closure. Because 0 is not a valid value for D, shape of these cover types is not comparable. Hardwood patches decreased in boundary complexity from 1955 to 1990 by 21 percent. Results indicated that D also declined by 12 percent for pure pine stands, respectively. Hardwood-pine patches and open pine-hardwood stands both increased by approximately 8 percent (Table 2). Cover types showing less change over time were glades (-4 percent), water (-4 percent), and pine hardwood (0 percent). Fractal dimension (F) changed 8.7 percent from 1.38 in 1955 to 1.26 in 1990.

By considering patch shape values as indicators of directional change in patch shape over time, patch shapes were extrapolated 35 years into the past and future to show how shape may have changed over a longer time period (Table 3). Consideration of change in patch shape at a time scale more suitable to that of forest dynamics is helpful in determining how the study area may have been in the past and what it may become in the future.

Mean patch size for the entire MCWA increased by approximately 84 percent since 1955. Cover types such as water and hardwood-pine increased by more than 300 percent. Pine-hardwood and open pine-hardwood stands increased in mean patch size by approximately 150 percent (Table 4). Cover types that showed a decrease in mean patch size were pure pine and pure hardwood cover types, both decreasing by 40 to 50 percent. Because hardwood woodland was not observed in 1990, mean patch size resulted in a decrease of 100 percent (Table 4).

Results indicated that richness decreased by 22 percent between 1955 and 1990, and dominance increased by 45 percent, respectively. Diversity analysis indicated that

Shannon's diversity index decreased by 23 percent, respectively, while Inverse Simpson's index increased by 3 percent, respectively. Two texture measures, contagion and angular second moment, were calculated for MCWA for 1955 and 1990. The average value for contagion in 1955 was 2.17. Contagion increased by 9 percent in 1990 to 2.36. The average value for angular second moment was 0.18 in 1955 and 0.23 in 1990, resulting in an increase of 28 percent.

Shortleaf pine density

The stem density of dominant and codominant shortleaf pine increased (P = 0.0001) from 1955 to 1990. Stem density of pine in 1955 was 72.6 stems/ha (S.E. = 1.5) in 1955, and 93.3 stems/ha (S.E. = 1.7) in 1990. Stem density from only dominant and codominant shortleaf pine from variable radius plots in 1994 was 118.8 stems/ha (Kreiter 1995).

DISCUSSION

Change in landscape measures such as patch shape, patch size, diversity, and texture clearly indicate that rapid change in landscape pattern and structure has occurred on MCWA since 1955. Frequent fire has occurred on MCWA at least since 1800, but has greatly diminished in extent and frequency since 1956 (Masters et al. 1994). Comparisons of landscape indices over relatively short periods of time often make it difficult to determine the cause of change in landscape structure. However, several sources of evidence such as the abrupt change in the natural disturbance regime in 1956, agreement between codominant and dominant shortleaf pine samples in 1990 and 1994, complimentary results of landscape indices, and changes from 1896 - 1994 at General Land Office survey points (Kreiter 1995), indicate that the detected changes may be representative of the dynamics of MCWA landscape since 1955.

This evidence, however, does not rule out subsequent error from comparison of various scales of photography, error in photointerpretation, as well as the inherent error in GIS technology. More accurate conclusions could possibly be drawn if additional samples were taken from another point in time either between 1955 and 1990 or prior to 1955. Since photography prior to 1955 is not available for the area, it may be useful to do an additional landscape analysis including a time between 1955 and 1990 in order to more accurately depict landscape change through time.

The mean patch shape index for all patches was greater than 1 indicating that the average patch shape was non-circular. Mean patch shape decreased by six percent between 1955 and 1990. Although this was not a large change, this suggests that the average patch had a slightly more complex shape in 1955 than in 1990. Patch shape can be an indicator of whether a patch is expanding or contracting. Patches with complex boundaries composed of a series of convexities and concavities accelerate succession, increase patchiness of woody plants, expand the area of edge, and increase landscape diversity (Hardt and Forman 1989, Forman and Godron 1986).

Hardwood woodland changed the most since 1955 because it was not observed in 1990. This cover type likely succeeded to a hardwood or hardwood and pine mixture. Other cover types that changed considerably were pure pine and pure hardwood stands, both of which decreased in patch complexity. Mixed hardwood and pine stands increased in complexity. This may indicate that the landscape is moving toward a more homogeneous pine and hardwood mix. Boundary complexity was much higher for water than for other cover types because of the long and narrow nature of streams on MCWA. Change observed for water is most likely a result of the development of Broken Bow Reservoir in 1965, which enters the southeast corner of the study area. Fractal dimension decreased by nearly 9 percent since 1955. This change in fractal dimension (F) is complimentary to the change in mean patch shape (D) suggesting that patches have become somewhat less complex over the last 35 years.

Patch size

Mean patch size on MCWA increased nearly two fold between 1955 and 1990. A larger overall mean patch size indicates a more homogeneous landscape. All mixed hardwood and pine stands increased in mean patch size by an average of 200 percent, while pure pine and pure hardwood stands decreased in mean patch size by 50 percent. This is consistent with the change in patch shape, which indicated that the landscape is moving toward a more homogeneous mixed pine and hardwood dominated landscape.

Diversity indices

Richness is simply the number of different patch attributes present in the sampling area. The MCWA had a total of 9 attributes in 1955 and 7 attributes in 1990. This change occurred because of elimination of the developed/disturbed cover type and the hardwood woodland cover type. The developed/disturbed cover type existed in 1955 because of the fence and fire guard that were constructed in the late 1940's around the outer boundary of MCWA. This path cut around the boundary was still very visible on the 1955 photography (Figure 1), but has since grown in. Thus, these areas were mapped as undisturbed cover types.

Hardwood woodland was also not observed in 1990. Large portions of the area in 1955 were covered with low density hardwood stands. These areas have since succeeded to dense hardwood or dense mixed hardwood and pine stands. Disregarding hardwood woodland, cover types remained relatively the same for 1955 and 1990.

Shannon's diversity index (H) combines richness and evenness, where richness refers to the number of patch attributes present in the sampling area, and evenness refers to the distribution of area among different patch types. The larger the value of H, the more diverse the landscape (O'Neill et al. 1988). Shannon's index decreased by 23 percent between 1955 and 1990. This indicates that MCWA was more diverse in 1955 than it was in 1990.

Simpson's index is a measure of the probability of encountering two pixels with the same attribute when taking a random sample of two pixels. A higher value for Simpsons index indicates greater diversity. Inverse Simpson's only increased slightly since 1955 (3 percent). This indicates that the area is slightly more diverse. However, such a small change may also be a function of error or scale differences.

Landscape dominance (D) measures cover type dominance or the tendency for one or a few cover types to comprise the majority of the landscape (O'Niell et al. 1988). This index is related to Shannon's index, but emphasizes the deviation from evenness. Large values of D indicate a landscape that is dominated by one or a few cover types represented in approximately equal proportions. Low values of D indicate a landscape that has many cover types represented in approximately equal proportions. This analysis showed a 45 percent higher dominance value in 1990 than 1955, indicating that MCWA in 1955 was somewhat more diverse in 1990. In other words, the cover types in the 1955 MCWA landscape were more evenly proportioned than in 1990.

Considering all of the diversity measures as a whole, trends for each measure suggest that MCWA has become less diverse since 1955. Since 1955 there has been a decrease in landscape richness and Shannon diversity, and an increase in Simpson's index and in dominance. All of these changes point to a higher level of diversity in 1955 than in 1990.

Texture

Contagion (C) quantifies the extent to which landscape elements are clumped or aggregated. Higher values of contagion may result from landscapes with a few large, contiguous patches, whereas lower values generally characterize landscapes with many small and dispersed patches. Therefore, a landscape consisting of patch types that are aggregated into larger, contiguous patches will have a greater contagion than a landscape with many small fragmented patches (McGarigal and Marks 1994). Contagion increased between 1955 and 1990 by 8 percent. This increase suggests that cover types were somewhat more interspersed in 1955 than in 1990. Frequent disturbance in a landscape would likely increase patchiness in a landscape, thus decreasing contagion.

Angular second moment is a measure of homogeneity in the landscape. Larger values for angular second moment indicate more homogeneity. Angular second moment increased by 28 percent between 1955 and 1990. This change suggests that MCWA landscape has become less heterogeneous since 1955. Landscapes frequently affected by natural disturbance are known to be more heterogeneous (Foreman and Godron 1986, Pickett and White 1985). Suppression of fire on MCWA would likely result in an a temporal increase in homogeneity. Considering texture measures for MCWA as a whole, results for contagion and angular second moment suggest that the area has become more homogeneous since 1955. Absence of natural disturbance such as fire would likely result in a landscape that is more homogeneous.

Management implications

O'Neill et al. (1986) stressed the importance of viewing the world in the space and time scale at which it responds rather than the space and time frame in which humans operate. Forest landscape processes are generally thought to occur over long periods of time. Because of constraints presented by lack of time, money, and data availability, sampling strategies are often not derived from preliminary studies of the landscape of interest (Cullinan and Thomas 1992). This study is based on results derived from data covering a time period of 35 years. Thus, it is difficult to determine whether observed changes on MCWA were simply short term fluctuations in the natural dynamics of the system, or were a result of alteration of the natural disturbance regime. To the contrary, such change detected over a short term indicates that forests may experience rapid change over relatively little time. Cause of such change can likely be attributed change in climate or in the disturbance regime. Stahle et al. (1985) suggested that climate had not changed recently on MCWA. Previous studies, (e.g., Foti and Glenn 1991, Masters et al. 1994, Kreiter 1995), however, strongly support the presumption that rapid change is a result of the exclusion of fire.

A critical question to ask when setting goals for MCWA in relation to landscape pattern is whether the current conditions of the area are more or less diverse today than 100 years ago before fire suppression began to alter landscape pattern. This study, as well as others, (e.g. Foti and Glenn 1991, Masters et. al. 1994, Kreiter 1995) describe landscape patterns much different from those occurring before effective fire suppression. Results from this study indicate that MCWA is becoming a less diverse and more homogeneous landscape. Species compositions are tending toward a pine and hardwood mixture, where stands of pure pine and pure hardwood are diminishing. This is consistent with studies that have shown that that fire suppression has led to the development of dense midstories and in some instances replacement of predominantly pine forests with hardwood forests (Bruner 1931, Guldin 1986, Cain 1987).

Although dominant and codominant shortleaf pine density has increased since 1955, very little shortleaf pine recruitment is evident on MCWA (Kreiter 1995). This suggests that shortleaf pine populations on MCWA have reached a critical successional stage, where most of the population are mature or have moved into the canopy. With a current estimated annual mortality rate of 3.4 to 5.8 percent (Masters et al. 1989) and an increase in hadwood density (Kreiter 1995) shortleaf pine could potentialy begin to decline at an increasingly higher rate. Although there will always be a significant shortleaf pine component on MCWA, the development of a relatively old population may result in a decrease in total numbers as older members die and are replaced by more shade tolerant hardwood species.

Examination of such change in vegetation pattern can allow for assessment of risk to wildlife that may be sensitive to habitat fragmentation (Jurgensen 1993). Rare and sensitive species will likely be susceptible to fragmentation by loss of habitat, as well as from isolation of constituents of the population when habitats become fragmented (Lehmkuhl et al. 1993). Changes in habitat can be expected to affect species that depend on those habitats. Replacement of early successional species such as shortleaf pine, with more shade tolerant species such as white oak (Quercus alba) and mockernut hickory (Carya tomentosa) (e.g. Kreiter 1995) may affect species such as the red-cockaded woodpecker, which is associated with such habitats. Changes in landscape indices such as patch shape and size for pure shortleaf pine stands reflect the decline of sensitive species such as that of the red-cockaded woodpecker.

Restoration of MCWA presettlement landscape should focus on reconstruction of landscape patterns found before supression of fire. This could best be accomplished by reintroduction of the natural disturbance regimes. When disturbance size and frequency are eliminated, forest change on the landscape may occur immediately (shape, Shannon diversity, richness), may occur over several decades (fractal dimension), or over several hundred years (size, angular second moment). In contrast, when disturbance size decreases and frequency increases (prescribed fire) more landscape measures respond immediately (shape, Shannon diversity, richness, angular second moment), but there is little effect on other measures such as size and fractal dimension (Baker 1992).

Landscape managers must continue to develop plans to approximate natural processes. Based on previous studies (Masters et al 1994, Wilson 1994) fire intensity and frequency should likely be increased in order to mimic the anthropogenic and lightning-caused fire regime that historically shaped the system. More importantly, however, managers must become more knowledgeable of the ecological effects of natural disturbances such as fire. This study is one of the first attempts at such an assessment and it describes the potential for rapid change in forest landscape pattern. Future research needs to be done to assess different landscape management configurations and desired future conditions for MCWA. Additional research also should be done to determine how changes in landscape pattern have affected the potential spread of fire, insects, and disease across the system.

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Table 1. Total area in hectares for all cover types on McCurtain County Wilderness Area, Oklahoma for years 1955 and 1990. Totals based on GIS/GRASS vegetation layers derived from aerial photography.

	Year		
Patch type	1955 (ha)	1990 (ha)	% Change
Pine	159	77	-52
Hardwood	168	1473	+777
Pine-hardwood	1477	1064	-28
Hardwood-pine	943	2019	+114
Pine-hardwood open	556	768	+38
Hardwood woodland	476	0	-100
Developed/disturbed	81	0	-100
Water	56	89	+59

Table 2. Mean patch shape (D), standard deviation (SD), and percent change for 1955 and 1990 cover types on the McCurtain County Wilderness Area, Oklahoma. Shape indices calculated with GRASS4.0/raster landscape ecological programs. D = (0.282 * perimeter) / (area).

	Year				
	1955		1990		
Patch Type	D	SD	D	SD	% Change
Pine	2.00	0.78	1.75	0.42	-12.50
Hardwood	2.66	2.75	2.10	1.13	-21.05
Pine-hardwood	2.10	1.07	2.11	0.87	+0.48
Hardwood-pine	2.08	0.91	2.27	1.46	+9.13
Pine-hardwood open	2.14	0.86	2.31	1.00	+7.94
Hardwood woodland	3.07	1.79	0.00	0.00	N/A
Glade	1.90	0.64	1.83	0.43	-3.68
Water	14.62	9.58	14.00	8.54	-4.24
Developed/Disturbed	3.82	3.21	0.00	0.00	N/A
Entire landscape	2.38	2.28	2.24	1.716	-5.88

Table 3. Projected mean patch shape (D) for 1955 and 1990 cover types on the McCurtain County Wilderness Area, Oklahoma. Shape indices calculated with GRASS4.0/raster landscape ecological programs. D = (0.282 * perimeter) / (area).

	Year			
Patch Type	1920	1955	1990	2025
Pine	2.25	2.00	1.75	1.50
Hardwood	3.22	2.66	2.10	1.54
Pine-hardwood	2.09	2.10	2.11	2.12
Hardwood-pine	1.89	2.08	2.27	2.46
Pine-hardwood open	1.97	2.14	2.31	2.48
Hardwood woodland	6.14	3.07	0.00	0.00
Glade	1.97	1.90	1.83	1.76
Water	15.24	14.62	14.00	13.38
Developed/Disturbed	7.64	3.82	0.00	0.00
Entire landscape	2.52	2.38	2.24	2.10

Table 4. Mean patch size (S) in pixels, standard deviation (SD) and percent change for 1955 and 1990 cover types on the McCurtain County Wilderness Area, Oklahoma. Size indices calculated with GRASS4.0/raster landscape ecological programs.

	Year				
	1955		1990		
Patch Type	S	SD	S	SD	% Change
Pine	408.36	738.26	202.25	417.05	-50.47
Hardwood	1708.28	8720.05	948.85	4760.35	-44.46
Pine-hardwood	585.92	2505.70	1437.21	4592.30	+145.29
Hardwood-pine	488.04	1745.66	2013.55	7548.29	+312.58
Pine-hardwood open	469.74	1348.58	1275.49	2525.24	+171.53
Hardwood woodland	1180.78	2612.43	0.00	0.00	-100.00
Glade	134.02	297.67	159.13	373.76	+18.74
Water	516.71	709.39	2541.64	5050.59	+391.89
Developed/Disturbed	1271.40	2707.14	0.00	0.00	-100.00
Entire landscape	672.71	3559.70	1236.02	5058.56	+83.74

Table 5. Diversity measures and percent change for 1955 and 1990 cover types on the McCurtain County Wilderness Area, Oklahoma. Diversity indices calculated with GRASS4.0/raster landscape ecological programs.

	Year		
Measure	1955	1990	% Change
Richnes	9.00	7.00	-22.22
Shannon diversity	1.57	1.21	-22.93
Dominance	0.51	0.74	+45.10
Inverse Simpson's	3.79	3.89	+2.64

Figure 1. McCurtain County Wilderness Area, Oklahoma. Cross-hatched portion of area not included in analysis region because of inconsistencies in 1955 aerial photography flight dates.

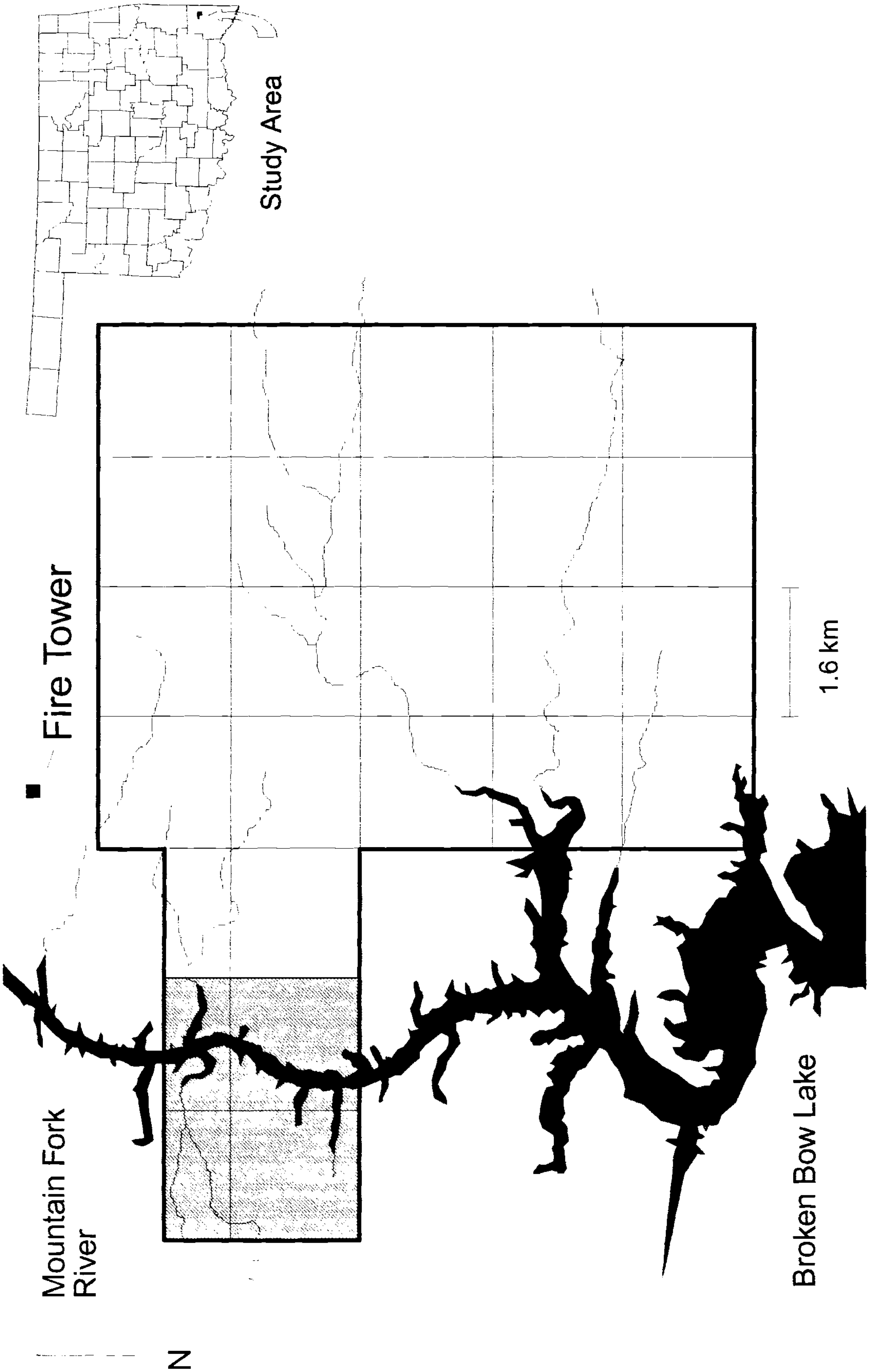
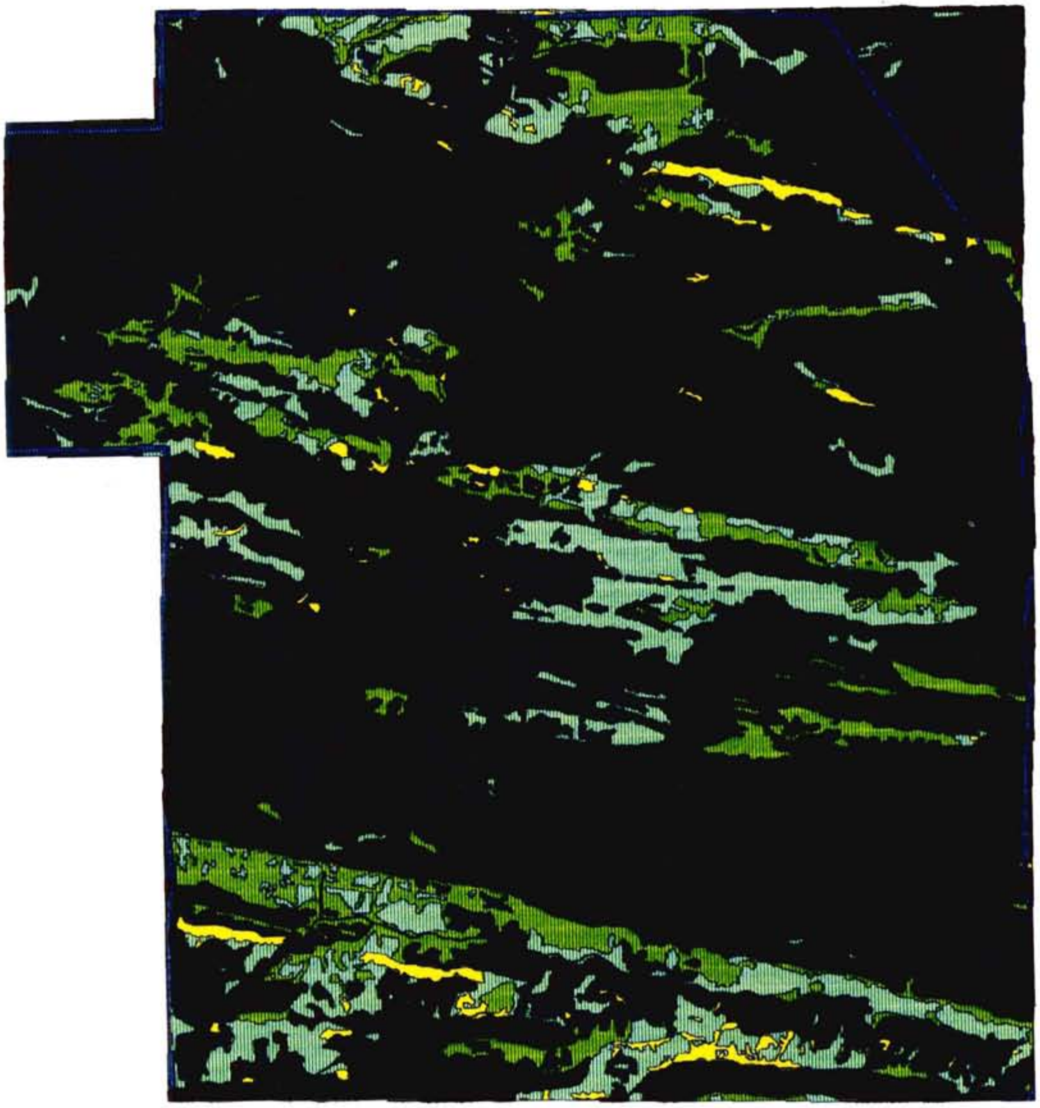

Study Area
Fire Tower
1.6 km
Mountain Fork River
Broken Bow Lake
N

Figure 2. Vegetation map for the McCurtain County Wilderness Area, Oklahoma, April, 1955. Vegetation map derived from 1:7,920 scale balck and white aerial photography. Cover types derived using the following criteria: pine (80 - 100 % pine dominated), hardwood (80-100% hardwood dominated), pine - hardwood (60 - 80% pine dominated), hardwood - pine (60 - 80% hardwood dominated), pine - hardwood, low to medium density (60 - 80% pine dominated, land surface visible), hardwood woodland (80 - 100% hardwood, low density), glade (80 - 100% grassland), water, and developed/disturbed.

MCWA VEGETATION 1955

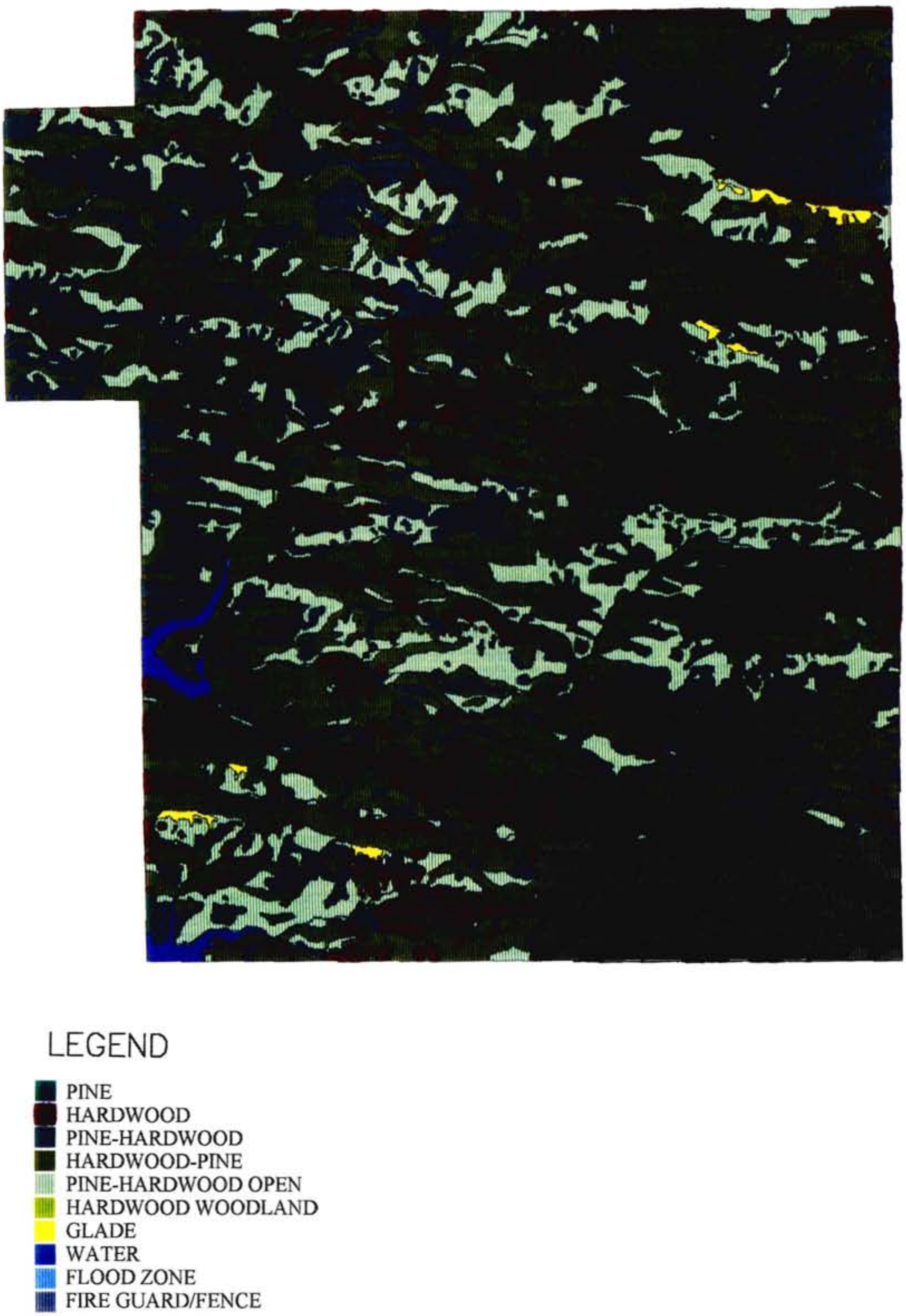


LEGEND

- PINE
- HARDWOOD
- PINE-HARDWOOD
- HARDWOOD-PINE
- PINE-HARDWOOD OPEN
- HARDWOOD WOODLAND
- GLADE
- WATER
- FLOOD ZONE
- FIRE GUARD/FENCE

Figure 3. Vegetation map for the McCurtain County Wilderness Area, Oklahoma, April, 1990. Vegetation map derived from 1:3,960 scale black and white aerial photography. Cover types derived using the following criteria: pine (80 - 100 % pine dominated), hardwood (80-100% hardwood dominated), pine - hardwood (60 - 80% pine dominated), hardwood - pine (60 - 80% hardwood dominated), pine - hardwood, low to medium density (60 - 80% pine dominated, land surface visible), hardwood woodland (80 - 100% hardwood, low density), glade (80 - 100% grassland), water, and developed/disturbed.

MCWA VEGETATION 1990



APPENDIX

Table 1. Black oak (Quercus velutina) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	108118			0		
(1) 0-9 degrees	33209	46.0	10.1	8	0.443	1
(2) 10-18 degrees	28564	39.5	8.7	7	0.332	1
(3) 19-27 degrees	9469	13.1	2.9	7	5.873	1
(4) 28-36 degrees	929	1.3	0.3	0	0.283	1
(5) 37-45 degrees	53	0.1	0.0	0	0.016	1
Totals	72224	100.0	22.0	22	6.947	4

Table 2. Black oak (Quercus velutina) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	106796			0		
(1) north aspect	3742	18.7	4.1	6	0.868	1
(2) northeast aspect	7202	9.8	2.2	6	6.865	1
(3) east aspect	5454	7.4	1.6	0	1.631	1
(4) southeast aspect	7109	9.7	2.1	3	0.359	1
(5) south aspect	12854	7.5	3.8	1	2.105	1
(6) southwest aspect	10123	13.8	3.0	1	1.358	1
(7) west aspect	7209	9.8	2.2	3	0.330	1
(8) northwest aspect	8172	1.1	2.4	2	0.081	1
(9) no aspect (flat)	1681	2.3	0.5	0	0.503	1
Totals	73546	100.0	22.0	22	14.100	8

Table 3. Black oak (Quercus velutina) observed versus expected occurrence by slope (degrees) and aspect on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	108118			0		
(1) 0-9 degrees			0.1	0	0.112	1
(2) 0-9 degrees; northeast	3216	4.5	1.0	3	4.167	1
(3) 0-9 degrees; east	2961	4.1	0.9	0	0.902	1
(4) 0-9 degrees; southeast	3831	5.3	1.2	0	1.167	1
(5) 0-9 degrees; south	4305	6.0	1.3	0	1.311	1
(6) 0-9 degrees; southwest	4639	6.4	1.4	0	1.413	1
(7) 0-9 degrees; west	4295	5.9	1.3	3	2.187	1
(8) 0-9 degrees; northwest	4105	5.7	1.3	1	0.050	1
(9) 0-9 degrees; no	1623	2.2	0.5	0	0.494	1
(10) 10-18 degrees; north	6575	9.1	2.0	1	0.502	1
(11) 10-18 degrees; northeast	3003	4.2	0.9	3	4.754	1
(12) 10-18 degrees; east	2025	2.8	0.6	0	0.617	1
(13) 10-18 degrees; southeast	2503	3.5	0.8	1	0.074	1
(14) 10-18 degrees; south	5367	7.4	1.6	0	1.635	1
(15) 10-18 degrees; southwest	3674	5.1	1.1	1	0.013	1
(16) 10-18 degrees; west	2302	3.2	0.7	0	0.701	1
(17) 10-18 degrees; northwest	3115	4.3	0.9	1	0.003	1
(18) 19-27 degrees; north	2551	3.5	0.8	4	13.368	1
(19) 19-27 degrees; northeast	800	1.1	0.2	0	0.244	1
(20) 19-27 degrees; east	367	0.5	0.1	0	0.112	1
(21) 19-27 degrees; southeast	626	0.9	0.2	2	17.168	1
(22) 19-27 degrees; south	2468	3.4	0.8	1	0.082	1

Table 3 (cont.)

(23) 19-27 degrees; southwest	1459	2.0	0.4	0	0.444	1
(24) 19-27 degrees; west	438	0.6	0.1	0	0.133	1
(25) 19-27 degrees; northwest	760	1.1	0.2	0	0.232	1
(26) 28-36 degrees; north	100	0.1	0.0	0	0.030	1
(27) 28-36 degrees; northeast	35	0.0	0.0	0	0.011	1
(28) 28-36 degrees; east	29	0.0	0.0	0	0.009	1
(29) 28-36 degrees; southeast	34	0.0	0.0	0	0.010	1
(30) 28-36 degrees; south	460	0.6	0.1	0	0.140	1
(31) 28-36 degrees; southwest	149	0.2	0.0	0	0.045	1
(32) 28-36 degrees; west	45	0.1	0.0	0	0.014	1
(33) 28-36 degrees; northwest	77	0.1	0.0	0	0.023	1
(34) 37-45 degrees; north	31	0.0	0.0	0	0.009	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.003	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.002	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.002	1
Totals	72224	100.0	22.0	22	52.137	36

Table 4. Black oak (Quercus velutina) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, Fall 1896

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees	31599	44.8	10.6	13	1.009	1
(2) 10-18 degrees	28530	40.4	9.1	9	0.001	1
(3) 19-27 degrees	9466	13.4	3.0	0	3.015	1
(4) 28-36 degrees	929	1.3	0.3	0	0.296	1
(5) 37-45 degrees	53	0.1	0.0	0	0.017	1
Totals	70577	100.0	23.0	23	4.438	4

Table 5. Black oak (Quercus velutina) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	108504			0		
(1) north aspect	13729	19.1	4.3	5	0.151	1
(2) northeast aspect	7182	10.0	2.2	1	0.654	1
(3) east aspect	5425	7.6	1.7	5	6.709	1
(4) southeast aspect	7069	9.8	2.2	3	0.322	1
(5) south aspect	12846	17.9	3.9	4	0.001	1
(6) southwest aspect	10088	14.0	3.1	1	1.413	1
(7) west aspect	7180	10.0	2.2	2	0.018	1
(8) northwest aspect	8133	11.3	2.5	0	2.491	1
(9) no aspect (flat)	186	0.3	0.1	2	18.613	1
Totals	71838	100.0	23.0	23	30.372	8

Table 6. Black oak (Quercus velutina) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees; north	4225	6.0	1.3	5	10.300	1
(2) 0-9 degrees; northeast	3202	4.5	1.0	1	0.000	1
(3) 0-9 degrees; east	2945	4.2	0.9	4	10.347	1
(4) 0-9 degrees; southeast	3793	5.4	1.2	2	0.565	1
(5) 0-9 degrees; south	4301	6.1	1.3	0	1.341	1
(6) 0-9 degrees; southwest	4608	6.5	1.4	0	1.436	1
(7) 0-9 degrees; west	4272	6.1	1.3	0	1.332	1
(8) 0-9 degrees; northwest	4077	5.8	1.3	0	1.271	1
(9) 0-9 degrees; no	176	0.2	0.1	2	4.256	1
(10) 10-18 degrees; north	6574	9.3	2.0	0	2.049	1
(11) 10-18 degrees; northeast	3000	4.3	0.9	0	0.935	1
(12) 10-18 degrees; east	2014	2.9	0.6	1	0.221	1
(13) 10-18 degrees; southeast	2501	3.5	0.8	1	0.062	1
(14) 10-18 degrees; south	5365	7.6	1.7	4	3.240	1
(15) 10-18 degrees; southwest	3671	5.2	1.1	1	0.018	1
(16) 10-18 degrees; west	2298	3.3	0.7	2	2.300	1
(17) 10-18 degrees; northwest	3107	4.4	1.0	0	0.969	1
(18) 19-27 degrees; north	2551	3.6	0.8	0	0.795	1
(19) 19-27 degrees; northeast	799	1.1	0.2	0	0.249	1
(20) 19-27 degrees; east	366	0.5	0.1	0	0.114	1
(21) 19-27 degrees; southeast	626	0.9	0.2	0	0.195	1
(22) 19-27 degrees; south	2468	3.5	0.8	0	0.769	1

Table 6 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	0.5	0	0.455	1
(24) 19-27 degrees; west	438	0.6	0.1	0	0.137	1
(25) 19-27 degrees; northwest	759	1.1	0.2	0	0.237	1
(26) 28-36 degrees; north	100	0.1	0.0	0	0.031	1
(27) 28-36 degrees; northeast	35	0.0	0.0	0	0.011	1
(28) 28-36 degrees; east	29	0.0	0.0	0	0.009	1
(29) 28-36 degrees; southeast	34	0.0	0.0	0	0.011	1
(30) 28-36 degrees; south	460	0.7	0.1	0	0.143	1
(31) 28-36 degrees; southwest	149	0.2	0.0	0	0.046	1
(32) 28-36 degrees; west	45	0.1	0.0	0	0.014	1
(33) 28-36 degrees; northwest	77	0.1	0.0	0	0.024	1
(34) 37-45 degrees; north	31	0.0	0.0	0	0.010	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.003	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.002	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.002	1
Totals	70577	100.0	23.0	23	43.925	36

Table 7. Hickory (Carya spp.) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees	31599	44.8	27.3	23	0.681	1
(2) 10-18 degrees	28530	40.4	24.7	18	1.798	1
(3) 19-27 degrees	9466	13.4	8.2	17	9.505	1
(4) 28-36 degrees	929	1.3	0.8	3	6.012	1
(5) 37-45 degrees	53	0.1	0.0	0	0.046	1
Totals	70577	100.0	61.0	61	18.041	4

Table 8. Hickory (Carya spp.) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	108504			0		
(1) north aspect	13729	19.1	11.7	10	0.236	1
(2) northeast aspect	7182	10.0	6.1	5	0.198	1
(3) east aspect	5425	7.6	4.6	7	1.244	1
(4) southeast aspect	7069	9.8	6.0	5	0.167	1
(5) south aspect	10088	14.0	8.6	7	0.286	1
(7) west aspect	7180	10.0	6.1	6	0.002	1
(8) northwest aspect	8133	11.3	6.9	4	1.223	1
(9) no aspect (flat)	186	0.3	0.2	0	0.158	1
Totals	71838	100.0	61.0	61	6.916	8

Table 9. Hickory (Carya spp.) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees; north	4225	6.0	3.7	3	0.116	1
(2) 0-9 degrees; northeast	3202	4.5	2.8	2	0.213	1
(3) 0-9 degrees; east	2945	4.2	2.5	2	0.117	1
(4) 0-9 degrees; southeast	3793	5.4	3.3	3	0.024	1
(5) 0-9 degrees; south	4301	6.1	3.7	3	0.138	1
(6) 0-9 degrees; southwest	4608	6.5	4.0	0	3.983	1
(7) 0-9 degrees; west	4272	6.1	3.7	6	1.442	1
(8) 0-9 degrees; northwest	4077	5.8	3.5	4	0.064	1
(9) 0-9 degrees; no	176	0.2	0.2	0	0.152	1
(10) 10-18 degrees; north	6574	9.3	5.7	2	2.386	1
(11) 10-18 degrees; northeast	3000	4.3	2.6	3	0.064	1
(12) 10-18 degrees; east	2014	2.9	1.7	4	2.932	1
(13) 10-18 degrees; southeast	2501	3.5	2.2	2	0.012	1
(14) 10-18 degrees; south	5365	7.6	4.6	3	0.578	1
(15) 10-18 degrees; southwest	3671	5.2	3.2	4	0.216	1
(16) 10-18 degrees; west	2298	3.3	2.0	0	1.98	1
(17) 10-18 degrees; northwest	3107	4.4	2.7	0	2.685	1
(18) 19-27 degrees; north	2551	3.6	2.2	5	3.544	1
(19) 19-27 degrees; northeast	799	1.1	0.7	0	0.691	1
(20) 19-27 degrees; east	366	0.5	0.3	1	1.478	1
(21) 19-27 degrees; southeast	626	0.9	0.5	0	0.541	1
(22) 19-27 degrees; south	2468	3.5	2.1	9	22.106	1

Table 9 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	1.3	2	0.433	1
(24) 19-27 degrees; west	438	0.6	0.4	0	0.379	1
(25) 19-27 degrees; northwest	759	1.1	0.7	0	0.656	1
(26) 28-36 degrees; north	100	0.1	0.1	0	0.086	1
(27) 28-36 degrees; northeast	35	0.0	0.0	0	0.030	1
(28) 28-36 degrees; east	29	0.0	0.0	0	0.025	1
(29) 28-36 degrees; southeast	34	0.0	0.0	0	0.029	1
(30) 28-36 degrees; south	460	0.7	0.4	2	6.458	1
(31) 28-36 degrees; southwest	149	0.2	0.1	1	5.894	1
(32) 28-36 degrees; west	45	0.1	0.0	0	0.039	1
(33) 28-36 degrees; northwest	77	0.1	0.1	0	0.067	1
(34) 37-45 degrees; north	31	0.0	0.0	0	0.027	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.010	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.005	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.004	1
Totals	70577	100.0	61.0	61	59.610	36

Table 10. Hickory (Carya spp.) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees	31599	44.8	3.2	2	0.461	1
(2) 10-18 degrees	28530	40.4	2.8	4	0.548	1
(3) 19-27 degrees	9466	13.4	0.9	1	0.007	1
(4) 28-36 degrees	929	1.3	0.1	0	0.090	1
(5) 37-45 degrees	53	0.1	0.0	0	0.005	1
Totals	70577	100.0	7.0	7	1.112	4

Table 11. Hickory (Carya spp.) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	108504			0		
(1) north aspect	13729	19.1	1.3	2	0.367	1
(2) northeast aspect	7182	10.0	0.7	1	0.129	1
(3) east aspect	5425	7.6	0.5	0	0.529	1
(4) southeast aspect	7069	9.8	0.7	0	0.689	1
(5) south aspect	12846	17.9	1.3	2	0.447	1
(6) southwest aspect	10088	14.0	1.0	0	0.983	1
(7) west aspect	7180	10.0	0.7	1	0.144	1
(8) northwest aspect	8133	11.3	0.8	1	0.054	1
(9) no aspect (flat)	186	0.3	0.0	0	0.018	1
Totals	71838	100.0	7.0	7	3.532	8

Table 12. Hickory (Carya spp.) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees; north	4225	6.0	0.4	1	0.805	1
(2) 0-9 degrees; northeast	3202	4.5	0.3	0	0.318	1
(3) 0-9 degrees; east	2945	4.2	0.3	0	0.292	1
(4) 0-9 degrees; southeast	3793	5.4	0.4	0	0.376	1
(5) 0-9 degrees; south	4301	6.1	0.4	0	0.427	1
(6) 0-9 degrees; southwest	4608	6.5	0.5	0	0.457	1
(7) 0-9 degrees; west	4272	6.1	0.4	1	0.424	1
(8) 0-9 degrees; northwest	4077	5.8	0.4	0	0.404	1
(9) 0-9 degrees; no	176	0.2	0.0	0	0.017	1
(10) 10-18 degrees; north	6574	9.3	0.7	1	0.18	1
(11) 10-18 degrees; northeast	3000	4.3	0.3	0	0.298	1
(13) 10-18 degrees; southeast	2501	3.5	0.2	0	0.248	1
(14) 10-18 degrees; south	5365	7.6	0.5	2	4.049	1
(15) 10-18 degrees; southwest	3671	5.2	0.4	0	0.364	1
(16) 10-18 degrees; west	2298	3.3	0.2	0	0.228	1
(17) 10-18 degrees; northwest	3107	4.4	0.3	1	1.533	1
(18) 19-27 degrees; north	2551	3.6	0.3	0	1.289	1
(19) 19-27 degrees; northeast	799	1.1	0.1	1	10.698	1
(20) 19-27 degrees; east	366	0.5	0.0	0	0.036	1
(21) 19-27 degrees; southeast	626	0.9	0.1	0	0.062	1
(22) 19-27 degrees; south	2468	3.5	0.2	0	0.245	1

Table 12 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	0.1	0	0.145	1
(24) 19-27 degrees; west	438	0.6	0.0	0	0.043	1
(25) 19-27 degrees; northwest	759	1.1	0.1	0	0.075	1
(26) 28-36 degrees; north	100	0.1	0.0	0	0.010	1
(27) 28-36 degrees; northeast	35	0.0	0.0	0	0.003	1
(28) 28-36 degrees; east	29	0.0	0.0	0	0.003	1
(29) 28-36 degrees; southeast	34	0.0	0.0	0	0.003	1
(30) 28-36 degrees; south	460	0.7	0.0	0	0.046	1
(31) 28-36 degrees; southwest	149	0.2	0.0	0	0.015	1
(32) 28-36 degrees; west	45	0.1	0.0	0	0.004	1
(33) 28-36 degrees; northwest	77	0.1	0.0	0	0.008	1
(34) 37-45 degrees; north	31	0.0	0.0	0	0.003	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.001	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.001	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.000	1
Totals	70577	100.0	7.0	7	24.253	36

Table 13. Northern red oak (Quercus rubra) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees	31599	44.8	16.1	2	12.366	1
(2) 10-18 degrees	28530	40.4	14.6	20	2.039	1
(3) 19-27 degrees	9466	13.4	4.8	14	17.421	1
(4) 28-36 degrees	929	1.3	0.5	0	0.474	1
(5) 37-45 degrees	53	0.1	0.0	0	0.027	1
Totals	70577	100.0	36.0	36	32.328	4

Table 14. Northern red oak (Quercus rubra) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	116490		0			
(1) north aspect	13729	19.1	6.9	13	5.444	1
(2) northeast aspect	7182	10.0	3.6	0	3.599	1
(3) east aspect	5425	7.6	2.7	8	10.260	1
(4) southeast aspect	7069	9.8	3.5	5	0.600	1
(5) south aspect	12846	17.9	6.4	4	0.923	1
(6) southwest aspect	10088	14.0	5.1	2	1.847	1
(7) west aspect	7180	10.0	3.6	1	1.876	1
(8) northwest aspect	8133	11.3	4.1	3	0.284	1
(9) no aspect (flat)	186	0.3	0.1	0	0.093	1
Totals	71838	100.0	36.0	36	24.925	8

Table 15. Northern red oak (Quercus rubra) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees; north	4225	6.0	2.2	0	2.155	1
(2) 0-9 degrees; northeast	3202	4.5	1.6	0	1.633	1
(3) 0-9 degrees; east	2945	4.2	1.5	0	1.502	1
(4) 0-9 degrees; southeast	3793	5.4	1.9	0	1.935	1
(5) 0-9 degrees; south	4301	6.1	2.2	1	0.650	1
(6) 0-9 degrees; southwest	4608	6.5	2.4	0	2.350	1
(7) 0-9 degrees; west	4272	6.1	2.2	1	0.638	1
(8) 0-9 degrees; northwest	4077	5.8	2.1	0	2.080	1
(9) 0-9 degrees; no	176	0.2	0.1	0	0.090	1
(10) 10-18 degrees; north	6574	9.3	3.4	5	0.809	1
(11) 10-18 degrees; northeast	3000	4.3	1.5	0	1.530	1
(12) 10-18 degrees; east	2014	2.9	1.0	7	34.725	1
(13) 10-18 degrees; southeast	2501	3.5	1.3	2	0.411	1
(14) 10-18 degrees; south	5365	7.6	2.7	2	0.198	1
(15) 10-18 degrees; southwest	3671	5.2	1.9	1	0.407	1
(16) 10-18 degrees; west	2298	3.3	1.2	0	1.172	1
(17) 10-18 degrees; northwest	3107	4.4	1.6	3	1.264	1
(18) 19-27 degrees; north	2551	3.6	1.3	8	34.486	1
(19) 19-27 degrees; northeast	799	1.1	0.4	0	0.408	1
(20) 19-27 degrees; east	366	0.5	0.2	1	3.543	1
(21) 19-27 degrees; southeast	626	0.9	0.3	3	22.505	1
(22) 19-27 degrees; south	2468	3.5	1.3	1	0.053	1

Table 15 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	0.7	1	0.088	1
(24) 19-27 degrees; west	438	0.6	0.2	0	0.223	1
(25) 19-27 degrees; northwest	759	1.1	0.4	0	0.387	1
(26) 28-36 degrees; north	100	0.1	0.1	0	0.051	1
(27) 28-36 degrees; northeast	35	0.0	0.0	0	0.018	1
(28) 28-36 degrees; east	29	0.0	0.0	0	0.015	1
(29) 28-36 degrees; southeast	34	0.0	0.0	0	0.017	1
(30) 28-36 degrees; south	460	0.7	0.2	0	0.235	1
(31) 28-36 degrees; southwest	149	0.2	0.1	0	0.076	1
(32) 28-36 degrees; west	45	0.1	0.0	0	0.023	1
(33) 28-36 degrees; northwest	77	0.1	0.0	0	0.039	1
(34) 37-45 degrees; north	31	0.0	0.0	0	0.016	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.006	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.003	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.003	1
Totals	70577	100.0	36.0	36	115.743	36

Table 16. Northern red oak (Quercus rubra) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees	31599	44.8	17.9	18	0.000	1
(2) 10-18 degrees	28530	40.4	15.4	17	0.027	1
(3) 19-27 degrees	9466	13.4	5.1	4	0.002	1
(4) 28-36 degrees	929	1.3	0.5	0	0.500	1
(5) 37-45 degrees	53	0.1	0.0	0	0.029	1
Total	70577	100.0	39.0	39	0.557	4

Table 17. Northern red oak (Quercus rubra) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	116490			0		
(1) north aspect	13729	19.1	7.3	8	0.075	1
(2) northeast aspect	7182	10.0	3.8	4	0.168	1
(3) east aspect	5425	7.6	2.9	2	0.264	1
(4) southeast aspect	7069	9.8	3.7	2	0.809	1
(5) south aspect	12846	17.9	6.8	9	0.715	1
(6) southwest aspect	10088	14.0	5.3	5	0.021	1
(7) west aspect	7180	10.0	3.8	7	2.700	1
(8) northwest aspect	8133	11.3	4.3	2	1.232	1
(9) no aspect (flat)	186	0.3	0.1	0	0.098	1
Totals	71838	100.0	39.0	39	6.082	8

Table 18. Northern red oak (Quercus rubra) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees; north	4225	6.0	2.3	4	1.308	1
(2) 0-9 degrees; northeast	3202	4.5	1.7	0	1.724	1
(3) 0-9 degrees; east	2945	4.2	1.6	1	0.216	1
(4) 0-9 degrees; southeast	3793	5.4	2.0	1	0.532	1
(5) 0-9 degrees; south	4301	6.1	2.3	5	3.111	1
(6) 0-9 degrees; southwest	4608	6.5	2.5	2	0.093	1
(7) 0-9 degrees; west	4272	6.1	2.3	4	0.428	1
(8) 0-9 degrees; northwest	4077	5.8	2.2	1	0.651	1
(9) 0-9 degrees; no	176	0.2	0.1	0	0.095	1
(10) 10-18 degrees; north	6574	9.3	3.5	4	0.060	1
(11) 10-18 degrees; northeast	3000	4.3	1.6	2	0.092	1
(12) 10-18 degrees; east	2014	2.9	1.1	1	0.007	1
(13) 10-18 degrees; southeast	2501	3.5	1.3	1	0.089	1
(14) 10-18 degrees; south	5365	7.6	2.9	1	1.235	1
(15) 10-18 degrees; southwest	3671	5.2	2.0	3	0.530	1
(16) 10-18 degrees; west	2298	3.3	1.2	4	6.169	1
(17) 10-18 degrees; northwest	3107	4.4	1.7	0	1.673	1
(18) 19-27 degrees; north	2551	3.6	1.4	0	1.374	1
(19) 19-27 degrees; northeast	799	1.1	0.4	1	0.755	1
(20) 19-27 degrees; east	366	0.5	0.2	0	0.197	1
(21) 19-27 degrees; southeast	626	0.9	0.3	0	0.33	1
(22) 19-27 degrees; south	2468	3.5	1.3	3	2.102	1

Table 18 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	0.8	0	0.786	1
(24) 19-27 degrees; west	438	0.6	0.2	0	0.236	1
(25) 19-27 degrees; northwest	759	1.1	0.4	1	0.856	1
(26) 28-36 degrees; north	100	0.1	0.1	0	0.054	1
(27) 28-36 degrees; northeast	35	0.0	0.0	0	0.019	1
(28) 28-36 degrees; east	29	0.0	0.0	0	0.016	1
(29) 28-36 degrees; southeast	34	0.0	0.0	0	0.018	1
(30) 28-36 degrees; south	460	0.7	0.2	0	0.248	1
(31) 28-36 degrees; southwest	149	0.2	0.1	0	0.080	1
(32) 28-36 degrees; west	45	0.1	0.0	0	0.024	1
(33) 28-36 degrees; northwest	77	0.1	0.0	0	0.041	1
(34) 37-45 degrees; north	31	0.0	0.0	0	0.017	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.006	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.003	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.003	1
Totals	70577	100.0	39.0	39	24.967	36

Table 19. Oak (Quercus spp.) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees	31599	44.8	63.1	45	5.206	1
(2) 10-18 degrees	28530	40.4	57.0	62	0.439	1
(3) 19-27 degrees	9466	13.4	18.9	33	10.496	1
(4) 28-36 degrees	929	1.3	1.9	1	0.395	1
(5) 37-45 degrees	53	0.1	0.1	0	0.10	1
Totals	70577	100.0	141.0	141	16.642	4

Table 20. Oak (Quercus spp.) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	116490			0		
(1) north aspect	13729	19.1	26.9	36	3.042	1
(2) northeast aspect	7182	10.0	14.1	13	0.085	1
(3) east aspect	5425	7.6	10.6	17	3.789	1
(4) southeast aspect	7069	9.8	13.9	14	0.001	1
(5) south aspect	12846	17.9	25.2	22	0.410	1
(6) southwest aspect	10088	14.0	19.8	20	0.002	1
(7) west aspect	7180	10.0	14.1	9	1.840	1
(8) northwest aspect	8133	11.3	16.0	10	2.228	1
(9) no aspect (flat)	186	0.3	0.4	0	0.365	1
Totals	71838	100.0	141.0	141	11.762	8

Table 21. Oak (Quercus spp.) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees; north	4225	6.0	8.4	5	1.403	1
(2) 0-9 degrees; northeast	3202	4.5	6.4	5	0.305	1
(3) 0-9 degrees; east	2945	4.2	5.9	5	0.133	1
(4) 0-9 degrees; southeast	3793	5.4	7.6	3	2.765	1
(5) 0-9 degrees; south	4301	6.1	8.6	7	0.295	1
(6) 0-9 degrees; southwest	4608	6.5	9.2	10	0.068	1
(7) 0-9 degrees; west	4272	6.1	8.5	6	0.753	1
(8) 0-9 degrees; northwest	4077	5.8	8.1	4	2.109	1
(9) 0-9 degrees; no	176	0.2	0.4	0	0.352	1
(10) 10-18 degrees; north	6574	9.3	13.1	17	1.138	1
(11) 10-18 degrees; northeast	3000	4.3	6.0	7	0.169	1
(12) 10-18 degrees; east	2014	2.9	4.0	10	8.877	1
(13) 10-18 degrees; southeast	2501	3.5	5.0	6	0.202	1
(14) 10-18 degrees; south	5365	7.6	10.7	7	1.290	1
(15) 10-18 degrees; southwest	3671	5.2	7.3	6	0.243	1
(16) 10-18 degrees; west	2298	3.3	4.6	3	0.551	1
(17) 10-18 degrees; northwest	3107	4.4	6.2	6	0.007	1
(18) 19-27 degrees; north	2551	3.6	5.1	14	15.555	1
(19) 19-27 degrees; northeast	799	1.1	1.6	1	0.223	1
(20) 19-27 degrees; east	366	0.5	0.7	2	2.20	1
(21) 19-27 degrees; southeast	626	0.9	1.3	5	11.240	1
(22) 19-27 degrees; south	2468	3.5	4.9	8	1.911	1

Table 21 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	2.9	3	0.002	1
(24) 19-27 degrees; west	438	0.6	0.9	0	0.875	1
(25) 19-27 degrees; northwest	759	1.1	1.5	0	1.516	1
(26) 28-36 degrees; north	100	0.1	0.2	0	0.200	1
(27) 28-36 degrees; northeast	35	0.0	0.1	0	0.070	1
(28) 28-36 degrees; east	29	0.0	0.1	0	0.058	1
(29) 28-36 degrees; southeast	34	0.0	0.1	0	0.068	1
(30) 28-36 degrees; south	460	0.7	0.9	0	0.919	1
(31) 28-36 degrees; southwest	149	0.2	0.3	1	1.657	1
(32) 28-36 degrees; west	45	0.1	0.1	0	0.090	1
(33) 28-36 degrees; northwest	77	0.1	0.2	0	0.154	1
(34) 37-45 degrees; north	31	0.0	0.1	0	0.062	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.022	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.012	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.010	1
Totals	70577	100.0	141.0	141	57.505	36

Table 22. Oak (Quercus spp.) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees	31599	44.8	107.1	97	0.959	1
(2) 10-18 degrees	28530	40.4	92.1	102	01.053	1
(3) 19-27 degrees	9466	13.4	30.5	32	0.069	1
(4) 28-36 degrees	929	1.3	3.0	2	0.332	1
(5) 37-45 degrees	53	0.1	0.2	0	0.171	1
Totals	70577	100.0	233.0	233	2.583	4

Table 23. Oak (Quercus spp.) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	116490			0		
(1) north aspect	13729	19.1	43.5	56	3.577	1
(2) northeast aspect	7182	10.0	22.8	30	2.279	1
(3) east aspect	5425	7.6	17.4	15	0.326	1
(4) southeast aspect	7069	9.8	22.6	22	0.014	1
(5) south aspect	12846	17.9	40.6	38	0.173	1
(6) southwest aspect	10088	14.0	32.0	27	0.783	1
(7) west aspect	7180	10.0	22.8	24	0.059	1
(8) northwest aspect	8133	11.3	26.0	18	2.466	1
(9) no aspect (flat)	186	0.3	5.2	3	0.289	1
Totals	71838	100.0	233.0	233	10.632	8

Table 24. Oak (Quercus spp.) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees; north	4225	6.0	13.6	21	3.945	1
(2) 0-9 degrees; northeast	3202	4.5	10.3	10	0.009	1
(3) 0-9 degrees; east	2945	4.2	9.5	6	1.273	1
(4) 0-9 degrees; southeast	3793	5.4	12.2	13	0.003	1
(5) 0-9 degrees; south	4301	6.1	13.8	14	0.002	1
(6) 0-9 degrees; southwest	4608	6.5	14.8	9	3.378	1
(7) 0-9 degrees; west	4272	6.1	13.7	12	0.546	1
(8) 0-9 degrees; northwest	4077	5.8	13.1	9	1.290	1
(9) 0-9 degrees; no	176	0.2	0.6	3	0.333	1
(10) 10-18 degrees; north	6574	9.3	21.2	23	0.035	1
(11) 10-18 degrees; northeast	3000	4.3	9.7	18	7.132	1
(12) 10-18 degrees; east	2014	2.9	6.5	7	0.042	1
(13) 10-18 degrees; southeast	2501	3.5	8.1	6	0.519	1
(14) 10-18 degrees; south	5365	7.6	17.3	16	0.614	1
(15) 10-18 degrees; southwest	3671	5.2	11.9	14	0.407	1
(16) 10-18 degrees; west	2298	3.3	7.4	12	2.817	1
(17) 10-18 degrees; northwest	3107	4.4	10.0	6	0.897	1
(18) 19-27 degrees; north	2551	3.6	8.2	12	0.952	1
(19) 19-27 degrees; northeast	799	1.1	2.6	2	0.126	1
(20) 19-27 degrees; east	366	0.5	1.2	2	0.575	1
(21) 19-27 degrees; southeast	626	0.9	2.0	3	0.483	1
(22) 19-27 degrees; south	2468	3.5	8.0	6	0.473	1

Table 24 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	4.7	4	0.020	1
(24) 19-27 degrees; west	438	0.6	1.4	0	1.409	1
(25) 19-27 degrees; northwest	759	1.1	2.5	3	0.995	1
(26) 28-36 degrees; north	100	0.1	0.3	0	1.431	1
(27) 28-36 degrees; northeast	35	0.0	0.1	0	0.113	1
(28) 28-36 degrees; east	29	0.0	0.1	0	0.093	1
(29) 28-36 degrees; southeast	34	0.0	0.1	0	0.109	1
(30) 28-36 degrees; south	460	0.7	1.5	2	0.183	1
(31) 28-36 degrees; southwest	149	0.2	0.5	0	0.479	1
(32) 28-36 degrees; west	45	0.1	0.1	0	0.145	1
(33) 28-36 degrees; northwest	77	0.1	0.2	0	0.248	1
(34) 37-45 degrees; north	31	0.0	0.1	0	0.100	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.035	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.019	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.016	1
Totals	70577	100.0	233.0	233	29.926	36

Table 25. Post oak (Quercus stellata) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, Summer 1994.

Site Characteristics	cells freedom	% cover	expected cover	actual sites	chi sites	degrees square
(0)	109765			0		
(1) 0-9 degrees	31599	44.8	10.7	11	0.006	1
(2) 10-18 degrees	28530	40.4	9.7	8	0.298	1
(3) 19-27 degrees	9466	13.4	3.2	4	0.190	1
(4) 28-36 degrees	929	1.3	0.3	1	1.481	1
(5) 37-45 degrees	53	0.1	0.0	0	0.018	1
Totals	70577	100.0	24.0	24	1.993	4

Table 26. Post oak (Quercus stellata) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, Summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	108504			0		
(1) north aspect	13729	19.1	4.6	3	0.549	1
(2) northeast aspect	7182	10.0	2.4	0	2.399	1
(3) east aspect	5425	7.6	1.8	4	2.640	1
(4) southeast aspect	7069	9.8	2.4	1	0.785	1
(5) south aspect	12846	17.9	4.3	7	1.709	1
(7) west aspect	7180	10.0	2.4	1	0.816	1
(8) northwest aspect	8133	11.3	2.7	1	1.085	1
(9) no aspect (flat)	186	0.3	0.1	0	0.062	1
Totals	71838	100.0	24.0	24	13.955	8

Table 27. Post oak (<u>Quercus</u> <u>stellata</u>) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, Summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees; north	4225	6.0	1.4	1	0.133	1
(2) 0-9 degrees; northeast	3202	4.5	1.1	0	1.089	1
(3) 0-9 degrees; east	2945	4.2	1.0	2	0.996	1
(4) 0-9 degrees; southeast	3793	5.4	1.3	1	0.065	1
(5) 0-9 degrees; south	4301	6.1	1.5	3	1.616	1
(6) 0-9 degrees; southwest	4608	6.5	1.6	2	0.120	1
(7) 0-9 degrees; west	4272	6.1	1.5	1	0.141	1
(8) 0-9 degrees; northwest	4077	5.8	1.4	1	0.108	1
(9) 0-9 degrees; no	176	0.2	0.1	0	0.060	1
(10) 10-18 degrees; north	6574	9.3	2.2	2	0.025	1
(11) 10-18 degrees; northeast	3000	4.3	1.0	0	1.020	1
(12) 10-18 degrees; east	2014	2.9	0.7	1	0.145	1
(13) 10-18 degrees; southeast	2501	3.5	0.9	0	0.850	1
(14) 10-18 degrees; south	5365	7.6	1.8	3	0.758	1
(15) 10-18 degrees; southwest	3671	5.2	1.2	2	0.453	1
(16) 10-18 degrees; west	2298	3.3	0.8	0	0.781	1
(17) 10-18 degrees; northwest	3107	4.4	1.1	0	1.057	1
(18) 19-27 degrees; north	2551	3.6	0.9	0	0.867	1
(19) 19-27 degrees; northeast	799	1.1	0.3	0	0.272	1
(20) 19-27 degrees; east	366	0.5	0.1	1	6.159	1
(21) 19-27 degrees; southeast	626	0.9	0.2	0	0.213	1
(22) 19-27 degrees; south	2468	3.5	0.8	1	0.031	1

Table 27 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	0.5	2	4.558	1
(24) 19-27 degrees; west	438	0.6	0.1	0	0.149	1
(25) 19-27 degrees; northwest	759	1.1	0.3	0	0.258	1
(26) 28-36 degrees; north	100	0.1	0.0	0	0.034	1
(27) 28-36 degrees; northeast	35	0.0	0.0	0	0.012	1
(28) 28-36 degrees; east	29	0.0	0.0	0	0.010	1
(29) 28-36 degrees; southeast	34	0.0	0.0	0	0.012	1
(30) 28-36 degrees; south	460	0.7	0.2	0	0.156	1
(31) 28-36 degrees; southwest	149	0.2	0.1	1	17.787	1
(32) 28-36 degrees; west	45	0.1	0.0	0	0.015	1
(33) 28-36 degrees; northwest	77	0.1	0.0	0	0.026	1
(34) 37-45 degrees; north	31	0.0	0.0	0	0.011	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.004	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.002	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.002	1
Totals	70577	100.0	24.0	24	39.993	36

Table 28. Post oak (Quercus stellata) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells freedom	% cover	expected cover	actual sites	chi sites	degrees square
(0)	109765			0		
(1) 0-9 degrees	31599	44.8	17.0	16	0.060	1
(2) 10-18 degrees	28530	40.4	15.4	18	0.494	1
(3) 19-27 degrees	9466	13.4	5.1	4	0.236	1
(4) 28-36 degrees	929	1.3	0.5	0	0.499	1
(5) 37-45 degrees	53	0.1	0.0	0	0.029	1
Totals	70577	100.0	38.0	38	0.999	4

Table 29. Post oak (<u>Quercus</u> <u>stellata</u>) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells freedom	% cover	expected cover	actual sites	chi sites	degrees square
(0)	108504			0		
(1) north aspect	13729	19.1	7.3	7	0.009	1
(2) northeast aspect	7182	10.0	3.8	5	0.380	1
(3) east aspect	5425	7.6	2.9	2	0.264	1
(4) southeast aspect	7069	9.8	3.7	4	0.018	1
(5) south aspect	12846	17.9	6.8	9	0.715	1
(6) southwest aspect	1008	14.0	5.3	6	0.083	1
(7) west aspect	7180	10.0	3.8	5	0.380	1
(8) northwest aspect	8133	11.3	4.3	0	4.302	1
(9) no aspect (flat)	186	0.3	0.1	0	0.098	1
Totals	71838	100.0	38.0	38	6.250	8

Table 30. Post oak (Quercus stellata) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, Fall 1896

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees; north	4225	6.0	2.3	3	0.231	1
(2) 0-9 degrees; northeast	3202	4.5	1.7	3	0.944	1
(3) 0-9 degrees; east	2945	4.2	1.6	0	1.586	1
(4) 0-9 degrees; southeast	3793	5.4	2.0	2	0.001	1
(5) 0-9 degrees; south	4301	6.1	2.3	4	1.225	1
(6) 0-9 degrees; southwest	4608	6.5	2.5	2	0.093	1
(7) 0-9 degrees; west	4272	6.1	2.3	2	0.039	1
(8) 0-9 degrees; northwest	4077	5.8	2.2	0	2.195	1
(9) 0-9 degrees; no	176	0.2	0.1	0	0.095	1
(10) 10-18 degrees; north	6574	9.3	3.5	4	0.438	1
(11) 10-18 degrees; northeast	3000	4.3	1.6	2	0.092	1
(12) 10-18 degrees; east	2014	2.9	1.1	2	0.773	1
(13) 10-18 degrees; southeast	2501	3.5	1.3	1	0.089	1
(14) 10-18 degrees; south	5365	7.6	2.9	4	0.428	1
(15) 10-18 degrees; southwest	3671	5.2	2.0	2	0.000	1
(16) 10-18 degrees; west	2298	3.3	1.2	3	2.511	1
(17) 10-18 degrees; northwest	3107	4.4	1.7	0	1.673	1
(18) 19-27 degrees; north	2551	3.6	1.4	0	1.374	1
(19) 19-27 degrees; northeast	799	1.1	0.4	0	0.430	1
(20) 19-27 degrees; east	366	0.5	0.2	0	0.197	1
(21) 19-27 degrees; southeast	626	0.9	0.3	1	1.304	1

Table 30 (cont.)

(22) 19-27 degrees; south	2468	3.5	1.3	1	0.081	1
(23) 19-27 degrees; southwest	1459	2.1	0.8	2	1.878	1
(24) 19-27 degrees; west	438	0.6	0.2	0	0.236	1
(25) 19-27 degrees; northwest	759	1.1	0.4	0	0.409	1
(26) 28-36 degrees; north	100	0.1	0.1	0	0.913	1
(27) 28-36 degrees; northeast	35	0.0	0.0	0	0.019	1
(28) 28-36 degrees; east	29	0.0	0.0	0	0.016	1
(29) 28-36 degrees; southeast	34	0.0	0.0	0	0.018	1
(30) 28-36 degrees; south	460	0.7	0.2	0	0.248	1
(31) 28-36 degrees; southwest	149	0.2	0.1	0	0.080	1
(32) 28-36 degrees; west	45	0.1	0.0	0	0.024	1
(33) 28-36 degrees; northwest	77	0.1	0.0	0	0.041	1
(34) 37-45 degrees; north	31	0.0	0.0	0	0.017	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.006	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.003	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.003	1
Totals	70577	100.0	38.0	38	19.537	36

Table 31. Shortleaf pine (Pinus echinata) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, Summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees	31599	44.8	66.7	71	0.276	1
(2) 10-18 degrees	28530	40.4	60.2	62	0.052	1
(3) 19-27 degrees	9466	13.4	20.0	16	0.794	1
(4) 28-36 degrees	929	1.3	2.0	0	1.961	1
(5) 37-45 degrees	53	0.1	0.1	0	0.112	1
Totals	70577	100.0	149.0	149	3.195	4

Table 32. Shortleaf pine (Pinus echinata) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, Summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	116490			0		
(1) north aspect	13729	19.1	28.5	31	0.224	1
(2) northeast aspect	7182	10.0	14.9	14	0.054	1
(3) east aspect	5425	7.6	11.3	15	1.248	1
(4) southeast aspect	7069	9.8	14.7	9	2.186	1
(5) south aspect	12846	17.9	26.6	40	6.695	1
(6) southwest aspect	10088	14.0	20.9	16	1.159	1
(7) west aspect	7180	10.0	14.9	16	0.082	1
(8) northwest aspect	8133	11.3	16.9	8	4.663	1
(9) no aspect (flat)	186	0.3	0.4	0	0.386	1
Totals	71838	100.0	149.0	149	16.697	8

Table 33. Shortleaf pine (Pinus echinata) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, Summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees; north	4225	6.0	8.9	12	1.064	1
(2) 0-9 degrees; northeast	3202	4.5	6.8	8	0.227	1
(3) 0-9 degrees; east	2945	4.2	6.2	5	0.238	1
(4) 0-9 degrees; southeast	3793	5.4	8.0	6	0.503	1
(5) 0-9 degrees; south	4301	6.1	9.1	20	13.132	1
(6) 0-9 degrees; southwest	4608	6.5	9.7	10	0.008	1
(7) 0-9 degrees; west	4272	6.1	9.0	8	0.115	1
(8) 0-9 degrees; northwest	4077	5.8	8.6	2	5.072	1
(9) 0-9 degrees; no	176	0.2	0.4	0	0.372	1
(10) 10-18 degrees; north	6574	9.3	13.9	16	0.324	1
(11) 10-18 degrees; northeast	3000	4.3	6.3	6	0.018	1
(12) 10-18 degrees; east	2014	2.9	4.3	6	0.719	1
(13) 10-18 degrees; southeast	2501	3.5	5.3	3	0.985	1
(14) 10-18 degrees; south	5365	7.6	11.3	14	0.631	1
(15) 10-18 degrees; southwest	3671	5.2	7.8	4	1.815	1
(16) 10-18 degrees; west	2298	3.3	4.9	7	0.952	1
(17) 10-18 degrees; northwest	3107	4.4	6.6	6	0.048	1
(18) 19-27 degrees; north	2551	3.6	5.4	3	1.057	1
(19) 19-27 degrees; northeast	799	1.1	1.7	0	1.687	1
(20) 19-27 degrees; east	366	0.5	0.8	4	13.480	1
(21) 19-27 degrees; southeast	626	0.9	1.3	0	1.322	1
(22) 19-27 degrees; south	2468	3.5	5.2	6	0.120	1

Table 33 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	3.1	2	0.379	1
(24) 19-27 degrees; west	438	0.6	0.9	1	0.006	1
(25) 19-27 degrees; northwest	759	1.1	1.6	0	1.602	1
(26) 28-36 degrees; north	100	0.1	0.2	0	0.211	1
(27) 28-36 degrees; northeast	35	0.0	0.1	0	0.074	1
(28) 28-36 degrees; east	29	0.0	0.1	0	0.061	1
(29) 28-36 degrees; southeast	34	0.0	0.1	0	0.072	1
(30) 28-36 degrees; south	460	0.7	1.0	0	0.971	1
(31) 28-36 degrees; southwest	149	0.2	0.3	0	0.315	1
(32) 28-36 degrees; west	45	0.1	0.1	0	0.095	1
(33) 28-36 degrees; northwest	77	0.1	0.2	0	0.163	1
(34) 37-45 degrees; north	31	0.0	0.1	0	0.065	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.023	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.013	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.011	1
Totals	70577	100.0	149.0	149	47.946	36

Table 34. Shortleaf pine (Pinus echinata) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees	31599	44.8	7.8	5	0.476	1
(2) 10-18 degrees	28530	40.4	6.7	4	1.475	1
(3) 19-27 degrees	9466	13.4	2.2	8	12.924	1
(4) 28-36 degrees	929	1.3	0.2	0	0.237	1
(5) 37-45 degrees	53	0.1	0.0	0	0.014	1
Totals	70577	100.0	17.0	17	15.176	4

Table 35. Shortleaf pine (Pinus echinata) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	116490			0		
(1) north aspect	13729	19.1	3.4	3	0.056	1
(2) northeast aspect	7182	10.0	1.8	1	0.355	1
(3) east aspect	5425	7.6	1.4	0	1.359	1
(4) southeast aspect	7069	9.8	1.8	1	0.336	1
(5) south aspect	12846	17.9	3.2	7	4.442	1
(6) southwest aspect	10088	14.0	2.5	2	0.110	1
(7) west aspect	7180	10.0	1.8	2	0.802	1
(8) northwest aspect	8133	11.3	2.0	1	0.529	1
(9) no aspect (flat)	186	0.3	0.0	0	0.047	1
Totals	71838	100.0	17.0	17	8.036	8

Table 36. Shortleaf pine (Pinus echinata) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, Fall 1896

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	117751			0		
(1) 0-9 degrees; north	4225	6.0	1.1	1	0.006	1
(2) 0-9 degrees; northeast	3202	4.5	0.8	0	0.817	1
(3) 0-9 degrees; east	2945	4.2	0.8	0	0.751	1
(4) 0-9 degrees; southeast	3793	5.4	1.0	0	0.967	1
(5) 0-9 degrees; south	4301	6.1	1.1	1	0.009	1
(6) 0-9 degrees; southwest	4608	6.5	1.2	0	1.175	1
(7) 0-9 degrees; west	4272	6.1	1.1	2	3.350	1
(8) 0-9 degrees; northwest	4077	5.8	1.0	1	0.002	1
(9) 0-9 degrees; no	176	0.2	0.0	0	0.045	1
(10) 10-18 degrees; north	6574	9.3	1.7	2	0.062	1
(11) 10-18 degrees; northeast	3000	4.3	0.8	1	0.072	1
(12) 10-18 degrees; east	2014	2.9	0.5	0	0.514	1
(13) 10-18 degrees; southeast	2501	3.5	0.6	0	0.638	1
(14) 10-18 degrees; south	5365	7.6	1.4	0	1.368	1
(15) 10-18 degrees; southwest	3671	5.2	0.9	1	0.004	1
(16) 10-18 degrees; west	2298	3.3	0.6	0	0.586	1
(17) 10-18 degrees; northwest	3107	4.4	0.8	0	0.792	1
(18) 19-27 degrees; north	2551	3.6	0.7	0	0.651	1
(19) 19-27 degrees; northeast	799	1.1	0.2	0	0.204	1
(20) 19-27 degrees; east	366	0.5	0.1	0	0.093	1
(21) 19-27 degrees; southeast	626	0.9	0.2	1	4.423	1
(22) 19-27 degrees; south	2468	3.5	0.6	6	45.823	1

Table 36 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	0.4	1	1.060	1
(24) 19-27 degrees; west	438	0.6	0.1	0	0.112	1
(25) 19-27 degrees; northwest	759	1.1	0.2	0	0.194	1
(26) 28-36 degrees; north	100	0.1	0.0	0	0.026	1
(27) 28-36 degrees; northeast	35	0.0	0.0	0	0.009	1
(28) 28-36 degrees; east	29	0.0	0.0	0	0.007	1
(29) 28-36 degrees; southeast	34	0.0	0.0	0	0.009	1
(30) 28-36 degrees; south	460	0.7	0.1	0	0.117	1
(31) 28-36 degrees; southwest	149	0.2	0.0	0	0.038	1
(32) 28-36 degrees; west	45	0.1	0.0	0	0.011	1
(33) 28-36 degrees; northwest	77	0.1	0.0	0	0.020	1
(34) 37-45 degrees; north	31	0.0	0.0	0	0.008	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.003	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.002	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.001	1
Totals	70577	100.0	17.0	17	63.967	36

Table 37. White oak (Quercus alba) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, Summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees	31599	44.8	21.5	19	0.289	1
(2) 10-18 degrees	28530	40.4	19.4	24	1.089	1
(3) 19-27 degrees	9466	13.4	6.4	5	0.321	1
(4) 28-36 degrees	929	1.3	0.6	0	0.632	1
(5) 37-45 degrees	53	0.1	0.0	0	0.036	1
Totals	70577	100.0	48.0	48	2.367	4

Table 38. White oak (Quercus alba) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, Summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	108504			0		
(1) north aspect	13729	19.1	9.2	12	0.871	1
(2) northeast aspect	7182	10.0	4.8	7	1.010	1
(3) east aspect	5425	7.6	3.6	2	0.728	1
(4) southeast aspect	7069	9.8	4.7	3	0.629	1
(5) south aspect	12846	17.9	8.6	7	0.292	1
(6) southwest aspect	10088	14.0	6.7	10	1.576	1
(7) west aspect	7180	10.0	4.8	3	0.673	1
(8) northwest aspect	8133	11.3	5.4	4	0.379	1
(9) no aspect (flat)	186	0.3	0.1	0	0.124	1
Totals	71838	100.0	48.0	48	6.282	8

Table 39. White oak (Quercus alba) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, Summer 1994.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees; north	4225	6.0	2.9	3	0.006	1
(2) 0-9 degrees; northeast	3202	4.5	2.2	2	0.015	1
(3) 0-9 degrees; east	2945	4.2	2.0	0	2.003	1
(4) 0-9 degrees; southeast	3793	5.4	2.6	1	0.967	1
(5) 0-9 degrees; south	4301	6.1	2.9	3	0.002	1
(6) 0-9 degrees; southwest	4608	6.5	3.1	8	7.556	1
(7) 0-9 degrees; west	4272	6.1	2.9	0	2.905	1
(8) 0-9 degrees; northwest	4077	5.8	2.8	2	0.215	1
(9) 0-9 degrees; no	176	0.2	0.1	0	0.120	1
(10) 10-18 degrees; north	6574	9.3	4.5	7	1.430	1
(11) 10-18 degrees; northeast	3000	4.3	2.0	4	1.882	1
(12) 10-18 degrees; east	2014	2.9	1.4	2	0.290	1
(13) 10-18 degrees; southeast	2501	3.5	1.7	2	0.053	1
(14) 10-18 degrees; south	5365	7.6	3.6	2	0.745	1
(15) 10-18 degrees; southwest	3671	5.2	2.5	2	0.099	1
(16) 10-18 degrees; west	2298	3.3	1.6	3	1.321	1
(17) 10-18 degrees; northwest	3107	4.4	2.1	2	0.006	1
(18) 19-27 degrees; north	2551	3.6	1.7	2	0.040	1
(19) 19-27 degrees; northeast	799	1.1	0.5	1	0.384	1
(20) 19-27 degrees; east	366	0.5	0.2	0	0.249	1
(21) 19-27 degrees; southeast	626	0.9	0.4	0	0.426	1
(22) 19-27 degrees; south	2468	3.5	1.7	2	0.062	1

Table 39 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	1.0	0	0.992
(24) 19-27 degrees; west	438	0.6	0.3	0	0.298
(25) 19-27 degrees; northwest	759	1.1	0.5	0	0.516
(26) 28-36 degrees; north	100	0.1	0.1	0	0.068
(27) 28-36 degrees; northeast	35	0.0	0.0	0	0.024
(28) 28-36 degrees; east	29	0.0	0.0	0	0.020
(29) 28-36 degrees; southeast	34	0.0	0.0	0	0.023
(30) 28-36 degrees; south	460	0.7	0.3	0	0.313
(31) 28-36 degrees; southwest	149	0.2	0.1	0	0.101
(32) 28-36 degrees; west	45	0.1	0.0	0	0.031
(33) 28-36 degrees; northwest	77	0.1	0.1	0	0.052
(34) 37-45 degrees; north	31	0.0	0.0	0	0.021
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.007
(36) 37-45 degrees; east	6	0.0	0.0	0	0.004
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.003
Totals	70577	100.0	48.0	48	23.249

Table 40. White oak (Quercus alba) observed versus expected occurrence by slope (degrees) class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees	31599	44.8	26.7	28	0.006	1
(2) 10-18 degrees	28530	40.4	22.9	23	0.025	1
(3) 19-27 degrees	9466	13.4	7.6	6	0.138	1
(4) 28-36 degrees	929	1.3	0.7	1	0.048	1
(5) 37-45 degrees	53	0.1	0.0	0	0.046	1
Totals	70577	100.0	58	58	0.263	4

Table 41. White oak (Quercus alba) observed versus expected occurrence by aspect class on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	108504			0		
(1) north aspect	13729	19.1	10.7	12	0.155	1
(2) northeast aspect	7182	10.0	6.1	7	0.002	1
(3) east aspect	5425	7.6	4.6	3	0.560	1
(4) southeast aspect	7069	9.8	6.0	7	0.166	1
(5) south aspect	12846	17.9	9.0	5	2.208	1
(6) southwest aspect	10088	14.0	8.6	7	0.037	1
(7) west aspect	7180	10.0	6.1	5	0.197	1
(8) northwest aspect	8133	11.3	6.9	11	5.377	1
(9) no aspect (flat)	186	0.3	0.2	0	0.158	1
Totals	71838	100.0	58.0	58	8.861	8

Table 42. White oak (Quercus alba) observed versus expected occurrence by slope and aspect on McCurtain County Wilderness Area, Fall 1896.

Site Characteristics	cells cover	% cover	expected sites	actual sites	chi square	degrees freedom
(0)	109765			0		
(1) 0-9 degrees; north	4225	6.0	3.7	4	0.033	1
(2) 0-9 degrees; northeast	3202	4.5	2.8	0	2.768	1
(3) 0-9 degrees; east	2945	4.2	2.5	1	0.938	1
(4) 0-9 degrees; southeast	3793	5.4	3.3	5	0.904	1
(5) 0-9 degrees; south	4301	6.1	3.7	3	0.138	1
(6) 0-9 degrees; southwest	4608	6.5	4.0	4	0.000	1
(7) 0-9 degrees; west	4272	6.1	3.7	5	0.463	1
(8) 0-9 degrees; northwest	4077	5.8	3.5	5	0.618	1
(9) 0-9 degrees; no	176	0.2	0.2	1	0.152	1
(10) 10-18 degrees; north	6574	9.3	5.7	6	0.018	1
(11) 10-18 degrees; northeast	3000	4.3	2.6	7	4.477	1
(12) 10-18 degrees; east	2014	2.9	1.7	1	0.315	1
(13) 10-18 degrees; southeast	2501	3.5	2.2	2	0.012	1
(14) 10-18 degrees; south	5365	7.6	4.6	1	1.500	1
(15) 10-18 degrees; southwest	3671	5.2	3.2	3	0.009	1
(16) 10-18 degrees; west	2298	3.3	2.0	0	1.986	1
(17) 10-18 degrees; northwest	3107	4.4	2.7	3	1.995	1
(18) 19-27 degrees; north	2551	3.6	2.2	2	0.287	1
(19) 19-27 degrees; northeast	799	1.1	0.7	0	0.691	1
(20) 19-27 degrees; east	366	0.5	0.3	1	1.478	1
(21) 19-27 degrees; southeast	626	0.9	0.5	0	0.541	1
(22) 19-27 degrees; south	2468	3.5	2.1	0	2.133	1

Table 42 (cont.)

(23) 19-27 degrees; southwest	1459	2.1	1.3	0	0.054	1
(24) 19-27 degrees; west	438	0.6	0.4	0	0.379	1
(25) 19-27 degrees; northwest	759	1.1	0.7	3	8.375	1
(26) 28-36 degrees; north	100	0.1	0.1	0	0.086	1
(27) 28-36 degrees; northeast	35	0.0	0.0	0	0.030	1
(28) 28-36 degrees; east	29	0.0	0.0	0	0.025	1
(29) 28-36 degrees; southeast	34	0.0	0.0	0	0.029	1
(30) 28-36 degrees; south	460	0.7	0.4	1	0.913	1
(31) 28-36 degrees; southwest	149	0.2	0.1	0	0.129	1
(32) 28-36 degrees; west	45	0.1	0.0	0	0.039	1
(33) 28-36 degrees; northwest	77	0.1	0.1	0	0.067	1
(34) 37-45 degrees; north	31	0.0	0.0	0	0.027	1
(35) 37-45 degrees; northeast	11	0.0	0.0	0	0.010	1
(36) 37-45 degrees; east	6	0.0	0.0	0	0.005	1
(37) 37-45 degrees; northwest	5	0.0	0.0	0	0.004	1
Totals	70577	100.0	58.0	58	31.629	36

VITA

Scott D. Kreiter

Candidate for the Degree of

Master of Science

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