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General Technical
Report SRS-35

Ozark-Ouachita Highlands Assessment

Terrestrial Vegetation and Wildlife

REPORT
5
OF 5

Cover photo: Kings Bluff in the Ozark Mountains of Arkansas.

Photo by A.C. Haralson, Arkansas Department of Parks and Recreation, Little Rock, AR.

Natural resource specialists and research scientists worked together to produce the five General Technical Reports that comprise the *Ozark-Ouachita Highlands Assessment*:

- Summary Report
- Air Quality
- Aquatic Conditions
- Social and Economic Conditions
- Terrestrial Vegetation and Wildlife

For information regarding how to obtain these Assessment documents, please contact: USDA Forest Service, P.O. Box 1270, Hot Springs, AR 71902 or telephone 501-321-5202.

To limit publication costs, few color maps and figures were used in the Assessment reports. For color versions of some of the Assessment figures and supplemental material, please see the Assessment's home page on the Internet at **<http://www.fs.fed.us/oonf/ooha/welcome.htm>**. The Assessment reports will be online for about 2 years after the date on this publication; then they will be archived.

Please note: When "authors" are agency or business names, most are abbreviated to save space in the citations of the body of the report. The "References" at the end of the report contain both the full name and abbreviations. Because abbreviations sometimes are not in the same alphabetical order as the references, for clarifications of abbreviations, consult the "Glossary of Abbreviations and Acronyms."

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Ozark-Ouachita Highlands Assessment:

Terrestrial Vegetation and Wildlife

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Preface

Change is evident across the Ozark and Ouachita Highlands. Whether paying attention to State and regional news, studying statistical patterns and trends, or driving through the Highlands, one cannot escape signs that growth may be putting strains on the area's natural resources and human communities. How people regard these changes varies widely, however, as does access to reliable information that might help them assess the significance of what is happening in the Highlands. The Assessment reports provide windows to a wealth of such information.

This report (*Terrestrial Vegetation and Wildlife*) is one of five that document the results of the Ozark-Ouachita Highlands Assessment. Federal and State natural resource agency employees and university and other cooperators worked together to produce the four technical reports that examine air quality; aquatic conditions; social and economic conditions; and terrestrial conditions (the topic of the present volume). Dozens of experts in various fields provided technical reviews. Other citizens were involved in working meetings and supplied valuable ideas and information during the process. The *Summary Report* provides an overview of the key findings presented in the four technical reports. Data sources, methods of analysis, findings, discussion of implications, and links to dozens of additional sources of information are discussed in more detail in the other reports.

The USDA Forest Service initiated the Assessment and worked with other agencies to develop a synthesis of the best information available on conditions and trends in the Ozark-Ouachita Highlands. Assessment reports emphasize those conditions and trends most likely to have some bearing on the future management of the region's three national forests—the Mark Twain, Ouachita, and Ozark-St. Francis. People who are interested in the future of the region's other public lands and waters or of this remarkable region as a whole should also find the reports valuable.

No specific statutory requirement led to the Assessment. However, data and findings assembled in the reports will provide some of the information relevant for an evaluation of possible changes in the land and resource management plans of the Highland's three national forests. The National Forest Management Act directs the Forest Service to revise such management plans every 10 to 15 years, which means that the national forests of Arkansas, Missouri, and Oklahoma should have revised plans in the year 2001. Due to restrictions in the appropriations bills that provide funding for the Forest Service, however, it is uncertain when these revisions can begin.

The charter for the Ozark-Ouachita Highlands Assessment established a team structure and listed tentative questions that the teams would address. Assembled in mid-1996, the Terrestrial, Aquatic and Atmospheric, and Human Dimensions (Social-Economic) Teams soon refined and condensed these questions and then gathered and evaluated vast quantities of information. They drafted their key findings in late 1997 and refined them several times through mid-1999. In addition to offering relevant data and key findings in the reports, the authors discuss some of the possible implications of their findings for future public land management in the Highlands and for related research. The Assessment reports, however, stop well short of making decisions concerning management of any lands in the Highlands or about future research. In no way do the reports represent "plans" or make land management decisions. Instead, the findings and conclusions offered in the Assessment reports are intended to stimulate discussion and further study.

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Chapter 4: Silvicultural Practices

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In addition, the Terrestrial Team appreciates the help of the individuals who reviewed various chapters of this General Technical Report. Their comments and suggestions contributed to the preparation of this document. Information about these reviewers follows.

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Executive Summary

The Terrestrial Team examined the terrestrial resources of the Ozark-Ouachita Highlands as a complete unit, spanning 20 ecological units (subsections) and encompassing 41,131,900 acres (64,269 square miles). A unique feature of the North American landscape, the Highlands are the only extended area of substantial local relief (high hills and mountains) between the Appalachians and the Rockies.

This richly forested region has a long history of human occupation and ecological change. The various tribes of Native Americans who lived throughout the Highlands until the 1840's (when most Indians were re-settled in what is now eastern Oklahoma); the European settlers and loggers who cleared forests extensively in the latter half of the 19th and early 20th centuries; the agencies who successfully led the effort to suppress and control forest fires in the Highlands in the 1930's; and modern day urban and suburban expansion all have exerted influence on the vegetation and wildlife of the area in many ways.

The Terrestrial Team was comprised of foresters, biologists, ecologists, pathologists, and entomologists representing several State and Federal agencies and other individuals who served as consultants. With input from concerned citizens, six key questions were developed to guide assessment of terrestrial (land-based) conditions in the Highlands. To answer these questions, the Team reviewed scientific literature and assembled data from unpublished sources, including State and Federal databases. Finally, they relied upon the professional judgment of individual team members and other experts whom they consulted. In some cases, the team could not fully answer the questions because insufficient information is available. Following are the questions and key findings from each chapter.

Chapter 1: Ecological Units of the Highlands

What are the ecological boundaries and subsections of the Highlands?

- The map of sections and subsections of the Ozark-Ouachita Highlands (Keys and others 1995) was revised to better meet the needs of the Assessment. Changes were largely limited to the Arkansas and Oklahoma portions of the Assessment area.
- The modified map of sections and subsections of the Highlands of Arkansas and Oklahoma is the first such delineation in Oklahoma and provides significant advancements over the earlier maps by Croneis (1930) and Foti (1974) in Arkansas.

Chapter 2: Prehistoric and Historic Ecological Changes

What were the historic and prehistoric ecological conditions in the Ozark-Ouachita Highlands?

- American Indians influenced vegetation patterns through their use of fire.
- European settlers began making dramatic changes to the land commencing in the 1830's through land clearing and the suppression of fire; settlers also had an impact on animals by reducing certain habitats and by overhunting.
- Because people have been a constant influence on plant communities and ecosystems of the Highlands for thousands of years, ideas of "natural" (i.e., not human-influenced) conditions need to be reviewed carefully, even challenged.

Chapter 3: Status and Trends of Vegetation

What trends in vegetation cover and land use have occurred over the past 50 years?

Are changes in vegetation cover—including age-class distribution, species composition (e.g. cover types) and fragmentation—taking place?

How are old-growth forest stands distributed? What is their management status? What is the potential for retention or restoration of such communities?

- As measured by Advanced Very High-Resolution Radiometer data, oak-hickory forest is the most extensive vegetation type of the Assessment area, covering 15 million acres (ac) or 36 percent of the area.
- Oak-pine forest is the second most extensive within the region, with 4.4 million ac (11 percent of the

Assessment area). The largest acreage of this type (660,000 ac) occurs within the Fourche Mountains subsection of the Ouachita Mountains.

- Nonindustrial private forest (NIPF) owners hold 68 percent of the 22.89 million ac of timberland in the Assessment area; forest industry owns 11 percent. Thus, private and corporate landowners together hold more than 79 percent of the timberland. The remaining 21 percent consists of public timberlands, three-fourths of which are within one of the national forests.
- The abundance of oak in the Ozark-Ouachita Highlands is matched by only two other regions in the United States, the Central Appalachian and Eastern Broadleaf Forest (Continental) Provinces.
- The annual net growth of hardwoods and softwoods is more than double the annual removals.
- Since the 1970's, forested area has increased in five of the six Forest Inventory and Analysis (FIA) survey regions in the Highlands and, in some instances, dramatically.

Chapter 4: Silvicultural Practices

What trends are taking place in silvicultural practices in the Assessment area?

What trends are taking place in silvicultural practices on the Highlands' national forests?

- Upland hardwood forests consist of relatively shade intolerant species that typically are best suited to even-aged management. Except for one case in Missouri, the few successful examples of uneven-aged management in upland oak forests required aggressive chemical control of competing hardwoods.
- Shortleaf pine forests can be managed with a variety of even-aged or uneven-aged methods, but successful regeneration under single-tree selection typically requires chemical and/or mechanical control of competing vegetation. Natural regeneration also depends upon the co-occurrence of good seed crops, suitable seedbeds, and sufficient light.
- Clearcutting declined on national forests from 27,729 ac in 1988 to 698 ac in 1996, a 97.5 percent decline. This decline in clearcutting was the single most significant silvicultural trend on national forests in the Assessment area.
- Reproduction cutting on the national forests using the seed tree method averaged 2,382 ac/year (8.6 percent of the 1988 clearcutting level) from 1991 through 1996. During the same period, the area harvested using the shelterwood method averaged 3,157 ac/year (11.4 percent of the 1988 clearcutting level).
- The largest increase of a silvicultural method on the national forests was in the use of the single-tree selection. This increase was due more to single-tree selection being the exact opposite of clearcutting rather than to any particular advantages for either pine or oak-hickory silviculture. Together, the Ozark and Ouachita National Forests applied single-tree selection on an average of 8,916 ac annually from 1991 through 1995.
- Herbicide application for site preparation declined on the national forests from 12,705 ac in 1988 to 2,132 ac in 1997, an 83 percent decline over the 10-year period. Conversely, acres burned in site preparation on the Ouachita National Forest increased from 536 ac in 1989 to 3,137 ac in 1997. Each year, more acres have been burned than in the previous year. This trend suggests that the limits to using prescribed fire for site preparation have not yet been reached.
- The use of prescribed burning as a tool for managing intermediate stands has increased nearly four-fold over the past 5 years and exceeded 100,000 ac in 1997 (due primarily to actions on the Ouachita National Forest). The Ouachita National Forest has increased the use of prescribed burning to restore shortleaf pine-bluestem grass communities over extensive areas of the western Ouachitas, to sustain wildlife habitat diversity, and to encourage natural regeneration.

Chapter 5: Plant and Animal Populations

What are the current and likely future trends for populations and/or habitats for: (1) federally listed threatened and endangered species; (2) other terrestrial and amphibious species with viability concerns; (3) species that are hunted; (4) neotropical migratory birds; and (5) animals that live in caves?

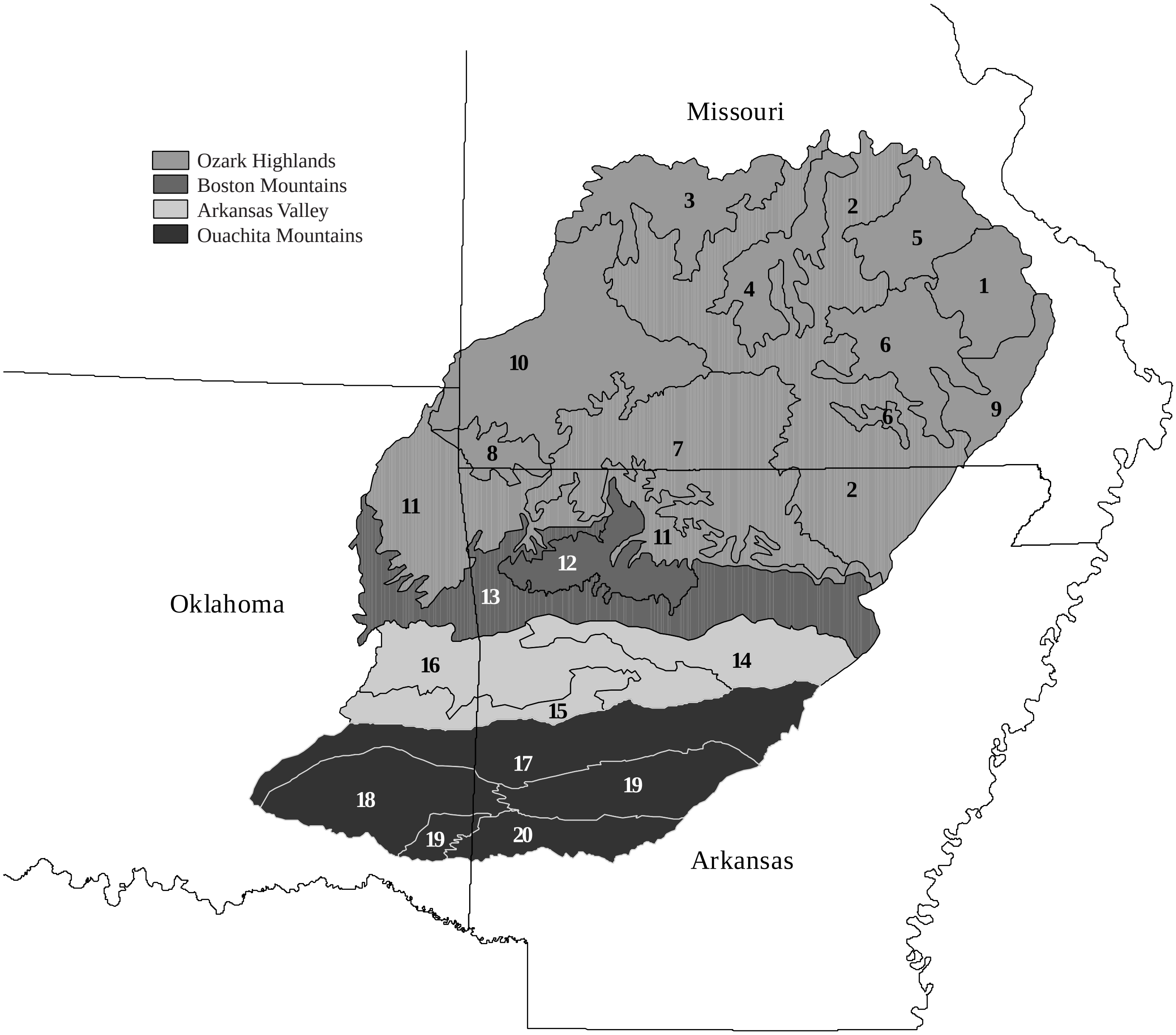
- Of the 333 plants and animals with viability concerns in the Ozark-Ouachita Highlands, 35 are imperiled

(having 20 or fewer known populations) or critically imperiled (5 or fewer known populations).
- More than half (53 percent) of the species with viability concerns in the Ozark-Ouachita Highlands are known to occur there only on national forest lands; about one-third of these species are known to occur there only on private lands.
- Sixteen species in the Ozark-Ouachita Highlands are federally listed as threatened or endangered.
- Available data for game species in the Highlands show that most populations have increased or remained stable since 1970.
- North American Breeding Bird Survey data revealed 21 of 90 species in the Ozark-Ouachita Highlands have declined significantly from 1966 to 1996. Six species showed a significant increase during the same period.

Chapter 6: Biological Threats to Forest Resources

What are the current and predicted trends for insect and disease infestations and outbreaks in the Assessment area?

- The European gypsy moth, a defoliator of hardwood trees, has been found in the Assessment area. The outbreaks have been minor, and eradication has been successful. Scientists expect that a general infestation might reach the Assessment area between 2025 and 2050.
- Red imported fire ants are invading the Assessment area from the south and are expected to continue a gradual northward expansion. Eradication is probably impossible. An integrated pest management program is the best approach to this problem.
- The southern pine beetle is indigenous to the southern part of the Assessment area. Serious outbreaks will continue to occur in the Ouachita Mountains Section. These outbreaks are cyclic and related to stand age and density of pine trees in a stand.
- Knapweeds, invasive nonnative plants, have been present for several decades on some roadsides in southern Missouri. There are health concerns for humans and livestock related to this plant. Precautions should be taken to minimize direct contact with this plant.
- Purple loosestrife, a serious pest in wetlands, is present in the Ozark-Ouachita Highlands and may spread.



Section name	Map code	Subsection name	Subsection number
Ozark Highlands	1	St.Francois Knobs and Basins	222Aa
Ozark Highlands	2	Central Plateau	222Ab
Ozark Highlands	3	Osage River Hills	222Ac
Ozark Highlands	4	Gasconade River Hills	222Ad
Ozark Highlands	5	Meramac River Hills	222Ae
Ozark Highlands	6	Current River Hills	222Af
Ozark Highlands	7	White River Hills	222Ag
Ozark Highlands	8	Elk River Hills	222Ah
Ozark Highlands	9	Black River Ozark Border	222Al
Ozark Highlands	10	Springfield Plain	222Am
Ozark Highlands	11	Springfield Plateau	222An
Boston Mountains	12	Upper Boston Mountains	M222Aa
Boston Mountains	13	Lower Boston Mountains	M222Ab
Arkansas Valley	14	Eastern Arkansas Valley	231Ga
Arkansas Valley	15	Western Arkansas Valley Mountains	231Gb
Arkansas Valley	16	Western Arkansas Valley	231Gc
Ouachita Mountains	17	Fourche Mountains	M231Aa
Ouachita Mountains	18	Western Ouachita Mountains	M231Ab
Ouachita Mountains	19	Central Ouachita Mountains	M231Ac
Ouachita Mountains	20	Athens Piedmont Plateau	M231Ad

Figure 1.1—Ecological sections and subsections of the Ozark-Ouachita Highlands Assessment area (sections and subsections modified from Keys and others 1995).

Chapter 1: Ecological Units of the Highlands

This report is one of a five developed for the Ozark-Ouachita Highlands Assessment. The team that produced this report was comprised of scientists from a variety of disciplines—wildlife biologists, foresters, ecologists, pathologists, and entomologists. They had in common an interest in the terrestrial vegetation and animal species of the Highlands and a willingness to examine the status of these "terrestrial resources."

Questions about the terrestrial animals, plants, and biological communities of the Highlands were developed at a series of Terrestrial Team meetings in the summer of 1997. No new information was collected in the field to address these questions. Instead, existing data from various agencies and individuals were gathered and analyzed. Two concerns emerged powerfully as sources of information were identified: while an overwhelming amount of information exists for the Highlands, many species have not been studied and the information that is available from various sources is often in different formats, covers different time periods, and/or covers different geographic areas.

One early and continuing challenge was how best to organize and present the information. The Terrestrial Team decided to use the ecologically defined units presented in this chapter to provide a consistent framework throughout the report. Chapter 2 presents an overview of prehistoric and more recent change in the Highlands. Current vegetation cover is examined in some detail in Chapter 3, and silvicultural practices receive in-depth treatment in Chapter 4. Chapter 5 examines many plant and wildlife species of special concern, and Chapter 6 covers current and future biological threats to forest resources.

Question 1.1: What are the ecological boundaries and subsections of the Highlands?

Key Findings

1. The map of sections and subsections of the Ozark-Ouachita Highlands (Keys and others 1995) was revised to better meet the needs of the Assessment. Changes were largely limited to the Arkansas and Oklahoma portions of the Assessment area.
2. The modified map of sections and subsections of the Highlands of Arkansas and Oklahoma is the first such delineation for Oklahoma and provides significant advancements over earlier maps for Arkansas by Croneis (1930) and Foti (1974).

The Ozark-Ouachita Highlands Assessment Area

This report contains data and key findings in the context of an ecologically defined area—the Ozark-Ouachita Highlands (fig. 1.1). Although the term "Interior Highlands" is familiar to geographers and biologists, it is not commonly recognized in other circles. Most people are more familiar with "the Ozarks" and "the Ouachita Mountains" than they are with the older geographic name for the two areas. Thus, the Assessment team leaders chose to use a term likely to be more widely recognized—the Ozark-Ouachita Highlands.

The Ozark-Ouachita Highlands is an appropriate area to assess because it has relatively consistent ecological characteristics and is distinctively different from surrounding landscapes. Consisting mostly of hilly to mountainous topography over substrates of Paleozoic age, the Highlands have long been recognized as a distinct physiographic and natural region (Fenneman 1938, Braun 1950). Upland hardwood and upland pine-hardwood forests characterize much of the area. Lower-lying plains with more recent geological substrates also occur in portions of the Highlands, including much of the Arkansas Valley section. The vegetation of these plains ranges from tallgrass prairie to lowland pine-hardwood and bottomland hardwood forests.

Even though the Ozark-Ouachita Highlands have some consistent general characteristics, there are also striking differences within it. Therefore, most descriptions and studies divide the region into smaller, more uniform areas. Authors have generally recognized at least two provinces, the Ozark Mountains and the Ouachita Mountains (Fenneman 1938, Thornbury 1965, Braun 1950, Croneis 1930, Foti 1974). Sometimes, the Arkansas Valley has been considered a separate province or natural division (Foti 1976, Pell 1983, Omernik 1987). While most authors treated the Boston Mountains as a subdivision of the Ozark Mountains, Omernik (1987) recognized it as a separate ecoregion (natural division). These provinces, natural divisions, or sections are often subdivided as well.

Data Sources

To facilitate agency ecosystem management efforts, the USDA Forest Service developed a new regionalization framework for the Eastern United States (Keys and others 1995, henceforth referred to as "Keys and others" or the "Keys map") based on a national map of ecoregions of the United States by Bailey and others (1994). The new framework is hierarchical (like older efforts) but is based on a more holistic consideration of landscape properties than some earlier maps, with climate and soil playing prominent roles along with physiography. The new framework is also designed to rationally subdivide landscapes in ways meaningful to ecosystem management. The older and newer maps coincide most closely at the level of section (Keys and others), province (Fenneman 1938), and natural division (Foti 1974). Although differences occur at this level they are usually in the form of one unit in one system equating to two units in another system. The new framework is often more detailed at lower levels in the hierarchy than older maps.

The Terrestrial Team examined the Keys and others (1995) framework to determine whether the ecological units and their boundaries were adequate for Assessment purposes. Important considerations were that the sections and subsections and their boundaries be ecologically meaningful and consistent across State lines. Examination of the Keys map and comparison with other regional maps and geological and topographical base maps revealed that sections and subsections and their boundaries were not consistently meaningful and accurate across the Assessment area. The Missouri units and their boundaries have been settled for years; therefore, the Keys map simply adopted those boundaries, and changes needed for the Assessment were very minor.

In contrast, the Arkansas units and boundaries needed considerable revision because: (1) the Keys and others (1995) approach departs substantially and without convincing rationale from long-standing delineations (Croneis 1930, Foti 1974) and (2) locally created maps were not available. The Keys map is also problematic in Oklahoma, because in that State only general regions have been defined (OK BTF 1996), boundaries are not detailed, and subdivisions are not mapped. Furthermore, the Keys map appears to be derived from low-detail base maps, and its boundaries were judged to be too general for this Assessment. The Keys map and supporting materials do not explicitly define the source or rationale for boundaries; therefore, revision of the map sometimes required a determination of the defining physical feature and use of an appropriate base map.

Although production of the new map (fig. 1.1) involved many changes to the Keys and others (1995) map, few changes were made in the list of sections and subsections. (A map illustrating the changes the team made to subsection boundaries is available on the Web site for the Assessment, <http://www.fs.fed.us.oonf>.) The emphasis was on employing clearly-stated boundary definitions that in most cases were first articulated by Croneis (1930), and then using appropriate digital base maps to create an accurate final product. Many changes were made to the Croneis (1930) and Foti (1974) maps, however, primarily by adding detail to the older maps. (See, for examples, the White River Hills and Central Plateau subsections [which are nested within the Salem Plateau of Croneis 1930], the Upper and Lower Boston Mountains subsections [nested within the Boston Mountain subdivision of Foti 1974], or the three new subsections within the Arkansas Valley.)

Croneis (1930) and Foti (1974) presented rationales for many regional boundaries in Arkansas and Oklahoma, most of which were adopted for this revision. All boundaries are based on either geology or topography, although soils maps were used for comparison in some cases. The geologic base map was the 1:2,500,000-scale geology of the conterminous United States (Schruben and others 1994). The topographic base map was created for this project from 30-meter (m) USGS digital elevation model files by the Spatial Analysis Laboratory of the School of Forest Resources, University of Arkansas at Monticello.

Ecological Units

The following discussion describes the ecological units used in the Ozark-Ouachita Highlands area and the factors on which the boundaries were based along with changes from the Keys map. Alphanumeric codes used here are the same as those used in the Keys map.

The modified map of sections and subsections of the Highlands of Arkansas and Oklahoma (fig. 1.1) is the first such delineation for Oklahoma and provides four significant advancements over earlier maps for Arkansas by Croneis (1930) and Foti (1974):

- Boundaries are defined and mapped consistently across the three States sharing the Highlands;
- Boundaries based on topography are much more accurate than previous maps due to the use of 30-m digital elevation models;
- Changes in section and subsection definitions that have occurred since production of the earlier maps are incorporated; and
- The map produced by this team is in digital form and freely available on the Assessment Web site.

Ozark Highlands Section (222A)

Six subsections in Missouri and Illinois were not included in the Assessment area: 222Ai (Prairie Ozark Border); 222Aj (Inner Ozark Border); 222Ak (Outer Ozark Border); 222Ao (Mississippi River Alluvial Plain); 222Ap (Missouri River Alluvial Plain); and 222Aq (Illinois Ozarks). These were excluded because they are on the periphery of the region, are not included in some data sets used for the Assessment, and would have complicated the analysis by extending it to an additional State. Following are the subsections that were included in the Assessment area and brief descriptions of each.

222Aa—The St. Francis Knobs and Basins, which cover 1,108,009 acres (ac), occur only in Missouri. They consist of steep hills (but not an eroded plateau like the other Ozark subsections) that are 400 to 1,700 feet (ft) in elevation and underlain by Cambrian and Precambrian igneous and sedimentary rocks. The subsection is covered with acid glades, oak woodlands, and dry-mesic oak forests. No changes were made in the Keys map boundaries.

222Ab—The Central Plateau subsection occurs in Missouri (5,006,390 ac) and Arkansas (1,335,220 ac) and consists of irregular plains 300 to 1,600 ft in elevation with karst features on Ordovician cherty dolomite, sandstone, and cherty clay residuum covered with prairies, oak woodlands, and dry-mesic oak forests. The Keys map boundary with the White River Hills subsection was altered to follow the break in topography between these subsections.

222Ac—The Osage River Hills (1,550,855 ac) occur only in Missouri, where they consist of hills with entrenched valleys 600 to 1,100 ft in elevation that were formed by streams downcutting to the Osage River. Underlain by Ordovician cherty dolomite, sandstone, and cherty clay residuum, this subsection is covered with pine-oak and oak woodlands and forests. No changes were made in the Keys map boundaries.

222Ad—The Gasconade River Hills subsection (1,098,006 ac) occurs only in Missouri. Similar to the Osage River Hills, this subsection consists of hills with entrenched valleys and karst features and was formed by streams downcutting to the Gasconade River. Underlain by Ordovician cherty dolomite, sandstone, and cherty clay residuum, the Gasconade River Hills range from 600 to 1,100 ft in elevation and are covered with pine-oak and oak woodlands and forests. No changes were made in the Keys map boundaries.

222Ae—The Meramac River Hills (1,136,219 ac) occur only in Missouri. (The correct spelling of the river for which this subsection is named is "Meramec," but the team left the Keys and others [1995] name unchanged.) This subsection consists of hills with entrenched valleys formed by streams downcutting to the Meramec River. Underlain by Cambrian and Ordovician cherty dolomite and cherty clay residuum and ranging from 500 to 1,300 ft in elevation, this subsection is covered with pine-oak and oak woodlands and forests. No changes were made in the Keys map boundaries.

222Af—The Current River Hills (1,563,186 ac) occur in Missouri and consist of entrenched valleys with karst features formed by streams downcutting to the Current River. Underlain by Cambrian and Ordovician cherty dolomite and sandstone with cherty clay residuum and ranging from 400 to 1,300 ft in elevation, the Current River Hills are covered with pine-oak and oak woodlands and forests. No changes were made in the Keys map boundaries.

222Ag—The White River Hills subsection occurs in Missouri (2,155,950 ac) and Arkansas (1,577,221 ac) and consists of hills with entrenched valleys and karst features. It was formed by streams downcutting to the White River. Underlain by Ordovician cherty dolomite with cherty clay residuum and ranging from 600 to 1,600 ft in elevation, this subsection is covered with alkaline glades and oak woodlands and forests. Changes were made in the Arkansas portion of the Keys map boundaries to better follow the break in topography from the surrounding plains.

222Ah—The Elk River Hills occur in Missouri (356,326 ac), Arkansas (57,433 ac), and Oklahoma (32,334 ac) and consist of hills with entrenched valleys and karst features. Formed by streams downcutting to the Neosho River, the subsection is underlain by Mississippian cherty limestone with cherty clay residuum, ranges from 900 to 1,400 ft in elevation, and is covered with oak woodlands and forests. Changes were made in the Arkansas portion of the Keys map boundaries to better follow the break in topography from the surrounding subsections.

222Al—The Black River Ozark Border (859,059 ac) occurs only in Missouri. It consists of irregular plains and low hills with karst features. Underlain by Ordovician sandstone and cherty dolomite with cherty clay residuum, this subsection ranges from 300 to 900 ft in elevation and is covered with pine-oak and oak woodlands and forests and oak-sweetgum forests. The Keys map boundaries were modified to eliminate this subsection from Arkansas.

222Am—The Springfield Plain lies in Missouri (3,136,051 ac) and Oklahoma (161,881 ac) and is a smooth plain with karst features underlain by Mississippian limestone (sometimes very cherty) and cherty clay residuum. Ranging from 800 to 1,700 ft in elevation, this subsection is covered with prairie and oak woodlands and forest. No changes were made in the Keys map boundaries.

222An—The Springfield Plateau subsection occurs in Oklahoma (1,486,718 ac), Arkansas (1,579,841 ac), and Missouri (56,326 ac) and consists of smooth to irregular plains 800 to 1,400 ft in elevation with karst features. Underlain by Mississippian limestone (sometimes very cherty) and cherty clay residuum, this subsection is covered with prairie and oak woodlands and forest, alkaline, and acid glades. Detail changes were made in the Keys map boundaries to better follow the break in topography to the Elk River Hills and to more closely follow the boundaries with older and younger geological substrates throughout the rest of the subsection perimeter.

Boston Mountains Section (M222A)

In earlier maps, with the exception of Omernik (1987), this section was treated as a subsection or equivalent.

M222Aa—The Upper Boston Mountains (1,106,642 ac) occur only in Arkansas. They consist of low mountains 1,000 to 2,700 ft in elevation underlain by Pennsylvanian sandstone and shale with sandy residuum and loamy colluvium. This subsection is covered with oak woodlands and forests. Detail changes were made in the Keys map boundaries to better follow the geologic boundary with the Springfield Plateau and to better follow the corresponding land type association boundaries developed by the Ozark-St. Francis National Forests elsewhere along the perimeter of the subsection. This subsection was defined on the basis of elevation (approximating the 1,800-ft elevation contour), which corresponds to areas of lower temperature and higher rainfall and consequent changes in plant community composition. The Keys map name for this subsection (Boston Mountains) and the following subsection (Boston Hills) were changed to reflect that both are parts of the vernacular and physiographic Boston Mountains.

M222Ab—The Lower Boston Mountains subsection occurs in Oklahoma (834,553 ac) and Arkansas (2,471,699 ac) and consists of high hills 500 to 1,800 ft in elevation underlain by Pennsylvanian sandstone and shale with sandy residuum and loamy colluvium. The

Lower Boston Mountains are covered with pine-oak and oak woodlands and forests. Detail changes were made to the Keys map boundaries to better follow the corresponding landtype association boundaries developed by the Ozark-St. Francis National Forests for the Upper Boston Mountains and to better follow the boundary with younger and older geologic substrates elsewhere along the northern, eastern, and western perimeter of the subsection and the topographically defined southern boundary (the escarpment to the Arkansas Valley section [Croneis 1930, Foti 1974]). The Keys map name for this subsection (Boston Hills) was changed as explained in the description of the Upper Boston Mountains.

Arkansas Valley Section (231G)

231Ga—The Eastern Arkansas Valley (1,490,182 ac) lies entirely in Arkansas, where it consists of plains with hills 300 to 500 ft in elevation. Underlain by Pennsylvanian sandstone and shale with sandy residuum, this subsection is covered with pine-oak and pine woodlands and forests. Northern and eastern boundaries were modified in detail to better match topographic and geologic boundaries, respectively. The southern boundary was redefined to match the traditional physiographic boundary, Cadron Ridge (Croneis 1930, Foti 1974). The southwestern boundary was redefined to place all Arkansas River bottomlands within the Western Arkansas Valley subsection; topographic and geologic boundaries also contributed to the modified subsection boundary. The Keys map name was changed to eliminate “and Ridges” since the redefined southern boundary eliminated the most prominent structural ridges from the subsection (one of the reasons for redefining that boundary).

231Gb—The Western Arkansas Valley Mountains occurs in Oklahoma (494,643 ac) and Arkansas (433,498 ac). It consists of low mountains and ridges and some wide valleys as well. Ranging from 750 to 2,800 ft in elevation, the Western Arkansas Valley Mountains are underlain by Pennsylvanian sandstone and shale with sandy residuum and covered with pine-oak and oak woodlands and forests and prairies. The eastern, northern, and western boundaries as delineated on the Keys map were modified somewhat to better include the mountains and exclude the plains that were continuations of those in the Western Arkansas Valley. The southern boundary was changed to follow the northern boundary of the physiographic Ouachita Mountains (Croneis 1930, Foti 1974). The Keys map name (Mount Magazine) was changed to reflect the importance of other mountains within this subsection.

231Gc—The Western Arkansas Valley subsection includes portions of Oklahoma (829,099 ac) and Arkansas (1,354,977 ac) and consists of plains, low hills, and ridges 300 to 1,000 ft in elevation underlain by Pennsylvanian sandstone and shale with sandy and clayey residuum along with Holocene sandy alluvium. This subsection is covered with pine-oak and oak woodlands and forests, substantial bottomland forests, and prairies. One major low mountain, Petit Jean Mountain, was included within this section because it was disjunct from the Western Arkansas Valley Mountains, in which it would otherwise have been included. The northern, eastern, and southern boundaries of the Keys map were refined based on topography and geology to place all of the Arkansas River alluvial plains, the most extensive alluvial plains of its major tributaries, and almost all of the Pennsylvanian eroded plains within this subsection. A substantial area that extended up the Canadian River at the western end of this subsection on the Keys map was eliminated on the basis of geology, topography, and the definition of the Arkansas Valley as lying between the Ouachita Mountains and the uplifted plateaus of the Ozark Mountains (Croneis 1930).

Ouachita Mountains Section (M231A)

M231Aa—The Fourche Mountains occur in Oklahoma (743,093 ac) and Arkansas (2,148,080 ac) where they form open, low to relatively high mountain ridges, often with wide valleys. Elevations range from 750 to over 2,600 ft, among the highest in the Assessment area. Ridges are underlain by Pennsylvanian and Mississippian sandstone and shale valleys by sandy residuum. Slopes and ridges are covered with pine-oak and oak woodlands and forests. The northern boundary was modified from Keys to coincide with the physiographic boundary based on topography (Croneis 1930, Foti 1974). The southern boundary was modified to match the boundary with Mississippian Arkansas

Novaculite and toward the west to follow the long narrow ridges and include the Pennsylvanian Jackfork Sandstone.

M231Ab—The Western Ouachita Mountains subsection occurs in Oklahoma (1,623,109 ac) and Arkansas (109,249 ac) and consists of open high hills and low mountains, often with wide valleys, with elevations ranging from 750 to 2,500 ft. The subsection is underlain by Mississippian sandstone and shale with clayey colluvium, covered with pine-oak and oak woodlands and forests, along with prairies. The Keys map boundaries were modified using geology (Arkansas Novaculite) to eliminate portions of the Central Ouachita Mountains from this subsection. The word "Central" was eliminated from the Keys map name (West Central Ouachita Mountains) because a substantial part of the subsection lies along the southern boundary of the Ouachita Mountains section.

M231Ac—The Central Ouachita Mountains occur in Oklahoma (244,015 ac) and Arkansas (1,401,574 ac). They consist of open high hills and low mountains, often with wide valleys, and they range from 750 to 2,500 ft in elevation. The Central Ouachita Mountains are underlain by Mississippian sandstone and shale with clayey colluvium and covered with pine-oak and oak woodlands and forests. The Keys map boundaries were modified using geology (Arkansas Novaculite); a large disjunct area with consistent characteristics is newly delineated in southeastern Oklahoma. The Keys map name was changed by dropping "East" as it was no longer needed (because of the name change to Western Ouachita Mountains).

M231Ad—The Athens Piedmont Plateau occurs in Oklahoma (56,546 ac) and Arkansas (837,602 ac). It consists of open high hills underlain by Mississippian (with small amounts of Pennsylvanian) sandstone and shale with sandy and clay-loam colluvium covered with pine-oak and pine woodlands and forests. The Keys map boundary was refined using geology (Arkansas Novaculite) for north and west boundaries and Tertiary and Cretaceous deposits on the south and east.

Chapter 2: Prehistoric and Historic Ecological Changes

Question 2.1: What were the historic and prehistoric ecological conditions in the Ozark-Ouachita Highlands?

Change occurs constantly in the Ozark-Ouachita Highlands, as it does in all ecosystems. Since the last glacial period, 20,000 years ago, when continental glaciers approached the Highlands, climate, natural communities, and species have been in constant flux. Even now, natural occurrences such as droughts, floods, and tornadoes cause dramatic changes in the landscape and in relationships among species. Such events are not only natural, they are vital to the way ecosystems function.

Human activities also cause changes. Some activities may only alter patterns of "natural change" including, for example, prevention and suppression of fire, some forms of timber management, and controlled hunting and fishing. Such activities may affect biodiversity—the variety of species interacting within an ecosystem. They may also alter the structure or dynamic processes of an ecosystem. Where natural processes are significantly altered, ecosystems can be stressed and vulnerable to further damage.

Some activities, such as conversion of forest land for agriculture, mineral extraction, plantation-based timber production, or urban development, can cause large-scale changes that reduce and/or fragment wildlife habitat for some species, which, if sufficiently severe, can mean their extinction. Such changes may completely supplant long-standing ecological relationships and cause revolutionary, rather than evolutionary effects. Contamination of groundwater, introduction of nonnative species, and overhunting of game are other human actions that fundamentally change ecosystems.

The interaction of different change factors, or what ecologists often call "disturbance factors," has consequences, as well. For example, floods in heavily managed or developed watersheds may be more destructive than in less altered watersheds. Even activities outside the local ecosystem may cause effects within it, such as altered climate or acid rain.

An understanding of earlier conditions helps research scientists and managers evaluate the ecological potentials of various landscapes or sites and identify opportunities for appropriate management actions. If shortleaf pine production or pine woodland restoration is an objective, it is useful to know the prehistoric range of this species and what kept it from dominating in other areas. In developing landscape management plans, it is important to know what percentage of the landscape was typically in a regenerating condition at any point in time, how regeneration took place, how much was woodland or prairie, how much was "old growth," and the dynamic equilibrium that existed among these various states which, together, sustained the biota.

Knowledge of historic vegetation and patterns of change aids in the identification of current old-growth areas and selection of appropriate management techniques for them. It also provides a useful baseline for evaluating the effects of management on natural systems. Differences between structure and function of existing and historic forests and between effects of management techniques and natural disturbance processes may be estimated using information about past vegetation.

Key Findings

1. American Indians influenced vegetation patterns through their use of fire.
2. European settlers began making dramatic changes to the land commencing in the 1830's through land clearing and the suppression of fire; settlers also had an impact on animals by reducing certain habitats and by overhunting.
3. Because people have been a constant influence on plant communities and ecosystems of the Highlands for thousands of years, ideas of "natural" (i.e., not human-influenced) conditions need to be reviewed carefully, even challenged.

Data Sources

Clues to the composition and structure of the Highlands in history and prehistory are provided by historical descriptions, evidence in old-growth forests and natural areas, tree rings and pollen evidence, and field notes of General Land Office (GLO) surveyors of the 19th century.

Travel accounts and other historic descriptions are important sources of information on past conditions. Dunbar and Hunter led an expedition, commissioned by Thomas Jefferson, to the hot springs of the Ouachita Mountains in 1804 and 1805 (Rowland 1930). Edwin James (1823), botanist for the Stephen Long expedition to the Rocky Mountains in 1819–1820, described the Ouachita Mountains and Arkansas Valley. Thomas Nuttall (1821) provided a very detailed description of the Arkansas Valley and the western portions of the Ouachita Mountains. Henry Rowe Schoolcraft's (1821) account of his 1818 and 1819 travels through the Ozarks is the most widely cited description of that region. Gerstäcker (1881) provided descriptions of the Ouachitas and Ozarks of the late 1830's, at approximately the time of the GLO surveys. Ladd (1991) provided a comprehensive survey of historic references to vegetation and fire in Missouri, including the Missouri Ozarks.

GLO surveys of parts of the Assessment area are important sources. Foti and Glenn (1991) used notes from the original 1830's Federal land survey to analyze vegetation at three locations in the Assessment area: a site east of Waldron, AR, at the southern edge of the Arkansas Valley Mountains subsection, known as Bee Mountain; a site south of Waldron, in the Fourche Mountains, that currently supports a red-cockaded woodpecker population; and a north-to-south transect crossing the Fourche Mountains, Western Ouachita Mountains, and Athens Piedmont Plateau subsections near the Arkansas-Oklahoma State line, covering more of the range of sites of the region.

In addition, Kreiter (1995) analyzed historic vegetation of the McCurtain County Wilderness Area, an old-growth forest that has not been subject to timber harvest in the Central Ouachita Mountains subsection of eastern Oklahoma. He used GLO Survey notes from 1896 and compared them to a new survey of vegetation at the same points. Lockhart and others (1995) and Harmon and others (1996) used GLO and modern data to characterize the vegetation of the Lee Creek Unit of the Ozark-St. Francis National Forests. Nelson (1997) analyzed witness trees and narrative notes along the 5th Principal Meridian through Arkansas and Missouri, comparing statistics of the Ozark Plateau (principally in Missouri), the Mississippi Alluvial Plain (in Arkansas), and the Dissected Till Plain (in Missouri). Schroeder (1982) used GLO notes and maps to map the presettlement distribution of prairies in Missouri. Finally, Fletcher and McDermott (1957) used historic sources to map the presettlement range of shortleaf pine in the Ozark Highlands.

All historic sources must be used with caution, since many writers are not scientists and their descriptions are not often subject to independent verification. However, all of the travel writers listed above except Gerstäcker were scientists. In several instances their travel routes have been followed and key findings verified. Of these, Schoolcraft may be the most controversial, since he was cited by both sides in a rancorous dispute over vegetation of the Ozarks (Beilman and Brenner 1951, Steyermark 1959), where Beilman and Brenner argued for rapid change in vegetation in the Highlands whereas Steyermark argued for stability. However, when read as a whole, the Terrestrial Team considers his account a reliable historic source. The GLO surveys have been widely used and widely criticized, since they represent the only comprehensive, quantitative data on vegetation of the early to mid-1800's, and yet were not collected for scientific purposes by scientists. Their validity should be assessed on a township-by-township basis before placing reliance on them.

Grazing data reflects the Forest Service's Grazing Statistical Summary and the Natural Resource Conservation Service's National Resource Inventory, as well as published reports. Data concerning the volume of grazing on national forest lands are reported in Animal Unit Months while, for other lands, the data consist of acreage devoted to grazing.

Patterns and Trends

Major Changes in Vegetation

As recently as 20,000 years ago, continental glaciers advanced near the Highlands (to central Illinois). Although glaciers have never encroached on the Highlands proper, climatic effects during glacial periods totally changed the region's ecosystems. Cool, damp, glacial-front climate led to dominance of boreal spruce, fir, and jack pine forests throughout the region for about 6,000 years after the latest glacial maximum.

Oak, ash, elm, and other deciduous trees became dominant around 14,000 years ago and prairies became established in eastern Oklahoma about 2,000 years later (Delcourt and Delcourt 1991). The oak-hickory woodlands and forests characteristic of the region today may have persisted in sheltered coves throughout the glacial interval and subsequently increased in abundance or retreated elsewhere and returned. Presence of numerous endemic species in the Highlands flora and fauna argues for at least some continuity of the biota even during these periods of dramatic change (Hawker n.d.).

Some 10,000 years ago, at the same time that humans arrived in the Highlands, the climate became warmer and drier for a period of several thousand years, allowing expansion of prairies, oak savannas, and oak-hickory forests or woodlands (Delcourt and Delcourt 1991). As prairies and savannas spread over the region, mesic (moist soil) oak-hickory forest communities again retreated to sheltered coves and moister sites or migrated away from the region.

Only in the past several thousand years has climate in the region changed enough to support an upland hardwood forest, and only during this latest interval (the past 4,000 years) has pine forest become dominant in parts of the region (Delcourt and Delcourt 1991). Over this interval, a prairie-dominated landscape changed to a forest-dominated landscape with inclusions of prairie (Albert and Wyckoff 1981). Even during the last 550 years there have been at least three dry intervals severe enough to reduce pine dominance in the Ouachitas (Albert and Wyckoff 1981).

American Indians played a part in shaping these changes in vegetation. At least in portions of the Highlands, Indian populations may have peaked in the 16th century at the time of De Soto's incursion, after which smallpox and other factors reduced their numbers. Prior to that time, productive areas were settled and agriculture was practiced. Even small populations could have had major effects on the landscape through their use of fire.

European settlers began making major changes in the region's landscapes by the 1830's, both through clearing of land and changes in natural processes such as fire regimes. This trend reached a peak from the late 18th to early 19th centuries, when railroads carried away much of the standing timber and brought farmers and even tourists, causing massive and irreversible changes in the landscapes of the Highlands. Forests became shrubby second growth or cotton fields that were abandoned and only after decades became forests again. Fires often increased in intensity and frequency as the slash dried and burned and then decreased as areas became more settled. Open woodlands, savannas, and prairies became forests or shrubby thickets.

Changes in Wildlife and Plant Populations

Expanding settlements caused long-term changes in the populations of game species. Deer populations in the Highlands have fluctuated greatly, from abundance in the early 1800's to near extirpation in the early 1900's. Deer recovery began in the 1930's (but only reached substantial proportions decades later) with closed seasons, strict law enforcement, and restocking (Halls 1984). Refuges on national forest lands also supported the recovery of deer populations in the Assessment area.

Early reports of eastern wild turkeys in the Highlands suggest densities of 5 to 10 birds per square mile. By the early 1900's, the bird's population was drastically lower over most of the region (Lewis 1992), due to overharvesting. By the 1940's, only isolated populations remained. Habitat for wild turkeys began to improve on public lands after initiation of fire and timber management programs and the closing of "open range"—areas where anyone's stock was allowed to graze.

The black bear was a common resident of the Highlands during the 1800's but was rare by 1850 because of overhunting (McKinley 1962). During the period from 1890 to 1920, much of the Highlands' forest was systematically logged and cleared, eliminating the black bear population from the region (Clark 1988). The Arkansas Game and Fish Commission successfully re-established black bears in the Ozark-Ouachita Highlands of Arkansas between 1959 and 1967 (Rodgers 1973, Pharris 1981). Since then, populations have grown and expanded, increasing the sightings of bears in adjacent areas of Oklahoma and Missouri.

At times, the Highlands have had large populations of gray and fox squirrels. During the 19th century, individual hunters could easily kill more than 100 squirrels a day. The "big squirrel kills" were a thing of the past by 1934, due to habitat reductions.

Clearing of forests supported expanding populations of bobwhite quail, with the bird's numbers peaking immediately after areas were cleared for agriculture, then abandoned. But populations declined by the 1920's as land use became more intensive. Populations stabilized by the 1940's, albeit at lower levels than historically, to provide consistent bird crops, but fluctuated again in the 1960's (Stanford 1970).

Similarly, clearing of forests led to expanding populations of eastern cottontail rabbits, which inhabit prairies, glades, and open woods with grassy understories. The rabbit reached a population peak during the pioneer agricultural period (Anderson 1940). "Ozark" rabbits were said to command a premium price because of their size and grading. During the early 1900's, Springfield, MO, was the largest reshipping center in the region, with an annual output of 2 million rabbits (Leopold 1931).

Raccoon populations have increased in the past 50 years. A population explosion began with the 1943 breeding season, and the species has remained at high levels since (Sanderson 1987). It is estimated today there are 15 to 20 times as many raccoons in North America as there were during the 1930's. (See Chapter 5 for recent trends for game species.)

At least 25 species of terrestrial plants, vertebrates, and invertebrates existing historically in the Ozark-Ouachita Highlands are extirpated. (An extirpated species, as used here, is one eliminated as a wild species from all or part of its historical range.) Mammal and bird species congregating in large numbers, including bison and Carolina parakeets, or which people considered destructive predators, such as golden eagles and mountain lions, are gone from the Highlands landscape (although the occasional reintroduced bison can be spotted in a few pastures).

Major factors contributing to the extirpation of these species in the Ozark-Ouachita Highlands included loss of habitat and overhunting. Plant species at the edges of their ranges and parts of rare communities also have been vulnerable to loss of habitat and to extirpation (see "Rare Communities" in Chapter 3). The following species have been extirpated in the Assessment area (and, in some cases, throughout their range):

Species	**Major factor in extirpation**
American swallow-tailed kite	Loss of habitat
Bison	Overhunting
Black-fruit mountain-ricegrass	Loss of habitat
Black lordithon rove beetle	Unknown
Carolina parakeet	Overhunting
Clustered poppy-mallow	Loss of habitat
Creamflower tick-trefoil	Loss of habitat
Ditch-grass	Loss of habitat
Eastern prairie white-fringed orchid	Loss of habitat
Eaton's lipfern	Loss of habitat
Field sedge	Loss of habitat
Golden eagle	Predator control
Horsetail spikerush	Loss of habitat
Ivory billed woodpecker	Loss of habitat
Marsh blazing star	Loss of habitat
Missouri blackberry	Loss of habitat
Mountain lion	Predator control
Northern raven	Predator control
Osprey	Predator control
Passenger pigeon	Overhunting
Peregrine falcon	Predator control
Red wolf	Predator control
Torrey's bulrush	Loss of habitat
Yellowleaf tinker's-weed	Loss of habitat

Historic Changes by Ecological Section

Historic accounts and GLO data reveal more details about the historic period in various ecological sections and subsections of the Highlands. (Ecological units are displayed in fig. 1.1.)

Ozark Highlands

Schoolcraft's account of the White River country in 1818–1819 indicates rich biodiversity and varied ecological communities in the Ozark Highlands. His daily log, with distances traveled and vegetation encountered each day, is an invaluable record of the area he crossed (all page references for this section are to Rafferty 1996).

He described the Meramec River Hills subsection as "hills crowned with oaks" (p. 21), then "yellow pine [and] the soil being sterile, and vegetation scanty" (p. 22) with rich forest lands along the Fourche a Courtois (p. 23) followed by "a succession of sterile ridges, thinly covered with oaks" (p. 24). The Osage Fork of the Meramec had "extensive prairies all along its banks" (p. 24). He also found "barren prairie country" (p. 26). The Current River Hills subsection had "lofty forests of pine" and along the Current River the "soil [was] rich and covered with a heavy growth of trees" (p. 26), as well as ridges covered "thinly with yellow pine, and shrubby oaks . . . ." (p. 35).

He described the Central Plateau subsection as "highland prairie, with little timber, or underbrush and covered with grass. It is a level woodless barren covered with wild grass and resembling the natural meadows or prairies of the western country in appearance, but lacks their fertility, their wood, and their remarkable equality of surface" (p. 35–36).

In the White River Hills subsection, on the headwaters of the North Fork of White River, travel was initially over "rich bottom lands, covered with elm, beech, oak, maple, sycamore and ash" (p. 41). Turning west from the stream "to completely disengage ourselves from the pine-forest . . . we found ourselves on an open barren, with very little timber . . . we passed over a sterile soil, destitute of wood" (p. 44). Following a tributary to the west, Schoolcraft found the going rough, owing to thickets along the stream. Attempting to cross canebrakes and a swamp, his horse became mired: "sunk in soft black mud so deep that the upper part of his back and head were only visible" (p. 58). He and his companion eventually extricated the horse from what must have been a deep muck fen, an unusual community type in the Ozarks.

In the White River Hills subsection Schoolcraft found cane thickets and forests of oak, ash, maple, walnut, mulberry, sycamore, hickory, and elm on alluvial soils. He found prairies of coarse grass and "scanty" timber on the limestone hills and "bald mountains." He was most taken with the Springfield Plain and a 2-mile-wide strip of vigorous forest bordering the James River, within extensive prairies covered with tall grasses.

Nelson's (1997) study of tree densities in various physiographic sections indicated that open woodlands were more common in the Ozarks and the Till Plain, whereas closed forests prevailed on the bottomlands of the Mississippi Alluvial Plain. Soil conditions were often described as harsh and no doubt played a role in forest structure, but fire also probably played a part (Nelson 1997). "Thinly timbered" conditions were described in 8.8 percent of GLO mile notes for the Ozarks, and an average of only eight trees per acre prevailed in these places, indicating savanna communities (Nelson 1997). Only one prairie and one glade were recorded.

Similarly, using all GLO notes in Missouri, Schroeder (1982) mapped few prairies outside of the Springfield Plain and Osage Plain. However, even some areas described as "heavily timbered" were also described as having grassy ground cover, indicating relatively open, periodically burned conditions (Ladd 1991).

Pine was especially prominent where the topography was rolling to steep and the sandstone component of the residuum was high. Inadequate winter precipitation limited pine to the southeastern part of this section. Deeper loess deposits, the presence of soil fragipans, and the Jefferson City geologic formation also were barriers to pine. The Current River Hills subsection and parts of surrounding subsections comprised the heart of shortleaf pine country in Missouri (Fletcher and McDermott 1957).

Much historic vegetation in the Ozark Highlands section remains today: upland hardwood forests, pine forests, open oak woodlands, bottomland forests, mesic hardwood forests, prairies, and even fens. Primary changes between 1819 and today are that fertile prairies have been cultivated; many of the poor prairies, barrens, and open woodlands have grown more woody and dense due to fire suppression; and most large bottomland forest areas have been inundated as a result of flood control.

Boston Mountains

Near the upper White River in the Upper Boston Mountains subsection, Gerstäcker (1881) described the vegetation:

> There was no trace of fir [cedar]; the mountains were covered with oak, beech, and hickory . . . . It struck me as extraordinary that the best and most fertile land was on the hill tops, where in other

places, it is generally the worst; here grew black walnut, wild cherry, with stems sometimes twenty inches in diameter, black locust, and sugar maple, trees which generally grow only on the richest soils. (p. 282)

The dominant trees in the Lower Boston Mountains subsection in 1837 to 1843 were white oak, black oak, and post oak, with appreciable numbers of hickory. White oaks were most commonly on steep slopes and higher elevations. Post oaks were most commonly on high elevations, upper stream valley floodplains, and intermediate flat uplands. Black oak and hickories were distributed across all landform types (Lockhart and others 1995, Harmon and others 1996).

A comparison of the available information on historic vegetation with modern vegetation indicates fewer major historic changes than in other sections of the Highlands. However, literature on this section is skimpy, and research on historic vegetation should be a priority.

Arkansas Valley

Historically, the Eastern Arkansas Valley section was mostly forested. Further west, out of the bottomlands, were open oak woods, the ground layer of which was partly covered with grasses. Bottomlands were heavily wooded.

Near Fort Smith, prairies became predominant, with both oak- and pine-covered ridges. The Western Arkansas Valley Mountains were forested, with pine and oaks codominant. Pine was typically on south-facing and northwest-facing aspects, white oaks on northwest to northeast aspects, black oaks on west-facing slopes, and post oaks most commonly on shallow slopes. Although more open than forests of the area today, these were not savannas, although the GLO survey notes documented forests with a relatively low density and basal area, consistent with frequent burning. Savannas may have existed in smaller areas than those that may be discerned by this approach. Understory was typically described as "oak bushes," which is indicative of periodic fire (Foti and Glenn 1991).

Nuttall (1980, but describing conditions in 1819) described the effects of intentional burning on prairies near Forth Smith in the Arkansas Valley:

> I took an agreeable walk into the adjoining prairie, which is about two miles wide and seven long. I . . . could perceive no reason for the absence of trees, except the annual conflagration . . . . The numerous rounded elevations which [checker] this verdant plain, are so many partial attempts at shrubby and arborescent vegetation, which nature has repeatedly made, and which have only been subdued by the reiterated operation of annual burning, employed by the natives, for the purpose of hunting with more facility and of affording a tender pasturage for game. (p. 158)

On his return from the Red River, Nuttall found "pine ridges" and "oak ridges" in the Western Arkansas Valley subsection (p. 164).

A botanist with Stephen Long's expedition (James 1823) described a similar scene. Traveling east from Fort Smith, their path lay "through open woods of post oak, black jack, and hickory, occasionally traversing a narrow prairie. In these open plains, now covered with rank grass and weeds, we discovered here and there some traces, such as a skull or hoof of a bison" (p. 264). There were "heavily wooded low grounds" near present-day Paris (p. 266), while the summit of Short Mountain in that vicinity was "covered with small trees, among which the red cedar, or some other evergreen tree predominates . . . . The upland forests are almost exclusively of oak, with some . . . hickory, dogwood, and black gum. They are open, and the ground is in part covered with coarse grasses" (p. 267).

Further east, within the Central Arkansas Valley subsection, Nuttall climbed Petit Jean Mountain in 1819 and saw "a vast wilderness . . . covered with trees . . . . To the east a considerable plain stretches out, almost uninterrupted by elevations . . . . Over the vast plain immediately below me, appeared here and there belts of cypress . . . they seemed to occupy lagoons and swamps, at some remote period formed by the rivers" (pp. 120–121).

Ouachita Mountains

In the eastern part of the Ouachita Mountains, oak and pine forests of relatively small trees occurred, along with dense forests of oak, ash, and sugar maple. The historical literature and GLO surveys support the view that the forest was more open at the time of European settlement and that fires contributed to that low density (Foti and Glenn 1991). In the western Ouachita Mountains, oak savanna was documented. Only in the valleys of the western Ouachita Mountains and westernmost Fourche Mountains did prairies become dominant in the landscape. In that area, ridges were predominantly pine or oak-pine. Oaks dominated shaley rolling uplands of the Athens Piedmont Plateau subsection, while pine and stunted hardwoods were more common on the sandstone ridges.

In general, pine was virtually ubiquitous in the historic forests of the Ouachitas, but it varied greatly in dominance. Hardwoods, primarily oaks, were also a major component on most sites (Foti and Glenn 1991). On very high ridges in the western Fourche Mountains, stunted forests of white oak and post oak occurred (Nuttall 1980), while mesic forests with beech occurred in protected areas (Foti and Glenn 1991). In the more easterly Fourche Mountains and Central Ouachita Mountains, hardwoods—primarily oaks—were dominant on sandstone while pine became dominant on novaculite. In the extreme eastern Fourche Mountains, barrens dominated by stunted oaks occurred in the dry valleys. Cane grew along bottomland streams.

During an expedition to the hot springs of Arkansas in 1804 and 1805 (Rowland 1930), Dunbar and Hunter found cane along the margin of the Ouachita River within the Central Ouachita Mountains and noted that some of the hills were barren. Oak species dominated between Gulpha Creek and the hot springs, although the travelers also recorded "pine woods." From Hot Springs Mountain in what is now Hot Springs National Park, they wrote that "the timber here is not large[,] consisting of oak, pine, cedar, holly, hawthorn, with many others common to this climate, with a great variety of vines" (p. 274).

James, the botanist with the Long expedition of 1819–1820, described the Ouachita Mountains between present-day Dardanelle and Hot Springs (Fourche Mountains subsection) as covered with small and scattered trees or nearly treeless (James 1823). Oak species and Ozark chinkapin occurred on sandstone and pine forests on novaculite (p. 287). However, not all of the area James described was barren. Dense forests of oak, ash, and sugar maple occurred along the bases of mountains east of present-day Hot Springs (p. 297).

Thomas Nuttall (1980) described prairie "full of luxuriant grasses about knee high, in which we surprised herds of fleeing deer" (p. 163) in the Ouachita Mountains landscape between Fort Smith and the Red River, in what is now eastern Oklahoma (Western Ouachita Mountains subsection). On his return, he found an area of bushes and half-burnt trees along the lower Kiamichi River, which he described as "horrid, labyrinthine thickets and cane-brakes [with] very little prairie" (p. 162); he also noted hills covered in pine. He found an "extensive cove, covered with grass, and mostly a prairie of undulated surface" with thickets of greenbriar along streams at the junction of Jack Fork and Kiamichi Rivers (pp. 162–163). In the Fourche Mountains, he also described dwarf white oak forests like those currently found on the crest of Rich Mountain (p. 164).

"The barrens that lie betwixt these ridges" in the extreme eastern Fourche Mountains subsection north of Little Rock were very dry and dominated by stunted oaks (Featherstonhaugh 1844, p. 39). Similar vegetation can be seen today on National Guard Camp Joe T. Robinson in North Little Rock, along Featherstonhaugh's route. In the 1830's, pines dominated the northern Ouachita Mountains as well as the Arkansas Valley (Foti and Glenn 1991). Mesic forests occurred on north slopes. Undergrowth tended to be "oak bushes," a growth form that can result from frequent low-intensity fires. Cane apparently grew only along major rivers, and vines and briars were not common. Surveyors did not mention grass but referred to sites with "no undergrowth," perhaps indicating that there was no woody undergrowth but there was grass undergrowth, as surveyors once made this observation in the same mile where they recorded a "prairie" (Foti and Glenn 1991).

In the Western Ouachita Mountains subsection, a survey in 1896 found white oak, northern red oak, post oak, shortleaf pine, black oak, and hickories, in that order, dominant in the area. Density was low enough that the area should be described as savanna. At the same corners in 1994, dominants were shortleaf pine, white oak, mockernut hickory, northern red oak, post oak, and black oak, in that order (Kreiter 1995).

Red-cockaded woodpeckers are currently located in an area of the Fourche Mountains that had an abundance of pines in the pre-settlement forest; this area was superior habitat for the species in the past and has remained so. In 1819 and 1820, the Ouachita Mountains between present-day Dardanelle and Hot Springs (Fourche Mountains subsection) were covered with small and scattered trees or were nearly treeless (James 1823). Oak species and Ozark chinquapin occurred on sandstone with pine forests on novaculite (p. 287). However, not all of the area James described was barren. Dense forests of oak, ash, and sugar maple occurred along the bases of mountains east of Hot Springs (p. 297).

Effects of Disturbances on Highlands Ecosystems

As the prehistory and history of the Ozark-Ouachita Highlands demonstrate, climate (both long-term changes and short-term events), fire, and biotic factors, such as outbreaks of insects, are important natural disturbance factors in its ecosystems. Human-caused factors, such as flood control, introduction of nonnative species, and the prevention, suppression, or setting of fire, also can disturb ecosystems either in fairly "naturalistic" ways or in "catastrophic" ways. People have been a constant influence on plant communities and ecosystems of the Highlands, so the idea of a "natural" environment, free from human influence, is false. Human and nonhuman disturbance and vegetation in the Ozark-Ouachita Highlands are inextricably intertwined. Ecosystems change constantly as they respond to various disturbance events.

Climatic Disturbance Factors

Climate is the most important influence on vegetation in the Ozark-Ouachita Highlands. Although climate is often thought of as relatively stable, "average" climatic conditions seldom occur. (See Chapter 1 of the companion report *Aquatic Conditions* [USDA Forest Service 1999a] for a complete treatment of climatic patterns in the Highlands). Extremes of temperature and precipitation function as disturbances in particular ecosystems and may have more impact on the distribution of species than long-term averages. Native species, particularly those that are long-lived, must deal with many extreme episodes. Animal species may adjust to climatic extremes by moving to cooler, warmer, or more protected places or by becoming dormant. Plant species may respond to short-term stresses by reducing transpiration, shedding leaves, or otherwise becoming dormant, and may respond to long-term or repeated stresses with genetic changes or population shifts.

Ice and Snow

Ice and snow occasionally damage pole-sized shortleaf pines in plantations, but most native trees of the Assessment area are fairly well adapted to ice and snow. Late frosts can damage spring buds, especially in valleys subject to cold-air drainage, but rarely cause mortality. However, periodic severe ice storms cause extensive damage and are to be expected over the life span of dominant trees. This is one of the stand-replacing disturbances of the region.

Species such as loblolly pine, abundant in the Coastal Plain forests south and east of the Assessment area but only recorded in the Highlands historically in moist areas of the southernmost Ouachitas, have been widely planted in the southern half of the Highlands and are more susceptible to winter damage (Burns and Honkala 1990).

A few mountains in the Assessment area, notably Rich and Black Fork Mountains in the Ouachitas, are high and exposed enough to experience montane conditions—cold and windy, with considerable fog and ice. As a result, oaks on the crests of these mountains are stunted, only reaching heights of a few feet to about 30 feet.

Wind

The frequency, intensity, and scale of wind disturbances can cause significant variations in forest regeneration processes and resulting communities. In relatively low-intensity events, wind is responsible for "gap-phase" dynamics, the process by which a forest is renewed by death and replacement of individual trees or small groups of trees. Occasionally, severe windstorms or tornadoes destroy all or most trees within a large area, especially when preceded by soil-saturating rains.

A 19th-century traveler in Arkansas noted that tornadoes "will sweep a district of a mile in width and several miles in length, leveling everything in their path." After a time, the tornado-swept land became "impenetrable [thickets of] blackberries, thorns and creepers" important for wildlife such as bear (Gerstäcker 1881: p. 273).

Among the more notable recent blowdowns, a tornado leveled a portion of Winona Research Natural Area on the Ouachita National Forest in 1986. Its swath is still visible in young stands along the track today. In fact, high winds blow down trees in the Ouachitas nearly every year. High winds or tornadoes hit the Eleven Point District of the Mark Twain National Forest in the spring of 1997, knocking down or breaking off many oaks and pines.

Such intensive, large-scale damage is often likened to the effects of clearcutting (see Chapter 4), but windstorms seldom remove all canopy trees uniformly, nor do they cause the uniform soil disturbance often associated with site preparation. Severe storms may, however, remove virtually all canopy trees, and uprooted trees do cause significant soil disturbance.

Drought and Fire

Droughts can limit the distribution of plant and animal species. The Assessment area experiences more frequent and severe droughts than areas to the east. Droughts damaged vegetation in some areas of the Ozarks and Ouachitas in 1980 and 1981, leading to a 10 to 15 percent tree mortality in some places in 1983 and 1984 (Nelson 1985).

Drought can interact with other disturbance factors to cause greater change. For example, the phenomenon of oak decline (see Chapter 6) has been attributed in part to drought (Kessler 1992). In Missouri, overstocking of scarlet and black oaks on sites where post and white oaks and shortleaf pine are better adapted apparently contributes to drought-caused disturbance. Both competition and site adaptation may play roles here.

Wildfires, more common during drought years, can lead to the natural regeneration of new forest stands. Mattoon (1915) reported that almost all pure stands of shortleaf pine in western Arkansas (Montgomery and Pike Counties) dated from approximately 1740 or 1850. Those years may have followed ones marked by exceptionally dry periods during which stand-replacing wildfires were common. These dates roughly coincide with those of high charcoal deposition in a bog and natural lake in the western Ouachitas: fire occurrence there peaked during the Altithermal period of approximately 5,000 years before present (B.P.) and then again about 1700 B.P. and 200 B.P., but occurred throughout the record preserved in the sediments (Albert and Wyckoff 1981).

Before fire prevention and suppression became common, forests in the Assessment area typically had fewer trees, spaced much further apart, than do today's stands (Batek 1994, Schroeder and others 1997). Fire is probably the second-most important natural change process in the Highlands, following climate. Fire is a natural factor to which many species and ecosystems have adapted (USDA Forest Service 1997). The importance of fire as a landscape process in the Highlands has been emphasized by many ecologists, beginning with the study of Beilman and Brenner (1951).

The Assessment area lies at the southern and eastern edge of the Midwestern prairies, which owe their existence to climate, fire, and grazing. The pine and oak forests of the Assessment area were strongly influenced by fires as well (Spurr and Barnes 1980, Abrams 1992).

Likewise, the glades of the White River Hills—openings of tallgrass prairie in the surrounding oak woodlands—evolved with and depended upon fire as an agent of primary decomposition and nutrient recycling. Grassland plants produce fuel conditions that make fire almost inevitable, and only plant species that are extremely fire-tolerant or fire-dependent persist there.

Data on present-day lightning-set fires show a high peak in August, with high numbers also in July and September (Foti and Glenn 1991). Fires were also frequent in April, but not nearly as numerous as in August. The same general pattern was shown in the eastern Oklahoma Ouachitas, but with the highest peak in July (Masters 1994).

Society in the Ozark-Ouachita Highlands has long attempted to control the effects of fire, first by setting fires to extend its benefits and later by preventing and suppressing fires. Before European settlement, American Indians regularly set fires that burned across huge areas and stopped only at large rivers or when rain intervened (Williams 1994), apparently to thin woods, promote grazing land, and drive game into confined areas, making hunting easier.

Fire frequencies varied among the subsections of the Missouri Ozarks (Guyette and McGinnes 1982, Ladd 1991, Ladd and Huemann 1994, Nelson 1993, Rebertus 1994); the Arkansas Ozarks (Jenkins and others 1997);

and the Ouachita Mountains (Foti and Glenn 1991, Johnson and Schnell 1985, Masters and others 1994). Fire frequencies ranged from 2 to 40 years. Longer frequencies occurred during the settlement period; most frequencies are longer than the measured fire-return interval, since only fires intense enough to produce scars would be seen in the record.

In the late 1720's, Le Page du Pratz of Natchez traveled through Louisiana Territory "from the Natchez to the St. Francis" (du Pratz 1774), apparently reaching northeastern Arkansas. Although he made no specific references to fire in the Highlands, he made this general comment that may be assumed to pertain at least to the southern Highlands:

> We set out in the month of September, which is the best season of the year for beginning a journey in this country: in the first place, because, during the summer, the grass is too high for travelling; whereas in the month of September, the meadows, the grass of which is then dry, are set on fire, and the ground becomes smooth, and easy to walk on: and hence it is, that at this time, clouds of smoke are seen for several days together to extend over a long track [sic] of country; sometimes to the extent of between twenty and thirty leagues in length [a league is variously 1.6 to 3.2 miles, usually estimated at about 3 miles], by two or three leagues in breadth, more or less, according as the wind sets, and is higher or lower. (p. 134)

An "immense conflagration" occurred in an area 12 miles wide between ridges of the Ouachita Mountains in late November 1835 (Featherstonhaugh 1844, p. 36). Similarly, in Lincoln County, MO, just north of the Ozark Highlands, Joseph Mudd (1888, quoted in Ladd 1991) noted:

> Annually, after this rank growth of vegetation had become frosted, dead, and dry, the Indians set fire to it and burned it from the entire surface of the country. When this annual burning ceased, the germs of underbrush and young timber began to grow . . . .

Ladd (1991) provides many other similar descriptions.

As burning declined with European settlement, the forest's understory redeveloped rapidly. Gerstäcker (1881) described using fire to hunt deer at night: "The fire being kept behind your head, the eyes of the game will glow like balls of [fire]. [The] deer, accustomed to the frequent fires in the forest, are not alarmed" (p. 217). Gerstäcker observed in another area that "the forests not having been burnt for many years, were so thickly overgrown with underwood, that it was impossible to find the deer, or to shoot game enough to live upon" (p. 226). James (1823) noted that, "Since their occupation by permanent inhabitants, the yearly ravages of fire have been prevented, and a dense growth of oaks and elms has sprung up."

Since lightning-set fires and the fires referred to in the historic record occurred at approximately the same time (lightning-set fires concentrated in July–September and human-caused fires occurring September–November), it seems clear that American Indians did not impose a new disturbance regime, but modified the natural regime by increasing the frequency, reducing the intensity, or shifting the timing of fires to later in the autumn, when damage to vegetation was less (Foti and Glenn 1991). In general, fires can only be set when fuel is dry enough, and this is the time vegetation would burn, either from lightning strikes or anthropogenic starts. There is a smaller peak in lightning-set fires in March–April that is seldom mentioned in the historic record. Fires early in the growing season may have had much more impact on vegetation composition structure and composition than those in late summer.

Therefore, American Indians and early settlers did not produce the overall vegetation patterns of the Assessment area but rather apparently modified and emphasized the effects of lightning-caused fire (Foti and Glenn 1991). This conclusion is disputed by the studies of Kreiter (1995), however, and questioned by others.

Fire suppression became a significant disturbance factor in the Assessment area in the 1930's, as ownership of depleted farm and forestland reverted to State or Federal Governments. Reaction to damage from careless burning nationwide led to virtual exclusion of fire from all ecosystems and Smokey Bear became the symbol of forest protection. Through direct action (fire control) and indirect action (land development, grazing, reservoir construction, and logging), natural fires were for all practical purposes eliminated. As an example, fire suppression increased the fire return interval at an average site in Hot Springs National Park from 41.4 years to 1,200 years during the period 1700–1980

(Johnson and Schnell 1985). Similarly, the mean fire return interval for McCurtain County (OK) Wilderness Area increased from 29.9 years to 547 years (Masters and others 1995). In each of these cases, it should be understood that fire histories as reconstructed from fire scars underestimate the return interval. Therefore, the measured intervals are longer than the actual intervals.

In general, the forests of the Assessment area are more closed and less biologically diverse than the open oak and pine woodlands of the past. Extensive areas of pine-dominated forest are now rare in Missouri (Nigh and others 1992), and fire suppression has led to overstocking of black and scarlet oaks on sites where post and white oaks and shortleaf pine are better adapted. After 60 years of effective fire suppression, the shortleaf pine forests of the Ozarks and Ouachita Mountains are no longer open and no longer support the grass and forb understory described as characteristic of these forests in earlier times (Martin and Kline 1985, Bukenhofer and Hedrick 1997).

Oak forests also benefit from fire (even though individual trees may be damaged from an economic viewpoint). Fire helps maintain valuable timber- and mast-producing oak forests by a number of mechanisms, but especially by giving oak reproduction the competitive advantage over other species (Abrams 1992, Johnson 1993, Lorimer 1992, Van Lear and Watt 1992). (See Chapter 4 for discussion of oak silviculture.) While perhaps not as serious a problem in the relatively dry Ozarks as it is further to the north and east, oaks are gradually giving way to maples, blackgum, tulip-poplar, and other tree species on some sites (Packard 1991).

When fire is removed from a natural grassland community, fire-sensitive species such as eastern red cedar quickly invade, and fire-dependent species such as the prairie legumes and tallgrass prairie species lose vigor and dominance.

Today, under conditions greatly different than those prevalent 200 years ago, most wildfires in the Assessment area result from human accidents or arson. Between 1981 and 1996, for example, lightning caused only 2, 6, and 15 percent of the wildfires on the Mark Twain, Ozark-St. Francis, and Ouachita National Forests, respectively (table 2.1). The rates of lightning-caused fires on non-Federal lands in the Assessment area States were less than 2 percent (table 2.2).

Floods

Flash floods can have significant effects on riparian ecosystems in the Assessment area. Comparison of aerial photographs of 1935 with recent ones shows that dynamic riverside forests continually change in reaction to floods, with bands of sycamores and river birch trees moving across bottomlands as sand and gravel bars migrate. The Arkansas River submerges large bottomlands in the Arkansas Valley Section for long periods. Although levees, dams, and flood-control reservoirs in the watershed prevent or alter many of these natural

Table 2.1—Wildfires, including number of lightning-caused ignitions and acres burned, on the Highlands' national forests, 1981 through 1996

National forest	Total number of wildfires	Average annual number of fires: Total	Average annual number of fires: Lightning-caused	Acres burned
Mark Twain	3,231	202	4	94,456
Ozark-St. Francis	1,233	77	5	20,257
Ouachita	1,689	106	16	26,810
Total	6,153	385	25	141,523

Table 2.2—Lightning-caused and human-caused fires on State and private lands from 1981 to 1996

State	Average annual lightning-caused fires	Average annual human-caused fires
Missouri	14	2,290
Arkansas	33	1,815
Oklahoma	27	1,606

Source: File records of the Arkansas Forestry Commission, Oklahoma Department of Agriculture (Forestry Division), and Missouri Department of Conservation (Forestry Division).

changes, significant areas of bottomland forest still exist along the Arkansas River and its tributaries. Floods in developed watersheds are usually more severe and destructive than those in naturally forested ones.

Studies are underway to determine how flash floods affect the Little Piney and Jack's Fork watersheds in Missouri (Jacobson 1995). Such studies may provide additional insight into an important change process.

Biotic Disturbance Factors

Biotic factors can be very significant in ecosystems, particularly as they interact with other disturbance factors. For example, southern pine beetles may not have been a serious threat to forest health as long as fire helped maintain relatively open forests and woodlands. But the insect can be a significant disturbance factor in dense pine stands.

Human introductions of nonnative species can significantly change ecosystems, as well. The gypsy moth's destruction of forests in the Eastern United States is one of the best known examples. The looming arrival of the gypsy moth "front" to the Assessment area could be an unprecedented disturbance event, with negative effects on many organisms and positive effects on others. (See Chapter 6 for discussion of biological threats to forest resources.)

In the meantime, one of the ongoing biotic disturbances of interest to public land managers and others is livestock grazing. Use of open forests, savannas, woodlands, and native grasslands for grazing occurred in the Ozark-Ouachita Highlands well before European settlement and continues today, albeit at lower levels. For early settlers on small farms in the Ozark-Ouachita Highlands, livestock was a minor to very significant source of income. Much of the livestock economy (cattle, hogs, horses, and sheep) depended upon free and unrestricted, year-round ("open-range") grazing of public lands and some private lands. Immigrants found a wide variety of such grazing opportunities in the Highlands. By the mid-1900's, enactment of laws limiting "woods burning" and development of a strong fire prevention program greatly reduced the occurrence of fires and allowed tree canopies to expand and grasses to decline in many prairies and woodlands.

Increasingly dense tree canopies and protection from fire reduced available forage on many lands in the Highlands, including the national forests. Improvement of pastures on private land, as well as conflicts with other resource uses, such as recreation, wildlife, and intensified timber management on national forests, also contributed to a decline in grazing on national forest lands (Lee 1980). Other factors contributing to the decline of range grazing in the Assessment area include legal prohibition of open-range grazing on public and private lands; increased grazing fees on national forest lands in an effort to recover "fair market value"; permittees on national forest lands reducing their operations or retiring; and the movement of younger people away from single-family farms. Still, range grazing continues to be an important biotic disturbance factor in the Highlands.

In 1992, about 13,595,600 acres of non-Federal lands within the Assessment area were devoted to grazing, down only about 5 percent compared to 1982 levels (USDA NRCS 1997). (Much of the grazing land was converted to other uses such as urban and residential expansion, agricultural crops, or timber.) On the three national forests, 131 permittees were grazing cattle in 1996, down from 401 in 1987; Animal Unit Months (AUM's) under permit declined from over 75,000 to about 28,000 during the same period (table 2.3).

The timing and intensity of grazing are key variables affecting its impacts on an ecosystem. Early and continuous overgrazing can cause the loss of topsoil by erosion and limit recovery of the vegetation. Overgrazing depletes the reserves in perennial plants and eventually kills them. In the long term, more palatable species are replaced by less palatable ones.

Table 2.3—Animal Unit Months (AUM's) and number of grazing permittees on national forests of the Highlands in 1987 and 1996

	1987		1996	
National forest	AUM's	Permittees	AUM's	Permittees
Ozark-St. Francis	20,809	112	10,262	35
Ouachita (AR)	22,742	140	4,271	34
Ouachita (OK)	8,000	33	1,438	9
Mark Twain	23,717	116	12,151	53
Total	75,268	401	28,122	131

Even light or seasonal grazing can favor the spread of certain less favorable species (Smith 1940). Penfound (1964) found protection from grazing led to rapid plant succession, decrease in forage, and increase in mulch. Hazell (1964) found heavy grazing decreased range conditions and vigor, while increasing undesirable grasses and forbs. Similarly, Jensen and Schumacher (1969) found the more desirable native bluestems decreased and less desirable species increased in numbers under long-term grazing.

Trampling by cattle can bury seeds and encourage seedling establishment. Winkel and Roundy (1991) found disturbance by cattle or mechanical methods may enhance vegetation establishment during years with moderate rainfall (depending on species and soil) but may be unnecessary during wet years. They found that during dry years it was futile to attempt to establish seedlings. Thill (1984) found cattle grazing on newly-harvested forest sites could benefit white-tailed deer by improving accessibility to sites, slowing plant succession, and possibly increasing preferred foods, such as lespedezas, by reducing competing vegetation.

Implications and Opportunities

Several points emerge from the discussion of prehistoric and more recent change: 1) constantly changing vegetation characterizes the Ozark-Ouachita Highlands; 2) the prominence of endemic species in the regional biota indicate that even during extremes of climate, refugia of oak-hickory forest existed; and 3) humans were present (having arrived some 10,000 years ago) during the assembly of "modern" communities and ecosystems and very likely influenced their structure and function.

Because people have been a constant influence on plant communities and ecosystems of the Highlands for thousands of years, ideas of "natural" (i.e., not human-influenced) conditions need to be reviewed carefully, even challenged. Human and nonhuman disturbance events are inextricably intertwined with the vegetation and wildlife of the Ozark-Ouachita Highlands. Society cannot preserve ecosystems in unchanged states, nor can it regulate them precisely to produce constant flows of desired outputs or conditions—whether those desired outputs are scenery, water, old-growth characteristics, wildlife diversity, endangered species, or wood products. Scientists face the challenge of countering long-held ecological views and public policies that ignore the consequences of disturbance and presume a constant environment.

Knowledge of how ecosystems change enables managers to take a more ecological approach to planning, implementation, and monitoring (Averill and others 1994, Pyne 1982, Williams 1993). For example, harvesting methods may mimic some types of wind-caused disturbance. Single-tree selection may mimic low-intensity wind disturbance; group selection can mimic gap-phase regeneration; and clearcutting may mimic intensive disturbance, as from a tornado (see Chapter 4).

Knowledge of "natural" fire regimes gives forest managers valuable perspective on modern questions such as whether prescribed fire is necessary in specific circumstances, when it should occur, what intensity is appropriate, and what are the most effective ways of controlling wildfires. Wildlife, aesthetic, ecological, and recreation values are served when fire is restored to glades, savannas, and woodlands. Careful monitoring of air, water, and soil qualities is an essential component of efforts to ensure that prescribed fires remain a positive overall environmental influence and that trade-offs are understood. Studies that address the effects of reintroducing fire to oak ecosystems in the Highlands would be helpful.

Similarly, information about past vegetation conditions in the Highlands may expand the options that can be considered by public land managers, research scientists, and interested citizens. Information about presettlement vegetation of the Boston Mountains is particularly sketchy. Priority should be given to increasing knowledge of historic vegetation in this section.

Expanded efforts to reintroduce the American elk to the Ozark-Ouachita Highlands deserve consideration. Populations have already been established at Cookson Hills and Pushmataha Wildlife Management Areas in Oklahoma and the Buffalo National River in Arkansas. The more widespread reintroductions of elk suggested by Bukenhofer and Hedrick (1997) would need to be undertaken carefully, taking into consideration possible diet overlaps with cattle, deer, and other species, as well as possible physical changes to the forest.

Chapter 3: Status and Trends of Vegetation

Question 3.1: What trends in vegetation cover and land use have occurred over the past 50 years?

Question 3.2: Are changes in vegetation cover—including age-class distribution, species composition (e.g., cover types), and fragmentation—taking place?

Question 3.3: How are old-growth forest stands distributed? What is their management status? What is the potential for retention or restoration of such communities?

This chapter provides information about the vegetation cover of the Assessment area. The types and areal extent of vegetation in the Highlands are of interest for many reasons. Vegetation cover largely determines the availability of habitat for terrestrial animals, plants, and other organisms. Vegetation cover strongly influences what uses (e.g., timber, forage, recreation) people can make of natural biological resources. Vegetation cover plays a major role in maintaining desired riparian and aquatic conditions (see USDA FS 1999a). Many people care (for aesthetic and other personal, largely noneconomic reasons) about the extent and types of vegetation cover in the Highlands and the changes it may be undergoing. Finally, information about vegetation cover enhances the ability of scientists to study the availability of plant and animal habitats over large areas and gives all interested parties a clearer picture of the changing representation of various cover types (e.g., conifer-dominated vs. hardwood-dominated forest or forests vs. pasture land) over time.

Key Findings

1. As measured by Advanced Very High-Resolution Radiometer data, oak-hickory forest is the most extensive vegetation type in the Assessment area, covering 15 million acres (ac) or 36 percent of the area.
2. Oak-pine forest is the second most extensive vegetation type within the region, with 4.4 million ac (11 percent of the Assessment area). The largest acreage of this type (660,000 ac) occurs within the Fourche Mountains subsection of the Ouachita Mountains.
3. Nonindustrial private forest (NIPF) owners hold 68 percent of the 22.89 million ac of timberland in the Assessment area; forest industry owns 11 percent. Thus, private and corporate landowners together hold more than 79 percent of the timberland. The remaining 21 percent consists of public timberlands, three-fourths of which are within one of the national forests.
4. The abundance of oak in the Ozark-Ouachita Highlands is matched by only two other regions in the United States, the Central Appalachian and Eastern Broadleaf Forest (Continental) Provinces.
5. The annual net growth of hardwoods and softwoods is more than double the annual removals.
6. Since the 1970's, forested area has increased in five of the six Forest Inventory and Analysis (FIA) survey regions in the Highlands and, in some instances, dramatically.

Vegetation Cover

A Comparison of the Highlands to Surrounding Ecoregions

Processes and patterns at local, landscape, and regional scales influence the distribution of species and local biological diversity, thus making assessments at each of those scales important. The following sections compare the composition and patterns of land cover in the Ozark-Ouachita Highlands to land cover in surrounding ecological provinces and to the Eastern United States.

Data Sources and Methods of Analysis

This analysis was conducted at the province level of the National Hierarchical Framework of Ecological Units (McNab and Avers 1994). The Assessment area includes parts of two ecological provinces, the Southeastern Mixed Forest (map units 231and M231 in Keys and others 1995) and Eastern Broadleaf Forest (Continental) Provinces (units 222 and M222 in Keys and others 1995). The Team compared land cover of the Assessment area to the remaining parts of provinces 222 and 231 and to provinces M221, 221, 232, 234, 251, and 255 (fig. 3.1). The Team also compared the land cover of the Assessment area to that of the Humid Temperate Domain, which essentially corresponds to the Eastern United States.

The Team used land cover units mapped by the U.S. Department of Agriculture, Forest Service, from Advanced Very High Resolution Radiometer (AVHRR) data. Land cover types include 13 forest types, a nonforest class, and an aquatic class. The classes are mapped as 1-kilometer-square pixels. These data provide a large scale but coarse-grained assessment of land cover (fig. 3.2).

Because of the large scale and large pixel size, this report includes only a few landscape statistics, including the percentage of each land cover, the percentage of coverage in all forest types combined, the mean forest patch size, and the total area. Percent forest cover and mean-patch size are useful statistics for a coarse-grained assessment of forest fragmentation (Robinson and others 1995). When the percentage of forest cover and mean patch sizes are relatively low, the forest is more fragmented than when the percentage of forest cover and mean patch size are high.

Patterns and Trends

Oak-hickory, oak-pine, and loblolly-shortleaf pine forests cover large portions of the Assessment area (fig. 3.2 and table 3.1). Compared to other parts of the Eastern United States, the Assessment area has the third highest proportions of these forest types. Because of its geographic location and the dominance of these three forest types, the Assessment area has fewer forest types than provinces that include more northern types (white-red-jack pine, spruce-fir, maple-beech-birch, aspen-birch) or southeastern forest types (longleaf-slash pine).

Notable differences exist in land cover between the Assessment area and surrounding provinces. The Assessment area is in the mid-range of values for percentage of forest cover and mean forest patch size in the provinces and above these values for the Eastern United States (table 3.1).

Implications and Opportunities

The prominence of oak in the Highlands is matched by only two other provinces in the United States, marking it as an especially significant forest resource. The high percentage of forest cover and the large mean forest patch size indicate low levels of forest fragmentation. As a result, the area is of high value to wildlife species that are sensitive to fragmentation of forest cover by nonforest land uses.

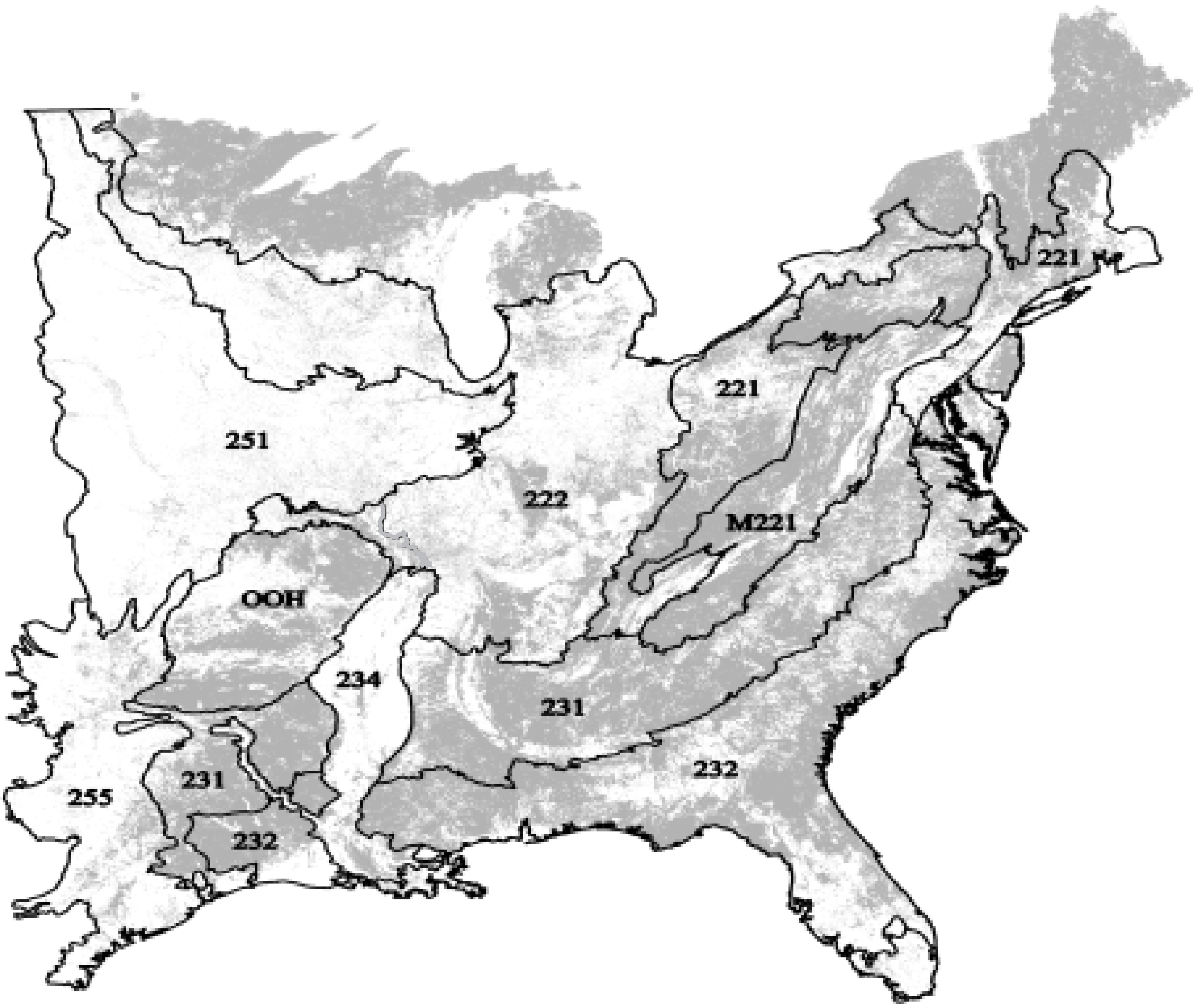
Forest Cover in the Highlands Based on FIA Data

Data Sources and Methods of Analysis

The Forest Inventory and Analysis (FIA) research work units of the USDA Forest Service are the primary sources of data on land use and forest cover types within the Assessment area. The research division of the Forest Service conducts surveys of forest land in each State approximately every 10 years, depending on budgets, available personnel, cooperation by States, and other variables. These surveys supply intensive probability-based sample data available on a regional scale in the United States. Data in these surveys summarize general forest conditions in each State.

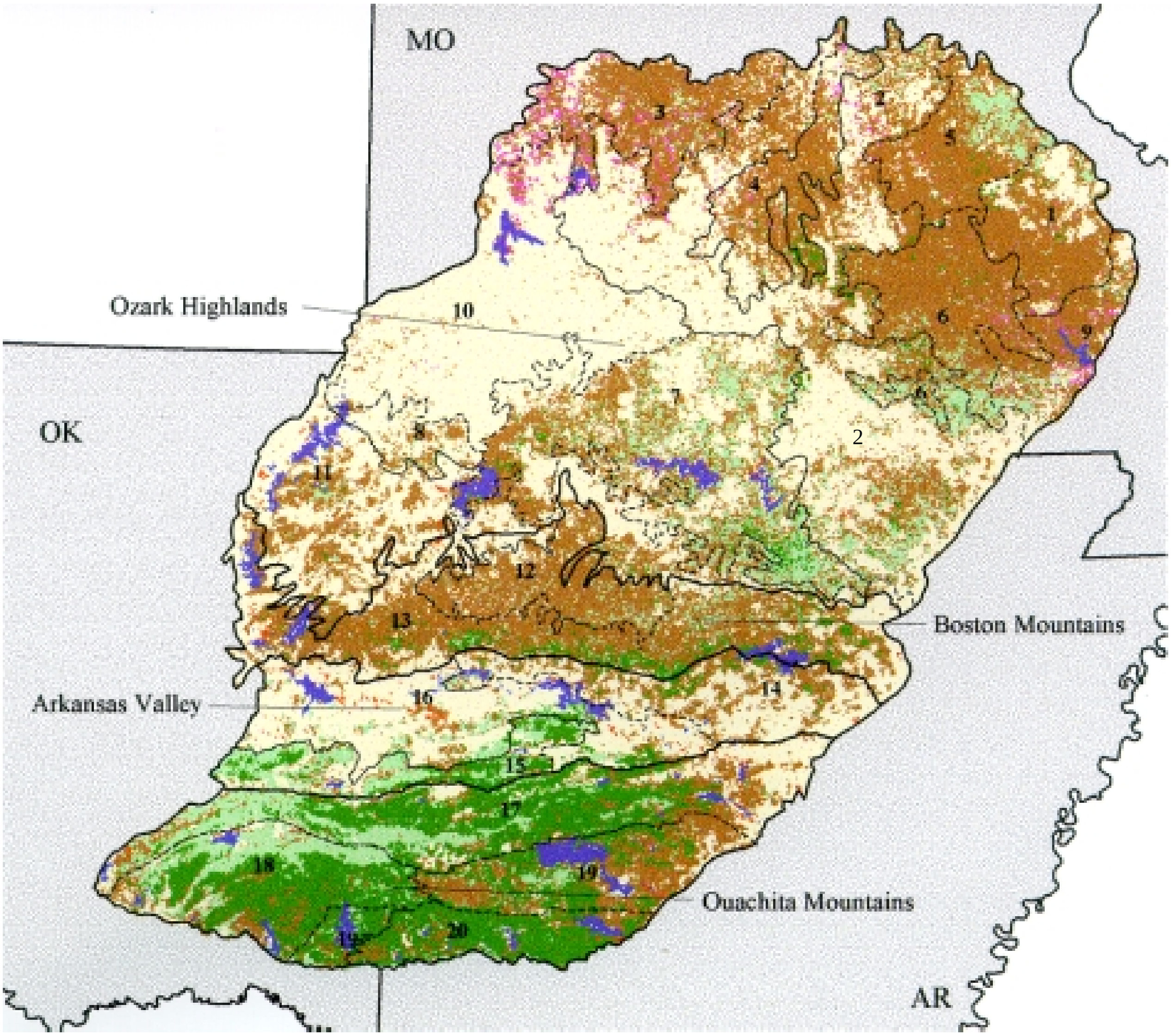
Two separate FIA research units conduct surveys in the Ozark-Ouachita Highlands. The FIA research unit of the Southern Research Station in Starkville, MS, is responsible for surveying forest land in Arkansas and Oklahoma, and the FIA research unit of the North Central Forest Experiment Station, in St. Paul, MN, is responsible for surveying forest land in Missouri.

Forest Inventory and Analysis researchers use a large sampling network of permanent plots on public and private lands across each State. Each plot is revisited and measured on a predetermined schedule. All related data for the plots are combined in a given area (such as a region or State) to provide the general estimate of forest conditions for that area. When recent data from a



OOH Ozark-Ouachita Highlands Assessment Area
221 Eastern Broadleaf Forest (Oceanic) Province
M221 Central Applachian Broadleaf-Coniferous Forest Meadow Province
222 Eastern Broadleaf Forest (Continental) Province
231 Southern Mixed Forest Province
232 Outer Coastal Plain Mixed Forest Province
234 Lower Mississippi Riverine Forest Province
251 Prairie Parkland Temperate Province
255 Prairie Parkland Subtropical Province

Figure 3.1—Provinces included in the comparison of the Ozark-Ouachita Highlands Assessment area to other portions of the Humid Temperate Domain (the combination of all provinces shown; provinces from McNab and Avers 1994). Shaded areas represent forest; unshaded areas are nonforest.



Ecological section	Map code	Subsection name and number
Ozark Highlands	1	St. Francois Knobs and Basins - 222Aa
	2	Central Plateau - 222Ab
	3	Osage River Hills - 222Ac
	4	Gasconade River Hills - 222Ad
	5	Meramec River Hills - 222Ae
	6	Current River Hills - 222Af
	7	White River Hills - 222Ag
	8	Elk River Hills - 222Ah
	9	Black River Ozark Border - 222Al
	10	Springfield Plain - 222Am
	11	Springfield Plateau - 222An
Boston Mountains	12	Upper Boston Mountains - M222Aa
	13	Lower Boston Mountains - M222Ab
Arkansas Valley	14	Eastern Arkansas Valley - 231Ga
	15	Western Arkansas Valley Mountains - 231Gb
	16	Western Arkansas Valley - 231Gc
Ouachita Mountains	17	Fourche Mountains - M231 Aa
	18	Western Ouachita Mountains - M231Ab
	19	Central Ouachita Mountains - M231Ac
	20	Athens Piedmont Plateau - M231Ad

Cover types

- Loblolly-shortleaf pine
- Oak-pine
- Oak-hickory
- Oak-gum-cypress
- Elm-ash-cottonwood
- Nonforest
- Water

Figure 3.2—Generalized land cover of the Assessment area based on AVHRR data.

Table 3.1—Land cover statistics for the Ozark-Ouachita Highlands, surrounding ecological provinces, and the Eastern United States, based on AVHRR data

	Ecological region									
Habitat type	OOH	221	M221	222	231	232	234	251	255	Eastern U.S.
	Percent									
White-red-jack pine	0.0	5.3	1.8	0.5	0.0	0.0	0.0	0.0	0.0	2.0
Spruce-fir	0.0	0.9	0.3	0.0	0.0	0.0	0.0	0	0.0	1.7
Longleaf-slash pine	0.0	0.0	0.0	0.0	0.5	14.7	0.1	0	0.0	2.3
Loblolly-shortleaf pine	9.9	0.1	0.9	0.1	29.3	15.9	2.9	0	0.5	6.0
Oak-pine	10.8	5.3	11.9	1.0	19.0	8.2	1.3	0	1.5	4.8
Oak-hickory	35.4	37.4	50.9	13.8	17.3	4.1	2.5	2.6	9.5	12.1
Oak-gum-cypress	0.4	0.0	0.0	0.2	3.7	15.6	12.3	0	0.5	3.3
Elm-ash-cottonwood	0.9	0.0	0.0	1.8	0.0	0.0	0.2	1.2	0.0	0.5
Maple-beech-birch	0.0	8.5	5.3	5.2	0.1	0.0	0	0.4	0.0	5.7
Nonforest	40.3	41.5	28.6	75.7	28.4	40.3	79.3	95.3	85.8	51.9
Water	2.3	1.0	0.2	0.8	1.6	1.3	1.4	0.4	1.3	7.4
Total	57.4	57.6	71.1	23.5	69.9	58.5	19.3	4.3	12.8	40.9
	Thousand square miles									
Total area	64.3	95.2	65.5	232.2	167.2	210.2	47.5	200.5	88.8	1,413.5
	Square miles									
Mean forest patch size	2,828	2,764	9,095	430	6,487	3,310	868	87	419	—

AVHRR = Advanced Very High Resolution Radiometer; OOH = Ozark-Ouachita Highlands; 221 = Eastern broadleaf forest oceanic province; M221 = Central Appalachian broadleaf-coniferous forest meadow province; 222 = Eastern broadleaf forest continental province; 231 = Southern mixed forest province; 232 = Outer coastal plain mixed forest province; 234 = Lower Mississippi riverine forest province; 251 = Prairie parkland temperate province; 255 = Prairie parkland subtropical province; Eastern U.S. = Humid temperate domain (all but OOH from McNab and Avers 1994); — = not calculated.

given plot are compared with previous survey data, changes in forest condition can be determined. Details of the procedures used in collecting and analyzing FIA data can be found in Hansen and others (1992).

As with all sample-based information, survey data are subject to sampling errors. For most of the analyses in this section, survey data are based on a large number of plots, and sampling errors will generally be low. For example, the sampling error estimates for growing-stock volume by region is ± 5 percent.

The most recent reports of surveys in the Assessment area were in different years—Arkansas in 1997, Oklahoma in 1993, and Missouri in 1988 (table 3.2). (A new survey was under way in Missouri at the time of the Ozark-Ouachita Highlands Assessment.) The respective FIA units pooled data from those surveys to provide information about the Assessment area.

The Terrestrial Team performed three analyses of increasing complexity. The first analysis characterized forested conditions in the Assessment area, based on the most recent FIA data available. Only FIA sample plots within the Assessment area boundary were used. Thus, the current view is based on data obtained in Arkansas from 1995 to 1997, in Oklahoma in 1993, and in Missouri in 1988 (USDA FS 1997).

The second analysis evaluated changes in land use and forest cover in the Assessment area. Because historical plot data were inconsistent across States, it was impossible to develop a specific link to the Assessment area boundary. Therefore, the Team had to use

Table 3.2—FIA survey regions, survey years, and measurement intervals used for analysis of general trends in forest cover of the Assessment area

State (survey regions)	Year of field work	Measurement interval[a]
Oklahoma (East[b])	1956	1950's
	1966	1960's
	1976	1970's
	1986	1980's
	1993	1990's
Arkansas (Ouachita and Ozark)	1959	1950's
	1969	1960's
	1978	1970's
	1988	1980's
	1995	1990's
Missouri (Eastern Ozarks, Northwest Ozarks, Southwest Ozarks)	1947	1950's
	1959	1960's
	1972	1970's
	1988	1980's

[a] Measurement interval indicates how measurement year was stratified for analysis of trends over time.
[b] Combination of northeast and southeast Oklahoma regions.
Source: USDA FS (1997).

the traditional FIA regions, which correspond reasonably well with the Ozark-Ouachita Highlands (fig. 3.3).

The third analysis was an ecological assessment of forest cover in the Assessment area based on the most recent forest surveys. FIA data were stratified by ecological section and subsection (see following paragraph and, for more detail, Chapter 1) by locating FIA plots within these boundaries using a Geographic Information System (GIS). Plots within each subsection in the Assessment area were retained for analysis. By using this method, a separate FIA data set was prepared for the Assessment.

The sections included in the Assessment area are, from north to south: (1) the Ozark Highlands, (2) the Boston Mountains, (3) the Arkansas Valley, and (4) the Ouachita Mountains. Each section consists of several ecological subdivisions, called "subsections" (see fig. 3.2 or, for a simpler image, fig. 1.1 in Chapter 1), which represent areas of unique geological and ecological character. FIA data were used to evaluate each section in detail and to compare the sections with one another; subsections were compared where data permitted.

Assessment Area

Current Forested Area. According to FIA data, the Assessment area encompasses 37,286,600 acres (ac). Of this, 23,954,800 ac (more than 64 percent) are forested, and 13,331,400 ac (about 36 percent) are in nonforest uses such as agriculture, roads, towns, or cities (fig. 3.4).

Of the forested area, more than 95 percent is classified as timberland, which is land producing or capable of producing commercial timber harvests. Woodlands too unproductive to support commercial timber harvests and forests where timber harvests have been prohibited (Federal wilderness and other "reserved" areas) account for the remainder.

Land Ownership. Nonindustrial private forest (NIPF) owners, such as farmers, urban or suburban residents, and corporations not involved in the timber industry, hold 68 percent of the 22.89 million ac of timberland in the Assessment area; forest industry owns 11 percent (fig. 3.5). Thus, private and corporate landowners together hold 79 percent of the timberland.

Of the 21 percent of timberlands on public lands, 75 percent (16 percent of all timberlands) are in the National Forest System (i.e., part of the Mark Twain, Ouachita, or Ozark-St. Francis National Forests). The remaining 25 percent of public timberland consists of Federal, State, county, and municipal lands, including State forests, wildlife management areas, national wildlife refuges, military bases, and local parks.

General Attributes of Highlands Forests. Hardwoods are the dominant cover on 85 percent of the timberland in the Assessment area (fig. 3.6). The oak-hickory forest type is the most common in the region, occupying 67 percent of the timberland. Pine types, primarily shortleaf and loblolly pines, occupy only 15 percent of the timberland. Of this amount, 65 percent is in shortleaf pine stands of natural origin, and 35 percent is in plantations of either shortleaf or loblolly pine.

The timberlands in the Assessment area occupy relatively poor sites. Most of the timberland acres fall in the two lowest productivity classes; less than 2 percent fall within the two highest productivity classes (fig. 3.7).

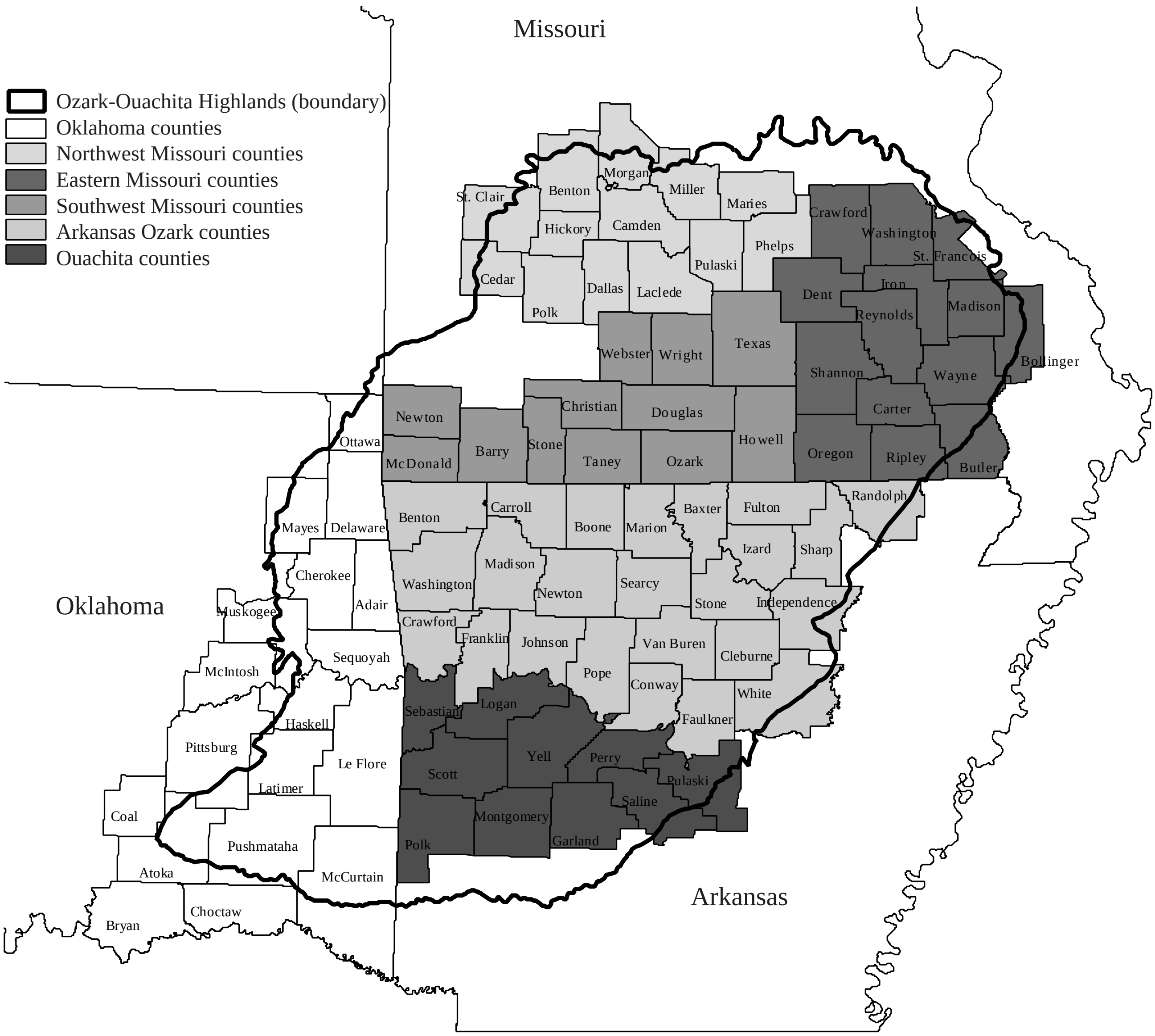


Figure 3.3—FIA regions lying wholly or partially within the Assessment area.

However, the forests within the Assessment area are, on average, adequately stocked (fig. 3.8). (Stocking is a relative measure of the degree to which the growth potential of the site is used by trees; for more information, refer to Hansen and others 1992.) Forests on more than 50 percent of the timberlands have stocking from 60 to 100 percent. Less than 33 percent of the timberlands are less than fully stocked (less than 60 percent stocking), and about 17 percent of the area is overstocked (greater than 100 percent stocking).

FIA analysts distinguish between live trees (all living trees), growing-stock trees (live trees of commercial species and potentially useful for harvest), and sawtimber trees (growing-stock trees large enough to use for saw logs) (Rosson and London 1997). Generally, live-tree comparisons best reflect the species composition and distribution of the forest. Growing-stock comparisons reflect the commercial or merchantable component of the forest, i.e., those trees that are suitable for pulpwood or saw logs. Sawtimber comparisons indicate

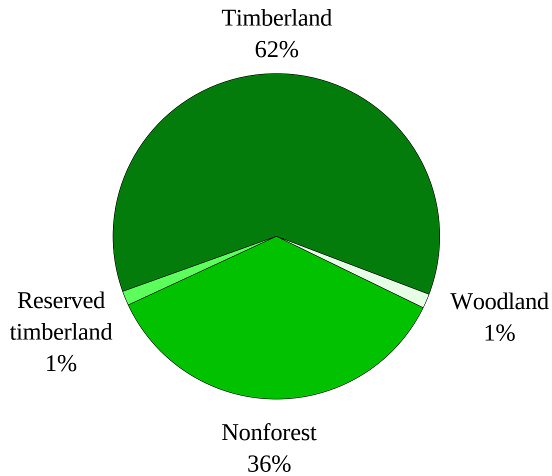


Figure 3.4—Distribution of land cover in the Ozark-Ouachita Highlands.

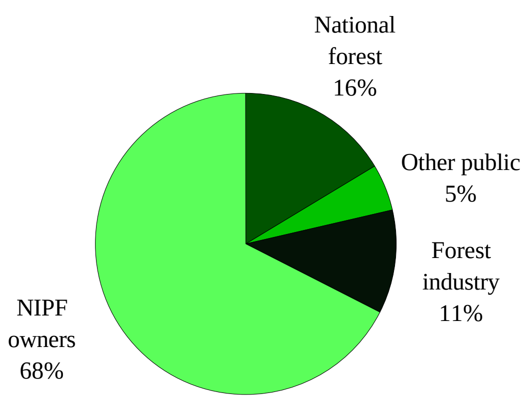


Figure 3.5—Ownership of timberland in the Ozark-Ouachita Highlands. (NIPF = nonindustrial private forest.)

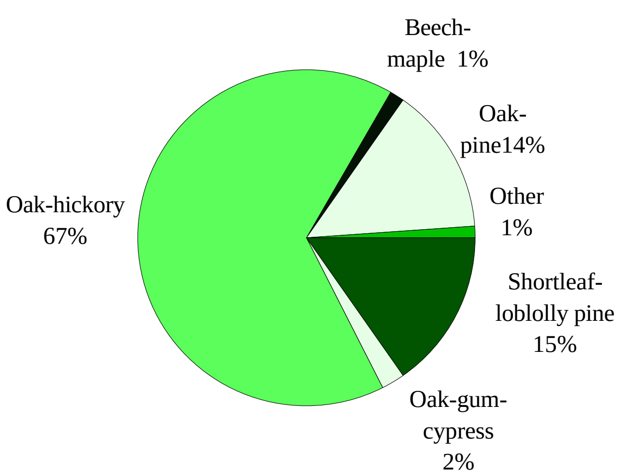


Figure 3.6—Representation of major forest types on timberland in the Ozark-Ouachita Highlands.

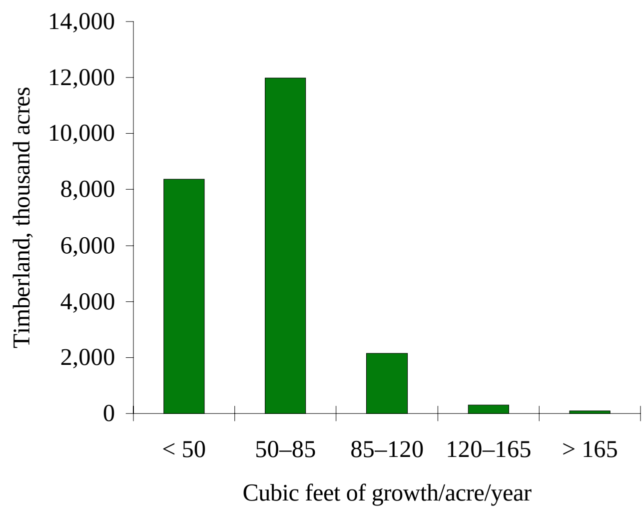


Figure 3.7—Area of timberland in the Ozark-Ouachita Highlands in five site productivity classes.

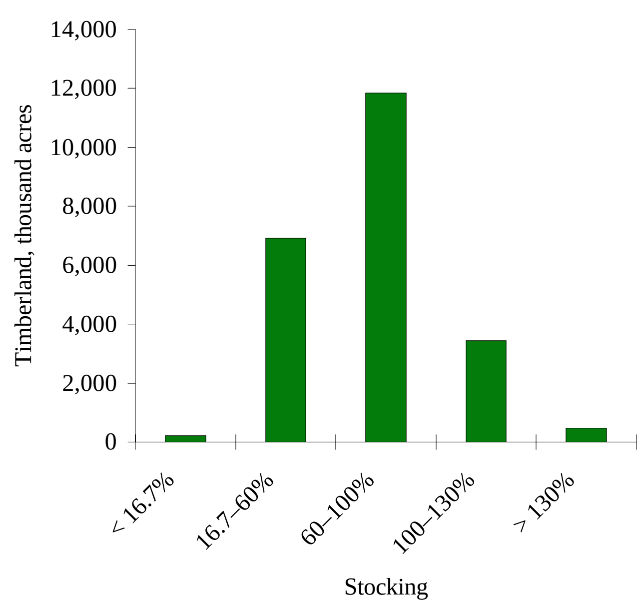


Figure 3.8—Area of timberland in the Ozark-Ouachita Highlands in five stocking classes.

forest conditions associated with large trees (trees 9 inches [in.] in diameter at breast height [d.b.h.] and larger) that are suitable for saw logs.

The average acre in the Assessment area contains 639 live trees, of which 200 trees are in the growing-stock category. Hardwoods account for 77 percent of live trees and 76 percent of growing-stock trees. The average live-tree volume in the Assessment area is 1,032 cubic feet/ac, of which 74 percent is hardwood and 26 percent conifer (pines and eastern red cedar) (table 3.3). Cubic volume decreases from live-tree to growing-stock to sawtimber categories. The distribution of cubic volume also changes, with the percentage of hardwoods declining and percentage of conifers increasing. Finally, the average acre in the Assessment area contains a sawtimber volume of 2,350 board feet (40 percent pine and 60 percent hardwood).

The five species with the largest live-tree volumes in the Assessment area are shortleaf pine, white oak, black oak, post oak, and northern red oak (table 3.4). Together, these five species account for 67 percent of the live-tree cubic volume, 70 percent of the growing-stock volume, and 76 percent of the sawtimber board-foot volume in the Assessment area. Oaks as a group (those just noted

Table 3.3—Average per-acre volumes (live tree, growing stock, sawtimber) of conifers and hardwoods in Assessment area timberlands

Tree type	Live-tree volume	Growing-stock volume	Sawtimber cubic volume	Sawtimber board-foot volume
	Cubic feet/acre			*Board feet/acre*[a]
Conifer	269.7 (26.1%)	261.1 (32.1%)	154.3 (39.2%)	929.6 (39.6%)
Hardwood	762.5 (73.9%)	552.8 (67.9%)	239.3 (60.8%)	1,420.4 (60.4%)
Total	1,032.2 (100%)	813.9 (100%)	393.6 (100%)	2,350.0 (100%)

[a] International ¼-inch rule.
Source: USDA FS (1997).

Table 3.4—Distribution of live-tree and sawtimber volume among major tree species in the Assessment area

Species	Live-tree volume		Sawtimber volume	
	Cubic feet/acre	*Percent*	*Board feet/acre*	*Percent*
Shortleaf pine	214.4	20.7	847.6	35.9
White oak	172.1	16.6	339.0	14.4
Black oak	140.8	13.6	317.5	13.5
Post oak	117.0	11.3	142.4	6.0
Northern red oak	53.0	5.1	140.1	5.9
Loblolly pine	39.5	3.8	69.3	2.9
Scarlet oak	24.1	2.3	49.7	2.1
Sweetgum	20.9	2.0	55.2	2.3
Blackjack oak	19.9	1.9	5.8	0.2
Southern red oak	18.2	1.8	48.9	2.1
Other species	214.3	20.7	344.8	14.6
Total	1,034.1	100	2,360.3	100

Source: USDA FS (1997).

and scarlet, blackjack, chinquapin, and southern red oak) account for about 50 percent of the live-tree volume and 44 percent of the sawtimber volume in the Assessment area. Shortleaf pine alone, however, accounts for 36 percent of the board-foot volume in area. Almost 50 percent of the shortleaf pine sawtimber board-foot volume in the Assessment area (9.56 billion board feet) is located on national forest land.

Loblolly pine is the sixth-ranked species and accounts for 3.8 percent of the live-tree volume in the Assessment area. This species is native only to a handful of counties along the southern boundary of the Assessment area, but it is commonly used in intensive plantation management by forest industry to the north of its natural range, especially in the Ouachita Mountains.

Distribution of Volume in the Assessment Area. Eighty percent of the growing-stock volume consists of oaks (50 percent) and pines (30 percent)(fig. 3.9).

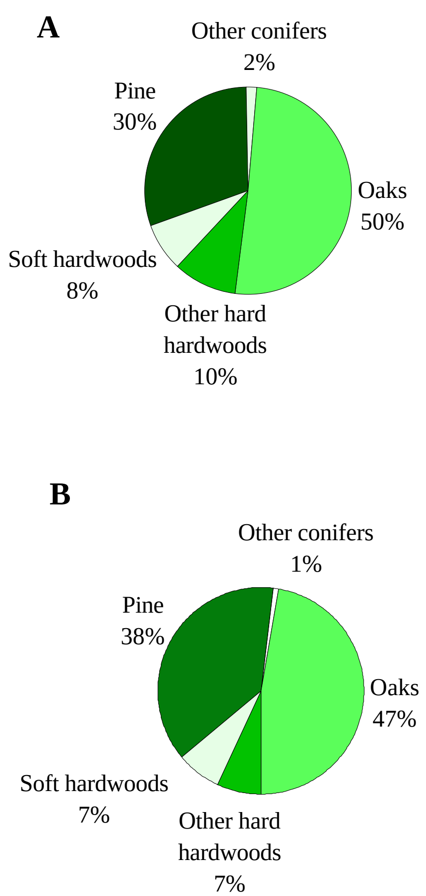


Figure 3.9—Distribution of (A) growing-stock volume and (B) sawtimber volume in the Ozark-Ouachita Highlands by species group.

Eighty five percent of the board-foot sawtimber volume is oak (47 percent) or pine (38 percent). More than 50 percent of the growing-stock volume and sawtimber volume are in hard hardwoods (primarily oaks but also hickories, hard maple, beech, ashes, and black walnut). Soft hardwoods (soft maples, sweetgum, tupelo, blackgum, cottonwood, and basswood) account for about 7 percent of the growing-stock and sawtimber volumes in the Assessment area.

Only 30 percent of the timberland acreage in the Assessment area have stand volumes greater than 1,000 cubic feet/ac (fig. 3.10). Ownership of this 30 percent is not typical of the average. National forests account for more than one-third (fig. 3.11), which is disproportionately high, given that national forests occupy just over 16 percent of the Assessment area. Conversely, NIPF landowners own nearly 75 percent of the stands with less than 1,000 cubic feet/ac, another disproportionately high percentage.

Figure 3.12 shows that there are more oaks than pines in the Assessment area throughout the range of diameter classes. Overall, there are 2.8 living oaks for every live pine in the Assessment area. For every live conifer (pines, eastern red cedar), there are 6.6 living

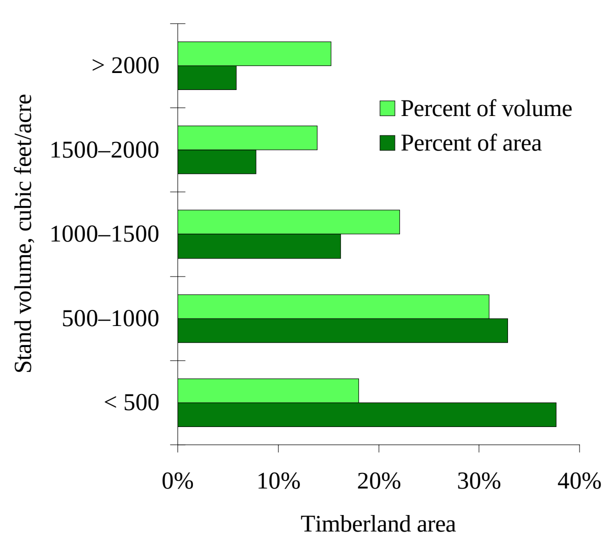


Figure 3.10—Distribution of growing-stock volume and timberland in the Ozark-Ouachita Highlands in stands of various stocking levels.

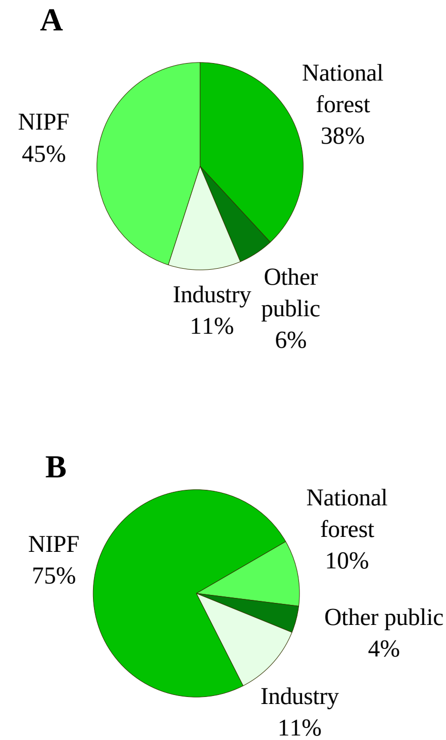


Figure 3.11—Ownership of forest stands in the Ozark-Ouachita Highlands with (A) greater than and (B) less than 1,000 cubic feet of growing-stock volume per acre.

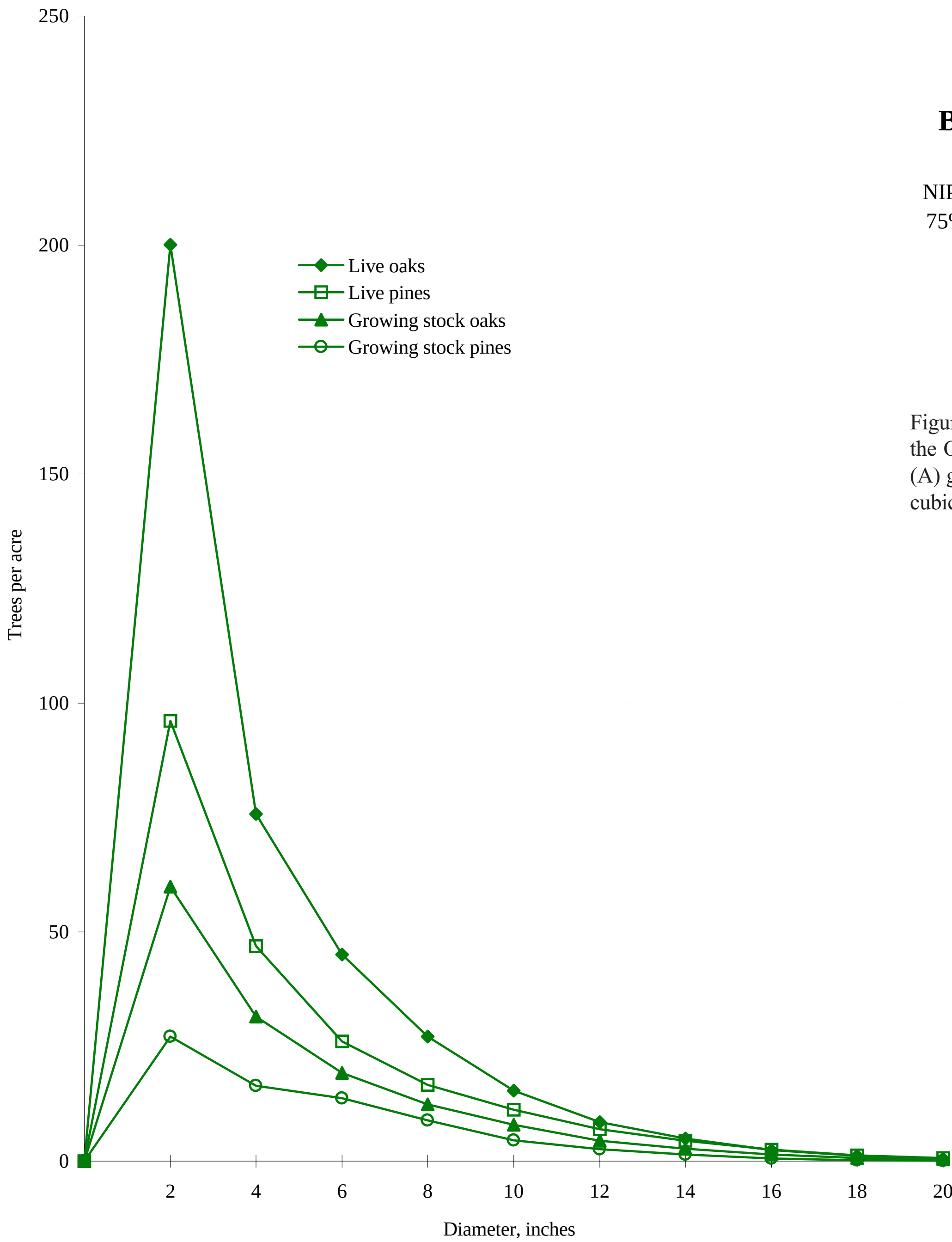


Figure 3.12—Size-class distribution of oak and pine trees per acre on timberland in the Ozark-Ouachita Highlands.

hardwoods. However, the proportion of conifers of growing-stock quality (merchantable or sawtimber category) is considerably higher than for hardwoods (table 3.5). For conifers in general and pines in particular, the ratio of growing-stock trees to live trees exceeds 80 percent in all diameter classes and 95 percent in the sawtimber size class. Conversely, the ratio does not exceed 70 percent for oaks in any of the broad size categories.

FIA analysts divide the live trees that are not of growing-stock quality into two categories: (1) rough trees, too gnarly or branched to qualify as growing stock, and (2) rotten trees, which have excessive internal defect. The volume of rough and rotten trees in proportion to growing-stock trees is much greater in the hardwood component, especially the hard hardwoods, than in the pine or other conifer components (fig. 3.13).

These data suggest that a larger proportion of the pines have potential commercial value than do oaks (or hardwoods in general) in the Assessment area. There are several causes for this trend. The determinate growth form of conifers—the tendency of conifers to produce a single stem—makes it easy to classify a conifer as having potential commercial value early in the tree's life. Conversely, the indeterminate growth habit of hardwoods—the tendency of hardwoods to form a crooked stem or multiple stems under partially shaded conditions—can result in a tree developing poor form,

Table 3.5—Percent of live trees that qualify as growing- stock trees by size category and species group

Species group	All species[a]	Merchantable[b]	Sawtimber[c]
	- - - - - -	*Percent*	- - - - - -
Pine	82.7	90.7	97.4
All conifers	83.3	89.3	95.4
Oak	66.1	69.1	64.9
All hardwoods	58.5	64.1	65.1
All trees	59.7	68.7	71.7

[a] "All sizes" consist of diameter classes 2 in. and larger.
[b] Merchantable size classes are diameter classes 4 in. and larger in the conifer components and 6 in. and larger in the hardwood components.
[c] Sawtimber size classes are diameter classes 10 in. and larger in the conifer components and 12 in. and larger in the hardwood components.
Source: USDA FS (1997).

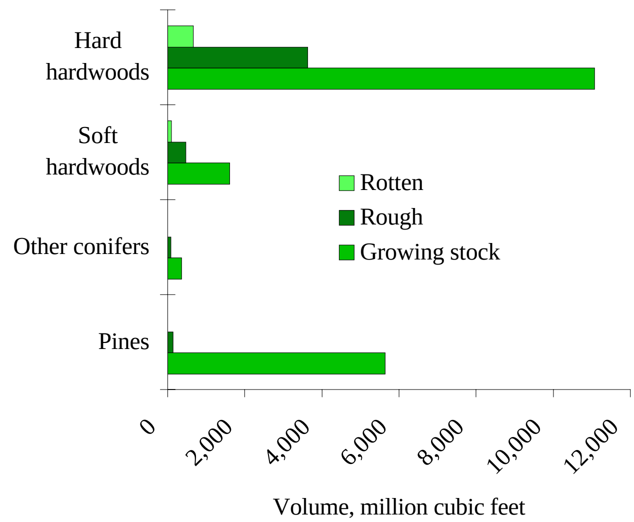


Figure 3.13—Growing-stock volume, rough tree volume, and rotten tree volume in the Ozark-Ouachita Highlands by species group.

which reduces its commercial value. However, lack of commercial value in no way diminishes the other resource values trees provide, including mast crops and cavities for use by wildlife.

Growth, Removals, and Mortality. The average acre in the Ozark-Ouachita Highlands supports an annual net growth of 29.6 cubic feet, most of which (85 percent) is in the pine and oak components (fig. 3.14). Average annual removals by harvesting amount to 14.5 cubic feet/ac, of which 88 percent is in the pine and oak components. The net result is that growth on the average acre in the Assessment area is more than double the removals. The oak component has a larger growth-removals ratio than the pines, 6.9 versus 5.3 cubic feet/ac per year.

The average annual mortality rate is 12.3 percent of the gross annual growth (3.7 cubic feet). However, mortality rates differ between conifers and hardwoods—5.8 percent and 17.4 percent of gross annual growth, respectively. Removals through harvest exceed natural mortality by only 1.6 times in the hardwood component but by over 9 times in the conifer component.

Differences Among Ecological Sections. The Ozark Highlands section dominates the Assessment area, containing 22.87 million ac or 61 percent of the total land area (fig. 3.15). The other three sections—the

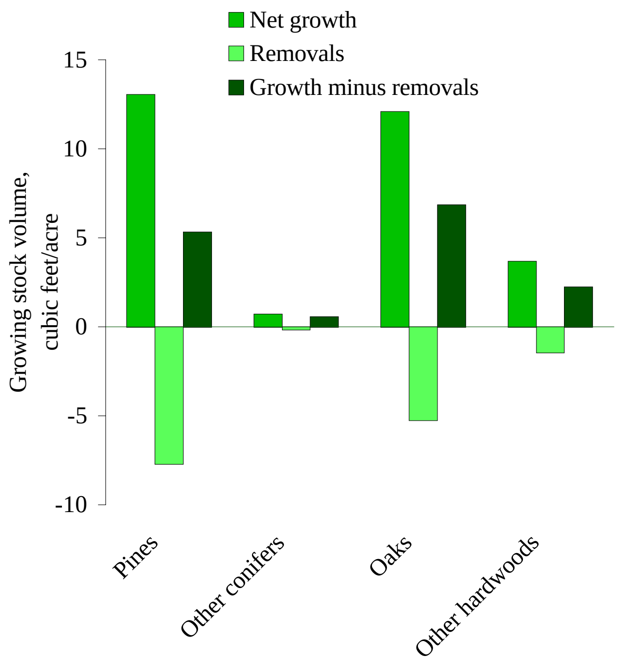


Figure 3.14—Average net annual growth, average annual removals, and growth minus removals for the average timberland acre in the Ozark-Ouachita Highlands.

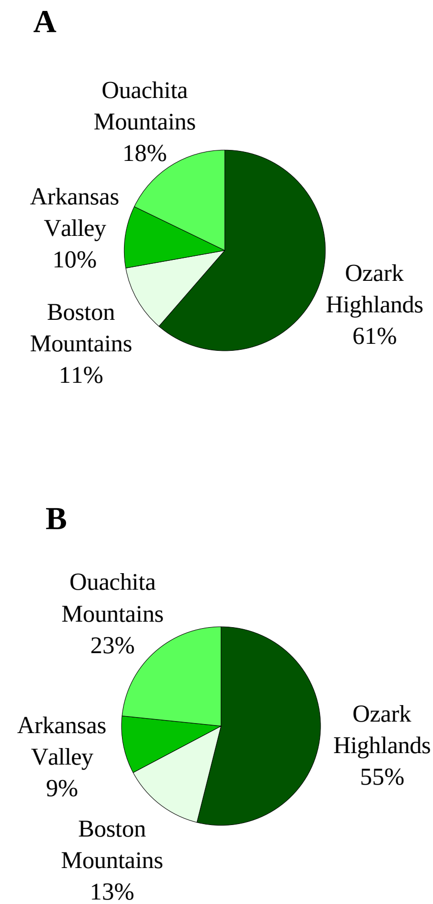


Figure 3.15—Distribution of (A) total land area and (B) forested land area in the Ozark-Ouachita Highlands by ecological section.

Ouachita Mountains, the Boston Mountains, and the Arkansas Valley—occupy 18 percent, 11 percent, and 10 percent, respectively, of the area. Of the 23.95 million ac of total forest and in the Assessment area, more than 50 percent are in the Ozark Highlands, again followed in rank order by the Ouachita Mountains, the Boston Mountains, and the Arkansas Valley. Total area, forest land, and timberland acreage by section and subsection are shown in table 3.6.

Within each section, the amount of forested land differs considerably (fig. 3.16). In the Ozark Highlands, only 56 percent of the land area is forested versus 60 percent in the Arkansas Valley, 78 percent in the Boston Mountains, and 85 percent in the Ouachita Mountains. The ratio of timberland to total forest land shows the small amount of reserved forest land (such as wilderness areas) and "other forest" in the Assessment area. More than 95 percent of the forested area is commercial timberland, i.e., capable of supporting commercial timber harvests.

Private lands held by NIPF owners and forest industry dominate the timberland acreage in the four

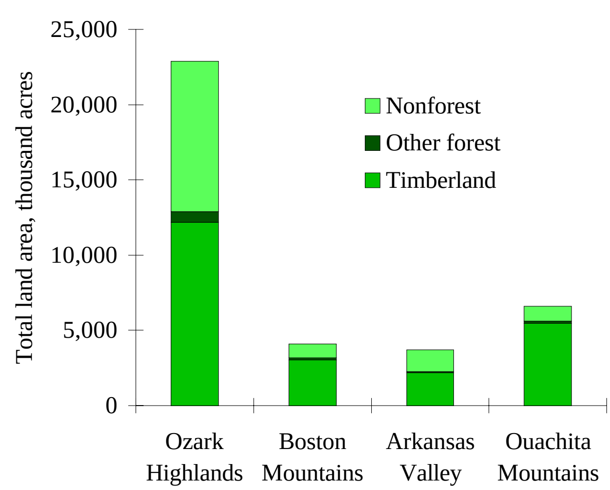


Figure 3.16—Distribution of total land area in the ecological sections of the Ozark-Ouachita Highlands by land category.

Table 3.6—Total land area, forested land area, and timberland area by ecological section and subsection in the Ozark-Ouachita Highlands (FIA data)

Ecological section Subsection[a]	Map code	Total land	Forest land	Timberland	
		Thousand acres			
Ozark Highlands Section	222	22,780.9	12,901.8	12,189.8	St.
Francois Knobs and Basins	222Aa	1,092.1	750.2	688.0	
Central Plateau	222Ab	6,338.7	3,099.1	3,013.9	
Osage River Hills	222Ac	1,399.2	855.3	778.9	
Gasconade River Hills	222Ad	1,087.5	654.3	612.9	
Meramac River Hills	222Ae	1,168.1	891.4	881.6	
Current River Hills	222Af	1,563.3	1,322.0	1,215.7	
White River Hills	222Ag	3,583.7	2,342.8	2,121.6	
Elk River Hills	222Ah	434.0	264.2	264.2	
Black River Ozark Border	222Al	860.7	677.1	665.7	
Springfield Plain	222Am	3,103.1	641.8	634.0	
Springfield Plateau	222An	2,240.4	1,403.6	1,313.3	
Boston Mountains Section	M222	4,090.1	3,181.7	3,035.3	
Upper Boston Mountains	M222Aa	1,129.7	904.9	837.0	
Lower Boston Mountains	M222Ab	2,960.3	2,276.8	2,198.3	
Arkansas Valley Section	231	3,725.1	2,253.3	2,192.8	
Eastern Arkansas Valley	231Ga	1,470.1	774.3	754.8	
Mount Magazine	231Gb	664.1	616.8	592.8	
Western Arkansas Valley Mountains	231Gc	1,590.9	862.2	845.2	
Ouachita Mountains Section	M231	6,600.1	5,617.9	5,477.0	
Fourche Mountains	M231Aa	2,740.8	2,147.3	2,050.6	
West Central Ouachita Mountains	M231Ab	1,443.2	1,421.8	1,406.8	
East Central Ouachita Mountains	M231Ac	1,526.6	1,292.4	1,263.2	
Athens Piedmont Plateau	M231Ad	889.5	756.4	756.4	
Total		37,286.2	23,954.8	22,894.9	

[a] See figure 1.1 for locations.
Source: USDA FS (1997).

sections (fig. 3.17). In each section, more than 70 percent of timberland is in private ownership. In the Ozark Highlands and the Arkansas Valley, this figure exceeds 83 percent. However, the character of private ownership differs by section. In the Ozark Highlands, Boston Mountains, and the Arkansas Valley, more than 96 percent of the private timberlands are in NIPF ownership. But in the Ouachita Mountains, NIPF owners own slightly less than one-half of the private sector timberlands. Forest industry owns more than 2 million ac of timberland in the Ouachitas—80 percent of the 2.5 million ac of forest industry timberland in the entire Assessment area.

An examination of the distribution of types of forests shows hardwood forests are more widely distributed than pine-dominated types in each section, but the proportions shift from north to south (left to right in fig. 3.18). Oak or oak-pine forests are dominant on 90 percent of timberland in the Ozark Highlands and Boston Mountains, but they account for 78 percent of the timberland in the Arkansas Valley and 58 percent in the Ouachita Mountains. Generally, the percentage of pine forest acreage increases directly with the decreasing proportion of oak types. This relationship is most evident in the Ouachita Mountains, where pine types occupy slightly over 40 percent of the timberland area.

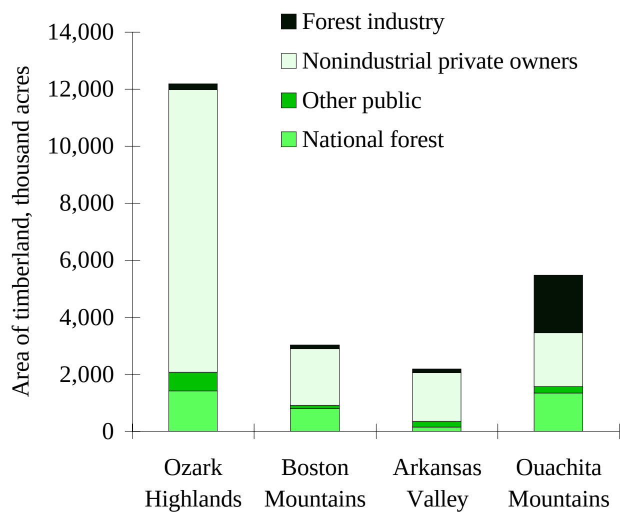


Figure 3.17—Distribution of timberland in the ecological sections of the Ozark-Ouachita Highlands by ownership category.

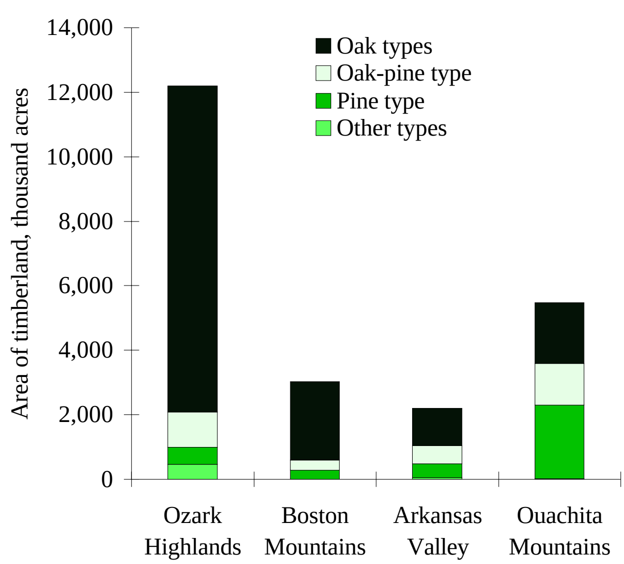


Figure 3.18—Distribution of timberland in the ecological sections of the Ozark-Ouachita Highlands by forest type.

Overall, site productivity is inversely related to latitude, with poorer productivity in the north. This trend is especially apparent in the lowest site productivity class (fig. 3.19). More than 90 percent of the timberland in the Ozark Highlands and the Boston Mountains falls in the two poorest classes. The only section with more than 25 percent of timberland in the moderately productive class (85 to 120 cubic feet/ac per year) is the Ouachita Mountains. Less than 5 percent of the timberland in any section has growth rates exceeding 120 cubic feet/ac per year.

Conversely, stocking of timberland does not differ greatly among sections (fig. 3.20). The Boston Mountains and Ouachita Mountains both have slightly less timberland in understocked stands and slightly more in overstocked stands than the Ozark Highlands or Arkansas Valley sections. However, these differences are not prominent. In addition the percent of area occupied by sawtimber, pulpwood, and seedling-sapling stands is similar across sections. There is a slightly higher percentage of area occupied by stands of sawtimber in the Ozark Highlands and Boston Mountains, but again the differences among sections are not prominent.

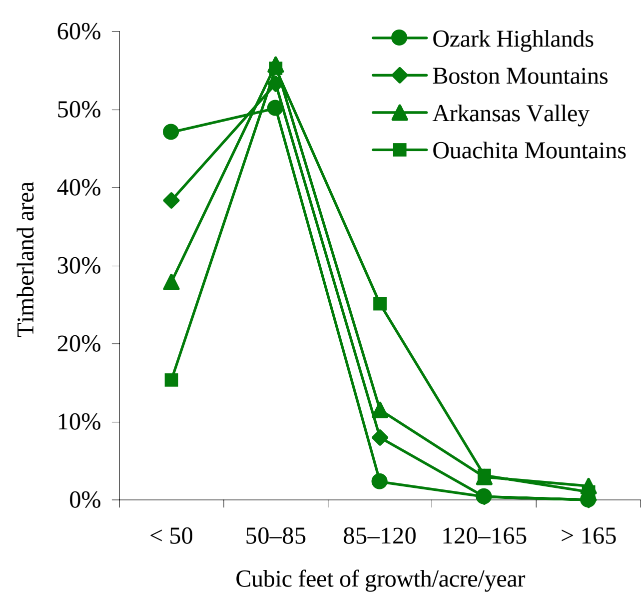


Figure 3.19—Distribution of timberland in the ecological sections of the Ozark-Ouachita Highlands by site quality (productivity) class.

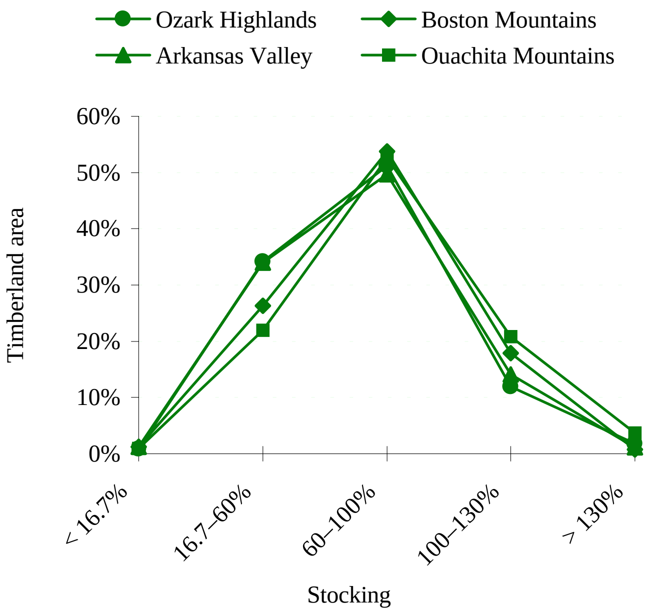


Figure 3.20—Distribution of timberland in the ecological sections of the Ozark-Ouachita Highlands by stocking class.

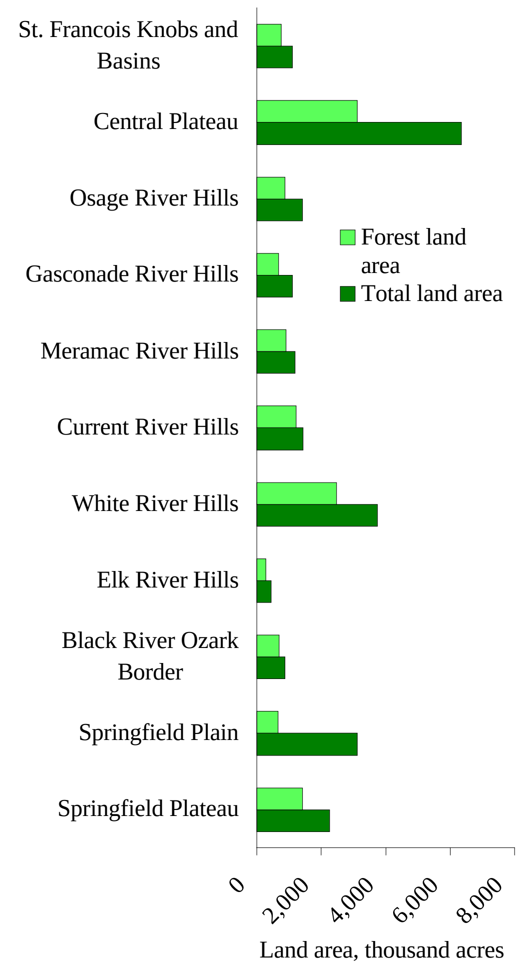


Figure 3.21—Distribution of forested land and total land area of the Ozark Highlands section by ecological subsection.

Ozark Highlands

General Land Attributes. The portion of the Ozark Highlands section that lies within the Assessment area includes 11 ecological subsections. Three of these—the Central Plateau, the White River Hills, and the Springfield Plain—account for more than 50 percent of the land area in this section. The Central Plateau and the Springfield Plain are the only subsections with less than 50 percent of the land area in forest (fig. 3.21). When these two subsections are excluded, the rest of the Ozark Highlands is more than 66 percent forested, a figure close to the Assessment area average. Percentage of land in forest cover varies from a low of 20 percent in the Springfield Plain subsection to a high of 85 percent in the Current River Hills subsection.

NIPF owners hold the majority of timberland in all but one of the subsections (fig. 3.22). NIPF ownership ranges from 49 percent in the Current River Hills to 97 percent in the Elk River Hills. Ten of the 11 subsections have greater than 70 percent NIPF ownership of timberland, and 6 have greater than 85 percent. Conversely, public ownership of timberland varies from 3 percent in the Elk River Hills subsection to just over 50 percent in the Current River Hills subsection. Figure 3.23 shows acres in public ownership by subsection. The four subsections with greater than 20 percent Federal ownership are the Gasconade River Hills, the Meramac River Hills, the Current River Hills, and the Black River Ozark Border. An inverse relationship exists between percent of timberland ownership in the NIPF sector and percent forest cover in this section—the higher the percentage of timberland in NIPF ownership, the lower the percent forest cover.

Oaks, especially the oak-hickory forest type, dominate the timberlands of the Ozark Highlands in all subsections (fig. 3.24). The percentage of oak types (oak-hickory, oak-pine, and oak-gum-cypress) does not fall below 87 percent in any of the subsections.

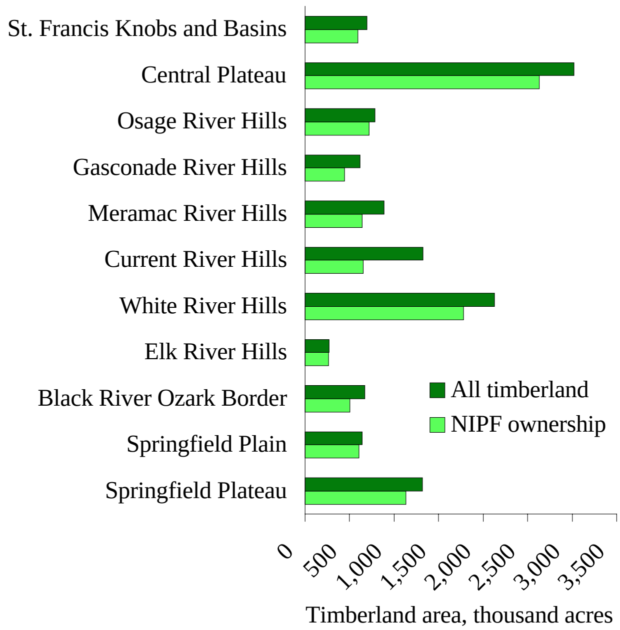


Figure 3.22—Distribution of total timberland and nonindustrial private forest in the Ozark Highlands section by ecological subsection.

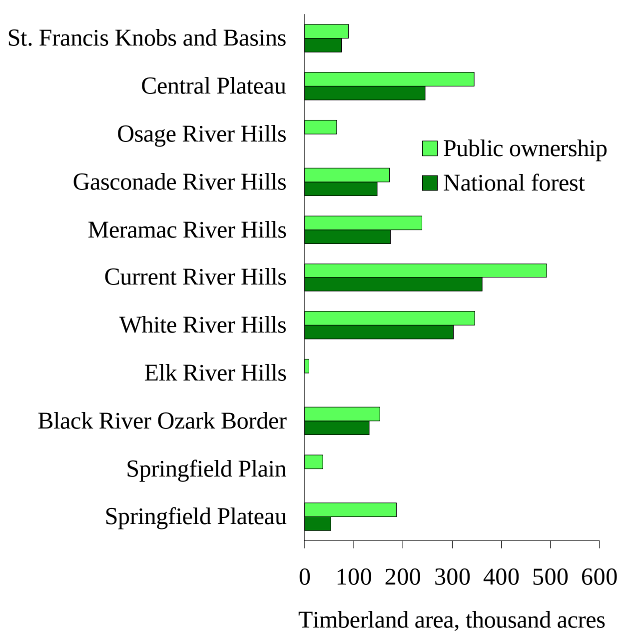


Figure 3.23—Distribution of timberland in public ownership and national forest ownership in the Ozark Highlands by ecological subsection.

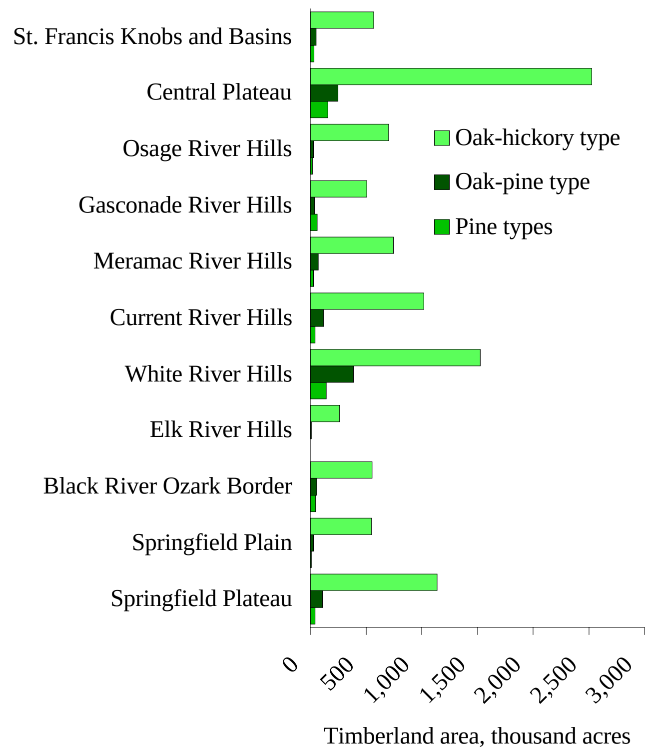


Figure 3.24—Distribution of timberland in the Ozark Highlands by forest type and ecological subsection.

Pine types are a minor component in all subsections, reaching a maximum of 9 percent of timberland area in the Gasconade River Hills subsection. This dominance of oaks is also reflected in growing-stock and sawtimber volume data. Hard hardwoods (such as oaks, hickory, hard maple, and black walnut) account for 81 percent of growing-stock volume and 79 percent of sawtimber board-foot volume on timberland across the Ozark Highlands. The range in hard hardwood volume on timberlands among subsections varies from 74 percent to 94 percent for growing-stock volume and from 71 to 94 percent for sawtimber board-foot volume.

General Forest Attributes. An average acre of timberland in the Ozark Highlands section has 582 live trees, of which 432 trees qualify as growing stock. These data are higher than for the Assessment area as a whole. Nearly 80 percent of the trees are in the 2-in. and 4-in. diameter classes, which is high relative to normal stocking standards. Softwoods account for less than 10 percent of the live trees and 11 percent of growing-stock trees per acre. Live-tree basal area of the average timberland acre is 79.7 square feet, of which 66 percent is in growing stock. The quadratic mean diameter of the average tree on the average timberland acre is 5 in.

More than 33 percent of the timberland area in the Ozark Highlands is either poorly stocked or nonstocked. As shown in fig. 3.25, national forests have the highest proportion of lands either moderately stocked (defined by FIA as between 60 to 100 percent stocked) or fully stocked (defined by FIA as from 100 to 130 percent stocked). The NIPF sector has the lowest proportion of lands in these classes. Further, the NIPF sector has the largest percentage of timberland (39 percent) in the two poorest stocking classes, whereas national forests have the smallest (slightly over 10 percent).

The average timberland acre in the Ozark Highlands has a live-tree volume of 961 cubic feet, a growing-stock volume of 660 cubic feet, a sawtimber cubic volume of 304 cubic feet, and a sawtimber board-foot volume of 1,800 board feet. Thus, the Ozark Highlands appear to have stands with lower volumes, on average, than the Assessment area as a whole (refer to table 3.3 for the latter). The contribution of pine to the volume components increases slightly, from 7 percent of live-tree volume to 14 percent of sawtimber volume, while that of hard hardwoods decreases from 84 percent to 78

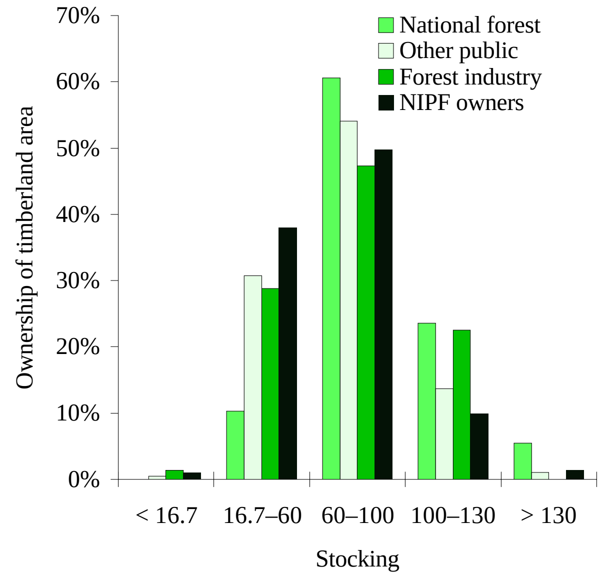


Figure 3.25—Distribution of timberland in the Ozark Highlands by stocking level and ownership category.

percent across the same range. Thus, pine appears to contribute only in a minor way to the character of the average acre in the Ozark Highlands.

The six species with the greatest volumes in the Ozark Highlands are black oak, white oak, post oak, shortleaf pine, scarlet oak, and northern red oak. Together they make up 74 percent of the live-tree volume, 77 percent of the growing-stock volume, and 81 percent of the sawtimber board-foot volume in this section. Almost 24 percent of the growing-stock volume of these six species is found on public lands, which consists of 17 percent of the section's timberland area. Nearly 50 percent of the shortleaf pine and 40 percent of the scarlet oak growing-stock volume in this section are on public lands (fig. 3.26).

Conversely, the NIPF class owns 81 percent of the timberland area but has only 74 percent of the volume. Post oak is the only species on NIPF lands that has a proportional growing-stock volume that exceeds the proportion of timberland. These data suggest that timberland in the public sector supports a disproportionately high share of the growing-stock volume in this section.

Growth, Removals, and Mortality. The Ozark Highlands section shows a growth surplus in the major forest types (fig. 3.27). Average annual net growth per

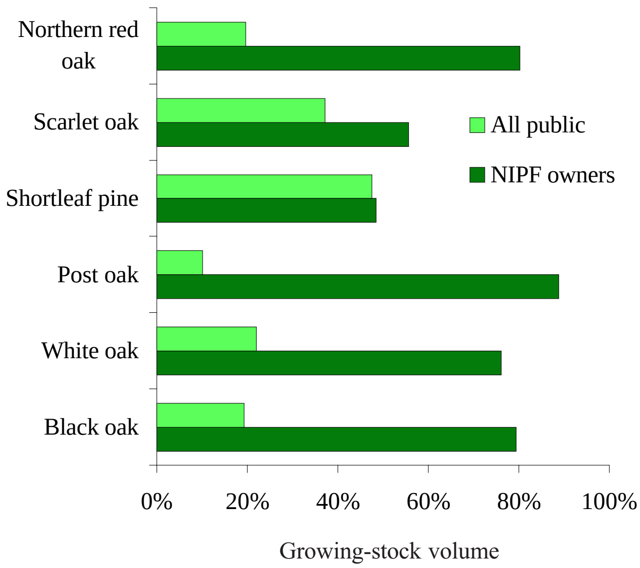


Figure 3.26—Distribution of growing-stock volume on public timberland and nonindustrial private forest land in the Ozark Highlands section.

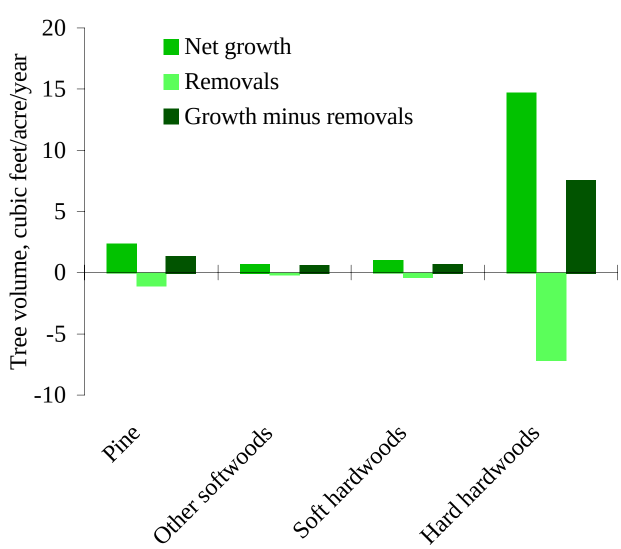


Figure 3.27—Growth, removals, and growth minus removals of growing-stock volume in the Ozark Highlands section by species group.

acre on timberland in this section is 18.8 cubic feet, of which 78 percent is in the hard hardwood component, and 16 percent is in the pine component. Average annual removals per acre total 8.5 cubic feet, of which 82 percent is hard hardwood and 15 percent is pine. Thus, growth exceeds removals by 10.3 cubic feet/ac annually.

Average annual mortality per acre on timberland in this section is 4.1 cubic feet—nearly 18 percent of gross annual growth per acre and slightly less than 50 percent of the level of removals. Hardwood mortality is nearly 20 percent of gross hardwood growth, whereas softwood mortality is 8 percent of growth—less than 50 percent of the mortality rate. The highest mortality rate is in the soft hardwoods—nearly 30 percent of gross growth.

Boston Mountains

General Land Attributes. The Boston Mountains section occupies about 4 million ac. It has two ecological subsections—the Upper Boston Mountains subsection (about 1 million ac) and the Lower Boston Mountains subsection (about 3 million ac). Both are entirely contained within the Assessment area and are about equally forested (fig. 3.28)—80 percent for the Upper Boston Mountains subsection and 77 percent for the Lower Boston Mountains. About the same physical area of each subsection is reserved woodland, which results in a slightly lower proportion of timberland in the Upper Boston Mountains subsection (92 percent) than in the Lower Boston Mountains (97 percent).

Land ownership in the subsections differs slightly (fig. 3.29). More than 33 percent of the Upper Boston Mountains subsection is public land, with 98 percent of that in national forest. The balance of slightly less than 66 percent of the timberland is in private ownership. In the Lower Boston Mountains subsection, about 27 percent of the timberland is public land, of which 84 percent is national forest. Of the 70 percent of Lower Boston Mountains timberland that is in private ownership, 6 percent is owned by forest industry and the balance by NIPF owners.

Forest types also differ in these subsections (fig. 3.30). More than 97 percent of the timberland area in the Upper Boston Mountains subsection is oak-dominated, with more than 92 percent in the oak-hickory

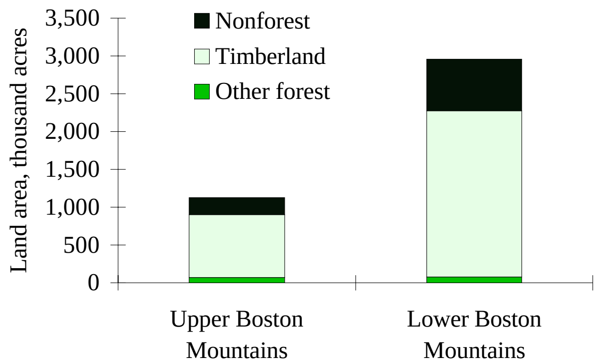


Figure 3.28—Distribution of timberland, other forest land, and nonforest land in the Boston Mountains section by ecological subsection.

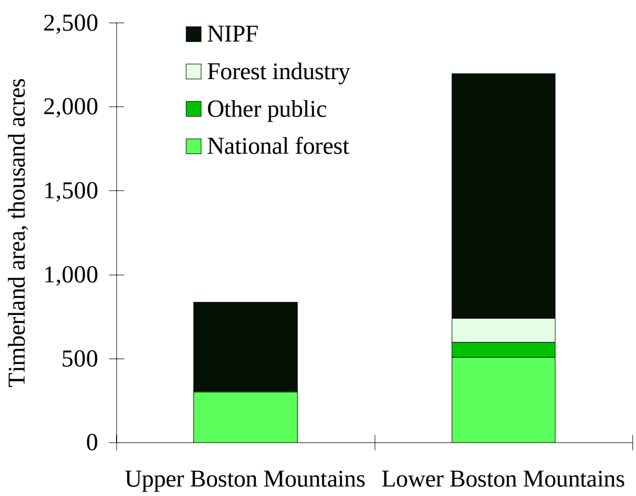


Figure 3.29—Distribution of nonforest land, timberland, and other forest land by ownership category in the Boston Mountains by ecological subsection. (NIPF = nonindustrial private forest)

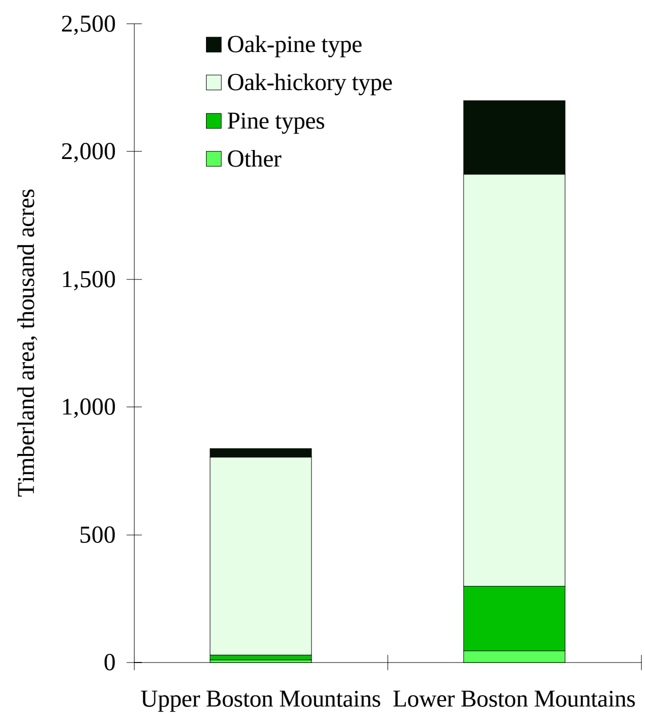


Figure 3.30—Distribution of timberland in the Boston Mountains by forest type and ecological subsection.

type alone. In the Lower Boston Mountains, pine and oak-pine types are more prominent (at 11 and 13 percent, respectively), although oak-hickory remains the most prevalent forest type.

The dominance of oaks in the Upper Boston Mountains and the higher amount of pine in the Lower Boston Mountains are also apparent in growing-stock and sawtimber-volume data (figs. 3.31 and 3.32). Hard hardwoods make up 82 percent of the growing-stock volume in the Boston Mountains and 80 percent of the sawtimber board-foot volume. These percentages are almost identical to those in the Ozark Highlands section. However, hard hardwoods only make up 64 percent of growing-stock volume and 58 percent of sawtimber board-foot volume in the Lower Boston Mountains subsection.

Conversely, pine increases from less than 5 percent of growing-stock volume and 6 percent of sawtimber board-foot volume in the Upper Boston Mountains to 20 percent of the growing-stock volume and more than 25

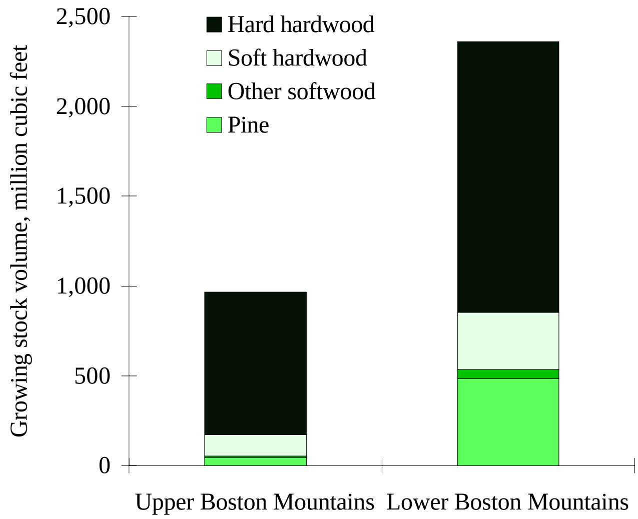


Figure 3.31—Distribution of growing-stock volume in the Boston Mountains by species group and ecological subsection.

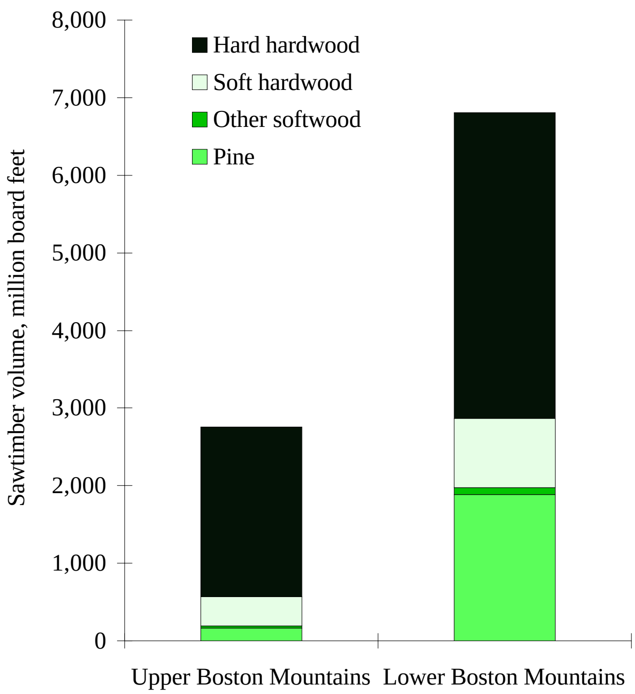


Figure 3.32—Distribution of sawtimber volume in the Boston Mountains by species group and ecological subsection.

percent of the sawtimber board-foot volume in the Lower Boston Mountains.

General Forest Attributes. The average acre of timberland in the Boston Mountains section has 612 live trees, of which 277 are of growing-stock quality. These values are greater than the average for the Assessment area. The 2-in. and 4-in. d.b.h. classes contain 75 percent of the live trees, but only 56 percent of growing-stock trees. Only 33 percent of the trees in these two classes are growing stock, compared to slightly more than 80 percent in the diameter classes 6 in. and larger.

Softwoods account for about 10 percent of the live trees and 18 percent of growing-stock trees, which is approximately equal to and slightly greater than the respective softwood percentages in the Ozark Highlands section. This also indicates an increasing prominence of softwoods in the growing-stock component of the Boston Mountains section.

Slightly more than 70 percent of the land in the Boston Mountains section is either fully stocked or overstocked, a higher percentage than for the Ozark Highlands section. All forest industry land and nearly 90 percent of national forest land are in these two stocking classes; however, less than 50 percent of the land in the "other public" sector is in these classes (fig. 3.33).

The average timberland acre in the Boston Mountains section has a live-tree volume of 1,242 cubic feet, a growing-stock volume of 1,096 cubic feet, a sawtimber cubic volume of 524 cubic feet, and a sawtimber board-foot volume of 3,151 board feet. These values are approximately 25 percent higher than the averages for the Assessment area (refer to table 3.3 for the latter).

The Boston Mountains section appears to have better sites and a higher percent stocking, on average, than the Ozark Highlands. Fifteen percent of the growing-stock volume and 21 percent of the sawtimber cubic foot volume is pine. Hard hardwoods account for 69 percent of the growing-stock volume and 64 percent of the sawtimber cubic-foot volume. These data support the previous observation that pine appears to be slightly more prominent in the Boston Mountains section than in the Ozark Highlands section.

White oak, shortleaf pine, northern red oak, black oak, and post oak have the greatest live-tree and growing-stock volumes in the Boston Mountains section. Together they make up 64 percent of the live-tree volume, 66 percent of the growing-stock volume, and 70

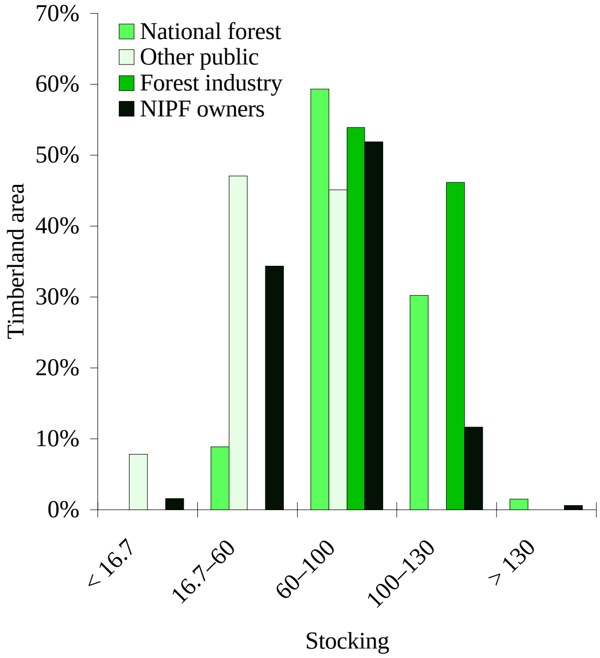


Figure 3.33—Distribution of timberland in the Boston Mountains by stocking class and ownership category.

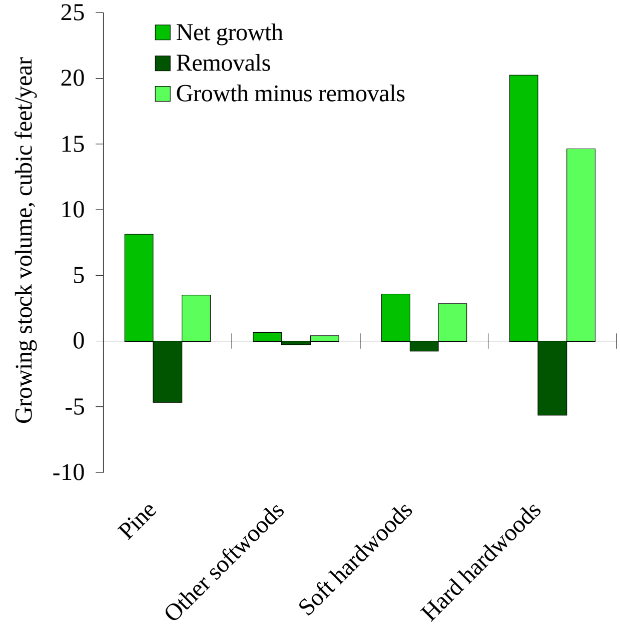


Figure 3.34—Growth, removals, and growth minus removals of growing-stock volume in the Boston Mountains by species group.

percent of the sawtimber board-foot volume in the section. Shortleaf pine displaces white oak as the top-ranking species in sawtimber board-foot volume; together, these two species account for 40 percent of the sawtimber board-foot volume (21 percent and 19 percent, respectively) in the section.

Growth, Removals, and Mortality. Analysis reveals a total annual growth surplus per acre of slightly more than 20 cubic feet in the Boston Mountains section (sum of the surpluses shown in light gray in fig. 3.34). The average annual net growth per acre on timberland in this section is 32.6 cubic feet, of which 62 percent is in the hard hardwoods and 25 percent is in pine. Average annual removals per acre total 11.2 cubic feet, 50 percent of which is hard hardwood removals and 41 percent pine removals. Thus, net growth is nearly three times the removals.

Average annual mortality per acre on timberland in this section is 4.3 cubic feet—slightly more than 11 percent of gross annual growth and less than 50 percent the level of removals. Hardwood mortality is nearly 14 percent of gross hardwood growth, whereas softwood mortality is 5 percent of growth. The highest mortality rate is in soft hardwoods, about 17 percent of gross net annual growth.

Arkansas Valley

General Land Attributes. The Arkansas Valley section, the smallest section in the Assessment area, contains 3.73 million ac. It contains three ecological subsections: the Western Arkansas Valley (1.59 million ac), the Western Arkansas Valley Mountains (664,000 ac), and the Eastern Arkansas Valley (1.47 million ac).

Both Eastern and Western Arkansas Valley subsections have slightly more than 50 percent of their area in timberland (fig. 3.35), but the Western Arkansas Valley Mountains subsection is 93 percent forested. The Western Arkansas Valley Mountains is also the only subsection in this section with any reserved forestland, but the other sections have lands in the "other woodland" category. Ninety-seven percent of the forestland in the Arkansas Valley is commercial timberland.

Virtually all of the Eastern Arkansas Valley subsection is in private ownership—95 percent is NIPF

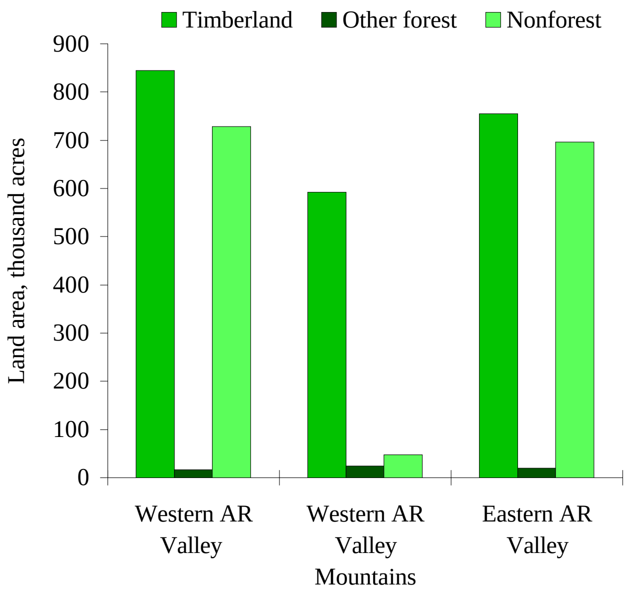


Figure 3.35—Distribution of timberland, other forest land, and nonforest land in the Arkansas Valley section by ecological subsection.

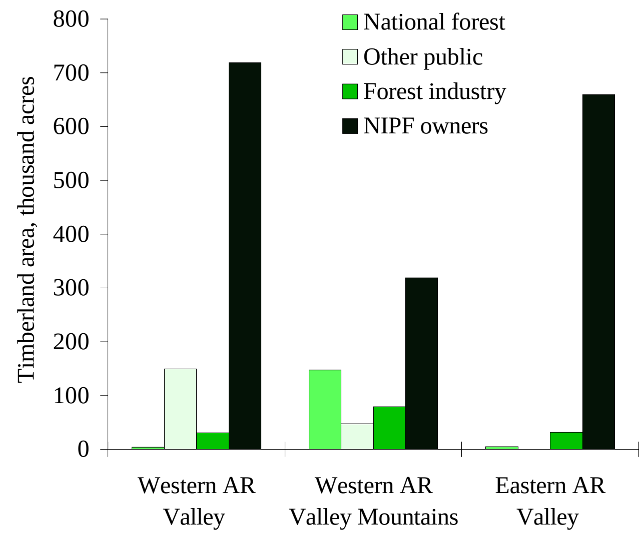


Figure 3.36—Distribution of timberland in the Arkansas Valley section by ownership category and ecological subsection.

holdings. Nearly 33 percent of the Western Arkansas Valley Mountains subsection consists of public lands (fig. 3.36). The Western Arkansas Valley subsection has 17 percent in public lands and 83 percent in private ownership, similar to the average for the Arkansas Valley section as a whole.

Differences in forest types are also prominent (fig. 3.37). In the Western Arkansas Valley, 86 percent of the timberland area is in oak-dominated types. However, in the Eastern Arkansas Valley 76 percent is in oak-dominated types and almost 20 percent is in pine types. Oak-dominated forests cover 70 percent of the Western Arkansas Valley Mountains.

Figures 3.38 and 3.39 provide growing-stock and sawtimber-volume data for this section, which contrasts markedly from the two sections to the north. In the Western Arkansas Valley subsection, hardwoods make up 72 percent of growing-stock volume and 63 percent of the sawtimber board-foot volume on timberland. But hard hardwoods are only 42 percent of the growing-stock volume and 38 percent of the sawtimber volume in this subsection—50 percent less timberland volume in hard hardwoods than in the Boston Mountains or Ozark Highlands.

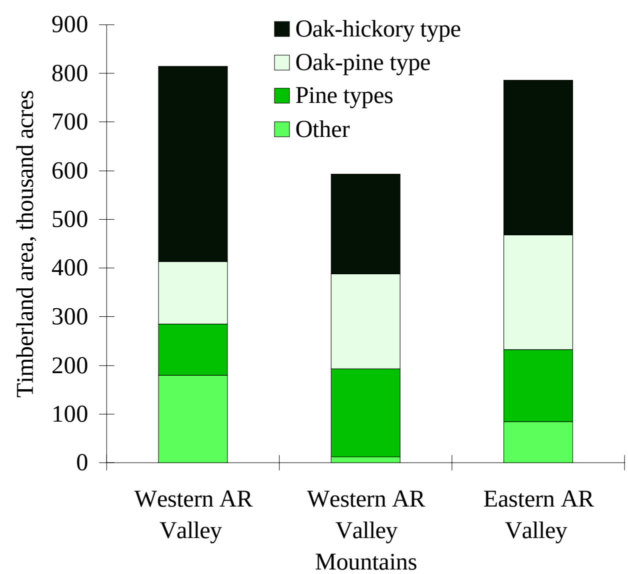


Figure 3.37—Distribution of timberland in the Arkansas Valley section by forest type.

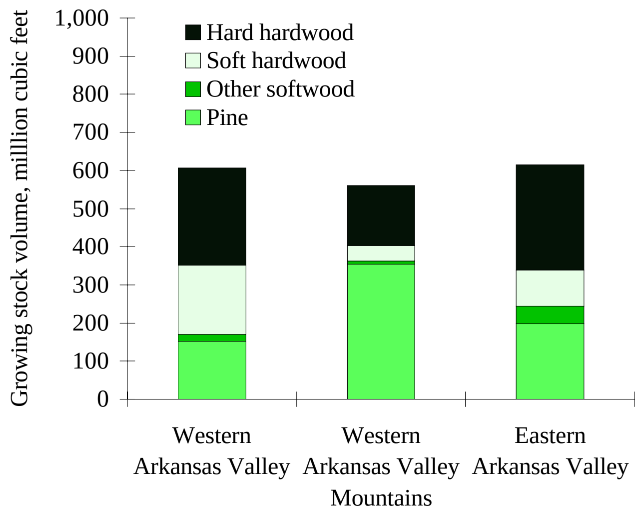


Figure 3.38—Distribution of growing-stock volume in the Arkansas Valley section by species group.

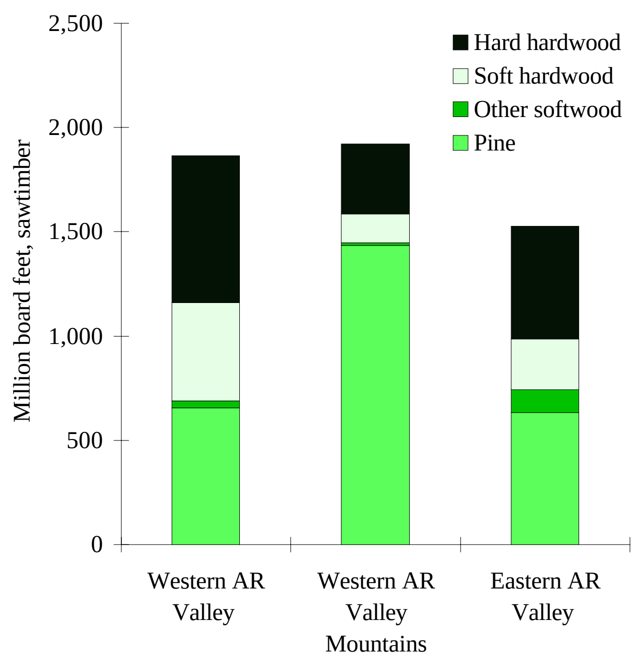


Figure 3.39—Distribution of sawtimber volume in the Arkansas Valley section by species group.

The gain is in softwoods, which are 25 percent of the growing-stock volume and 33 percent of the sawtimber volume in the Western Arkansas Valley subsection. Softwoods are even more prominent in the Eastern Arkansas Valley subsection, where they make up nearly 40 percent of growing-stock volume and nearly 50 percent of sawtimber volume; hard hardwood volume declines to 45 percent of growing-stock volume and 35 percent of sawtimber volume.

Finally, the Western Arkansas Valley Mountains subsection is the first area from north to south in the Assessment area where softwoods consistently show higher volume than hardwoods. About 65 percent of growing-stock volume and 75 percent of sawtimber board-foot volume are in softwoods; hard hardwoods are reduced to 28 percent of the growing-stock volume and 17 percent of sawtimber board-foot volume.

General Forest Attributes. The average acre of timberland in the Arkansas Valley section has 579 live trees, of which 288 are of growing-stock quality. Only 41 percent of the trees in the 2-in. and 4-in. class are growing-stock trees, compared with slightly more than 75 percent of trees 6 in. and larger. Softwoods account for about 29 percent of the live trees and 46 percent of growing-stock trees—much higher percentages than in the Ozark Highlands or Boston Mountains.

Live-tree basal area of the average timberland acre is about 90 square feet, of which nearly three-fourths are in growing-stock. The quadratic mean diameter is 5.2 in. for the average live tree and 6.6 in. for the average growing-stock tree. Growing-stock hardwoods have a slightly larger quadratic mean diameter (6.7 in.) than growing-stock softwoods (6.3 in.).

Slightly less than 66 percent of the timberland in the Arkansas Valley section is either fully stocked or overstocked. As in most other sections, stocking varies markedly with ownership class (fig. 3.40). More than 95 percent of national forest land and 80 percent of forest industry land fall into these two classes. Nonindustrial private forestland is less well stocked, with 62 percent in the moderate- and fully-stocked classes. More than one-third of NIPF timberland is poorly stocked and over half of the "other public" sector is poorly stocked.

The average timberland acre in the Arkansas River Valley section has a live-tree volume of 959 cubic feet, a growing-stock volume of 812 cubic feet, a sawtimber cubic volume of 406 cubic feet, and a sawtimber

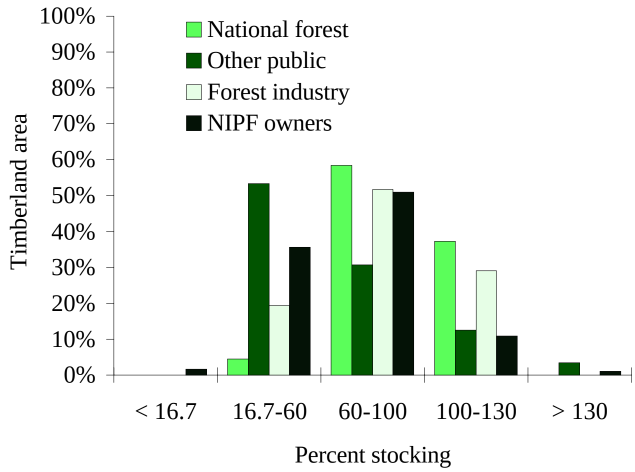


Figure 3.40—Distribution of timberland in the Arkansas Valley section by stocking class and ownership category.

board-foot volume of 2,418 board feet. These values are marginally lower in the live-tree and growing-stock volume categories, and marginally greater in the sawtimber categories, than the averages for the Assessment area (see table 3.3 for the latter).

Significant differences exist among subsections. The Western Arkansas Valley Mountains subsection has growing-stock volumes that are 16 percent greater and sawtimber board-foot volumes 34 percent greater than the section average. In the pine component alone, the Western Arkansas Valley Mountains has 85 percent more growing-stock volume than the section average and nearly double the sawtimber board-foot volume.

The five species with the greatest live-tree and growing-stock volumes on timberland in the Arkansas Valley section are shortleaf pine, post oak, sweetgum, white oak, and eastern red cedar. Together they make up 63 percent of the live-tree volume and 66 percent of the growing-stock volume in the section. For sawtimber board-foot volume, southern red oak replaces eastern red cedar in the top five, which then collectively make up 73 percent of the sawtimber board-foot volume in the section.

Shortleaf pine far exceeds the other species in these rankings; it has more than twice the live-tree volume, three times the growing-stock volume, and more than six times the sawtimber board-foot volume of the second-ranked species, post oak. Shortleaf in total represents 32 percent of the live-tree volume, 37 percent of growing-stock volume, and almost exactly 50 percent of the sawtimber board-foot volume in the section.

Growth, Removals, and Mortality. The Arkansas Valley section shows a total annual growth surplus per acre of 20 cubic feet (sum of the surpluses shown in fig. 3.41). Average annual net growth per acre on timberland in this section is 33.3 cubic feet, of which 48 percent is in the pine component and 47 percent is in the hardwood component. Average annual removals per acre total 13.3 cubic feet, 59 percent of which is in pine and 38 percent in hardwood. Thus, net growth is about two and one-half times the removals.

Average annual mortality per acre on timberland in this section is 5.1 cubic feet—slightly more than 13 percent of gross growth annually and less than 50 percent the level of removals. Hardwood mortality is nearly 20 percent of gross hardwood growth, whereas softwood mortality is about 6 percent of growth. The highest mortality rate is in the soft hardwoods, at 41 percent of gross net annual growth.

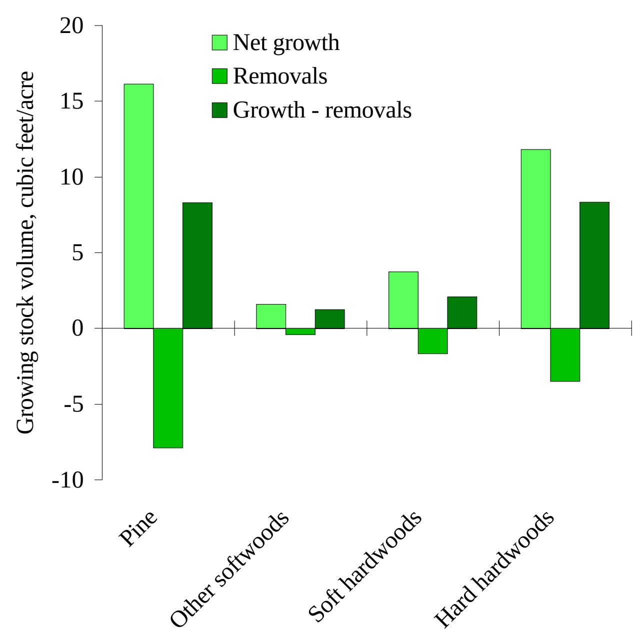


Figure 3.41—Growth, removals, and growth minus removals of growing-stock volume in the Arkansas Valley section by species group.

Ouachita Mountains

General Land Attributes. The Ouachita Mountains section is the second largest in the Assessment area, encompassing a total land area of 6.6 million ac. It contains four ecological subsections: the Fourche Mountains (2.74 million ac), the Western Ouachita Mountains (1.44 million ac), the Athens Piedmont Plateau (889,000 ac), and the Central Ouachita Mountains (1.53 million ac).

The Central subsection is subdivided into two units, one located in Arkansas and the other in Oklahoma. About 85 percent of the Ouachita Mountains are forested; subsections vary from 78 percent to nearly 100 percent forested (fig. 3.42). Slightly more than 97 percent of the total forest land in the Ouachita Mountains is in commercial timberland; subsections vary from 93 percent to 100 percent.

The ownership pattern in the Ouachita Mountains (fig. 3.43) has two attributes unique in the Assessment area. First, nearly 25 percent of the timberland in this section is in national forest ownership. More than 57 percent of the Fourche Mountains subsection is in public ownership, the highest proportion in any subsection of the Assessment area. Second, in the private sector, forest industry owns more land in the Ouachita Mountains than do NIPF owners; of the 71 percent of the section in private ownership, industry owns 51.6 percent. Forest industry timberland ownership varies from 25 percent of the Athens Piedmont Plateau section to 88 percent of the Central Ouachita Mountains subsection.

Forest type differences in the Ouachitas (fig. 3.44) are much less prominent than in the Arkansas Valley. Over the entire section, the proportion of pine forest is slightly greater than 40 percent. The percentage of pine type by subsections varies from 31 percent in the Central Ouachita Mountains to 51 percent in the Athens Plateau. However, oak forest types (which includes the oak-pine type) occupy a larger percentage of timberland than pine types in all subsections except the Athens Plateau.

The growing-stock and sawtimber-volume data clearly show the prominence of pine volume on timberland in the Ouachita Mountains (figs. 3.45 and 3.46). Pine makes up from 63.5 to 71.4 percent of growing-stock volume and from 71 to 81 percent of sawtimber

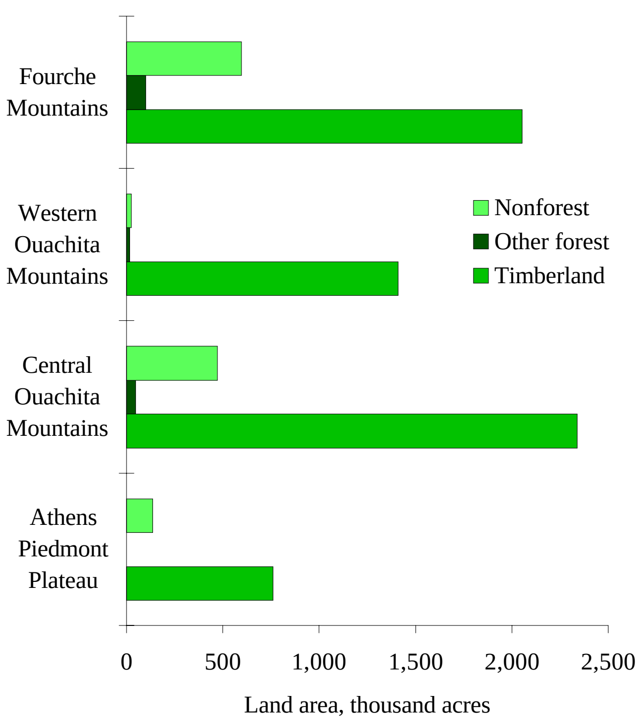


Figure 3.42—Distribution of nonforest land, timberland, and other forest land in the Ouachita Mountains section by ecological subsection.

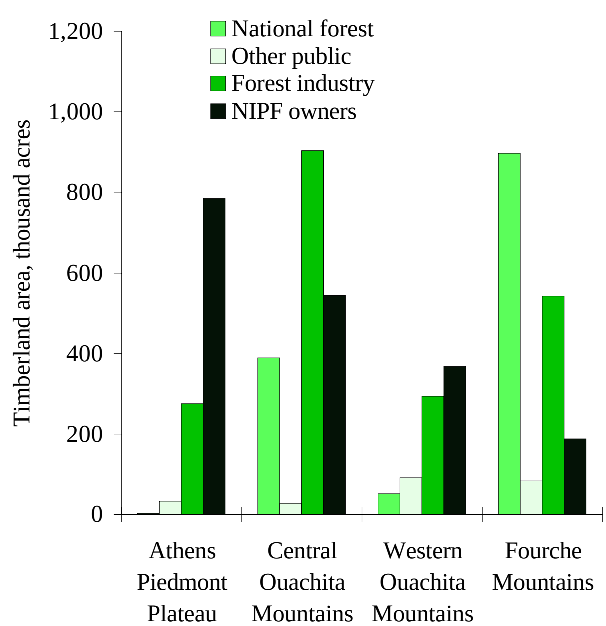


Figure 3.43—Distribution of timberland in the Ouachita Mountains by ecological subsection and ownership category.

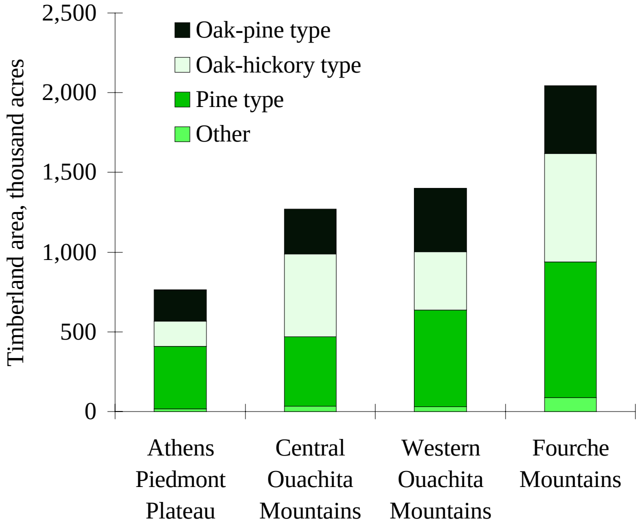


Figure 3.44—Distribution of timberland in the Ouachita Mountains by forest type and ecological subsection.

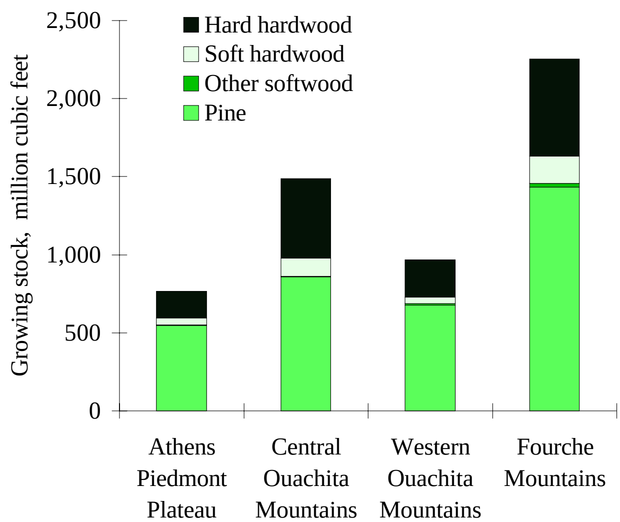


Figure 3.45—Growing-stock volume in the Ouachita Mountains by species group and ecological subsection.

board-foot volume in the five subsections of the Ouachitas. Conversely, hard hardwoods vary from 22 percent to 34 percent of growing-stock volume and from 15 percent to 24 percent of sawtimber board-foot volume, in these subsections.

General Forest Attributes. The average acre of timberland in the Ouachita Mountains section has 665 live trees, of which 363 are of growing-stock quality.

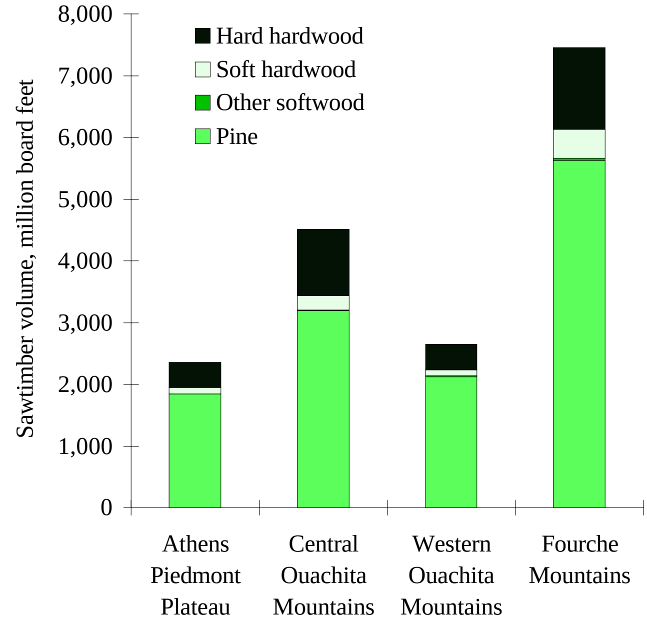


Figure 3.46—Sawtimber volume in the Ouachita Mountains by species group and ecological subsection.

Only 45 percent of the trees in the 2-in. and 4-in. classes are growing-stock trees, compared with slightly more than 83 percent of trees 6 in. and larger. Softwoods account for about 34 percent of the live trees and 52 percent of growing-stock trees—a higher percentage than in any other section, and further evidence of the prominence of pine in the Ouachita Mountains section.

Live-tree basal area of the average timberland acre is about 87 square feet, of which 76 percent is in growing stock. Stocking by ownership category is less variable in the Ouachita Mountains than in the other sections (fig. 3.47). About 66 percent of the timberland in the Ouachita Mountains is either fully stocked or overstocked, ranging from 62 percent in the other public sector to 84 percent on national forest land. As in the Arkansas Valley, the other public and NIPF ownership sectors have at least 33 percent of their timberland in the two poorest stocking classes. These lands are more likely to be poorly stocked than either forest industry timberland (17 percent poorly stocked) or national forest timberland (10 percent poorly stocked).

The average timberland acre in the Ouachita Mountains section has a live-tree volume of 1,104 cubic feet,

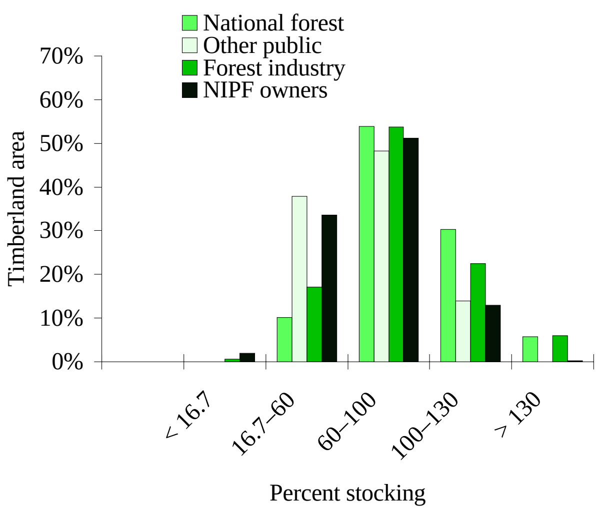


Figure 3.47—Distribution of timberland in the Ouachita Mountains by stocking class and ownership category.

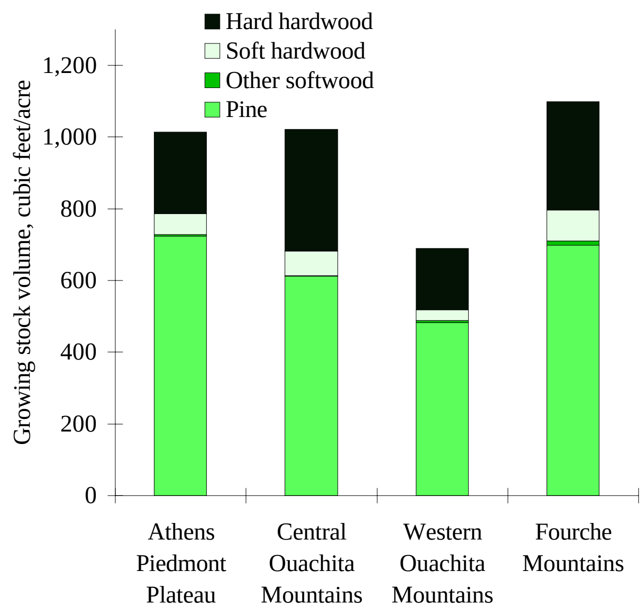


Figure 3.48—Growing-stock volume in the Ouachita Mountains by species group and ecological subsection.

a growing-stock volume of 1,000 cubic feet, a sawtimber cubic volume of 514 cubic feet, and a sawtimber board-foot volume of 3,097 board feet. These values are all greater than the averages for the Assessment area (refer to table 3.3 for the latter). However, volumes by subsection are quite variable (figs. 3.48 and 3.49). Growing-stock volume ranges from slightly less than 700 cubic feet/ac in the Western subsection to slightly more than 1,100 cubic feet/ac in the Fourche Mountains subsection. Three of the subsections—the Central Ouachita Mountains, the Fourche Mountains, and the Athens Piedmont Plateau—have growing-stock volumes in excess of 1,000 cubic feet/ac (fig. 3.48).

Sawtimber board-foot volume (fig. 3.49) ranges from slightly more than 1,500 board feet/ac in the Western Ouachita Mountains subsection to slightly more than 3,600 board feet/ac in the Fourche Mountains subsection. But the Central Ouachita Mountains, the Fourche Mountains, and the Athens Piedmont Plateau all have average sawtimber volumes in excess of 3,000 board feet/ac.

In no other section within the Assessment area is a single species as dominant in volume as shortleaf pine is in the Ouachita Mountains. Shortleaf pine accounts for 46 percent of the live-tree volume, 50 percent of the growing-stock volume, and slightly more than 67 percent of the sawtimber board-foot volume on timberland in the Ouachitas. Furthermore, 56 percent of all

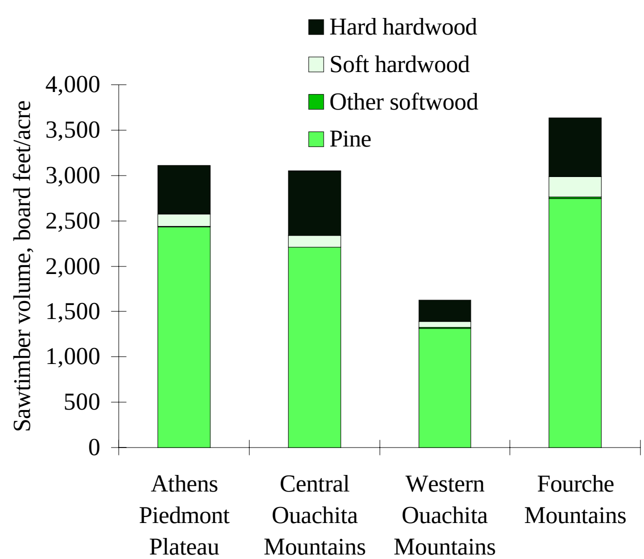


Figure 3.49—Sawtimber volume per acre in the Ouachita Mountains by species group and ecological subsection.

shortleaf pine volume in the Ouachita Mountains is on national forest land.

Growth, Removals, and Mortality. The Ouachita Mountains section shows a total annual growth surplus of 20 cubic feet/ac (sum of the surpluses shown in fig. 3.50). Higher net annual growth and higher annual removals are found here than in any of the other sections in the Assessment area.

Average annual net growth per acre on timberland in this section is slightly more than 50 cubic feet, of which more than 76 percent is in the pine component and 19 percent is in the hard-hardwood component. Average annual removals per acre total 30 cubic feet, 80 percent of which are pine removals and 16 percent of which are hardwood removals. Thus, net growth is about 1.7 times the removals.

Average annual mortality per acre on timberland in this section is 3.8 cubic feet—about 7 percent of gross annual growth and about 17 percent of removals. Hardwood mortality is 12 percent of gross hardwood growth—the lowest figure of any section in the Assessment area. Softwood mortality is about 5 percent of growth. Overall, mortality in the Ouachita Mountains section is fairly low.

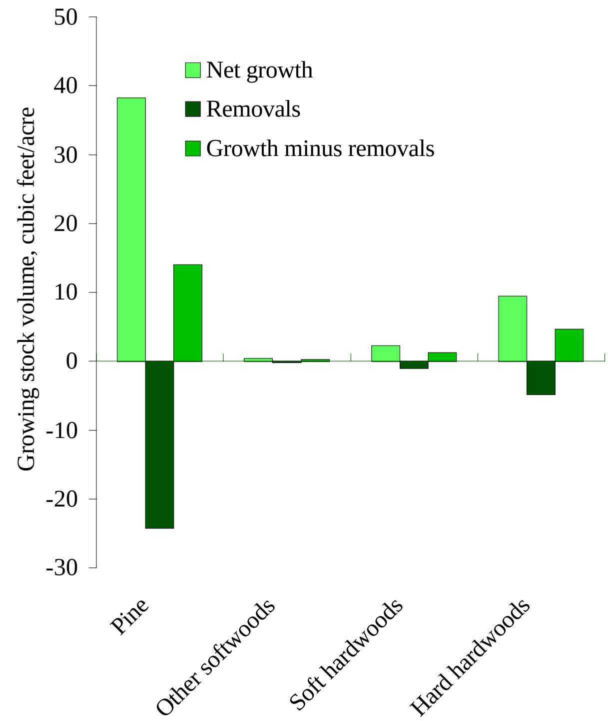


Figure 3.50—Growth, removals, and growth minus removals of growing-stock volume in the Ouachita Mountains by species group.

Implications and Opportunities

There is a significant relationship between forest cover and private land ownership—the larger the percentage of private timberland in a subsection, the smaller the percentage of timberland. Public land management typically involves timely reforestation and constraints on the conversion of forested land to other uses. NIPF owners are under no such limitations and often encounter different pressures concerning forest retention. NIPF management is based strictly on the will of the respective owner. On NIPF lands, owners have few incentives that would encourage long-term retention of forest cover. For example, some NIPF owners convert timberlands to more productive nonforest uses, which would not likely occur on public timberlands.

Vegetation Patterns Based on AVHRR Imagery

The previous section described vegetation of the Ozark-Ouachita Highlands based on FIA data. Other sources of data on regional vegetation exist that may provide different perspectives.

Of primary importance is digital satellite imagery. These images are relatively inexpensive to acquire and can be updated frequently. They provide a relatively high level of spatial detail and reveal patterns of land cover. Satellite and FIA data have complementary strengths and weaknesses.

FIA data are collected manually from a field sample plot with a high level of detail. The number of plots must, therefore, be relatively small and is usually limited to one plot every 3 miles. Plots over a relatively large area (typically the size of one of the sections of the Highlands) must be statistically aggregated to provide meaningful results. Therefore, spatial discrimination of FIA statistics is limited to relatively large areas where many plots can be aggregated. If a few plots of an uncommon vegetation type are tallied, even across a large area, the statistical error on the acreage estimate of that type will be relatively large.

In contrast, when satellite imagery is used, the land surface is completely covered by digital dots, called pixels, which correspond to individual sample plots of FIA. These pixels typically range in width from 33 feet (10 meters) to 3,300 feet (1 kilometer), depending on the satellite system. Therefore, areas much smaller than a section or subsection can be mapped using satellite imagery.

A disadvantage of satellite data is that few measurements are made at each point. To use these spectral data to map vegetation, the spectral signature (relationships in brightness among the various spectral bands) of points on the ground is compared to known vegetation. The relationships must be statistically characterized and used to infer the vegetation at other places. The accuracy of any classification so derived will vary with intrinsic similarity between vegetation types, time of year of the image, amount of ground-truth data, and other factors. Classifications based on satellite imagery utilize many sample points but have a relatively low level of detail. The FIA data entail relatively few plots but incorporate a high level of detail.

The limiting factor on accuracy of analyses based on the FIA data is the number of plots of a given vegetation type used for a specific analysis. In contrast, the limiting factor on satellite imagery is the reliability of prediction of vegetation types using spectral signatures. Satellite data can provide a good estimate of the acreage of a land cover type within a relatively small area, whereas estimates from FIA data are accurate only at regional and subregional (multi-county) scales. Satellite data should also provide more detailed information on spatial patterns if an accurate discrimination of vegetation types is achieved.

This section on vegetation patterns of the Highlands will concentrate on the most useful types of data from satellite imagery. These include the acreage of specific vegetation types by subsection and spatial patterns of these types, particularly fragment size and distance to nearest forest fragment.

Each State in the Highlands has developed or is developing a vegetation map under the National Gap Analysis Project (GAP), led by the U.S. Geological Survey, Biological Resources Division. These maps are based on Landsat Thematic Mapper imagery and show a relatively high level of detail (pixel size of 30 meters or 98 feet). Unfortunately, at of the time of this analysis, the GAP map was completed only for Arkansas.

Data Sources and Methods of Analysis

In the absence of a Highlands-wide GAP map, a national map based on AVHRR satellite imagery (USDA FS SFES 1992) was used as the source for this analysis. The National Oceanic and Atmospheric Administration (NOAA) collects AVHRR data for land cover characterization.

The pixel size is relatively large (1 kilometer or about 3,300 feet) and only four bands of data are collected, but worldwide, frequent coverage is available. The primary problem with using AVHRR data is the large pixel size. The spectral signature of the pixel is affected by all of the ground cover over 247 ac. Several vegetation types and other features can occur within an area this size. Therefore, errors in classification are bound to occur.

For this analysis, sections and subsections of the Ozark-Ouachita Highlands were overlaid on the AVHRR-based vegetation map to compute acreage and spatial statistics by subsection. This map uses the FIA classification system and so provides information on comparable vegetation types. Neither source classifies vegetation other than forest; therefore, prairie, improved grassland, shrubland, and open woodland (savanna) are not distinguished.

In addition to computing acreage of forest types by subsection, the program FRAGSTATS (McGarigal and Marks 1995) was used to compute mean forest-patch size, variation in patch size, and mean distance between forest patches within each subsection. To register as a forest patch, at least one pixel (247 ac) must contain sufficient tree cover to be classified as forest. A forest patch as defined in this analysis is a substantially forested area of at least 247 ac that is separated from other forest patches by a substantially nonforested belt at least 3,300 feet wide.

Patch size coefficient of variation and mean distance between patches were also calculated. Patch size coefficient of variation is a measure of the variability in patch size. When this number is high, it indicates that the patches range in size from very large to very small; when this number is relatively small, most patches are about the same size. Mean distance between forest patches is a measure of the dispersion across the landscape. For instance, there could be few patches widely spread apart or close together or many patches widely spread apart or close together. Generally, as mean patch size decreases, mean distance between patches increases.

Comparison of AVHRR and FIA Acres

The AVHRR-based estimate of the total acreage of the Assessment area is 9 percent larger than the FIA-based estimate (table 3.7). The maximum discrepancies for subsections are 29 percent for the Western Arkansas Valley Mountains subsection (231Gb), 27 percent for the Springfield Plateau subsection (222An), and 27 percent for the Western Arkansas Valley subsection (231Gc). However, the overall estimates of forested acreage, which both sources of data

Table 3.7—Total area, forest area, and percent of area forested by subsection, based on AVHRR and FIA data and showing the different results obtained from the two sources

	Total area			Forest area			Percent Forest		
Subsection	AVHRR	FIA	Difference	AVHRR	FIA	Difference	AVHRR	FIA	Difference
	- - Thousand acres - -		*Percent*	*- - Thousand acres - -*		*Percent*	*- Thousand acres -*		*Percent*
222Aa	1,148.5	1,092.1	4.9	862.6	750.2	13.0	75.1	68.7	6.4
222Ab	6,830.5	6,338.7	7.2	2,893.9	3,099.1	6.6	42.4	48.9	6.5
222Ac	1,633.1	1,399.2	14.3	1,256.3	855.3	31.9	76.9	61.1	15.8
222Ad	1,122.4	1,087.5	3.1	744.5	654.3	12.1	66.3	60.2	6.2
222Ae	1,178.4	1,168.1	0.9	1,069.2	891.4	16.6	90.7	76.3	14.4
222Af	1,498.4	1,563.3	4.1	1,444.1	1,322.0	8.5	96.4	84.6	11.8
222Ag	3,764.7	3,583.7	4.8	2,142.9	2,342.8	8.5	56.9	65.4	8.5
222Ah	435.2	434.0	0.3	125.0	264.2	52.7	28.7	60.9	32.1
222Al	876.5	860.7	1.8	660.8	677.1	2.4	75.4	78.7	3.3
222Am	3,502.2	3,103.1	11.4	234.0	641.8	63.5	6.7	20.7	14.0
222An	3,086.3	2,240.4	27.4	1,292.1	1,403.6	7.9	41.9	62.6	20.8
Total	25,076.3	22,870.8	8.8	12,725.4	12,901.8	1.4	50.7	56.4	5.7
231Ga	1,505.1	1,470.1	2.3	599.0	774.3	22.6	39.8	52.7	12.9
231Gb	939.2	664.1	29.3	724.5	616.8	14.9	77.1	92.9	15.7
231Gc	2,170.3	1,590.9	26.7	571.6	862.2	33.7	26.3	54.2	27.9
Total	4,614.7	3,725.1	19.3	1,895.1	2,253.3	15.9	41.1	60.5	19.4
M222Aa	1,081.6	1,129.7	4.3	928.9	904.9	2.6	85.9	80.1	5.8
M222Ab	3,270.7	2,960.3	9.5	2,135.5	2,276.8	6.2	65.3	76.9	11.6
Total	4,352.3	4,090.0	6.0	3,064.4	3,181.7	3.7	70.4	77.8	7.4
M231Aa	2,895.3	2,740.8	5.3	2,269.2	2,147.3	5.4	78.4	78.3	0.0
M231Ab	1,665.7	1,443.2	13.4	1,521.9	1,421.8	6.6	91.4	98.5	7.2
M231Ac	1,626.2	1,526.6	6.1	1,357.6	1,292.4	4.8	83.5	84.7	1.2
M231Ad	901.4	889.5	1.3	817.9	756.4	7.5	90.7	85.0	5.7
Total	7,088.7	6,600.1	6.9	5,966.6	5,617.9	5.8	84.2	85.1	0.9
Total	41,131.9	37,286.0	9.4	23,651.4	23,954.7	1.3	57.5	64.2	6.7

AVHRR = Advanced Very High Resolution Radiometer, FIA = Forest Inventory and Analysis.

emphasize, differ by only 1.3 percent, with maximum discrepancies of 64 percent for the Springfield Plain subsection (222Am) and 54 percent for the Elk River Hills subsection (222Ah). These two subsections have the least area of forest in the Assessment area.

The large differences may illustrate the problems with statistical extrapolation based on having only a few FIA plots. The difference in percentage of area forested by subsection is 7 percent. Maximum discrepancies are 32 percent for Elk River Hills and 28 percent for the Western Arkansas Valley (231Gc). These estimates are closely related given that the methods are dramatically different. They should reinforce reliance on both sets of data.

Forest Type Coverage

Loblolly-Shortleaf Pine Type. This type covers 4 million ac or almost 10 percent of the Assessment area (table 3.8). The largest acreage and percentage of this cover type occur in the subsections of the Ouachita Mountains, where it occupies 0.5 to 1 million ac and from 66 percent to 33 percent of each subsection's area. By contrast, the type does not occur in the Elk River Hills and only occurs on 247 ac (one pixel) in the Springfield Plain.

Oak-Pine Type. This type is the second most extensive within the Assessment area, covering 4.4 million ac or nearly 11 percent of the Highlands (table 3.8). The greatest acreage of this type occurs within the Fourche Mountains (M231Aa, 658,000 ac) and Western Ouachita Mountains (M231Ab, 440,000 ac) subsections, but its maximum percent cover is in the Western Arkansas Valley Mountains (376,000 ac, 40 percent). Oak-pine covers a mere 0.1 percent of the Springfield Plain subsection.

Oak-Hickory Type. This forest type is usually described as the characteristic vegetation cover of the northern two-thirds of the Interior Highlands (Ozark Highlands and Boston Mountains sections). As measured by AVHRR data, oak-hickory forest is the most extensive forest type in the Highlands, covering almost 15 million ac or almost 36 percent of the area (table 3.8). Oak-hickory cover is the most prevalent cover type in the Assessment area, exceeded by other types only in the Western Arkansas Valley Mountains and in three of the four subsections of the Ouachita Mountains.

The Central Plateau subsection (222Ab) has the greatest area of oak-hickory type (2.1 million ac) of any subsection, followed by 1.7 million ac in the Lower Boston Mountains (M222Ab). The greatest proportion of oak-hickory is 84 percent of the total cover in the Current River Hills (222Af) subsection and 76 percent in the Upper Boston Mountains (M222Aa). The lowest coverage of oak-hickory type (4.9 percent) occurs in the Springfield Plain, where only 6.7 percent of the landscape is forested.

Oak-Gum-Cypress Type. This swamp forest type is the least common in the Highlands and occupies only 164,000 ac or 0.4 percent of the area (table 3.8). The Western Arkansas Valley subsection has the highest acreage (35,000 ac) and highest percentage (1.6 percent) of area occupied by oak-gum-cypress forest. Oak-gum-cypress covers 26,000 ac in the Fourche Mountains subsection and 24,000 ac in the White River Hills subsection. It covers 1 percent of the Central Ouachita Mountains (M231Ac) and Athens Piedmont Plateau (M231Ad) subsections.

Elm-Ash-Cottonwood Type. This riverfront forest type covers only 360,000 ac (0.9 percent of the total area) within the Highlands (table 3.8). It occurs only within the Ozark Highlands section, where the largest area and largest percentage of area—148,000 ac, 9.1 percent—are within the Osage River Hills subsection (222Ac).

Forest Patch Size and Distribution Within Subsections

Comparing the Springfield Plain subsection to the Current River Hills subsection (222Am and 222Af, respectively) reveals extremes of forest patchiness (table 3.9). The Springfield Plain has many forest patches and a mean patch size of only about 900 ac, a high variation in patch size, and a high mean distance between patches. In contrast, the Current River Hills subsection has few patches, a low mean distance between patches, and a mean patch size of 481,000 ac. In many of these statistics, these two subsections are near or at the extreme values for the region. The exceptions are that four subsections have patches closer together than the Current River Hills. Tables 3.8 and 3.9 provide forest cover and forest area and patch statistics, respectively, for each subsection. A brief overview is presented here.

Table 3.8—Vegetation cover of the Assessment area (based on AVHRR data), showing thousands of acres and percent representation in each subsection of five forest cover types, nonforested land, and water

Subsection[a]	Loblolly-shortleaf		Oak-pine		Oak-hickory		Oak-gum cypress		Elm-ash-cottonwood		Nonforested		Water		Total
	k acres	*%*	*k acres*	*%*	*k acres*	*%*	*k acres*	*%*	*k acres*	*%*	*k acres*	*%*	*k acres*	*%*	*k acres*
Ozark Highlands Section															
222Aa	14.8	1.3	46.5	4.0	788.5	68.7	0	0	12.8	1.1	285.9	24.9	0	0	1,148.5
222Ab	78.8	1.2	627.4	9.2	2,119.4	31.0	13.6	0.2	54.6	0.8	3,931.2	57.6	5.4	0.1	6,830.5
222Ac	3.2	0.2	72.9	4.5	1,032.2	63.2	0	0	148.0	9.1	358.8	22.0	18.0	1.1	1,633.1
222Ad	26.2	2.3	50.2	4.5	648.2	57.7	0	0	20.0	1.8	377.8	33.7	0	0	1,122.3
222Ae	13.1	1.1	186.3	15.8	864.4	73.3	0	0	5.4	0.5	109.2	9.3	0	0	1,178.4
222Af	16.8	1.1	151.7	10.1	1,259.7	84.1	0	0	15.8	1.1	54.4	3.6	0	0	1,498.4
222Ag	113.7	3.0	799.4	21.2	1,205.6	32.0	23.5	0.6	0.7	0	1,462.1	38.8	159.6	4.2	3,764.6
222Ah	0	0	17.1	3.9	107.7	24.8	0.2	0.1	0	0	303.9	69.8	6.2	1.4	435.2
222Al	3.0	0.3	81.1	9.2	528.1	60.2	0	0	48.7	5.6	193.7	22.1	22.0	2.5	876.5
222Am	0.2	0	4.7	0.1	170.0	4.9	4.9	0.1	54.1	1.5	3,209.6	91.6	58.6	1.7	3,502.2
222An	26.7	0.9	183.8	6.0	1,071.7	34.7	9.9	0.3	0	0	1,695.4	54.9	98.8	3.2	3,086.3
Total	296.5	1.2	2,221.1	8.8	9,795.5	39.1	52.1	0.2	360.1	1.4	11,982.0	47.8	368.6	1.7	25,076
Arkansas Valley Section															
231Ga	72.9	4.8	28.7	1.9	493.7	32.8	3.7	0.2	0	0	854.0	56.7	52.1	3.5	1,505.1
231Gb	251.8	26.8	376.1	40.0	93.1	9.9	3.4	0.4	0	0	208.3	22.2	6.4	0.7	939.2
231Gc	100.3	4.6	211.5	9.7	224.6	10.3	35.1	1.6	0	0	1,495.2	68.9	103.5	4.8	2,170.3
Total	425	9.2	616.3	13.3	811.4	17.6	42.2	0.9	0	0	2,557.5	55.4	162	3.5	4,614.6
Boston Mountains Section															
M222Aa	5.9	0.5	99.1	9.2	823.8	76.2	0	0	0	0	152.7	14.1	0	0	1,081.6
M222Ab	246.1	7.5	196.9	6.0	1,676.6	51.3	15.8	0.5	0	0	1,017.3	31.1	117.9	3.6	3,270.7
Total	252	5.8	296	6.8	2,500.4	57.4	15.8	0.4	0	0	1,170	26.9	117.9	2.7	4,352.3
Ouachita Mountains Section															
M231Aa	1,074.7	37.1	658.3	22.7	510.5	17.6	25.7	0.9	0	0	580.7	20.1	45.5	1.6	2,895.3
M231Ab	843.4	50.6	440.3	26.4	235.0	14.1	3.2	0.2	0	0	111.4	6.7	32.4	1.9	1,665.7
M231Ac	535.0	32.9	143.6	8.8	663.0	40.8	16.1	1.0	0	0	116.4	7.2	152.2	9.4	1,626.2
M231Ad	599.2	66.5	50.7	5.6	159.4	17.7	8.6	1.0	0	0	35.8	4.0	47.7	5.3	901.4
Total	3,052.3	43.1	1,292.9	18.2	1,567.9	22.1	53.6	0.8	0	0	844.3	11.9	277.8	3.9	7,088.6
Assessment area	4,025.8	9.5	4,426.3	10.8	14,675.2	35.7	163.7	0.4	360.1	0.9	16,553.8	40.2	926.3	2.2	41,131.9

AVHRR = Advanced Very High Resolution Radiometer; k = thousand.
[a] See figure 1.1 for map of sections and subsections.

222Aa—St. Francis Knobs and Basins. Oak-Hickory forest dominates this subsection (789,000 ac, 69 percent). Other forest types make up 6.4 percent of the area. All patch statistics are intermediate in the range presented for the Assessment area.

222Ab—Central Plateau. This subsection has a relatively low forest cover dominated by oak-hickory forests (2.1 million ac, 31 percent). In addition, oak-pine forest covers 627,000 ac (9.2 percent). It has many patches, and the patch-size variance is high.

222Ac—Osage River Hills. The Osage River Hills are dominated by oak-hickory forest (1 million ac, 63 percent) with a high occurrence of elm-ash-cottonwood (148,000 ac, 9.1 percent). All patch statistics are intermediate except patches are close together.

222Ad—Gasconade River Hills. Oak-hickory forest dominates this subsection (648,000 ac, 58 percent). All patch statistics are intermediate.

222Ae—Meramac River Hills. The Meramec River Hills are dominated by oak-hickory forest

Table 3.9—Forest area, mean forest patch size, variation in patch size, and mean distance between forest patches, for each subsection, based on AVHRR data

Subsection[a]	Total area	Forest area		Mean forest patch size	Patch size coefficient of variation	Mean distance between patches
	- - *Thousand acres* - -		*Percent*	*k acres*		*Feet*
			Ozark Highlands			
222Aa	1,148	862	75.11	66.33	344.26	4,261.65
222Ab	6,828	2,893	42.37	6.82	708.04	4,753.15
222Ac	1,632	1,256	76.93	48.30	486.83	3,407.02
222Ad	1,122	744	66.34	14.88	630.23	4,299.08
222Ae	1,178	1,069	90.73	178.13	223.30	3,280.84
222Af	1,498	1,443	96.37	481.12	141.28	3,733.83
222Ag	3,763	2,142	56.92	15.19	1,118.53	4,413.75
222Ah	435	125	28.73	1.92	346.43	4,229.36
222Al	876	660	75.39	47.18	356.06	4,800.62
222Am	3,501	234	6.68	0.90	372.95	6,457.05
222An	3,085	1,292	41.87	5.79	513.28	4,788.35
			Arkansas Valley			
231Ga	1,504	599	39.80	7.13	417.09	4,526.90
231Gb	939	724	77.14	65.84	175.78	4,439.96
231Gc	2,169	571	26.33	3.17	570.07	5,218.37
			Boston Mountains			
M222Aa	1,081	928	85.88	116.06	263.29	3,690.94
M222Ab	3,269	2,135	65.29	15.14	1,069.37	5,161.22
			Ouachita Mountains			
M231Aa	2,894	2,268	78.37	40.50	723.54	4,308.53
M231Ab	1,665	1,521	91.37	69.15	454.98	3,825.20
M231Ac	1,626	1,357	83.48	84.81	316.43	5,659.68
M231Ad	901	818	90.73	204.39	172.86	3,280.84
Total	41,131	23,641	57.48			

AVHRR = Advanced Very High Resolution Radiometer; k = thousand.
[a] See fig. 1.1 for map of sections and subsections.

(864,000 ac, 73 percent). There are a few large patches of similar size and very close together.

222Af—Current River Hills. Oak-hickory forest dominates this subsection (1.3 million ac, 84 percent), with significant additional coverage by oak-pine forest (152,000 ac, 10 percent). There are a few very large patches close together.

222Ag—White River Hills. The White River Hills are co-dominated by oak-hickory forest (1.2 million ac, 32 percent) and oak-pine forest (799,000 ac, 21 percent). There are many forest patches of intermediate size and distribution.

222Ah—Elk River Hills. Forests are dominated by the oak-hickory type (108,000 ac, 25 percent of the area), but forest cover as a whole occupies only 29 percent of the subsection. Patches are small, on average, but have a high variability in size.

222Al—Black River Ozark Border. This subsection is dominated by oak-hickory forest (528,000 ac, 60 percent), with substantial coverage by oak-pine forest (81,000 ac, 9.2 percent). Elm-ash-cottonwood forest covers an additional 49,000 ac (5.6 percent). Patch characteristics are all intermediate.

222Am—Springfield Plain. This subsection is substantially nonforested, with no forest type exceeding 5 percent. Oak-hickory is the most prominent forest type (170,000 ac, 4.9 percent). There are many very small patches on average but with a high variability in size and spread far apart.

222An—Springfield Plateau. The subsection has relatively low forest cover, dominated by oak-hickory (1.1 million ac, 35 percent). In addition, oak-pine forest covers 184,000 ac (6.0 percent). There are many intermediate-sized patches with little variability in size.

231Ga—Eastern Arkansas Valley. The subsection has relatively low forest cover, dominated by the oak-hickory type (494,000 ac, 33 percent). All forest patch statistics are intermediate.

231Gb—Western Arkansas Valley Mountains. Although this subsection is co-dominated by oak-pine forest (376,000 ac, 40 percent) and loblolly-shortleaf pine forest (252,000 ac, 27 percent), oak-hickory forest also covers a substantial acreage (93,000 ac, 9.9 percent). There are a few patches with an intermediate mean but with a high variability in size.

231Gc—Western Arkansas Valley. The subsection has relatively low forest cover, co-dominated by oak-hickory (225,000 ac, 10 percent) and oak-pine forest (212,000 ac, 9.7 percent). There are many patches with a low to average size but with a high variability in size spaced far apart.

M222Aa—Upper Boston Mountains. This subsection is dominated by oak-hickory forest (824,00 ac, 76 percent) with a substantial coverage of oak-pine forest (99,000 ac, 9.2 percent). There are a relatively few but very large forest patches of similar size spaced close together.

M222Ab—Lower Boston Mountains. Dominated by oak-hickory forest (1.7 million ac, 51 percent), this subsection also has considerable coverage by loblolly-shortleaf pine forest (246,000 ac, 8 percent) and oak-pine forest (197,000 ac, 6.0 percent). All forest patch statistics are intermediate.

M231Aa—Fourche Mountains. This subsection is co-dominated by loblolly-shortleaf pine forest (1.1 million ac, 37 percent) and oak-pine forest (658,000 ac, 23 percent), but oak-hickory forest also covers a substantial area (511,000 ac, 18 percent). All forest patch statistics are intermediate.

M231Ab—Western Ouachita Mountains. Co-dominated by loblolly-shortleaf pine forest (843,000 ac, 51 percent) and oak-pine forest (440,000 ac, 26 percent), this subsection also has a substantial amount of oak-hickory forest (235,000 ac, 14 percent). All forest patch characteristics are intermediate.

M231Ac—Central Ouachita Mountains. Co-dominated by oak-hickory forest (663,000 ac, 41 percent) and loblolly shortleaf pine forest (535,000 ac, 33 percent), this subsection also has about 144,000 ac of oak-pine forest cover (8.8 percent). Patches are large, with little size variation, and spaced relatively far apart.

M231Ad—Athens Piedmont Plateau. This subsection is dominated by loblolly-shortleaf pine forest (599,000 ac, 67 percent), but oak-hickory forest covers significant acreage (159,000 ac, 18 percent). Oak-pine forest also covers an additional 51,000 ac (5.6 percent). There are a few very large patches, similar in size and spaced close together.

Trends in Vegetation Cover

Previous sections of this report have addressed current (or recent) vegetation cover. As outlined in the questions at the beginning of this chapter, the Terrestrial Team also sought to analyze changes in vegetation conditions over time. Although data to address these questions are limited, the results of surveys by the FIA units of the research branch of the USDA Forest Service show interesting trends in the Highlands since the 1940's in Missouri and the 1950's in Arkansas and Oklahoma.

Data Sources and Methods of Analysis

The FIA data used earlier to highlight current conditions by ecological section and subsection could not be used to consider historical trends in forests over time within the Assessment area. Sorting the plots by their respective ecological sections and subsections requires that data be available in computer files. Unfortunately, old FIA data are not computerized; calculations before the 1970's were done by hand. Therefore, the analysis of trends will be based on the six multi-county FIA regions in the Assessment area, which are shown in figure 3.3.

Forest Survey measurements of these six regions were not conducted in the same calendar year. Thus, for comparative purposes, each measurement was assigned to the decade or decennial (10-year) interval in which it was conducted. FIA region, year measured, decennial interval, and sources are shown in table 3.2. Trends were analyzed by comparing common variables in the Forest Survey reports from one measurement period to the next from the 1940's to the 1990's.

This approach is incomplete because several gaps in the data exist. For example, the Arkansas and Oklahoma regions have no survey data in the 1940's; conversely, the Missouri data have gaps in the 1960's and 1990's. Nevertheless, these are the most quantitative data available on trends over time. Data for all six regions are available for three periods—the 1950's, 1970's, and 1980's—allowing the Terrestrial Team to examine trends during the period of the 1950's through the 1980's.

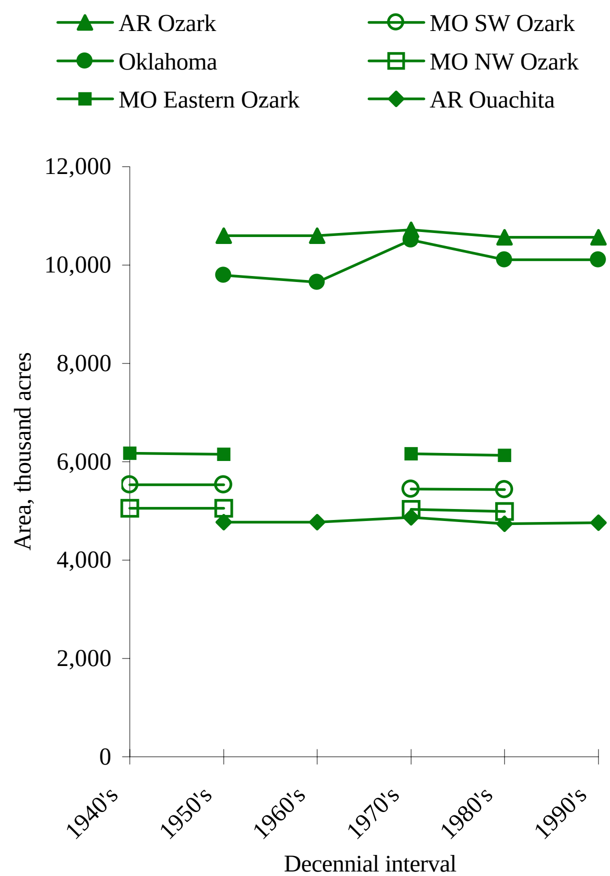


Figure 3.51—Total land area by FIA region, 1940's to 1990's.

Patterns and Trends

Area by Land Classes

The total land area of the FIA regions is relatively constant over time for all regions (fig. 3.51). The exception is Oklahoma, where region area was relatively unstable between the 1960's and 1980's because the Forest Survey included different counties in these surveys. These changes were due to questions about the natural limit of commercial forest land in the post oak belt of eastern Oklahoma. Minor variations in acreage for the other regions are due to changes in the process used by the Bureau of the Census to estimate county area.

The amount of forested land area has declined over time. In each of the six regions, the total forest area in the last decennial interval was less than four decades previous (fig. 3.52). From the 1940's to the 1980's in Missouri, forest area declined from 10.22 million ac to 8.78 million ac—a loss of 1.44 million ac (a 14.1 percent

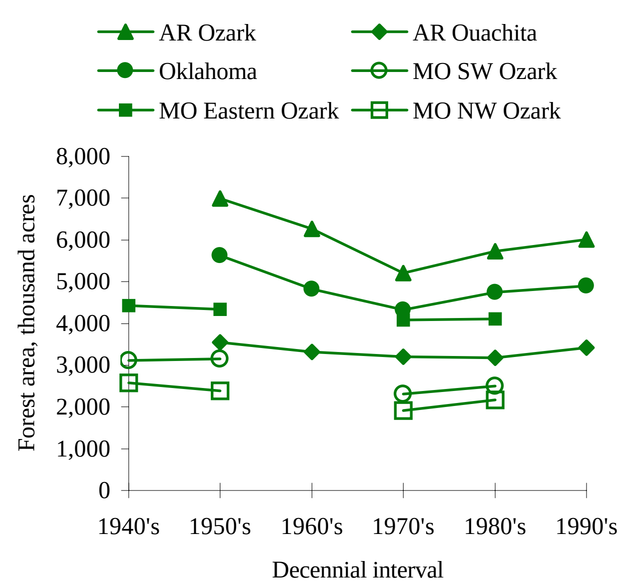


Figure 3.52—Total forest area by FIA region, 1940's to 1990's.

decline from the 1940's forest area). Similarly, from the 1950's to the 1990's in Arkansas and Oklahoma, forest area declined from 16.35 million ac to 15.23 million ac—a decline of 1.12 million ac (a 6.9 percent reduction from the 1950's forest area).

Forest area reached a four-decade minimum in the 1970's in five of the six regions (fig. 3.52). However, some regions lost a larger proportion of forest than did others. For example, forested area in the Arkansas Ozarks declined from 66.2 percent in the 1950's to 48.6 percent forested in the 1970's—a loss of nearly 2 million ac of forest land during that period. The loss of forest area from the 1950's to 1970's varied from 2.5 percent in the Missouri Eastern Ozarks to 17.5 percent in both Oklahoma and the Arkansas Ozarks.

Since the 1970's, forest area has increased in five of the six regions, in some instances dramatically. Between the 1970's and 1980's, the only region to lose forest area was the Missouri Eastern Ozarks, which lost 1.9 percent (134,000 ac). Gains in the other five regions varied from 1.2 percent in the Missouri Southwestern Ozarks to 10.9 percent in Oklahoma. When all six regions were combined, the net gain in forest area from the 1970's to the 1980's was slightly more than 1.89 million ac, or about 4.5 percent. Moreover, this trend of increasing forest area continued from the 1980's to the 1990's in Arkansas and Oklahoma. Forest area in the three regions increased 631,000 ac (5.8 percent).

Distribution by Ownership

Three of the six regions—the Arkansas Ouachitas, Arkansas Ozarks, and Missouri Eastern Ozarks—currently have more than 1 million ac in public forest area (fig. 3.53). From the 1970's to the 1980's, public forest ownership increased by approximately 289,000 ac. Total forest ownership, however, increased by 1.39 million ac. Therefore, the proportion of land in public ownership was fairly constant from the 1970's to 1980's. Overall, the area of public forest is relatively stable.

Private forest ownership is more variable over time, with the largest variations appearing in the Arkansas Ozarks and Oklahoma regions (fig. 3.54). Privately owned forest area reached a minimum in the 1970's, but trends show increases since then in most of the regions.

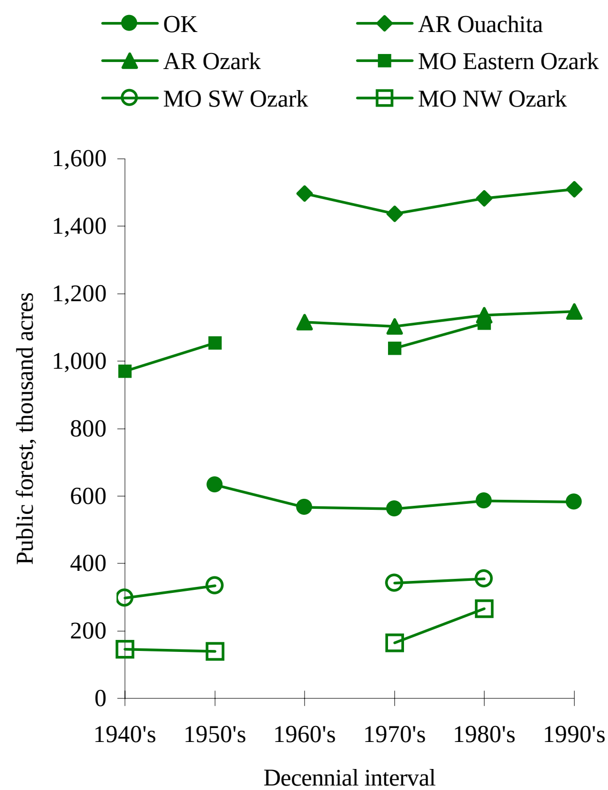


Figure 3.53—Total public forest area by FIA region, 1940's to 1990's.

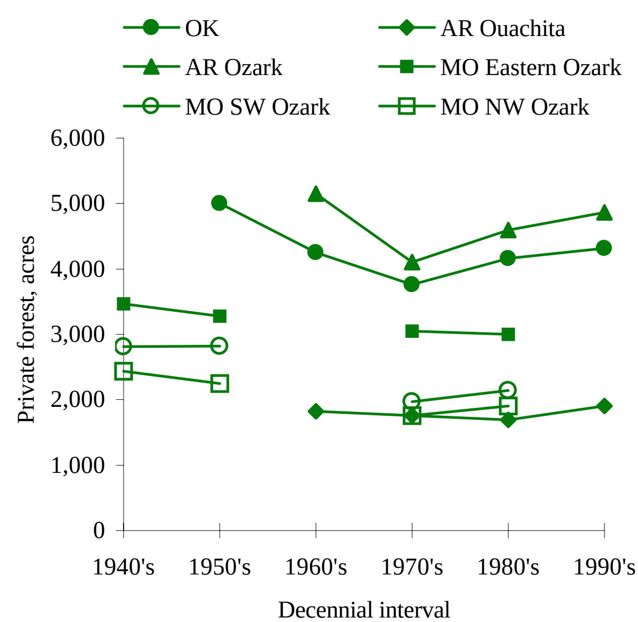


Figure 3.54—Total private forest area by FIA region, 1940's to 1990's.

Distribution by Size Class

The area occupied by sawtimber stands has increased dramatically over time in all six regions. Every region has shown increases in the amount of area in sawtimber-sized trees (fig. 3.55) and in the percentage of forest area occupied by sawtimber-sized trees (fig. 3.56). Between the 1970's and 1980's, total forest area increased by 1.39 million ac (6.5 percent), but forest area in sawtimber-sized trees increased by 2.08 million ac (34.4 percent).

From the 1940's to the 1980's, Missouri forests increased sawtimber area from 10 percent to 46 percent. From the 1950's to the 1990's, Arkansas and Oklahoma forests increased sawtimber area from 17 percent to 37 percent. In the most recent decennial interval, five of the six regions have more than 33 percent of their forest area in sawtimber. The exception is Oklahoma, with 31 percent sawtimber area.

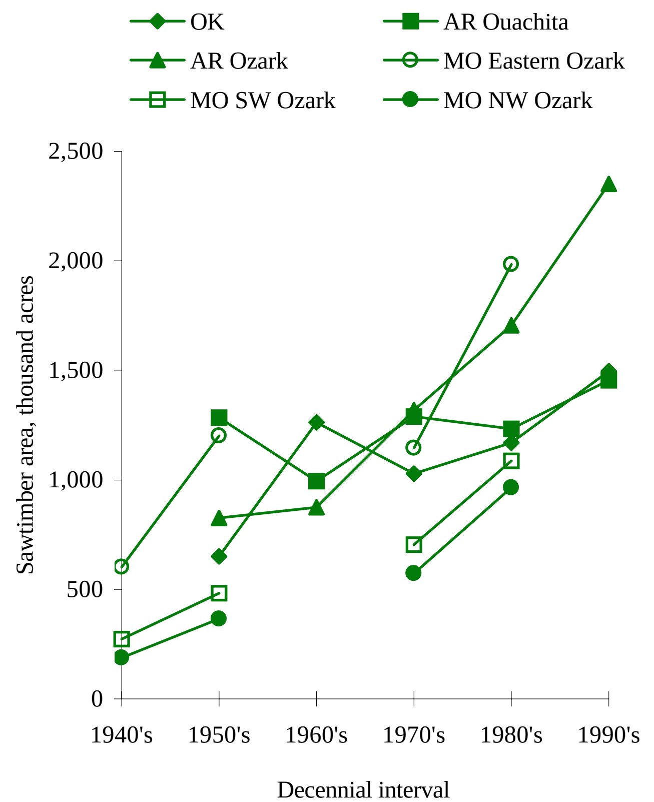


Figure 3.55—Commercial forest area occupied by sawtimber stands by FIA region, 1940's to 1990's.

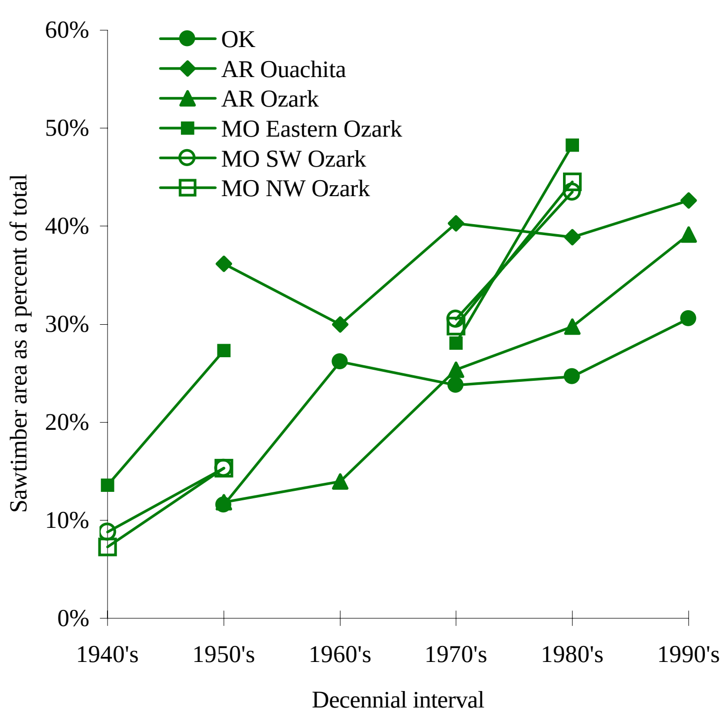


Figure 3.56—Percentage of commercial forest land area occupied by sawtimber stands by FIA region, 1940's to 1990's.

For the three intervals when all six regions were measured—the 1950's, 1970's, and 1980's—forest area in seedling/sapling- and poletimber-sized stands has decreased, and sawtimber area has increased (fig. 3.57). These data indicate an increasing maturity of the forests in the region over time. As stands recovered from the uncontrolled cutting at the turn of the century, tree size in stands increased. The ratio of area in these three size classes should stabilize at some point, but that does not appear to have happened yet.

Distribution by Forest Type

Loblolly-Shortleaf Pine Type. The loblolly-shortleaf pine type is somewhat of a misnomer in the Ozark-Ouachita Highlands. Shortleaf pine is the dominant naturally occurring pine in the region, with loblolly a distant second. Because over 90 percent of this type was in Arkansas and Oklahoma in the 1950's, the Missouri regions will not be included in the discussion.

Data show a prominent decrease in the pine type in the three survey regions in Arkansas and Oklahoma from the 1950's to the 1960's (fig. 3.58). This decrease was probably due in part to a real decline in acreage, and in part to changes in the way that FIA plots were measured and forest types assigned.

Nevertheless, the area in pine forest type in these three regions declined from 3.8 million ac in the 1950's to 2.2 million ac in the 1960's, a 1.6 million acre loss. Over 1 million ac were lost in the Ouachita region alone. By the 1990's, pine forest type had recovered to 1950's levels in Oklahoma and the Arkansas Ozarks, but was still only 60 percent of the 1950's level in the Ouachitas.

Another way to consider these data is that from the 1950's to the 1960's, these three regions lost nearly 1.78 million ac of timberland. Over the same time period, the pine type declined 1.61 million ac, or over 90 percent of the total forest area lost.

Several explanations are possible for this dramatic decline—all somewhat speculative. First, measurement standards for forest survey changed between the 1950's and 1960's (Hedlund and Earles 1970), and this may have affected the computation of area by forest type. The most logical direction for those changes would have been that some pine type areas were changed to oak-pine. However, the area of oak-pine type increased in only two of the three Arkansas and Oklahoma regions (fig. 3.59), and these increases fell short of the magnitude of the decline in the pine forest type. A second possibility for the decline might be that an increase in agricultural land uses took land from forest areas entirely. A third possibility might be that continued selective harvesting of pines converted some areas to oak-hickory and other hardwood types rather than oak-pine types. In all probability, a combination of these factors was responsible for the decrease.

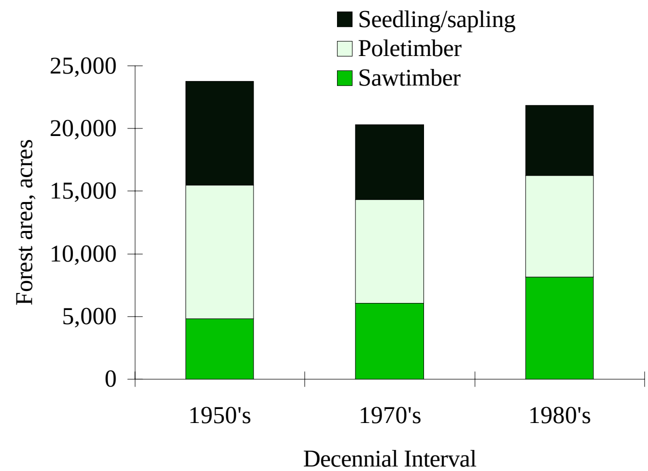


Figure 3.57—Distribution of commercial forest land area in the Assessment area by stand size class for the 1950's, 1970's, and 1980's.

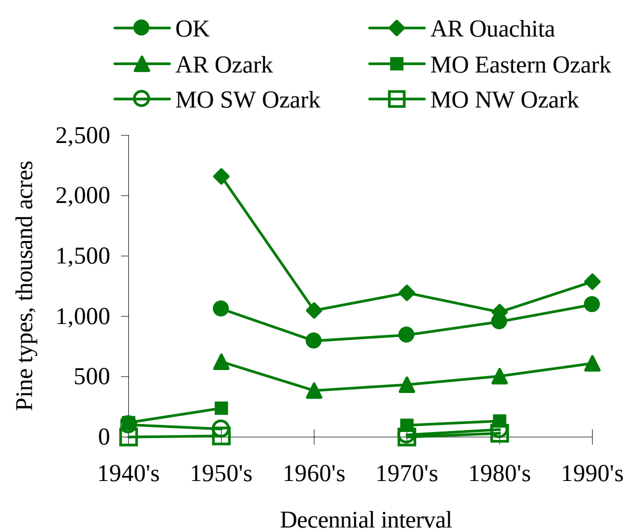


Figure 3.58—Commercial forest land area in the loblolly-shortleaf pine type by FIA region, 1940's to 1990's.

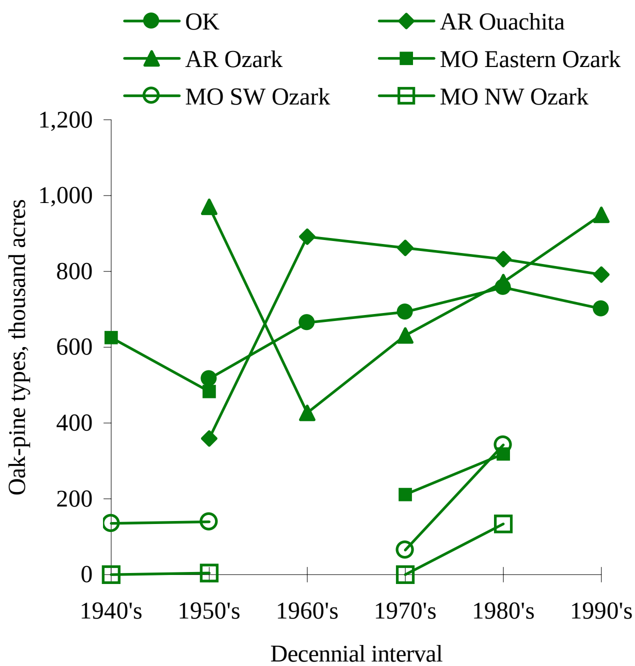


Figure 3.59—Commercial forest land area in the oak-pine type by FIA region, 1940's to 1990's.

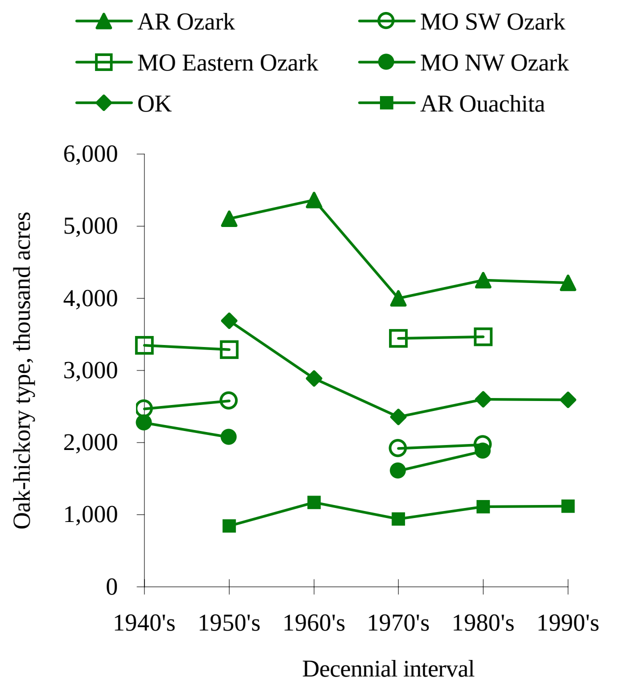


Figure 3.60—Commercial forest land area in the oak-hickory type by FIA region, 1940's to 1990's.

However, from the 1960's to the 1990's, pine-type areas increased 34 percent in the Oklahoma and Arkansas regions. Thus, the declines in pine-type areas seen between the 1950's and 1960's have been reversed, and pine area has generally increased over time since the 1960's.

Oak-Hickory Type. The oak-hickory type is the dominant forest type in the Arkansas and Missouri Ozarks and is also important in Oklahoma. Over time, the area in oak-hickory type has been relatively stable in Missouri and the Arkansas Ouachitas and less so in Arkansas and Oklahoma (fig. 3.60). A net decline of 1.7 million ac of this type occurred in the Arkansas and Oklahoma regions between the 1950's and 1990's. The largest drop was during the 1960's, probably due to the increased conversion of poor-quality oak-hickory stands to pasture land. This decline was partly offset by increases in pine percentage and partly by increases in other hardwood forest types.

In Missouri, percent forest area in the oak-hickory type has remained between 75 percent and 90 percent throughout the measurement period (fig. 3.61). In contrast, the Arkansas Ozark and Oklahoma regions have had steady declines in the proportion of total forest

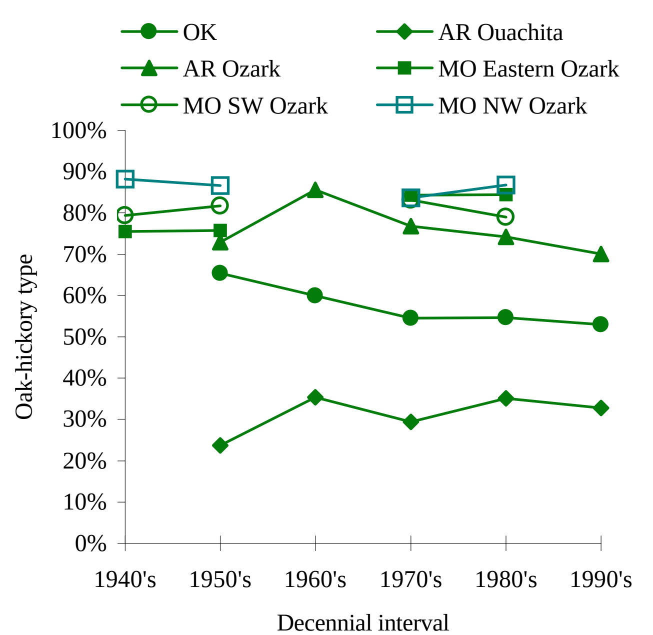


Figure 3.61—Percentage of commercial forest land area occupied by the oak-hickory type by FIA region, 1940's to 1990's.

area that oak-hickory type represents since the 1960's. Although the Ouachita region has the lowest percentage in the oak-hickory type—about 30 percent over the past three decennial intervals—its relative prominence on the landscape has increased since the 1950's.

Distribution by Growing-Stock Cubic Volume

Overall, the total growing-stock cubic volume increased in all regions over time (fig. 3.62). From the 1950's to the 1980's, growing-stock cubic volume nearly doubled, from 8.4 billion cubic feet to slightly more than 16 billion cubic feet. The distribution of this volume by State has been remarkably stable, as shown by the following tabulation:

State	Growing-stock volume 1950's	1980's
	- - - - - - *Percent* - - - - - -	
Arkansas	50.9	50.8
Missouri	33.5	35.3
Oklahoma	15.6	13.9

In addition, the rank by regions did not change from the 1950's to the 1980's—the Arkansas Ozarks had the greatest volume, the northwest Missouri Ozarks the lowest volume, and the other regions remained in the same rank order.

The growing-stock cubic volume of pine shows an increasing trend over time across all regions (fig. 3.63). Volumes generally increased from one decennial interval to the next. The exceptions were a decline in the Missouri Eastern Ozarks between the 1950's and 1960's, a decline between the 1970's and 1980's in the Ouachita region, and a slight decline in Oklahoma during that same interval. During the 1970's and 1980's, industry and national forests were actively cutting older pine stands and replacing them with fast-growing pine plantations. The increase in pine volume from the 1980's to the 1990's is consistent with this interpretation; plantations are now in their second and third decades of growth and, as a whole, contributed to the increased cubic volume over the past decennial interval.

The growing-stock volume of hard hardwood also shows a general increase over time (fig. 3.64). The area with the highest cubic volume of hard hardwoods is the

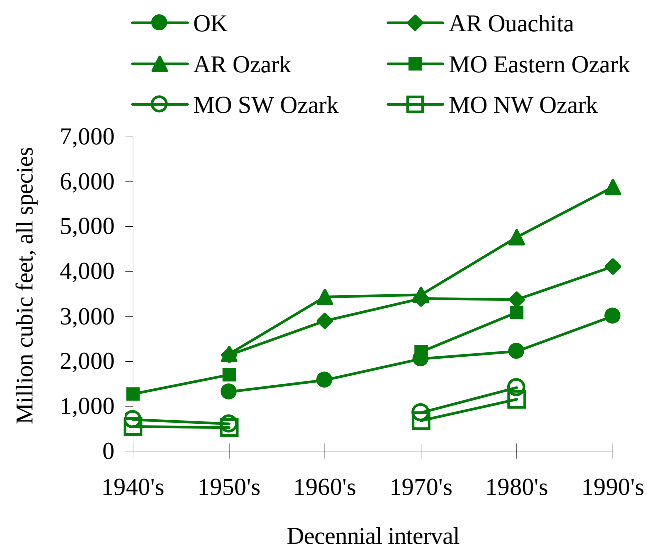


Figure 3.62—Growing-stock volume of all species on commercial forest land by FIA region, 1940's to 1990's.

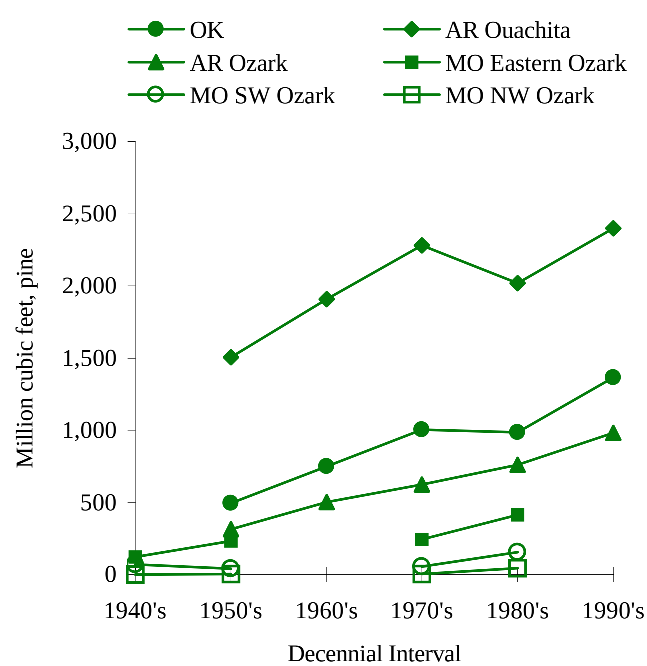


Figure 3.63—Growing-stock volume of the pine species group on commercial forest land by FIA region, 1940's to 1990's.

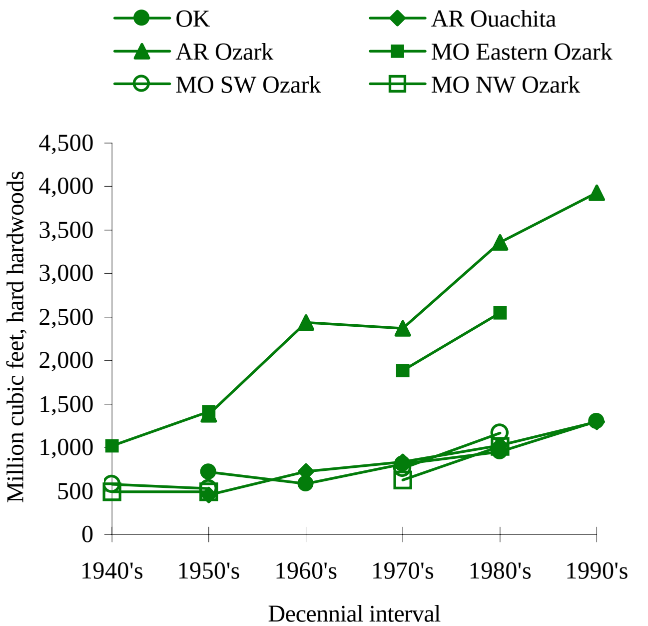


Figure 3.64—Growing-stock volume of the hard-hardwoods species group on commercial forest land by FIA region, 1940's to 1990's.

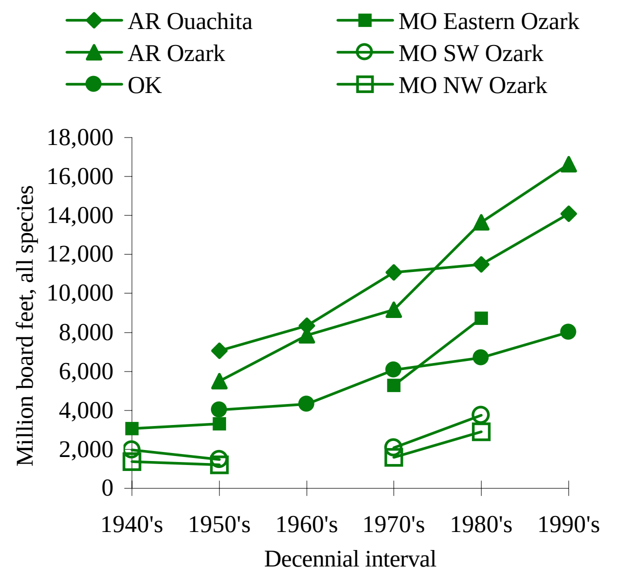


Figure 3.65—Sawtimber volume of all species on commercial forest land by FIA region, 1940's to 1990's.

Arkansas Ozarks, which increased from about 1.4 billion cubic feet in the 1950's to over 3.9 billion cubic feet in the 1990's. The slight decline in cubic volume from the 1960's to the 1970's suggests a withdrawal of marginal lands for agricultural use, which was common at the time. The eastern Missouri Ozarks show a similar increase in the hard-hardwood component over time, from roughly 1 billion cubic feet in the 1940's to slightly more than 2.5 billion cubic feet in the 1980's. Hard-hardwood volumes in the other regions roughly doubled across the four-decade span between the first and the latest decennial interval, and at the most recent interval all exceeded 1 billion cubic feet.

Distribution by Sawtimber Volume

Total sawtimber volume has increased over time (fig. 3.65). The biggest absolute increase from the 1950's to the 1980's was in the Arkansas Ozarks, which experienced an increase of 8 billion board feet. The largest percentage increase in sawtimber volume was in the eastern Missouri Ozarks, which had a 167 percent increase since the 1950's. In total, where the six regions were combined, they more than doubled in sawtimber volume over the past three decades, from 22 billion board feet to more than 45 billion board feet.

Pine-sawtimber volume has increased in all regions over time (fig. 3.66). The increases have been smallest in Missouri, larger in the Arkansas Ozarks and Oklahoma, and largest in the Arkansas Ouachita region. However, the percentage increase in pine-sawtimber volume has been greatest in the Missouri Ozarks, especially the eastern Missouri Ozark region, where pine volume has increased more than 400 percent relative to levels four decades previous. From the 1950's to the 1980's, pine-sawtimber volume across all six regions increased 77 percent.

Based on the 1980's decennial interval, the "other softwood (conifer)" component (primarily eastern red cedar) is about 2.5 percent of total softwood-sawtimber volume. However, volume in this species group has increased over time (fig. 3.67). From the 1950's to the 1980's, the other softwood-sawtimber volume increased more than any other species group, by more than 250 percent. Cedar is most prominent in the Arkansas Ozarks where, from the 1960's to the 1990's, cedar-sawtimber volume increased more than eightfold.

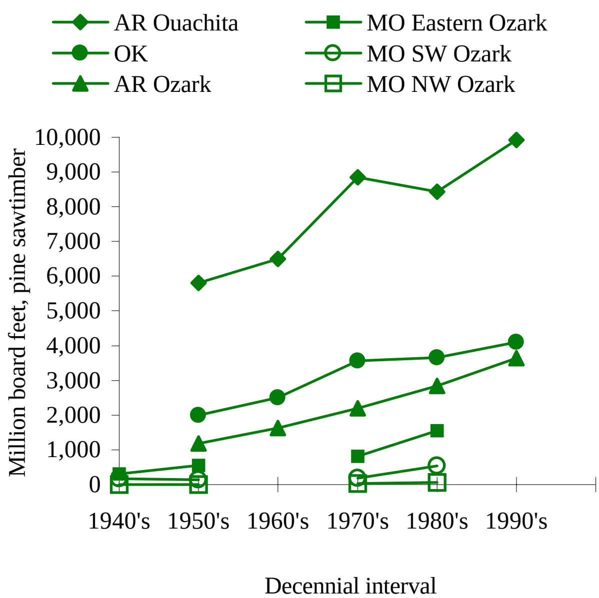


Figure 3.66—Sawtimber volume of the pine species group on commercial forest land by FIA region, 1940's to 1990's.

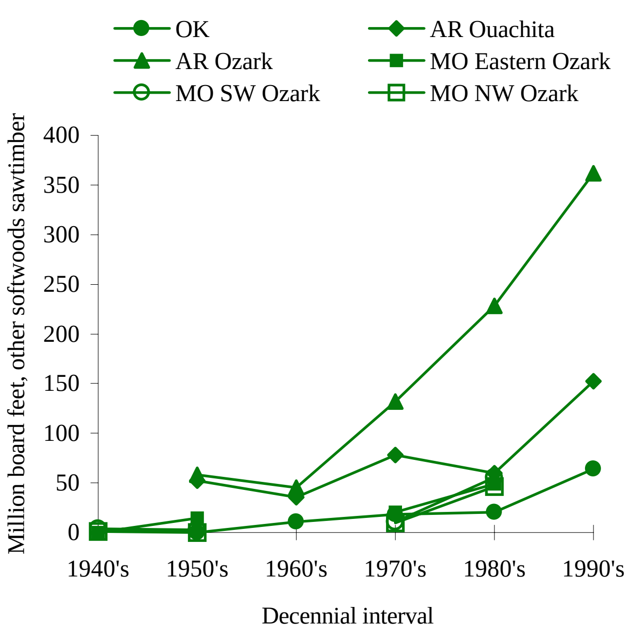


Figure 3.67—Sawtimber volume of the other softwoods species group on commercial forest land by FIA region, 1940's to 1990's.

Soft hardwoods had the smallest percentage increase in sawtimber volume of all four species groups (fig. 3.68). In the three Missouri regions, soft-hardwood sawtimber volume decreased sharply from the 1940's to the 1950's, but subsequently volumes have gradually increased.

The Oklahoma and Ouachita regions have seen slight increases in soft-hardwood sawtimber volume from one decade to the next, with volumes more than doubling over the four-decade interval. The largest increase in soft-hardwood-sawtimber volume has been in the Arkansas Ozarks, where volume almost doubled from the 1970's to the 1990's.

The hard-hardwood component has been the dominant sawtimber component in the Assessment area and continues to grow at a disproportional rate (fig. 3.69). Hard-hardwood volume increased from 10.6 billion board feet (47 percent of total sawtimber volume) in the 1950's to 26 billion board feet (55 percent of total sawtimber volume) in the 1980's.

Two of the six regions—the Arkansas Ozarks and the eastern Missouri Ozarks—had the greatest increases in hard-hardwood sawtimber volume. From the 1950's to the 1980's, these two regions supported an increase of greater than 10 billion board feet in hard-hardwood sawtimber volume—nearly 66 percent of the growth across the six regions.

Distribution of Volume in White Oak and Red Oak Groups

Together, the red oaks and white oaks are the major element of the hard hardwoods. But the dynamics of the two subgroups are slightly different over time. For example, across all regions, the percentage of oak volume in the red-oak group was relatively constant from the 1950's (48.5 percent of growing-stock cubic volume, 50.7 percent of sawtimber volume) to the 1980's (48.6 percent of growing-stock cubic volume, 55.5 percent of sawtimber volume).

The Ouachita, Oklahoma, and southwestern Missouri Ozarks regions, however, exhibit a trend in which the proportion of oak volume in the red oak group increases over time (fig. 3.70). The absolute volume of white oaks and red oaks is increasing. Differences between the two groups may be due to developmental dynamics or perhaps to different levels of harvest.

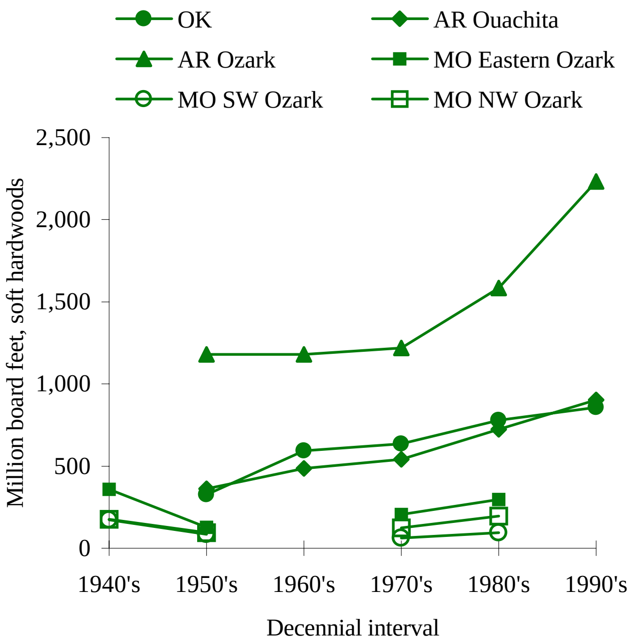


Figure 3.68—Sawtimber volume of the soft-hardwoods species group on commercial forest land by FIA region, 1940's to 1990's.

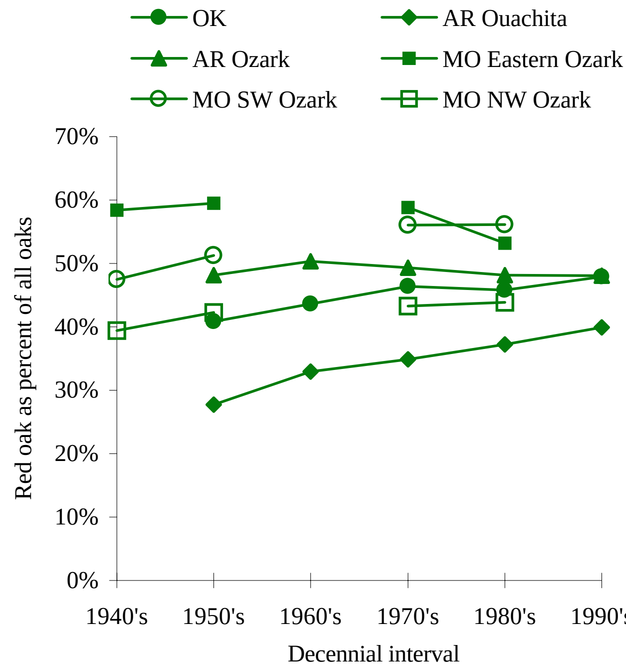


Figure 3.70—Red oak growing-stock volume as a percentage of all oak growing-stock volume on commercial forest land by FIA region, 1940's to 1990's.

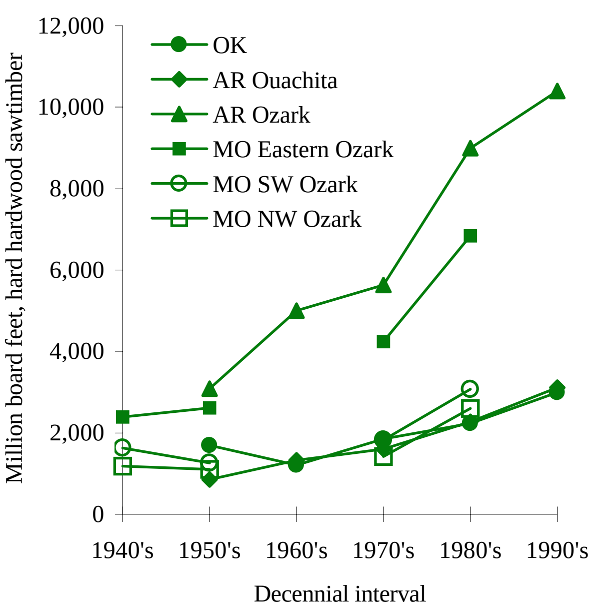


Figure 3.69—Sawtimber volume of the hard-hardwoods species group on commercial forest land by FIA region, 1940's to 1990's.

When the red oak and white oak groups are combined, they appear to account for a moderately increasing proportion of volume over time (figs. 3.71 and 3.72). For growing-stock cubic volume, the combined oaks constituted 48 percent of total volume in the 1950's and 52 percent in the 1980's. The increase is greater in sawtimber volume; oaks accounted for 39 percent of sawtimber volume in the 1950's and 47.6 percent in the 1980's.

Figures 3.71 and 3.72 show the proportion of oak cubic feet and sawtimber volume, respectively, by region. The Ouachita and Oklahoma regions have the lowest volume of the oaks (recall that the pine component dominates in these regions). Conversely, oaks provide over 70 percent of growing-stock and sawtimber volume in the three Missouri regions.

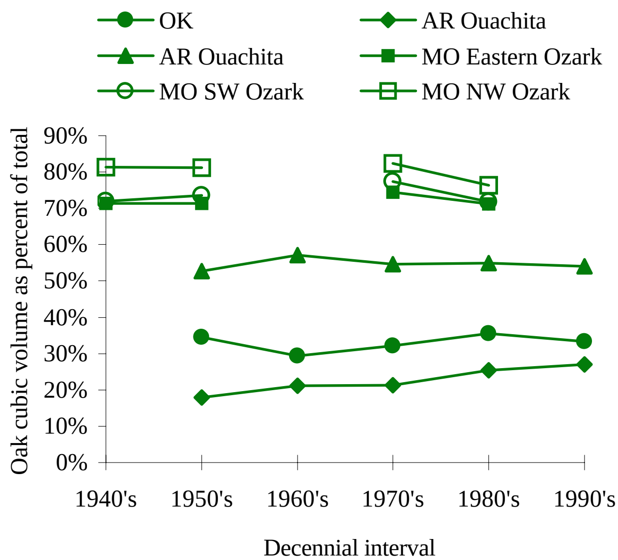


Figure 3.71—Oak growing-stock volume as a percentage of all species growing-stock volume on commercial forest land by FIA region, 1940's to 1990's.

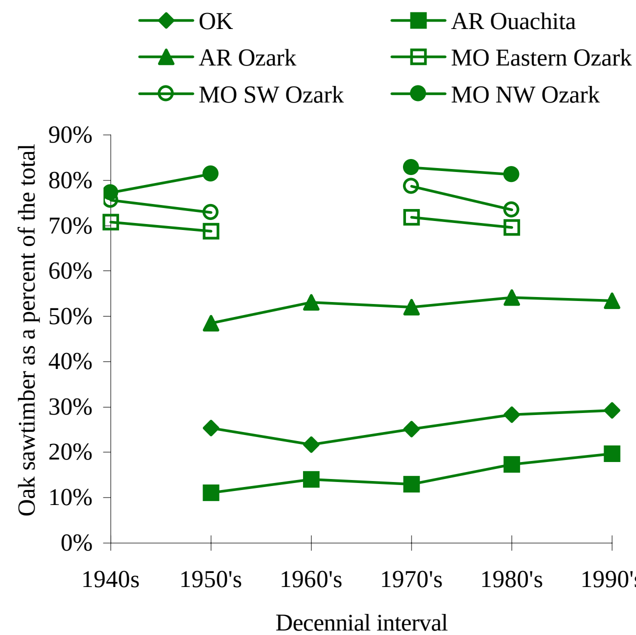


Figure 3.72—Oak sawtimber volume as a percentage of all species sawtimber volume on commercial forest land by FIA region, 1940's to 1990's.

Implications and Opportunities

National forests and other public lands will likely contribute significantly to the retention of forest cover in the region over the long term. Forests under public land management are unlikely to be converted to other uses. Furthermore, where timber harvests occur, the land is promptly reforested. Public lands, however, represent only 22 percent of the timberland acreage in the Highlands

Across the Highlands, the average annual net growth of trees is nearly 30 cubic feet/ac, while the average annual removals from harvesting are 14.5 cubic feet/ac. Mortality due to other causes claims 3.7 cubic feet/ac. Tree growth, therefore, exceeds "losses" by more than 11.8 cubic feet/ac per year. Removals and mortality, in other words, claim slightly less than 40 percent of annual tree growth. This is the first of many indicators that total tree biomass is increasing significantly in the Highlands.

The proportion of total forest cover represented by oak-hickory has declined steadily in the Arkansas Ozarks and slightly in Oklahoma over the past three decades. The simplest explanation is that, although total oak-hickory acres are stable or increasing, the acreage in pine and mixed pine-hardwood types is increasing even more rapidly. This trend is probably a result of oak-pine being replaced with pine.

The FIA trend data clearly show that the total volume of trees is increasing in the Highlands and has been for decades. Sawtimber volume and percent of forest in sawtimber are both substantially higher than in the 1970's in all six FIA regions. Sawtimber volume of hard hardwoods was four times greater in the 1990's than in the 1950's, and both oak cubic volume and oak sawtimber volume have remained steady as a percentage of total volume. Total cubic volume and cubic volume of both pines and hardwoods is substantially higher than in the 1950's. In the Arkansas Ozarks, the Ouachitas, and in easternmost Oklahoma, total cubic volume is two to three times greater than in the 1950's.

Old Growth

Scientists estimate that 90 percent of the virgin forests in the United States are gone. The remaining virgin stands are principally in the Northwest, on national park lands, or in isolated pockets on private or State lands (Noss and others 1995).

Very little virgin forest remains in the East, and most of it is in small, isolated stands. There are, however, stands having some characteristics of old-growth forest. Those characteristics typically include trees at least a century in age, the plants and animals associated with old trees, downed logs, and standing snags.

Disturbances, such as periodic fires, blow downs, and insect attacks, perpetuate these conditions in true old-growth forests. Old-growth conditions can gradually redevelop after timber harvests, natural catastrophic events, such as tornadoes, or even in agricultural fields.

At least 16 types of old-growth forests exist in the Southern United States. The Ozark-Ouachita Highlands could support seven of those types (Gaines and others 1997). The Terrestrial Team assessed existing and potential old-growth stands on the three national forests in the Ozark-Ouachita Highlands. Other Federal and State agencies could assess their lands for potential old growth, using the same criteria. In this report, the term "potential old-growth stand" refers to areas having some characteristics of old-growth stands, mainly trees of at least 100 years in age.

Data Sources

Any stand has the potential to become an old-growth forest. However, the presence of several characteristics of an old-growth forest can make a stand of public forest a better candidate for designation as potential old growth. The presence of old trees is a significant characteristic, yet many acres with suitably old trees lack other important characteristics, such as dead and downed trees or live trees with cavities for animal habitat.

The size of old-growth stands is another important consideration; plant and animal species utilizing old growth may respond differently to areas of various sizes. Gaines and others (1997) identified three size categories for management of old growth in the Southern Region: small patches of up to 99 ac, medium-sized patches of 100 to 2,499 ac, and large patches of 2,500 or more acres.

The process of identifying areas that merit designation begins with locating potential old-growth stands having some or all of the identified old-growth characteristics. After the stands have been located, an initial inventory of the oldest stands of different forest types must be conducted. Gaines and others (1997) have provided guidance to national forests in the South, and Tyrrel and others (1977) have provided guidance to national forests in the East for selecting stands for Federal designation as potential old-growth forests.

The Terrestrial Team used the Continuous Inventory of Stand Conditions, a geographic information system, to identify potential stands in the Ozark and Ouachita National Forests and the Combined Data System database to find potential stands in the Mark Twain National Forest. A spatial analysis of the Ozark and Ouachita National Forests' data enabled researchers to assemble adjacent potential old-growth stands of similar forest cover types on those forests.

Patterns and Trends

The Forest Service identified seven types of old-growth forests as potentially existing in the Ozark-Ouachita Highlands. Each is described below.

Dry and Xeric Oak Forest, Woodland, and Savanna

This widespread mix occurs on ridge tops and some southern slopes or rock outcrops of dry, infertile uplands where conditions are dry most of the year. Oaks, including post, black, white, and blackjack, dominate the overstory. The average ages of trees ranges from 65 to 150 years, depending on the species (Gaines and others 1997).

This community depends upon fire to control competition from smaller trees and other aggressive species of plants. Fires contribute to a more open canopy than in dry-mesic oak forests.

Xeric Pine and Pine-Oak Forest and Woodland

Shortleaf pines dominate stands of this type, which are found on dry, south-facing upper slopes where soils are acidic and poor in nutrients and little moisture is available. Black, blackjack, post, and white oaks are also part of the overstory and much of the mid- and lower-levels of the stand. Shortleaf pines average 200 years in age (Gaines and others 1997). The Lake Winona Research Natural Area in the Ouachita National Forest is an example of this type of old growth.

Frequent, low-intensity fires maintain this community's composition and structure. Windstorms, ice storms, and intense fires may cause large openings in these stands, and windblown trees may feed more intense fires. Pockets of younger trees then begin to renew the stand, as well as filling gaps caused by the deaths of individual trees from lightning, insect attack, or old age. The Ouachita National Forest is managing 38 sites for future xeric pine and pine-oak old-growth forests, using fire and other management techniques.

Dry-Mesic Oak Forest

This type occurs primarily on north-facing slopes and at the bottoms of south-facing slopes. The species in this type of old growth, which vary depending upon location and elevation, include oaks, hickories, and maples tolerant of dry conditions. Shortleaf pine may occur but does not make up more than 25 percent of the stand. Trees are more than 300 years old (Gaines and others 1997).

Fire is an important factor in maintaining these forest communities. Thick-barked oaks easily survive frequent, low-intensity fires, while more sensitive, thin-barked species, such as maples, succumb readily to fires. Thus, fires produce widely-spaced larger trees with understories of herbaceous plants, allowing germination of new growth in sunlit or mostly sunlit areas.

Dry and Dry-Mesic Oak-Pine Forest

This type develops on the same kind of sites as the dry-mesic oak forest. White oak dominates the stands with shortleaf pine occupying at least 20 percent. Oaks and pines can reach 300 years in age (Gaines and others 1997).

Frequent fire maintains the structure of this type of old-growth forest by recycling nutrients (releasing nutrients in dead and decaying material) and controlling competition. More intense fires renew stands by removing large patches of trees or individual trees.

Mixed Mesophytic and Western Mesophytic Forest

One of the most biologically diverse ecosystems in the United States, this type may occur in coves or on north- or east-facing slopes throughout the Ozark-Ouachita Highlands. Oaks dominate the communities in this broad category, but the forests may also include sugar maple, beech, basswood, and red maple. They are uneven- or all-aged stands, with the maximum age for basswood, the indicator or key species for this community, being 198 years (Gaines and others 1997).

Deaths of individual trees create small gaps in the canopy, permitting new growth in these stands. Less frequent disturbances from fire, windstorms, floods, and other natural events also create openings for renewal of the forest.

Seasonally Wet Oak-Hardwood Woodland

Hardwood species that thrive in wet conditions, such as willow oak, sweetgum, and red maple, make up this type. The semi-open woodlands require standing or subsurface water; upland trees cannot survive in this community. Large trees in this community are between 80 and 100 years old (Gaines and others 1997).

Infrequent fires in conjunction with dry years can eliminate woody debris and cause isolated tree deaths. These fires break down dead timber and leaf litter, improving the nutrient return to the soil and supporting new growth. Suppression of these renewing fires has caused stands of this type to develop into dense forests instead of open woodlands. Under this condition, growth of individual trees is poor, leaving the entire stand vulnerable to disease and insect threats.

River Floodplain Hardwood Forest

This type occurs along large rivers such as the Arkansas, the Current, the Eleven Point, and the White, often on the most productive soils in the area. A mix of oaks, red maple, hickory, birch, ash, sweetgum, and elms make up the tallest trees in the canopy. The dominant trees reach a maximum age of more than 100 years. American beech may be present at the first bench above the floodplain (Gaines and others 1997).

Catastrophic floods infrequently destroyed entire stands of this type in the past. With the damming of the Arkansas, Ouachita, and White Rivers to control floods, it is more typical for individual trees to succumb to changes in water level. Changes to a river's course occasionally isolate portions of these stands, causing them to lose their old-growth characteristics. Fires occur infrequently in these communities due to the year-round presence of moisture.

Designated Old Growth

Within the Assessment area, almost all designated old-growth stands (ones the national forests manage for old-growth characteristics) are xeric pine and pine-oak or dry and dry-mesic oak-pine forests (table 3.10). The only designated old-growth areas in the Highlands exceeding 2,500 ac are parts of federally designated wilderness. The national forests within the Ozark-Ouachita Highlands have the following numbers of wilderness areas and total acres of wilderness per forest:

National forest	Areas	Area
		Acres
Mark Twain	6	63,627
Ouachita	7	65,974
Ozark-St. Francis	5	66,931

In addition, the McCurtain County (OK) Wilderness Area, which the Oklahoma Department of Wildlife Conservation manages, includes approximately 13,000 ac of old-growth xeric pine and pine-oak (Kreiter 1995). The Buffalo National River in northern Arkansas contains three wilderness areas with 10,529 ac of dry-mesic oak, dry and xeric oak, and river floodplain hardwood.

The designation of land as wilderness can affect the potential for development of old growth because it restricts managers from using some techniques that would support restoration of old-growth characteristics. Thus, wilderness may not be the best choice for perpetuating some types of old growth.

Potential Old Growth

Each potential old-growth type is represented by existing forest cover on one or more of the Highland's national forests. Table 3.11 shows the percent cover of these types on the three national forests (excluding wilderness). On the Mark Twain National Forest, dry and xeric oak, xeric pine and pine-oak, and dry and dry-mesic oak-pine make up 98 percent of the existing forest types. On the Ozark National Forest, 66 percent of the existing forest cover is dry-mesic oak, and 29 percent is xeric pine and pine-oak. These figures are nearly reversed on the Ouachita National Forest, where xeric pine and pine-oak forests cover 69 percent of the area and dry-mesic oak covers 21 percent.

Table 3.10—Acreage and types of designated old-growth areas in the national forests of the Ozark-Ouachita Highlands

National forest	Area	Old-growth type
	Acres	
Ouachita	80,468	XP-PO, DDM-OP
Ozark	9,656	XP-PO, DDM-OP
Mark Twain	122,519	XP-PO, DDM-OP, DMO, DXO, RFH
Total	212,643	

XP-PO = xeric pine and pine oak; DDM-OP = dry and dry-mesic oak-pine; DMO = dry-mesic oak; DXO = dry and xeric oak; RFH = river floodplain hardwood.

Table 3.12 summarizes the estimated number of potential old-growth stands in the national forests by forest type and stand size class. No large stands (> 2,500 ac) of potential old-growth (of a given forest type) were identified on these national forests. However, it seems likely that if adjacent, medium-size stands (100–2,500 ac) of different forest types were considered, examples of the "large" size class could be identified. Xeric pine and pine-oak potential old-growth stands were the most numerous on the Ozark and Ouachita National Forests; dry and xeric oak stands were the most numerous potential old-growth stands on the Mark Twain National Forest.

Implications and Opportunities

Because they are more resilient, the more common types of old-growth forests may need relatively little intervention for conservation or restoration. Less common types may need more management, even

Table 3.11—Percent of existing forest cover in seven potential old-growth cover types, by national forest (excluding wilderness)

Cover type	Mark Twain NF	Ozark NF	Ouachita NF
Mixed and western mesophytic	0	0.25	0.13
River flood plain hardwood	1.23	0.51	0.30
Dry-mesic oak	0	65.86	20.60
Dry and xeric oak	70.12	0.01	0.69
Xeric pine and pine-oak	9.08	29.38	69.34
Dry and dry-mesic oak-pine	19.44	2.76	8.43
Seasonally wet oak-hardwood	0.13	1.32	0.52
Total[a]	100.00	100.00	100.00

[a] Percent totals rounded to 100.

Table 3.12—Number of potential old-growth stands in the three national forests of the Ozark-Ouachita Highlands by forest type and stand size

Old-growth forest type	Stand size class[a] Small	Medium	Large	Total
	Ozark National Forest			
Mixed and western mesophytic	0	0	0	0
River floodplain hardwood	623	859	0	1,482
Dry-mesic oak	1,385	437	0	1,822
Dry and xeric oak	0	0	0	0
Xeric pine and pine-oak	4,412	1,732	0	6,144
Dry and dry-mesic oak-pine	111	0	0	111
Seasonally wet oak-hardwood	97	0	0	97
Total	6,628	3,028	0	9,656
	Ouachita National Forest			
Mixed and western mesophytic	0	0	0	0
River floodplain hardwood	245	0	0	245
Dry-mesic oak	556	977	0	1,533
Dry and xeric oak	271	0	0	271
Xeric pine and pine-oak	16,960	15,572	0	32,532
Dry and dry-mesic oak-pine	360	415	0	775
Seasonally wet oak-hardwood	163	0	0	163
Total	18,555	16,964	0	35,519
	Mark Twain National Forest			
Mixed and western mesophytic	—	—	—	0
River floodplain hardwood	—	—	—	910
Dry-mesic oak	—	—	—	31,886
Dry and xeric oak	—	—	—	55,393
Xeric pine and pine-oak	—	—	—	723
Dry and dry-mesic oak-pine	—	—	—	4,953
Seasonally wet oak-hardwood	—	—	—	0
Total				93,865

— = not available.
[a] Small = 1 to 99 ac; medium = 100 to 2,499 ac; large = 2,500+ ac.

restoration, to perpetuate them as part of the Ozark-Ouachita Highlands. The emphasis should be to put together a desired condition and a clear set of guidelines for managers to follow for each type of old growth.

With most designated old-growth forest stands in the categories of xeric pine and pine-oak or dry and dry-mesic oak-pine, clear priorities for future old-growth stands are needed. Policymakers will need to determine whether each national forest should promote old-growth stands of each type or whether they concentrate on expanding the number and/or size of old-growth stands of the types most typical to the individual national forest. These old-growth forest types might represent the greatest opportunity for restoration.

Rare Communities

The concept of "rare community" is relatively new in ecology. For decades, scientists have identified certain species of plants and animals as rare. More recently, ecologists have recognized entire communities in nature may become rare or may have always been rare because they exist on restricted sites or because of a variety of imposed factors. Timber harvests; conversion of land for grazing, development, or other uses; flooding for lake systems; fire suppression; and other factors may cause declines in the health of various ecological communities so that some become rare. Types of rare communities include old-growth forest communities (see the preceding section) as well as prairies, glades, and shrublands.

Data Sources

There has been no thorough interagency inventory of rare communities, and therefore data concerning rare communities within the Assessment area are extremely limited. The list of rare communities in table 3.13 is based on a national classification system developed by The Nature Conservancy (Weakley and others 1996, 1997). The table is a preliminary summary and may exclude some types of rare communities that are actually present in the Highlands.

Patterns and Trends

Table 3.13 presents 21 types of rare communities that occur in the Assessment area. Types are in three categories: forests and woodland, shrubland, and grassland. Ten community types appear in the forest and woodland category, four in the shrubland category, and seven in the grassland category.

Implications and Opportunities

Conservation agencies in Missouri, Oklahoma, and Arkansas have met with representatives of the three national forests in the Assessment area to discuss management of rare communities, tracking actions, and naming systems. Revision of management plans for the national forests in the Assessment area will present additional opportunities for State and Federal agencies to collaborate in planning for the management or restoration of rare communities.

The three national forests and other cooperating agencies plan to use the National Classification System being developed by The Nature Conservancy. That system should be specific yet flexible enough to meet the needs of individual agencies while facilitating information sharing. When complete, this classification system may be a useful addition to Forest Service data bases.

Table 3.13—Types of rare communities in the Ozark-Ouachita Highlands, with TNC and State nomenclature, global ranking, States of occurrence, and reason for rarity

Nomenclature	Global rank[a]	States of occurrence	Reason for rarity
			Forest and Woodland Types
I.A.8.N.b.030. *Pinus echinata/Vaccinium* Dry shortleaf pine-oak forest	G2	AR, OK, MO	Few old growth examples
I.B.2.N.a.070. *Acer saccharum-Quercus rubra-Carya cordiformis* Mixed mesophytic forest	G2Q	AR, OK, MO	Limited distribution
I.B.2.N.b.070. *Q. alba/Vaccinium* spp. Stunted white oak woodland	G1G2	AR, OK	Limited distribution
I.B.2.N.a.280. *Q. alba-C. ovata/Ostrya virginiana* *Q. alba-C. ovata* forest association	G2G3	OK, MO	Few old growth examples
I.B.2.N.b.090. *Q. stellata montaine* Stunted post oak-blackjack oak woodland	G1	MO	Limited distribution
I.B.2.N.e.120. *Q. palustris-Q. bicolor/Carex critina/Sphagnum* spp. Pin oak-swamp oak seasonally flooded forest	G1Q	MO	Conversion to nonforest
I.C.3.N.a.050. *P. echinata-Q. velutina/Vaccinium* spp. Dry shortleaf-pine-oak-hickory forest	G2G3	AR, MO	Fire exclusion, few old growth examples
II.A.4.N.a.070. *P. echinata-Schizachyrium scoparium* Shortleaf pine-little bluestem woodland	G2	AR, OK, MO	Harvesting, fire exclusion
II.B.2.N.a.170. *Q.stellata-Q. velutina-Q. alba-(Q. falcata)/Croton michauxii* Post oak-black oak-white oak-croton woodland	G2Q	AR, MO	Disturbance, conversion
II.C.3.N.a.050. *P. echinata-Q. alba* Xeric shortleaf pine-white oak	G2		Fire exclusion
			Shrubland
III.A.2.N.g.010. *Aruninaria gigantea ssp. gigantea* Giant cane shrubland	G2	AR, OK	Disturbance, conversion
III.B.2.N.a.080. *Toxicodendron radicans/Polymnia canadensis* Poison ivy-leaf cup	G2	AR, OK	Infrequent on sandstone talus

(continued)

Table 3.13—Types of rare communities in the Ozark-Ouachita Highlands, with TNC and State nomenclature, global ranking, States of occurrence, and reason for rarity (continued)

Nomenclature	Global rank[a]	States of occurrence	Reason for rarity
			Shrubland (continued)
Toxicodendron radicans/Polymnia cossatotensis Poison ivy-leaf cup	G1	AR	Infrequent on novaculite talus
III.C.2.N.c.010. *Juniperus virginiana var. virginiana-Andrachne phyllanthoides* Eastern redcedar-andrachne	G2	AR, OK	Limited to certain streamside zones
			Grassland
V.A.5.N.a.010. *Andropogon gerardii-Panicum virgatum* Tallgrass prairie	G2G3	OK	Conversion, fire exclusion
Andropogon gerardii-Calamagrostis canadensis-Helianthus grosseserratus Bluestem tallgrass prairie	G2G3	AR, OK, MO	Conversion, fire exclusion
V.A.5.N.a.100. *Schizachyrium scoparium-Sorghastrum nutans-Aristida lanosa-Polypremum procumbens* Southern sand prairie	G1Q	AR, MO	Conversion, fire exclusion
Schizachyrium scoparium-Silene regia Lowland sand prairie	G2?	OK, MO	Conversion, fire exclusion
Schizachyrium scoparium-Sorghastrum nutans-Danthonia spicata-Silene regia Glade	G2	OK, MO	Limited distribution
V.A.5.N.c.110. *Schizachyrium scoparium-Sporobolus neglectus* Chert glade	G1?	OK, MO	Limited distribution
V.A.5.N.c.120. *Schizachyrium scoparium-Bouteloua curtipendula-Atrostis hyemalis-Eleocharis spp.* Little bluestem hardpan prairie	G2?	OK, MO	Limited distribution

TNC = The Nature Conservancy.
[a] Ranking based on known distribution, with global rank "1" (G1) representing the rarest element of interest and G5 the most common; see Chapter 5 for a complete description of global and state ranks.

Chapter 4: Silvicultural Practices

Question 4.1: Which silvicultural practices are best suited to the forests of the Assessment area?

Question 4.2: What trends are taking place in silvicultural practices on the Highlands' national forests?

The Terrestrial Team examined the silvicultural practices that foresters apply in the Ozark-Ouachita Highlands to provide a foundation for future discussions about forest management in this region. This chapter begins with a brief introduction to silviculture—the theory and practice of controlling forest establishment, composition, structure, and growth. Second, the chapter assesses current scientific knowledge of silvicultural systems in the major forest types of the Highlands. Third, it concludes by summarizing trends on the three national forests in the Highlands.

By presenting a chapter that is primarily about silviculture, the Terrestrial Team does not intend to imply that other fields, such as wildlife biology, ecology, or soil science, are less important to forest management. In fact, some findings and perspectives from these other fields are woven into the discussion that follows. Silvicultural practices, however, are likely to affect terrestrial forests, plants, and animals more than any other management activity that takes place on public lands and, therefore, deserve the extensive treatment offered here.

Key Findings

1. Upland hardwood forests consist of relatively shade intolerant species that typically are best suited to even-aged management. Except for one case in Missouri, the few successful examples of uneven-aged management in upland oak forests required aggressive chemical control of competing hardwoods.
2. Shortleaf pine forests can be managed with a variety of even-aged or uneven-aged methods, but successful regeneration under single-tree selection typically requires chemical and/or mechanical control of competing vegetation. Natural regeneration also depends upon the co-occurrence of good seed crops, suitable seedbeds, and sufficient light.
3. Clearcutting declined on national forests from 27,729 acres (ac) in 1988 to 698 ac in 1996, a 97.5 percent decline. This decline in clearcutting was the single most significant silvicultural trend on national forests in the Assessment area.
4. Reproduction cutting on the national forests using the seed tree method averaged 2,382 ac/year (8.6 percent of the 1988 clearcutting level) from 1991 through 1996. During the same period, the area harvested using the shelterwood method averaged 3,157 ac/year (11.4 percent of the 1988 clearcutting level).
5. The largest increase of a silvicultural method on the national forests was in the use of the single-tree selection. This increase was due more to single-tree selection being the exact opposite of clearcutting rather than to any particular advantages for either pine or oak-hickory silviculture. Together, the Ozark and Ouachita National Forests applied single-tree selection on an average of 8,916 ac annually from 1991 through 1995.
6. Herbicide application for site preparation declined on the national forests from 12,705 ac in 1988 to 2,132 ac in 1997, an 83 percent decline over the 10-year period. Conversely, acres burned in site preparation on the Ouachita National Forest increased from 536 ac in 1989 to 3,137 ac in 1997. Each year, more acres have been burned than in the previous year. This trend suggests that the limits to using prescribed fire for site preparation have not yet been reached.
7. The use of prescribed burning as a tool for managing intermediate stands has increased nearly four-fold over the past 5 years and exceeded 100,000 ac in 1997 (due primarily to actions on the Ouachita National Forest). The Ouachita National Forest has increased the use of prescribed burning to restore shortleaf pine-bluestem grass communities over extensive areas of the western Ouachitas, to sustain wildlife habitat diversity, and to encourage natural regeneration.

Silvicultural Systems

This section provides an overview of silvicultural systems. For people who want more detail about this section or other silvicultural topics, consult one of the textbooks commonly used in undergraduate forestry classes (e.g., Smith 1986, Daniel and others 1979).

Ecological Basis of Silvicultural Practices

Nature provides the models and patterns that silviculturists strive to follow or mimic. Two major ecological phenomena are particularly important. The first, succession, is defined as the normal growth and development of an established forest or stand (Kimmins 1987). The second, disturbance, is the partial or complete removal of a forest canopy through natural events (Spurr and Barnes 1980). Disturbance is the exact opposite of succession, and the interactions of disturbance and succession are major determinants of the ecological structure and function of all forests.

Foresters imitate the natural processes of succession and disturbance through the prudent use of carefully defined silvicultural treatments. For example, intermediate treatments, such as thinning, generally promote stand development in a manner similar to that of natural succession. Conversely, the cutting methods that foresters use to regenerate forest stands (called reproduction cutting methods) emulate natural disturbances that remove part or all of a forest canopy. Foresters try to imitate the natural variations in disturbance by using similar variations in reproduction cutting.

However, silviculture should not be considered an exact replication of natural succession and disturbance processes. The major difference is that most harvested wood is manufactured into wood products, and most trees felled or otherwise killed or cut back by natural disturbance remain in the forest. Other ecologically important differences exist. For example, windstorms often uproot trees, a practice that foresters rarely attempt to imitate. However, the ecological importance of the microtopographic variation created by uprooted trees for plants and animals is well established. As ecologists gain a better understanding of the ecological effects of natural succession and disturbance, silviculturists will seek ways to refine common silvicultural practices to better reflect both the obvious and the subtle ecological effects associated with natural events.

Succession

Secondary forest succession is usually thought of as the normal growth and development of a forest stand. Succession begins immediately after a disturbance when new trees and other plants begin to grow or older ones resprout. Succession continues through various stages that, if unaffected by additional major disturbances, culminate in an old growth forest stage (which remains susceptible to major disturbances).

Foresters modify stand development in different ways. They use active interventions such as thinning, release treatments, or controlled fires (in fire-adapted ecosystems) to influence the rate and direction of succession. At times, they implement passive alternatives, which include deferring treatments, conducting no treatments in a given area, or allowing naturally initiated disturbances, such as wildfire or insect outbreaks, to run their course. The practices that managers ultimately select, whether active or passive, are intended to influence the direction of stand development toward desired conditions and/or to achieve desired trends in landscapes. Essentially silviculture, however, is concerned only with stand-level conditions in a forest.

Traditionally, desired conditions have been heavily weighted toward timber production. A broader view provides for a full range of human needs and expectations, including ecological sustainability. Desired conditions must encompass ecological and aesthetic as well as economic objectives. For example, current forest management on national forest lands in the Ozark-Ouachita Highlands is trying to broaden the concept of acceptable stocking from nearly pure pine stands to mixtures of pines and hardwoods. These mixtures would be maintained at densities such that both kinds of trees would undergo acceptable development and be able to persist together in many stands.

As silviculturists seek to better approximate natural patterns and processes in the context of sustainable forest management (ecosystem management), the short-term goal is to ensure regeneration of desired species or mixtures of species after reproduction cutting. The long-term goal is to ensure that these mixtures and other desired conditions continue to develop or be sustained over time.

Disturbance

The most critical time in the life of a forest stand is after a major natural disturbance, an event that is inevitable in the life of a forest community. Windstorms, crown fires, insect outbreaks, and other natural events sometimes set forests back to their earliest stages of development. On other occasions, disturbances leave parts of the forest canopy intact but still change the structure and species composition of the stand. Many forest species, however, are able to reproduce and persist in particular forest landscapes because of periodic disturbances.

Disturbances vary according to three scales: intensity, frequency, and duration (White 1979). Intensity is the percentage of standing forest that undergoes mortality. Frequency is the rate at which existing disturbances recur, typically over spans of years. Frequent disturbances occur every few years, whereas some infrequent disturbances occur only once every few centuries. Finally, duration is the length of time that the disturbance occurs. Duration can vary from a few seconds or minutes (such as a wildfire) to several years (some droughts). By human time scales, major disturbances are relatively rare; however, they are no less important than more frequent but less intense disturbances.

Disturbance and stand structure are closely related. Some disturbances cause new trees to be established over large areas at the same time, creating even-aged stands. Others cause new trees to grow within very small openings in the canopy, creating uneven-aged stands.

Silvicultural Systems and Reproduction Cutting Methods

A silvicultural system is a long-term series of treatments. The series includes reproduction cutting (stand regeneration) by a particular method (the most prominent feature of any such system), the regeneration of new trees, intermediate treatments, and subsequent reproduction cutting. The goals of the silvicultural system are to use forest resources for the benefit of society and to maintain desired ecological conditions.

Reproduction cutting methods evolved in forestry to imitate different intensities of disturbance. Thus, the range of reproduction cutting treatments loosely approximates the intensities of natural disturbances. Even-aged reproduction cutting methods imitate intense but infrequent disturbances. Uneven-aged reproduction cutting methods imitate less intense disturbances that are more frequent. Regardless of the method, establishing new trees in place of harvested trees is the most important goal of a reproduction cutting method. Although the foregoing discussion implies that silvicultural methods are distinct from one another, in practice they represent gradations of light penetration to the forest floor. Clearcuts produce the greatest light penetration to the forest floor, and single-tree selection produces the least.

Not all silvicultural treatments result in a new stand becoming established. Intermediate treatments, such as commercial thinning, effectively imitate the natural stand dynamics that result from overcrowding (called “density-dependent mortality”). Instead of trees dying and falling to the forest floor, they are harvested for wood products. Commercial thinning is typically recommended in situations where the immediate objective is to allow the better trees in the stand to continue to grow, rather than to obtain a new stand of seedlings.

Clearcutting

Foresters use clearcutting to approximate very intense but infrequent disturbances, such as crown fires or catastrophic windstorms. Extreme natural disturbances occur at times in most ecosystems, occasionally covering extensive areas (see Chapter 2). Ecological conditions within such heavily disturbed areas promote species adapted to rapid colonization and growth.

After clearcutting, foresters accelerate the natural cycle by promptly reforesting the area, usually by planting a particular species. Often, the planted trees are from genetically improved stock chosen for rapid growth and survival. Clearcuts are usually planted in the spring immediately after a harvest, which minimizes the degree to which the site lies fallow.

Seed-Tree Method

The seed-tree method mimics a moderately extreme natural disturbance that eliminates most, but not all, of the canopy trees in a stand. Under natural disturbances, the trees that survive are usually found on the fringes of the extreme disturbances or scattered in less intensely affected spots of moderately severe disturbances. The trees that survive are typically spaced far enough apart that they do not cast sufficient shade to lessen the exposed ecological conditions on the forest floor. Conditions for the new stand are, thus, very similar to those found in open conditions. Foresters apply the seed-tree method to recreate such highly exposed conditions. The trees remaining after the regeneration cut, typically about 5 to 10 percent of those in the high canopy of the original stand, are called seed trees (because they subsequently cast the seeds that regenerate the site).

Shelterwood Method

The shelterwood method mimics a disturbance that affects the entire area but leaves more overstory trees than those disturbances the seedtree method imitates. During this hypothetical natural event, more residual trees survive the disturbance and promote a new wave of seedlings that grow under the shelter of the residual trees, and hence the name "shelterwood."

Foresters often prescribe the shelterwood method if a site is too harsh for seedlings to survive under the more open conditions created by clearcutting or seed-tree methods. The shelterwood method is also popular for species that have erratic or unreliable seed production. The additional seed trees in the shelterwood often make the difference between adequate and less-than-adequate stocking. In some applications, foresters prescribe harvest of the sheltering trees after young seedlings have grown sufficiently to compete well and re-establish the forest stand. Depending on management objectives, the forester may defer final harvest for up to half of the rotation length (time interval between reproduction cutting), which results in a two-aged stand. This method is called an irregular shelterwood. In mature stands where advance reproduction is present before treatment, a single removal cut is often feasible.

Group Selection Method

The group selection method imitates a small-scale disturbance that removes small groups or clusters of trees from several small portions of the stand. Examples of comparable natural events include localized insect infestations, such as those of the southern pine beetle, a severe lightning strike, a locally severe wind, or the flare-up of a surface fire. These small-scale disturbances cause openings in a stand, called gaps, within which regeneration occurs and develops. Seeds from trees bordering the gaps typically regenerate these patches naturally. The border trees also influence ecological conditions within the gap. If the gap is sufficiently large, microclimatic conditions at its center will allow early successional (shade intolerant) species to develop within the opening.

Foresters typically apply the group selection method when they want to use an uneven-aged silvicultural system to regenerate shade-intolerant species or provide openings in the forest for wildlife or both. Size, placement, and regulation of group openings are still not clearly established in silvicultural theory. The major ecological distinction between group selection and small clearcuts is that the group is typically small enough that its center is still influenced by the surrounding forest canopy, that is, still partially shaded. This is not the case with a small clearcut. Technical differences also exist in the way that openings are scattered within a given stand, but these differences are of greater interest to forest biometricians than to the public. Groups do resemble small clearcuts and, therefore, are still associated with the controversy surrounding clearcutting (see Chapter 9 of the *Social-Economic Conditions* report, USDA FS 1999b).

The ecological literature suggests that an opening with a diameter equivalent to two tree heights is the largest gap under which the center of the opening is still influenced by the adjacent stand. However, national forest policy maintains that an opening should be no more than 2 acres (ac), which, if imposed as a circle, would have a radius of 166.5 feet (ft).

Single-Tree Selection Method

Single-tree selection imitates the smallest scale of disturbance, i.e., when a single tree dies and/or falls in a forest. These small-scale disturbances are caused by insects, lightning, disease, wind, and other agents. If the dying tree had a large crown, seedlings will become established in the gap created in the canopy. In the smallest gaps, the canopy may close before saplings can grow into the main canopy. Saplings may persist without any further growth, or their growth may become suppressed. Multiple gaps (where a nearby tree succumbs and creates a second nearby opening, either at the same time or soon after the first) or the expansion of existing gaps (where gap-bordering trees fall) will favor regeneration, survival, and development. To maintain the vigor of the smallest trees, stands under single-tree selection typically have lower relative densities than fully stocked, even-aged stands. By definition, an uneven-aged stand has at least three age classes. In practice, age is not measured, and foresters manage stand structure by controlling the numbers of trees of various diameters according to various mathematical formulas or desired ecological relationships.

Silvicultural Distinctions

The term "selective cutting" needs to be explained. To the professional forester, selective cutting means no more than "select some trees and cut them." Selective cutting in no way refers to uneven-aged silviculture using the "selection method." In practice, selective cutting typically means the uncontrolled harvesting of trees (that is, removing all commercially desirable species), with no intention or provision for reforesting the stand. Therefore, professional foresters usually refer to this approach as "highgrading."

In fact, the forester's judgment is critical when determining if a harvest cut is considered good silviculture. Under the principles of silviculture, the goal of reproduction cutting is to reforest the site, and that decision is made before the harvest. The intensity of the harvest is a byproduct of the decisions regarding what ecological conditions are desired for regeneration. Under selective cutting, the goal is to harvest trees with commercial value.

Immediately after the trees are cut, selective cutting and reproduction cutting may seem to resemble one another. The difference, however, is established after reproduction cutting when treatments, such as site preparation and release, are used to ensure a new stand of desired species is established (see following section). Such treatments are absent under selective cutting. It is important to realize that even the most carefully planned reproduction cut can become a selective cut if subsequent site preparation and reforestation fail to regenerate the desired species. By intent or not, selective cutting is always detrimental to a forest. The site will become a forest of poor quality that has little benefit for timber, wildlife, or recreation.

Regeneration

Regeneration refers to the methods by which new seedlings are established after reproduction cutting or on lands that currently do not support trees. The two general categories of regeneration are artificial and natural. Artificial regeneration occurs when seeds, seedlings, or saplings are planted in an area. Natural regeneration results when trees provide new seedlings through natural seed-fall or by sprouting. Both methods are important in the forests of the Ozark-Ouachita Highlands.

Artificial Regeneration

Planting. Because of differences in regeneration biology, planting is used more often to regenerate pines than hardwoods. In pines, seeds fall, germinate, and grow in the open conditions that follow major disturbances (such as a tornado). Planting a seedling after a harvest imitates this natural process rather closely. Conversely, most hardwoods, especially oaks, are adapted to persist as seedlings and saplings in the understory for long periods before a disturbance. When a disturbance occurs, small hardwood stems are released from their suppressed condition and can grow to full size. However, few if any new seedlings become established. Thus, planting hardwoods after a disturbance does not imitate natural hardwood regeneration, except for a few species not commonly used in timber management, such as sweetgum and red maple.

Considerable effort has gone into developing the technology and procedures to produce high-quality shortleaf pine seedlings. Barnett and others (1986) reported three main opportunities associated with artificial regeneration of shortleaf pine: (1) poor-quality, natural stands can be rehabilitated, especially those supporting low-grade hardwoods as a result of high-grading pines and hardwoods; (2) tree growth can be increased by using genetically improved seedlings; and (3) productivity can be improved by controlling spacing between seedlings. Recommended seed sources of genetically improved shortleaf pine seedlings for use in the Ozark-Ouachita Highlands are those from within the region or from the more northern portions of the natural range of shortleaf pine (Wells 1969).

The Southern Region of the Forest Service maintains a shortleaf pine seed orchard on the Ouachita National Forest. This orchard is made up of families drawn from the highest quality trees in the Ouachitas, Boston Mountain, and Ozark Highlands. All shortleaf pine planted on national forest lands in the Ozark-Ouachita Highlands developed from seed produced by this orchard, which has implications for the prevailing genetic diversity of the shortleaf pine resource in the region. The high-grade harvesting that occurred at the turn of the century had a detrimental effect on the shortleaf pine gene pool because the highest quality trees were cut and the lowest quality trees were left to grow. Many of the shortleaf pine stands of today are from seedlings produced within this inferior gene pool. In this light, the seedlings produced through the shortleaf pine tree improvement program have value not only as fast growing trees for timber production but also as seed sources that can contribute to restoring the genetic diversity of the species.

The preparation of an ideal seedling, however, is only the first step in the process required to establish a new stand using artificial regeneration. The second step is to plant seedlings in such a way that they will become established and develop successfully (Hallgren and Ferris 1995, Hallgren and others 1993, Hallgren and Tauer 1989, Harrington and others 1989, Venator 1985, Dixon and others 1979). Site preparation (discussed later) is essential for the second step.

Direct seeding. Direct seeding has occasionally been used to reforest sites in the Ozark-Ouachita Highlands. Technology for the direct seeding of shortleaf pine has existed for about three decades (Derr and Mann 1971). Compounds that contain capsaicin are currently being developed to replace the fungicides made of chlorinated hydrocarbons used in the 1960's and 1970's. Typically about 0.5 pound of treated seeds (~23,000) per acre are broadcast (Lawson 1990). Seed should be applied only on sites that have been prepared to receive planted seedlings (Derr and Mann 1971).

Natural Regeneration

Natural regeneration refers to the naturally occurring processes in trees that result in new seedlings and sprouts. That the Ozark-Ouachita Highlands remain forested today is a tribute to the ability of the region's tree species to regenerate naturally.

When foresters are given a choice between trees (pines or hardwoods) of seed or sprout origin, they prefer trees from seeds. Regeneration from seeds is the result of natural processes of open pollination, flowering, fruiting, and seed-fall. Maternal flowers yield seed after viable pollen is borne to them by wind, pollinating organisms, or other agents. When the best formed, most vigorous trees are left in a given stand to produce seeds, the regeneration will more likely express desired genetic traits. The danger inherent in cutting the best trees and leaving the poorest trees to reforest the site is that the regenerated trees will have genetic traits that result in poor growth.

Pines and hardwoods that have light seeds are generally better adapted to germinate and grow after a disturbance. Under certain conditions, however, seedlings can exist as advance growth or advance regeneration in the understory of a well-stocked stand. If a disturbance should occur and growing space becomes available, the advance growth will be ready to respond and grow.

Shortleaf pine is an erratic seed producer. Good seed crops occur only every 3 to 6 years (Lawson 1990). Thus, it is often difficult to conduct a reproduction cut relying on natural regeneration. To overcome this limitation, a sufficient number of residual trees must remain on the site to ensure adequate seedfall. Site preparation treatments must be timed to coincide with expected seed crops. These requirements can be difficult to meet, especially on national forest lands, where multi-year harvesting contracts limit a forester's ability to coordinate the timing of harvesting with optimal conditions for seedfall, germination, and establishment. The most important influences on establishment of shortleaf pine are the condition of the seedbed and control of competing vegetation, especially competition from hardwoods (Shelton and Wittwer 1996, Boggs and Wittwer 1993, Yocom and Lawson 1977).

One unique advantage of shortleaf pine is its ability to resprout if top-killed at a young age (Lawson 1990).

This habit has unique adaptive value in an environment where frequent surface disturbances such as fire are common.

Conversely, the advance-growth attribute is more critical for hardwoods that have heavy seeds, such as oaks. Oaks are poorly adapted for seed (acorn) dispersal after a disturbance or for fast growth after acorns germinate. However, oaks disperse acorns in most years, and the resulting new seedlings are able to take advantage of light openings when part or all of the high canopy is removed. Oak seedlings usually need to be in place before harvest if they are to succeed in replacing the stand (Bey 1964, Sander 1966, Clark 1970, McQuilkin 1975, Sander and Clark 1971, Sander and others 1976, Loftis 1983, Janzen and Hodges 1987). Oak also has the ability to sprout vegetatively, even at an advanced age. The number of sprouts from a given stump depends on the size of the stump and on site quality. Sprouting is generally greater on better sites, but the bigger the stump, the less likely it is to sprout. Small stumps sprout much better than big ones. Regardless of the size of the originating stump, viable sprouts tend to be fast growing and well formed.

Site Preparation

Smith (1986) defines site preparation as those treatments designed to prepare and treat the site for regeneration. Treatment of unwanted standing trees and logging slash is generally the first practice undertaken following harvest. The methods used for this initial stage include felling unwanted trees with a chain saw, drum-chopping slash and small trees with a rolling chopper pulled by a bulldozer, or shearing unwanted trees with a bulldozer-mounted KG blade.

Controlling competing vegetation is a major goal during site preparation. Stump spouts can be controlled by increasing the intensity of mechanical treatment (such as using a root rake to push all stumps, slash, and tops into piles called windrows) or by applying herbicides. Generally, mechanical methods of site preparation alone do not control sprouting by unwanted hardwoods. Herbicides are often the only effective way to reduce or eliminate hardwood sprouts.

Several herbicides and application techniques are effective after a mechanical site preparation, from a topical application on individual stems to spraying the resprouting vegetation after leaves emerge. Herbicides approved for use in forestry in Arkansas include imazapyr, imazapyr-glyphosate mixtures, imazapyr-metsulfuron mixtures, picloram, picloram-triclopyr mixtures, and picloram-imazapyr mixtures (Baldwin and Boyd 1998). An effective low-cost method that minimizes resprouting is to combine chain-saw felling with an application of a liquid formulation of herbicide (commonly triclopyr) that is applied directly to the cut surface of the stems.

Fire is another tool occasionally used in site preparation. The broadcast burning of felled debris can dispose of slash, top-kill resprouting vegetation, and expose mineral soil, which may be desired for natural or artificial regeneration.

Treatment of mineral soil prior to reforestation can be important for either natural or artificial regeneration in the Ozark-Ouachita Highlands. If exposure of mineral soil is insufficient, implements mounted on small bulldozers can be used effectively to prepare seedbeds for shortleaf pine. Subsoiling or "ripping" is a popular technique for treating mineral soil before planting on both public and private lands in the Assessment area (Walker 1992, Wittwer and others 1986). Ripping breaks through the rocky substrate of the soils and provides seedlings with more moisture so that they have a better chance to become established. Typically, ripping is conducted using a heavy-duty steel implement attached to a large bulldozer. A pair of vertical steel bars is mounted at the ends of an 8- to 10-ft horizontal bar mounted behind the bulldozer. The ripping bars are oriented perpendicular to the soil surface and can be lowered into the soil using the hydraulic power of the bulldozer. The operator can raise or lower the bars from 2 to 3 ft into the soil, and the bars are fixed so that the furrows, or "rips," are 8 to 10 ft apart. The "rips" created by the steel bars break through the rocks commonly found at or near the surface of Ozark-Ouachita Highlands soils, especially in the heavily folded and faulted strata of the Ouachita Mountains.

After the rips are in place, rainfall erodes soil particles into the rips. This small-scale erosion deposits soil in the bottom of the rip and produces a more stable microenvironment for seedlings to become established and to survive. The beneficial effect is most pronounced late in the growing season, when rips retain soil moisture more effectively than unripped microsites.

Additional methods for site preparation can be found in the Vegetation Management Environmental Impact Statement (EIS) for the Ouachita and Ozark-St. Francis National Forests (USDA FS 1990) and the Forest Plan for the Mark Twain National Forest (USDA FS 1986).

Intermediate Treatments

Intermediate treatments represent the set of treatments foresters apply to stands where the desired species are larger than saplings (typically, greater than 0.5 inches [in.] in diameter) but not old enough for reproduction cutting. Smith (1986) defines four categories of intermediate treatments: thinning, release, improvement cutting, and salvage cutting. Three other intermediate treatments (not defined by Smith 1986) are also used.

Thinning

The most common intermediate treatment that foresters apply is thinning, which is defined as the harvesting of some immature trees of desired species so that other immature trees with better developmental potential might thrive. When properly applied, thinning will usually remove the poorer quality trees and improve the growing conditions for the better quality trees.

The thinning method used depends on the relative crown condition of the trees being cut and the trees being retained (Smith 1986). "Low thinning" is the removal of trees with small crowns to create less crowded conditions for trees with larger crowns. Conversely, "crown thinning" is the removal of large trees from the upper canopy of a stand so that the more desirable trees in the upper canopy can be released from competition for light. "Row thinning" is the removal of trees according to a predetermined spacing, such as in a plantation where all of the trees in every third or fourth row are removed. Row thinning is usually the first thinning in a young plantation. The most common thinning practice is "free thinning," in which the poorer trees, regardless of spacing or condition, are cut to release the better trees.

Some nonforesters use the term "selective" thinning to define any of the preceding forms of thinning. Foresters, however, generally object to this terminology because it carries no technical meaning beyond that some trees are "selected" to be cut. The term generally implies cutting the better trees and leaving the poorer ones for reasons that relate more to immediate financial returns than to long-term development of the stand. Selection thinning can also be confused with "selection cutting," which should be reserved for the uneven-aged methods of reproduction cutting.

If the trees cut during thinning are too small to be sold commercially, the thinning is called "precommercial thinning." If the trees cut can be sold to a commercial operator, the thinning is called "commercial thinning." However, thinning is rarely done strictly for commercial reasons. The purpose of thinning is to allow the uncut trees to continue developing at an acceptable rate by using some of the resources of the site (water, nutrients, and light) that the cut trees had been using before the thinning.

Release Treatments

Smith (1986) defines release treatments as those that free desired trees from competing vegetation in stands not yet past the sapling stage. Competitors can be smaller (grasses and other herbaceous plants) or of equal or larger size (woody shrubs and trees). In the Ozark-Ouachita Highlands, common competitors for oaks are other hardwood species that sprout more profusely. For pines, competitors include grasses and sprouting hardwood stems.

Release treatments commonly entail chemical applications, but mechanical methods and prescribed burning also can meet management objectives for release. A list of accepted methods for conducting release on national forests in the Ouachita Mountains and Ozark Plateaus of Arkansas and Oklahoma, including acceptable herbicides and application methods for release, is included in USDA Forest Service (1990). Baldwin and Boyd (1998) list herbicides and application methods approved for release in Arkansas.

Herbaceous weeds are increasingly recognized as significant competitors with newly planted seedlings, especially for soil moisture. Recent research in competition control points to the success of using herbicides for herbaceous weed control in promoting rapid early growth of planted seedlings (Yeiser and Barnett 1991, Yeiser and Cobb 1988). Herbicide release of pines or hardwoods from herbaceous competition is within the scope of approved practices on national forests in

Arkansas and Oklahoma (USDA FS 1990) but is rarely used. The technique is more common on private lands in the region. Treatment commonly includes the use of sulfometuron in mixture with other chemicals. Details regarding application methods and herbicides approved for use in Arkansas are available in Baldwin and Boyd (1998).

As competing vegetation gets larger and more woody, the choice of methods for release expands slightly. Felling with chain saws or other hand tools becomes an affordable alternative in some circumstances. The usual practice is to cut the stems in closest competition with the desired tree. In stands where pines are desired, prescribed fire is occasionally used as a tool for release. Surface fires will affect hardwoods more than pines, providing the latter with a temporary competitive advantage, although hardwood trees often resprout after fires.

Chemical methods are also highly effective for releasing desired stems from woody competitors. One approach is to apply an herbicide directly to the competitor of a desired sapling either by spraying the foliage or bark or by injecting the stem (Yeiser and others 1987, Yeiser 1986). Another approach is to apply an herbicide to the entire area in a way, or in the season, that takes advantage of the differences in susceptibility of hardwoods and pines. For example, pines become dormant in late summer when hardwoods are still actively growing. This window of differential metabolic activity provides an opportunity to apply herbicides in such a way that hardwoods are affected more adversely than pines.

Among the herbicides for which this tactic is approved for use in Arkansas are imazapyr, either alone or in mixture with glyphosate, and metsulfuron (Baldwin and Boyd 1998). Again, these application methods are not appropriate for national forest lands since they were not included in the vegetation management EIS for the Ozark and Ouachita National Forests. However, industrial and nonindustrial private forest (NIPF) landowners may find opportunities for their use.

Thus, the environment for developing a successful program for the release of desired species is well documented in the literature. Forest managers are offered a complicated series of choices to consider. On national forest lands, the options most often selected tend to be those that (1) minimize the use of intensive mechanical activity; (2) minimize the use of herbicides and, if used, limit their application to specific individuals rather than across the entire site; and (3) accept considerable latitude in the number of pines that represent "acceptable establishment."

On private industrial and NIPF lands, the options available to landowners are much broader. Private landowners are not constrained in their choice of the many site preparation methods discussed above, except insofar as they represent reasonable capital investments.

Improvement Cutting

Smith (1986) defines improvement cutting as a treatment applied to stands past the sapling stage (poletimber or sawtimber-sized stands) to remove trees of undesired or inferior species, quality, or condition that are in competition with desired trees. Other terms commonly used synonymously are "cull-tree removal" (which, in the private sector, has tax implications for expensing rather than compounding costs) or "timber stand improvement."

Generally, improvement cutting is the first practice conducted in stands that have been unmanaged or mismanaged for an extended time. If a stand has been attended to during younger ages, the need for improvement cutting is reduced. Improvement cutting is not commonly needed on public or private industry timberlands. The method is more likely to be used on private lands, especially NIPF lands, in the Assessment area.

If the trees removed are of merchantable size or value, improvement cutting often can be done at little or no cost to the landowner by simply selling the unwanted trees to a logging contractor or mill. However, if the trees are of low value and poor quality, as is commonly the case, options for commercial sale may be limited and the landowner may have to pay for the improvement cutting.

Typical ways to conduct improvement cutting by means other than timber sales are mechanical, chemical, or some combination of the two. Mechanical means include simply girdling unwanted trees with a sharp tool, such as a hatchet or machete, or cutting them down with a chain saw. It is generally easier and safer to use herbicides to kill undesired trees.

There are several simple and effective methods of applying herbicides to trees, including injection, hack-and-squirt with a hatchet and applicator bottle, and thin-line basal spray on the bark of the unwanted tree. As noted earlier, herbicides and application methods approved for use in Arkansas are listed in Baldwin and Boyd (1998).

Salvage Cutting

Smith (1986) defines salvage cutting as practices undertaken to cut trees that have succumbed, or are in danger of succumbing, to the actions of disturbance. Based on subjective reports from foresters in the region, the two disturbances that occur with the greatest frequency in the Ozark-Ouachita Highlands are windstorms and insect outbreaks.

Wind damage occurs when linear winds or tornadoes blow down or break trees. Salvage activities generally follow to reduce fuel buildup, reestablish access and power to affected areas, and restore forest health and/or appearance through the felling or harvesting of trees affected by the storms. Insect outbreaks are discussed in Chapter 6.

Other Intermediate Treatments

There are three subsets of intermediate treatments that Smith's (1986) definitions do not specifically address, and which are increasingly common in immature stands in the Ozark-Ouachita Highlands—prescribed burning, fertilization, and pruning.

Prescribed burning. Prescribed burning is the use of fire to achieve forest (or, more broadly, land) management objectives. In a sense, burning is a release or improvement "cutting" technique designed to promote desired fire-resistant species of sapling size or larger at the expense of fire-sensitive species or stems of sapling size and smaller (Yocom 1972). Prescribed burning has the concurrent benefit of restoring fire-adapted shrub and herbaceous communities, while reducing the influence of species not adapted to fire (Masters and others 1993, 1996).

Controlled burning in the Ozark-Ouachita Highlands Highlands is common on national forest lands (see data presented later in this chapter) but is much less common on other lands. Typically, prescribed fire is used in shortleaf pine stands for three primary reasons: to reduce fuel, to improve wildlife habitat, and to restore open forests and herbaceous (grass, forb) components in the ground layer.

Where consistently applied, prescribed fire has greatly benefited ecological restoration of the shortleaf pine-bluestem plant community and improved habitat for the endangered red-cockaded woodpecker and many other birds (Wilson and others 1995, Bukenhofer and Hedrick 1997). Another benefit, one noted by early foresters in the region, is that young shortleaf pines often sprout from the base if they are top-killed by fire (Mattoon 1915). The best opportunities for ensuring natural regeneration of shortleaf pine will probably be in pine forests managed under a prescribed burning regime.

Fertilization. Fertilization refers to the practice of applying a soil amendment to the stand to enhance tree growth. This practice is valuable in situations where soil or foliage analysis indicates that low amounts of one or more essential plant nutrients are limiting tree growth. Fertilization is more commonly used, however, in situations later in the life of the stand where the addition of nitrogen enhances growth within a few years of harvest. The added value of the wood in the stem then exceeds the cost of the fertilizer treatment. Fertilization is an option primarily for forest industry lands in the Ozark-Ouachita Highlands. Fertilization is never used on public timberlands and only rarely used on NIPF lands.

Pruning. Pruning refers to the practice of cutting the lower branches of young trees to develop stems free of knots, which enhances the quality of the wood. The practice is usually conducted by hand, with workers sawing off the branches flush with the stem. Only the first 17 to 18 ft of the bole are pruned, which enables the first 16-ft log in the tree to be "clear" of knots. As with fertilization, pruning is never done on public timberlands in the Ozark-Ouachita Highlands, and only the most zealous NIPF landowner will tackle this arduous task. However, pruning is being conducted extensively on some forest industry lands in the Ozark-Ouachita Highlands.

Silvicultural Practices for Oak-Hickory Stands in the Assessment Area

Much of the Eastern deciduous forest is presently oak-dominated, and foresters and ecologists usually place oak stands in the oak-hickory forest type. Oak-hickory forests, however, may be successionally stable (changing little until a major disturbance occurs) or transitional to forests dominated by other hardwoods (Barrett 1995).

A transitional oak-hickory stand typically has a higher site index (growing to 70 ft or more in 50 years) and is usually found on better soils than a successionally stable oak-hickory stand. But transitional oak-hickory stands are also the most difficult to regenerate to oak. In many cases, the dominant oaks in transitional stands developed after extensive and severe disturbances, such as wildfire, grazing, and/or mowing (Aust and others 1985, Lorimer 1989, Abrams 1992). In the absence of such disturbance, ecological succession on these sites tends toward more shade-tolerant and/or mesophytic (moisture-loving) species (Barrett 1995, Johnson 1993, Sander and Graney 1993).

Data from the Missouri River Hills, an area just north of the Assessment area, show that sugar maple is increasing in importance in the lower layers of oak-dominated stands where disturbance has been greatly reduced (Pallardy and others 1988, Nigh and others 1985). Such mixed hardwood stands, however, occur sporadically throughout the Ozarks and Ouachitas. They make up a relatively small portion of the forest cover of the region and typically are not under active silvicultural management. Therefore, the silviculture of mixed hardwood forests will not be discussed in this chapter.

However, oak-hickory stands themselves differ slightly in species composition across the Assessment area. Researchers think that oak-hickory stands in the Boston Mountains behave differently than oak-hickory stands in the Springfield Plateau. The major difference seems to be the increased prominence of red maple and hickories in the Boston Mountains. FIA data (previous chapter) show that the Boston Mountains contain fewer live hardwood trees per timberland acre than the Springfield Plateau, but 1.5 times the hardwood growing stock volume. Combining three species groups of interest—the soft maples, the hickories, and the tupelo-blackgum group—the Boston Mountains contain 2.6 times the number of live trees and 2.5 times the growing-stock volume per timberland acre than the Springfield Plateau. In addition, 62 percent of timberland acres in the Boston Mountains are capable of producing more than 50 cubic feet of hardwood per acre per year, compared with 53 percent of the timberland acres on the Springfield Plateau. Thus, available data suggest that hardwood stands in the Boston Mountains have slightly higher average productivity and a higher proportion of shade-tolerant midstory species than the Springfield Plateau does. These trends support the empirical observation of forest scientists in the region that oak regeneration is more difficult to obtain in the Boston Mountains than in the Springfield Plateau. These trends also suggest that there may be silvicultural differences in the management of the oak-hickory forest type between the regions.

Successionally stable oak-hickory stands are located on the much more abundant low- to medium-quality sites. These sites tend to be more prone to droughts and to support fewer tree species (Weitzman and Trimble 1957, Roach and Gingrich 1968, Sander and Clark 1971, Barrett 1995). These stands may develop a pool of oak reproduction containing stems established over several decades (Merz and Boyce 1956, Ward 1966, Clark 1970, Tryon and Powell 1984). Such ecosystems are said to be “autoaccumulating” (Johnson 1993).

Translating these observations of natural systems into practical silvicultural recommendations for managed oak-hickory stands has been a challenge. Roach (1962) suggests that if the object is simply to regenerate trees, the method used in the central hardwoods is irrelevant. However, if controlling species composition is an issue, the silvicultural method is paramount. Stout and others (1975) state that successional trends in a mixed species stand are probabilistic and may have multiple pathways depending on the initial species composition, site quality (environmental variables), and chance. Sims (1980) suggests that when oak fails to regenerate in the mid-south, the resulting stand consists of low-quality red maple, dogwood, and sassafras.

Graney (1989) is more blunt. He states that oak must be a significant component of regenerating stands in the Boston Mountains because the alternative is species that are less valuable economically and slower growing. Unfortunately, the species that are less valuable and slower growing tend to be very competitive, especially on better sites. At present, there are few options available for consistently securing oak reproduction.

Oaks must exist as advance growth—small saplings living in the understory before a major disturbance—to compete with other, faster growing vegetation following disturbance. In addition, the size of the advance-growth stem needed to compete is rather robust. Oaks must have a diameter at the root collar (the point where the stem emerges from the soil) of at least 0.5 inches (Sander 1971) or be 4.5 ft tall (Sander and others 1976) to have a high probability of successfully competing after release. Oak reproduction of sufficient size and numbers is usually present in autoaccumulating ecosystems.

Currently, the best available tool for estimating tree regeneration potential in the Ozark Highlands is A Comprehensive Ozark Regenerator (ACORn) (Dey and others 1996). ACORn is available as an MS-DOS computer program and users guide from the Forest Service, North Central Research Station in Columbia, MO. No comparable guidelines are available for the rest of the Assessment area, and it is rarely advisable to use a model outside of the region in which it was developed and tested.

Even-Aged Reproduction Cutting Methods

Conventional silvicultural wisdom suggests that upland hardwoods, oaks in particular, are best suited to even-aged management (Roach 1962, Roach and Gingrich 1968, Clark 1970, Sander 1980, Beck 1988). Roach and Gingrich (1968) compiled an even-aged silvicultural guide based on more than 20 years of research across the central hardwoods region. It includes a key for silvicultural decision-making based primarily on stand stocking percentage and average tree diameter. Site index is used to determine the preferred species mix and rotation length.

Sander (1977) also presents a decision key for tending and regenerating oak-dominated stands and oak mixtures. Regional physiography and site indexes are used to generate broad recommendations for silvicultural prescriptions. Both of these guides draw from experience in and data collected from Missouri and States to the north and east. Although the principles should apply to most oak-dominated systems, foresters should be cautious when applying them in the highlands of Arkansas and Oklahoma. The authors of this chapter know of no general silvicultural guides for the region as a whole. Roach and Gingrich (1968) and Sander (1977), therefore, are the best general resources currently available for even-aged hardwood silviculture in the Highlands.

Clearcutting Method

Clearcutting can be used to regenerate oak stands. Successful regeneration of oak after clearcutting depends on the presence of large oak advance reproduction before the cut. If advance-growth saplings are present, logging and site preparation will often break them off or sever their stems at the root collars. The resulting sprout from the topkilled sapling has among the best developmental potential of any tree in the stand. A sufficient number of advance-growth stems is needed to ensure the timely development of a suitable density of oaks in the future stand (Nyland 1996).

To ensure successful regeneration, the reproductive potential of a stand should be evaluated in advance of harvest. If sufficient reproduction is present, the stand may be regenerated. If not, one of two choices exists—the stand may be site-prepared to stimulate oak germination and establishment, or oak stump sprouts can be relied on to supplement the existing oak advance growth.

In successionally stable oak-hickory stands, the absence of large oak advance regeneration does not mean the site will never regenerate to oak. In fact, the authors were unable to find a single documented case in the Assessment area of a long-term compositional shift after an oak-hickory stand was clearcut and abandoned. However, if sufficient numbers of large advance reproduction and potential trees from sprouts are not present, the regenerating stand may remain covered by dogwood, sassafras, and/or woody shrubs for an extended period (30+ years). When the succeeding oak stand emerges from this brush stage, it is likely to be understocked and have many poorly formed (open-grown) trees.

Reliance on oak stump sprouts requires post-harvest treatment. When a stand is clearcut, all desired stems greater than 2 in. in diameter at breast height (d.b.h.) should also be cut. In the absence of additional treatment, these hardwoods will resprout. If sprouting is not desired from a given stem, it should be injected with herbicide or girdled instead of being cut. If cut, the stump should be treated with a herbicide (Roach and Gingrich 1968, Gottschalk 1983, Beck 1988).

Oak stump sprouts have good developmental potential. Based on a study of white oak, 10-year height growth of a stump sprout is approximately 35 percent greater than from sprouts of advance reproduction, and stem form is comparable (McQuilkin 1975). Height growth reaches a maximum in sprouts originating from stumps with a diameter of 6 in. (Johnson 1979).

Seed-Tree Method

This regeneration method typically is not used to regenerate oaks or other species with heavy seeds that rely on advance reproduction (Sander 1980, Gottschalk 1983). Hardwoods with light seeds, such as sweetgum, tend to remain viable on the forest floor for several years. These species tend to have adequate seed production annually (Roach and Gingrich 1968, Clark and Boyce 1964, Young and Young 1992, Gottschalk 1983); therefore, the seed-tree method is not suited for their regeneration, either.

The seed-tree method has been suggested for the oak-hickory type for purposes other than regeneration, including aesthetics, mast production (for wildlife), and structural diversity. Each of these objectives has merit but has little, if anything, to do with regeneration.

Shelterwood Method

In the event that a preharvest survey of regeneration potential indicates that advance reproduction and sprout potential are inadequate or of unacceptable composition, managers can use the shelterwood method to encourage the development of vigorous advance-growth oak saplings. The shelterwood method consists of several sequential cutting operations. Each cut leaves fewer residual trees than the previous one. This method is designed to favor the establishment and development of oak advance growth and to control competing vegetation. When the advance growth is sufficiently dense and of sufficient size, the final removal cut is made to promote its development into the future stand. When possible, stand density is reduced by thinning from below. Initial stocking levels of 60 percent are typically recommended to develop oak reproduction (Sander 1980, Gottschalk 1985). When properly applied, the shelterwood method is quite successful in regenerating oak (Loftis 1990, Graney 1989, Johnson 1993).

The remaining high canopy trees (overwood) should not be removed until the advance reproduction and sprout potential is sufficient to regenerate the stand. If adequate acorn crops are infrequent or establishment and development are slow, this process may take up to 30 years (Gottschalk 1983). An additional preparatory cut may be needed to maintain the vigor of the developing saplings if stand stocking reaches 75 to 80 percent during the period of regeneration. As the advance reproduction develops, overstory stocking may be reduced below the 60 percent level. Sander (1980) suggests reducing stocking to about 50 percent if a second preparatory cut is needed.

In the Boston Mountains, an initial shelterwood cut to 60 percent stocking resulted in the greatest increase in the numbers of oak, ash, and black cherry reproduction (Graney and Rogerson 1985). Additionally, fertilization increased 5-year height growth of ash and cherry but did not affect the oaks. A similar study found little difference in the growth rates of oak, ash, and cherry at stocking levels of 40 and 60 percent but noted a greatly increased amount of undesirable competition at the 40 percent stocking level (Graney 1989). This same study found that understory control (herbicide application of cut stems) decreased undesirable competition, and the intensity of competition control directly affected height growth of oak, ash, and cherry. Competition control may prove to be the most important factor in regenerating oak on these mixed-hardwood sites.

Where an extended regeneration period is not an option and natural regeneration has not produced the large advance reproduction needed to successfully regenerate a stand, underplanting may be an option. Johnson and others (1989) successfully established 30 to 50 percent of planted northern red oak in Missouri. They controlled the understory with herbicides, reduced overstory stocking to approximately 60 percent, planted large diameter seedlings (greater than 0.5 in. root collar diameter), and removed the shelterwood after three growing seasons. The total cost for this treatment was estimated to be between $200 and $400 for planting 400 to 800 seedlings. Establishment probabilities increase with an increase in seedling size but so do costs of nursery stock and planting.

When the reproduction beneath a shelterwood is sufficiently well established, the overwood is typically removed. However, the resulting visual impact is the same as that of a relatively young stand, which is not desirable in some instances. When a high-forest canopy is desired to meet aesthetic or forest-structure goals, and uneven-aged management is not an option, some portion of the overwood may be retained for a time, even indefinitely. This system is called an irregular shelterwood.

The irregular shelterwood may offer many advantages: (1) the maintenance of a high forest canopy; (2) opportunities to harvest timber and generate returns on a shorter cycle than for clearcutting; and (3) the regeneration period is extended as needed because of the on-site seed source. However, there are some important limitations. The remaining overstory trees are prone to epicormic branching (new branches sprout vertically from older branches suddenly exposed to full sun) and other structural defects. The overstory may suppress the development of the subordinate trees if not kept at a sufficiently low level of stocking. Finally, lightning and wind-throw may eliminate some or all of the residual overstory trees.

Research support, however, for the irregular shelterwood method in oaks is limited. The only long-term study of the method is in West Virginia, where Miller (1996) found that defects could be kept to an acceptable level by retaining only trees with little or no preharvest epicormic branching and the greatest vigor. The same relationships probably would apply in the Assessment area.

Uneven-Aged Reproduction Cutting Methods

Group Selection Method

Group selection may be an appropriate way to maintain shade-intolerant tree species in a stand when circumstances preclude the use of even-aged silvicultural systems (Roach and Gingrich 1968, Sander 1977). Law and Lorimer (1989) present a good overview of the method along with some general guidelines for implementation. Because regeneration occurs only in the openings ("groups") when using this method, some proportion of the stand must be regenerated on a regular basis to maintain a stable diameter structure. Size and placement of these groups are critical.

When using the relatively small openings of a group selection harvest, variation in size and orientation of openings affects their suitability for some species (Marquis 1965). Light management is the main issue affecting the size of group openings. Fischer (1981) developed a computer model, SHADOS, that calculates the effect of size, shape, and aspect on light availability in a group opening.

Decisions about placement of group openings must be made on site, not in the office. Foresters must examine local conditions to identify areas where robust advance reproduction (seedlings and saplings) is already available and ready for "release." In group openings where such seedlings and saplings are absent, oak regeneration is not likely to develop.

Group selection can be used to convert even-aged stands to ones with uneven-aged structure. In southern Illinois on an oak-hickory site, Schlesinger (1976b) found that both diameter structure and species composition were fairly stable after 16 years.

Murphy and others (1993) presented a thorough discussion of the group selection system, including alternative methods for dealing with stand regulation (area versus volume control) and a methodology for using group selection to convert even-aged stands. They also present an argument for placing a limit of two tree-heights on the size of group selection openings. Harvest openings significantly larger than this are considered patch cuts or clearcuts. Graney and Murphy (1997) recently installed a large-scale experiment to test the feasibility of converting even-aged stands in the Boston Mountains to uneven-aged structure using both single-tree selection and group selection.

Single-Tree Selection

Roach and Gingrich (1968) asserted that "upland hardwoods cannot be reproduced with single-tree selection." Although there is at least one major landowner in the Highlands whose experience suggests otherwise, there is substantial evidence that supports their finding as it pertains to mesic (moist) forests (Schlesinger 1976, Della-Bianca and Beck 1985, Trimble 1970, 1973). Most experimental trials of single-tree selection in oak-dominated forests, in fact, have been made in the more mesic portions of the central hardwoods forest where oaks tend to be displaced successionally. In such areas, single-tree selection accelerates the shift toward more shade-tolerant species.

On drier sites, there is evidence that the use of single-tree selection can sustain stands of oaks and other drought tolerant but shade-intolerant hardwoods (Johnson 1993, Loewenstein and others 1995, Loewenstein 1996). Pioneer Forest, a large, privately owned tract in the Ozark Highlands, has been managed with single-tree selection for over 45 years. During this time, the diameter structure of the forest has remained remarkably stable. Since 1957, the oak component plus shortleaf pine have made up over 90 percent of the total stems and the total basal area of the forest (Loewenstein and others 1995, Loewenstein 1996). A 1992 inventory showed white oak was the most common species in the understory (1.6 to 4.9 in. d.b.h.), which suggests that a compositional shift toward more shade-tolerant species is not occurring. Scientists speculate that oak apparently is able to regenerate under this system because the forest is autoaccumulating and its managers maintain stands at relatively low stocking levels (data on file at the North Central Forest Experiment Station, Columbia, MO).

The periodic reduction of stocking below full site utilization is essential to the periodic recruitment of oak into the stand (Larsen and others 1997). Preliminary silvicultural guidelines suggest a target diameter distribution defined by a residual stand stocking of between 50 and 55 percent, a cutting cycle of 15 to 20 years, and a q-value (quotient of the number of trees in the x^{th} diameter class divided by the number in the $(x+1)^{th}$ class such that the distribution of diameters across all classes forms a reverse J-shaped curve) of approximately 1.7 (2-in. diameter classes). The most critical variable in the target distribution is stocking; stand stocking should not exceed 75 percent, unless the youngest saplings succumb to mortality from competition for light, water, and nutrients.

Thinning

Thinning allows selected crop trees to grow more freely, modifies stand composition and structure, and reduces natural mortality. If a regular thinning schedule is begun early in the life of a stand, rotation length may be reduced by 40 percent (Gingrich 1970). The stimulating effect of thinning has been maintained for 20 years in pole-sized white oak (Schlesinger 1978) and 10 years in 40-year-old black and scarlet oaks (Durham and others 1983).

Trials conducted in the Missouri Ozarks suggest that the most profitable thinning schedule for black and/or scarlet oak stands (assuming a market for small diameter products is available) is to begin with a precommercial thinning at age 30 followed by additional thinnings at 10-year intervals to age 80 (Kurtz and others 1981). Even when there is no market for small diameter products, a single precommercial thinning to a residual basal area of 65 to 70 square feet per acre (ft^2/ac) at age 30 significantly increased value over not thinning (Kurtz and others 1981). In another study, beginning a thinning regime at age 40 and carrying the stand to age 63 yielded a financial gain of 35 percent in net present value (Dwyer and Kurtz 1991).

Proper residual stocking levels must be considered when developing a thinning schedule. Growth following thinning in mixed stands of black and scarlet oak seems little affected by residual basal areas in the range of 50 to 70 ft^2/ac (Durham and others 1983). If residual stand stocking is not reduced below 50 percent, tree quality is not seriously affected (Dale and Sonderman 1984). However, thinning to a level below full stocking wastes growing space and reduces yield and return (Durham and others 1983). Reducing the stocking to approximately 60 ft^2/ac (the "B-level" specified by Gingrich 1967) is the heaviest thinning recommended.

Often, foresters' first efforts at thinning occur in previously unmanaged stands. The last stocking-control thinning should be made at approximately two-thirds of the rotation age (60 to 70 years for oak on medium quality sites) (Roach and Gingrich 1968).

Graney (1989) says that oak must be a significant component in young stands in western Arkansas or the forest will be stocked with less valuable, slower growing species. An initial shelterwood cut to 60 percent stocking resulted in the greatest increase in the number of oak, ash, and black cherry reproduction (Graney and Rogerson 1985). A similar study found little difference in growth rates of oak, ash, and cherry at stocking levels of 40 and 60 percent but noted a greatly increased amount of undesirable competition at the 40-percent stocking level (Graney 1989). The same study concluded that understory control (herbicides applied to cut stems) decreased competition and that the intensity of competition control directly affected height growth of oak, ash, and cherry.

Silvicultural Practices for Shortleaf Pine Stands in the Assessment Area

Summaries of shortleaf pine literature, with special reference to silviculture, are found in several sources. Lawson (1990) and Lawson and Kitchens (1983) present information on silvicultural systems for shortleaf pine. Citations of older literature are found in a bibliography on shortleaf pine that covers literature from 1896 to 1984 (Hu and Burns 1987). However, this reference does not distinguish between citations about pure stands of shortleaf pine in the Ozark-Ouachita Highlands versus the very different stands of mixed loblolly-shortleaf pine (in which shortleaf is a minor and varying component) in the West Gulf Coastal Plain and in the southern and southeastern Piedmont and Coastal Plain. A third summary of shortleaf pine is found in the proceedings of the Symposium on the Shortleaf Pine Ecosystem, published as an unnumbered State Extension Service document (Murphy 1986). Papers in this publication refer more directly to the shortleaf pine type in the Highlands. Baker (1992) provides an overview of reproduction cutting methods and natural regeneration in shortleaf pine from a theoretical basis. Site quality assessment and site-index curves applicable to shortleaf pine in the Highlands are also available (Graney 1976; Ferguson and Graney 1972, 1975; Graney and Burkhart 1973; Graney and Ferguson 1972).

National forests in the Highlands rarely plant conifers other than shortleaf pine, the only native pine species in all but the southernmost part of the region. The private sector enjoys greater flexibility in terms of species to plant. In fact, a major forest industry in the Highlands has conducted extensive research on loblolly pine in the Highlands and planted this species well to the north of its natural range as defined in Critchfield and Little (1966).

Planting loblolly pine outside its range does involves some risk. Why the natural range of loblolly pine stops in the southernmost part of the Highlands is poorly understood. The risk is that the conditions that limit the range of loblolly pine naturally might adversely affect plantations at some point in their development. A 1980 drought in Arkansas, for example, killed loblolly trees in some plantations established from non-Arkansas seed sources (Lambeth 1984). Yet the 1-year drought in 1980 was not the worst on record in the State. A drought of similar intensity occurred during a 3-year period in the 1950's. There is a question as to whether loblolly plantations in the Highlands could survive an extended drought if one should occur. Because of the considerable economic benefits provided by widespread planting of loblolly pine in the Highlands, an environmental and economic risk analysis of the practice might be beneficial. Loblolly pine, however, is not discussed further in this section.

Even-aged Reproduction Cutting Methods

Clearcutting and Planting

Clearcutting and planting is an excellent reproduction cutting method for shortleaf pine stands in the Highlands. All clearcuts on public timberlands and almost all that are done on private timberlands owned by forest industry in the Assessment area are reforested by planting. This combination of clearcutting and planting is a highly reliable way to regenerate shortleaf pine and pine-hardwood stands in the Highlands.

Clearcutting typically results in harvest of all merchantable pines on the site. Site preparation begins after the harvest ends. It is usually done using mechanical means, such as shearing with a bulldozer-mounted KG blade, drum-chopping with a rolling chopper pulled by a bulldozer, or chainsaw felling. Occasionally, unharvested material is scraped into piles or windrows. Only the most intensive methods result in diminished hardwood sprouting. Herbicides generally must be used to further control sprouting. Several herbicides and application techniques are effective, including spraying resprouting vegetation (Baldwin and Boyd 1998).

Fire is frequently used for site preparation after clearcutting, since there is little concern about damage to residual trees. The major reason to use fire after clearcutting is to get rid of slash and other logging debris and to topkill unmerchantable small trees left behind after the clearcut. Even though fire will also expose the mineral soil, this is not an important result if the stand is to be planted.

Ripping is used after clearcutting to create furrows for planting. Shortleaf seedlings planted in “rips” have survival rates at least 20 percent greater than those planted on unripped sites (Walker 1992). Such differences often represent the difference between plantation success and failure in the Highlands.

The final step in establishing a new stand is to plant seedlings. Typical planting densities recommended for shortleaf pine depend upon landowner objectives. On national forest lands, densities resulting in 300 or more trees per acre of free-to-grow shortleaf pine stems are generally acceptable; greater densities allow more opportunities for commercial thinning to improve stand conditions over time. Generally, spacings of 6 by 8 ft (908 trees/ac) are recommended under the Conservation Reserve Program guidelines. National forest clearcuts typically have been replanted using spacings of from 7 by 8 ft (778 trees/ac) to 8 by 10 ft (544 trees/ac).

Clearcutting and plantations have been so unpopular with the general public in the region that national forests in the Highlands typically no longer clearcut and plant except under exceptional situations. These exceptions include the rehabilitation of poorly stocked lands that come into Government ownership and the reforestation of areas affected by catastrophic disturbance.

Natural regeneration after a clearcut is an option for shortleaf pine (Lawson and Kitchens 1983). The size of the clearcut, however, must be much smaller than the one designed to precede planting because seed dispersal is likely to be limited. In one approach, the stand is clearcut in a patch or in strips small enough that the seeds can blow in from surrounding trees. Seeds can travel 66 to 132 ft from the nearest producer (Yocom 1971). The most effective way to combine natural regeneration with clearcutting is to cut narrow strips no more than 2 to 4 chains (132 to 264 ft) wide, oriented perpendicular to the prevailing winds. However, the authors know of no instances in the Highlands where managers use strip clearcutting with natural regeneration.

The second option for natural regeneration is to rely on seeds already on the site. The stand can be felled in the autumn when cones are mature but before the seeds have dispersed. The tops of the harvested trees will dry out quickly; the cones will open; and mature seeds should fall to the ground, germinate, and become established (Smith 1986, Lawson 1990). While theoretically feasible, this option is risky. It only gives one chance for the overstory trees to naturally seed the site. If the technique does not result in successful seedling establishment, then the only option is the more expensive process of planting.

Seed-Tree Method

The seed-tree method can be an effective tool for regenerating shortleaf pine (Brinkman and Rogers 1967, Lawson and Kitchens 1983). Obviously, the trees that provide the seeds are critical. Brinkman and Rogers noted that 5 (preferably 10) well-spaced trees per acre were necessary; Lawson and Kitchens suggested 10 to 16 trees/ac. This range of from 5 to 16 trees would result in spacing between trees of from 93 to 52 ft. A spacing between trees of 66 ft, which according to Yocom (1971) would provide reliable seed dispersal in both windward and leeward directions, results in 10 trees/ac.

The ratio of seed coverage can be considered as well. If a tree disperses the seeds in a circle with a 66-ft radius circle, each tree covers 0.31 ac. Five and 16 trees/ac provide 1.57 and 5.02 ac of seedfall area per acre.

In Missouri, good shortleaf pine seed crops occur every 5 to 7 years (Brinkman and Rogers 1967). Other references cite data suggesting good seed crops occur every 3 to 6 years (Fowells 1965). In the most comprehensive study to date, Shelton and Wittwer (1992) reported three good or better seed crops over a 9-year period in the Highlands. However, there were periods and areas (especially the western Ouachitas) where seed production was more limited. Thinning trees several years before harvest was important because this allowed trees to enlarge their crowns and increased their likelihood of successful cone crops. As in other pines of the South, cone production is a highly inherited trait (Dorman 1976). Since shortleaf pine retains its cones well after seed dispersal, one of the keys to choosing seed trees is to look for evidence of cone production in the past.

Shelton and Wittwer (1996) and Guldin and others (1993) suggest that dense stands of shortleaf pine that have not been recently thinned contain many trees with small crowns and little evidence of cone production. Furthermore, crowns and cones respond to treatments that provide growing space in the canopy. Thus, in unthinned shortleaf stands, marking and leaving seed trees may be less effective than thinning before harvest, observing which of the residual trees become fruitful, then choosing seed trees based on direct evidence of cone production.

To the extent possible, site preparation after harvest should be associated with seedfall. Logging and mechanical site preparation after logging must be done carefully to minimize damage to the residual trees. Burning is easier to conduct before a harvest than after a harvest, because harvesting will add considerable inflammable material to the forest floor, thereby increasing the risk that overly hot fires will damage the residual trees. Logging by itself can provide sufficient exposure of mineral soil to ensure that favorable seedbeds exist for naturally regenerated seedlings to become established and to develop.

Shelterwood Method

The shelterwood method is another successful reproduction cutting method for shortleaf pine (Lawson and Kitchens 1983, Shelton 1997). Lawson and Kitchens report that recommended residual basal areas for the shelterwood method are between 50 and 60 ft^2/ac or when "half the stand" is retained. Shelton used target residual basal areas of 30 ft^2/ac. Other studies in the region used shelterwood prescriptions that leave 30 to 40 ft^2/ac of pine in the overstory (Guldin and others 1994).

Shelton (1997) reviewed the significance of hardwood competition for shortleaf pine. He observed that adding 15 ft^2/ac of hardwoods to 30 ft^2/ac of pines essentially doubled the effective canopy coverage. To meet a shelterwood target basal area for pine seedling development of 40 ft^2/ac by retaining both overstory pines and overstory hardwoods, the basal area of the hardwoods must be doubled and added to the pines. Both the seed-tree and shelterwood methods can probably be adapted to accommodate the added shade from hardwoods in mixed-species stands.

As with the seed-tree method, site preparation after harvest should be associated with seedfall. Logging and mechanical site preparation after logging must be done carefully to minimize damage to the seed-bearing trees—and the more trees that remain after harvest, the more difficult this becomes. Burning is easier before the harvest than after the harvest because harvesting will add considerable fuel to the forest floor, which will increase the possibility of damage to the residual trees.

Logging might provide sufficient exposure of some mineral soil to ensure favorable seedbeds for naturally regenerated seedlings. However, mineral soil exposure will probably be less than after a seed-tree harvest because fewer trees are being cut. Therefore, foresters must determine if mineral soil exposure is adequate and, if necessary, conduct a treatment to expose additional mineral soil. A scarification tool pulled by a small bulldozer has been effective for this sort of seedbed preparation in operational practice in shortleaf pine stands on national forests in Arkansas.

The timing and degree of overstory removal should be considered in the shelterwood method. Data suggest that natural, even-aged stands of shortleaf pine in the Ouachita Mountains add about 2 ft^2/ac annually (Murphy and others 1992). If the residual basal area under a shelterwood is 40 ft^2/ac, in 10 years the basal area will increase to 60 ft^2/ac. At this point, regeneration may become suppressed (Shelton 1997, Baker and others 1996). Thus, to ensure long-term sustainability, some removal cutting in the residual stand will become necessary. One option is to remove the overstory after natural regeneration is established. Another is to manage for a two-aged stand, removing part but not all of the residual overstory when sapling development might be suppressed.

In summary, the shelterwood method is an effective method for regenerating shortleaf pine in the Highlands. Where seed production is the most limiting factor for successful natural regeneration, the shelterwood method is preferable to the seed-tree method. Shelterwoods leave more residual trees and produce higher seedfall. If overstory hardwoods are mixed with pines in the shelterwood, care must be taken to ensure that the added cover from hardwoods does not impede regeneration. Long-term retention of the shelterwood overstory must be observed so that all or part of the canopy can be removed if regeneration is being adversely affected.

Uneven-Aged Reproduction Cutting Methods

Little is known about uneven-aged silviculture in shortleaf pine stands in the Ozark-Ouachita Highlands (Murphy and others 1991, 1993). However, research in the Coastal Plain loblolly-shortleaf stands at the Crossett Experimental Forest (e.g., Reynolds 1969, Reynolds and others 1984) provides considerable knowledge about uneven-aged silviculture in Arkansas pine stands. Two factors limit the interpretation of that work: (1) the differences in silvics, especially regeneration ecology, of loblolly pine compared with shortleaf pine; and (2) the difficulty of harvesting on the terrain in the Highlands. Experiments to test uneven-aged methods are in place to compare group selection and single-tree selection stands in the Ouachita Mountains and Arkansas Valley (Shelton and Murphy 1997, Guldin and others 1994).

Lawson and Kitchens (1983) reported that shortleaf pine can be managed using the selection system. They note that the system has been used in understocked stands and that control of hardwoods has been applied. They cite Reynolds (1969) to support their observations. At least one timber company in the Highlands uses uneven-aged silviculture for shortleaf pine. The goal of this company is to produce high-quality sawlogs, and they have found that uneven-aged silviculture best meets this goal. One key to that company's success is that it has controlled hardwoods with herbicides. In light of the observed effects of hardwood canopies on forest regeneration (Shelton 1997), it is unclear whether mixed pine-hardwood stands can be managed using uneven-aged reproduction cutting methods.

Group Selection

The group selection method increasingly is being used in shortleaf pine on national forest timberlands in the Assessment area. With this method, the stand is managed by periodically creating openings as large as 2 ac. The forest matrix between the openings is often thinned. No long-term research data exist that can enable scientists to determine if the method is sustainable either in the short term or the long term. Several studies are in place, however, to examine the feasibility of the method (Shelton and Murphy 1997, Guldin and others 1994).

The goal of the method is to develop a series of age classes so that the stand will be sustainable in regeneration, growth, and volume production. Natural seedfall from nearby stands, together with seeds produced on site during harvest, produce the regeneration. Generally, site preparation and release treatments take place only in the groups because regeneration is not expected between the groups. Loggers like to use the group openings as the concentration point for skidding logs from the woods and loading them onto their trucks. As a result, most of these openings are heavily disturbed during logging. This creates a suitable seedbed for pine seedlings to become established.

Regulation of group selection stands is the subject of considerable debate (Murphy and others 1993). Regulation methods that rely on assessment of structure or volume are generally thought to be more consistent with the philosophy of uneven-aged silviculture than regulation by area. Area-based regulation approaches to group selection tread closely to the notion of patch clearcutting.

Despite these theoretical concerns, group selection has recently been a popular choice in the Interior Highlands. Reliance on natural regeneration in the group openings suggests openings should be small and under the ecological influence of the surrounding stands. Preparation of the seedbed and control of competing vegetation is probably more important in the group selection method than other methods, since some alternatives for seedbed preparation, such as prescribed fire, are less feasible in group selection than in other reproduction methods.

Single-Tree Selection

The single-tree selection method is currently the subject of considerable interest in shortleaf pine stands in the Assessment area (Murphy and others 1991; Baker 1994; Guldin and others 1993, 1994; Shelton and Murphy 1997). Lawson and Kitchens (1983) reported shortleaf pine can be managed in uneven-aged stands, but they cited no data from pure shortleaf stands in the

Highlands to support the contention. Long-term data demonstrating the feasibility of the method do not yet exist.

However, empirical observations support the contention. A major timber company in the Assessment area has managed an extensive land base in the Highlands using the selection method for several decades. The timber company maintains a residual basal area in the stand after harvest of between 50 and 60 ft^2/ac, marking trees only from the sawtimber component of the stand, allowing the sub-sawtimber component to develop without regulation and managing primarily for pine. Herbicides are used during every cutting cycle harvest to control hardwoods.

As pointed out in Lawson and Kitchens (1983) and Baker (1992), Coastal Plain loblolly-shortleaf pine stands can be managed with single-tree selection. This provides a starting point for applying the method in shortleaf pine stands of the Assessment area, using adaptations of the method developed at Crossett. In southern Arkansas, foresters have regulated stands by either the volume control-guiding diameter limit method (Reynolds and others 1984) or the structural control method.

These efforts are directed toward obtaining shortleaf pine regeneration with every harvest and securing successful development from seedling to maturity. Shelton and Murphy (1997) observed that hardwoods severely affect environmental conditions in the understory and suppress pines. Shelton (1997) suggests that hardwoods have twice the apparent canopy cover of pines per square foot of basal area. Hardwoods may adversely affect pine establishment and development at pine basal areas close to 60 ft^2/ac (Shelton and Murphy 1997). Considerably more research is needed to quantify the relative influence of pines and hardwoods, especially at basal areas of 60 ft^2/ac and higher.

The most critical element in applying the single-tree selection method in shortleaf pine is to ensure regeneration establishment and development. Doing so requires a balance of proper shade management, appropriate actions for site preparation and preparation of the seedbed, and sensitivity to the early differences between height growth of sprouting hardwoods versus seed-origin pines (Baker and others 1996, Guldin and Baker 1998, Shelton and Murphy 1997). There is probably less room for error in the application of uneven-aged single-tree selection method than in any other reproduction cutting method. The tendency is to leave too many trees, provide too little mineral soil exposure for seedling establishment, and allow too much vegetation to compete with the pine seedlings. If regeneration fails, however, reproduction cutting can be reapplied or a supplemental site preparation treatment can be used.

In summary, application of the single-tree selection method in shortleaf pine is in its infancy in both research and practice. Data from empirical practice and research studies suggest careful attention to residual basal area, careful preparation of seedbed and site, and control of competing hardwoods are keys to success. Success must be defined in terms of establishment and development of pine regeneration, regardless of regulatory scheme. However, application of the method can be done conservatively, with opportunities for incremental retreatment of the overstory and/or understory if regeneration is not obtained.

Thinning

Shortleaf pine responds well to thinning, as Lawson (1990) and Lawson and Kitchens (1983) document. The advantages of thinning include accelerated diameter growth and development of larger trees more rapidly than in unthinned stands. The intensity of thinning depends on ownership objectives, since more intensive thinning enhance individual tree volume development at the expense of stand volume.

Wittwer and others (1996) note that shortleaf pine in the Ouachita Mountains responds to release, with diameter increases more pronounced in the eastern Ouachitas than the western Ouachitas. Nickles and others (1981) note that precommercial thinning can be accomplished with prescribed fire and herbicide application.

Numerous reports, then, demonstrate the response of shortleaf pine to thinning. As more models are developed with individual tree capability, the ability of forest managers and landowners to project the outcomes of alternative approaches will increase.

Silvicultural Practices on the Highlands' National Forests

The three national forests in the Assessment have undergone dramatic changes in silvicultural practices over the last 10 years. This section summarizes those changes.

Data Sources

Each national forest in the Assessment area provided data for 1986 through 1997 in the following broad categories of silvicultural activity: volumes offered and cut, reproduction cutting methods employed, reforestation, site preparation, release treatments, and intermediate treatments. Because of differences in reporting methods and requirements on each national forest, uniformity at a detailed level was not possible. However, general categories and trends were reported that offer insights into the changing nature of silvicultural activities on national forests over time.

National forests report the progress of their timber program in several ways. Briefly stated, three volume measurements are used. The first, "volume offered," is the total volume of timber offered to bidders in a given fiscal year (recorded at the point when the timber sale is advertised to the public). This is the primary variable national forests use to judge whether the timber program meets levels suggested by Congress and allocated by national and regional headquarters of the Forest Service.

A second, "volume sold," is the amount of timber actually sold for harvest. This measure generally reflects the volume offered on a year-by-year basis, after accounting for variation resulting from timber being offered at the end of a given fiscal year and sold in the subsequent year, since nearly all advertised timber sales are sold. If a forest did not report volume offered, volume sold was used for comparison.

Finally, "volume cut" is the amount of timber actually harvested in a given fiscal year. It does not exactly mirror the others, since timber purchasers generally are given contracts that span several years.

The Terrestrial Team requested data on reproduction cutting by type of cutting method, reported in acres treated per year. The Ouachita National Forest reported reproduction cutting data for 1986 through 1995 (uneven-aged methods) or 1996 (even-aged methods); the Ozark-St. Francis National Forests reported data for 1987 through 1997; the Mark Twain National Forest reported data for 1988 through 1995.

There were some differences in reporting by year in specific instances. For example, the Ouachita reported total uneven-aged reproduction cutting, but not single-tree and group selection totals, in 1996. The Team accounted for these discrepancies as missing data when preparing graphs.

The Team also requested reforestation data by planted versus naturally regenerated for pine, hardwood, and total. All forests provided total reforestation area. The Ozark-St. Francis National Forests were able to provide data broken down by species and whether reforestation was by planting or natural regeneration. The Ouachita National Forest provided data for pine seedlings planted and pine regenerated naturally.

The Team requested data on specific forms of site preparation: ripping, shear/rake/windrow, other scarifying, manual felling, chemical by area, chemical by stem, prescribed burning, and other. However, national forests do not track site preparation by such specific categories. Combinations are typical, and reporting requirements vary by region.

In addition, land managers use some site preparation techniques by themselves and others in combination. Records of these treatments may also vary. For example, if manual felling is done alone in one stand and done in conjunction with herbicide treatment in another, the method of recording the treatments may differ from one forest to another. Because of these limitations, only two of the three national forests were able to report on total site preparation, and these reports only included a subset of the requested categories.

The Team sought data concerning specific forms of release treatment: herbicide treatment using aerial spray, herbicide treatment of individual stems, manual cutting, and other methods. However, the same reporting difficulties described for site preparation apply for reporting of release treatments as well. Only two of the three national forests were able to report on release treatments, and these reports only included a subset of the requested categories.

The Team obtained some data regarding intermediate treatments, including (1) precommercial thinning,

(2) commercial thinning, (3) prescribed fire, (4) wildlife habitat improvement, (5) midstory removal, and (6) timber stand improvement. There was insufficient uniformity in the available information for the Team to assess use of these treatments across the Assessment area. Thus, total acres treated and trends in individual treatments are reported for each national forest.

Patterns and Trends

Volume Harvested

Over the last 12 years, the volume of timber offered on the three national forests in the Assessment area has declined, from slightly more than 300 million board feet in 1986 to 225 million board feet in 1997 (fig. 4.1). The highest volume offered was 340 million board feet in fiscal year 1987; the lowest was 150 million board feet in 1991.

The decline in volume from 1987 to 1991 was dramatic, and the result of both internal and external influences which together acted to limit the timber sale program. The total decline in volume offered on the three national forests between 1987 and 1991 was 192 million board feet, of which 70 percent occurred on the Ouachita National Forest and 21 percent on the Ozark National Forest.

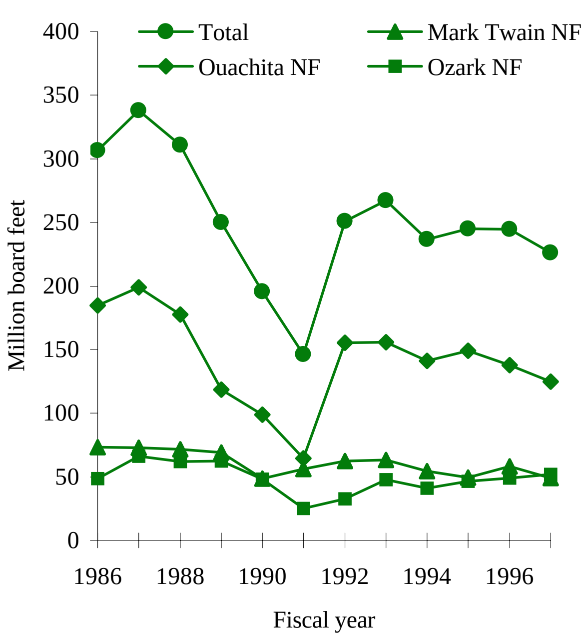


Figure 4.1—Timber volume offered (Ouachita National Forest) or offered and sold (Ozark-St. Francis and Mark Twain National Forests) on the national forests in the Assessment area, 1986 through 1997. (Comparable data were not available for all forests; volume offered and volume offered and sold in a given year tend to be nearly identical, however.)

Since 1992, however, the total volume offered by the three national forests has declined from slightly more than 250 million board feet in 1992 to slightly less than 225 million board feet in 1997. Of the three national forests, the Ouachita and Mark Twain National Forests have seen slight declines in volume offered over the past 6 years, whereas the Ozark-St. Francis National Forests have seen a slight increase.

The volume cut on the three national forests reflects the pattern in volume offered—declines from 1986 to 1992, followed by increases from 1993 through 1996 (fig. 4.2). Generally, the annual change in volume cut is less than that of volume offered, and variation in annual changes is less as well, as suggested in the following tabulation:

Annual change	Mean	Standard error
	- - - *Million board feet* - - -	
Volume offered	36.6	8.91
Volume cut	30.7	6.46

This relationship exists because the 3-year contract window typically given to timber purchasers attenuates the annual variation in volume offered. As with volume offered, the volume cut on the Ouachita National Forest has been much more variable than the volumes cut on either the Mark Twain National Forest or the Ozark-St. Francis National Forest.

The minimum for volume cut (which occurred in 1992) is a year later than the minimum for volume offered (fig. 4.3). Comparable time lags are apparent from 1988 through 1992, when volumes from national forests were declining. Timber purchasers were unable to maintain a backlog of purchased volume during these years and essentially cut the available amount soon after it was sold. Since 1992, the general trend has been for volume cut to be slightly less than the previous year's volume offered, suggesting some portion of volume offered is not being immediately cut.

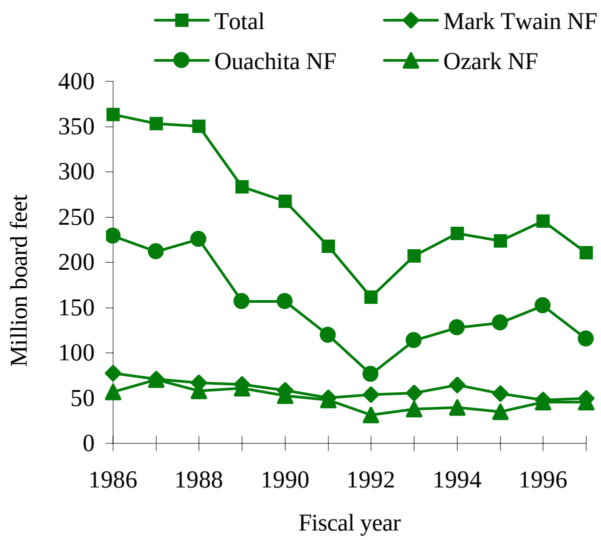


Figure 4.2—Timber volume cut on the three national forests in the Assessment area, 1986 through 1997.

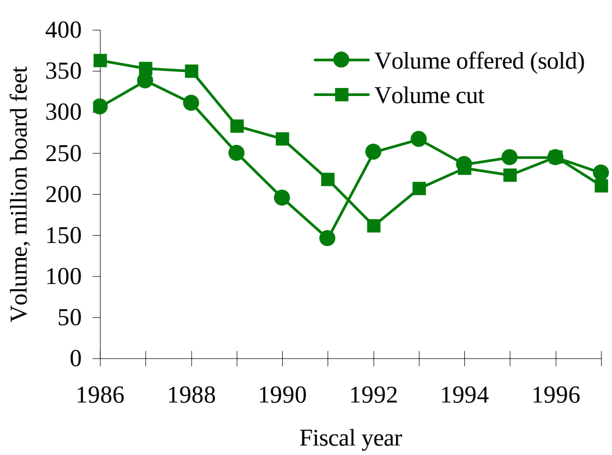


Figure 4.3—Timber volume offered (Ouachita National Forest) or offered and sold (Ozark-St. Francis and Mark Twain National Forests) and volume cut on the national forests in the Assessment area, 1986 through 1997. (Comparable data were not available for all forests; volume offered and volume offered and sold in a given year tend to be nearly identical, however.)

Reproduction Cutting

The three national forests in the Assessment area have virtually eliminated clearcutting (fig. 4.4). From 1988 through 1996, the area harvested through clearcutting declined from 27,729 ac to 698 ac—a decline of 97.5 percent. Each national forest contributed to the decline. In 1996, clearcutting was conducted at 5.4 percent of 1988 levels on the Mark Twain National Forest, and at 1 percent of 1987 levels on the Ozark-St. Francis National Forests. The Ouachita National Forest has conducted no operational clearcutting since 1991 (the 195 ac clearcut in 1993 were the "control" treatments in the Southern Research Station's Phase II stand-level ecosystem management research program).

Another way to quantify the decline in clearcutting is to track the proportion of total reproduction cutting area that this method represents each year. In 1988, clearcutting accounted for 93.5 percent of all acres subject to reproduction cutting on the three national forests in the Assessment area; by 1996, it accounted for only 2.6 percent. Without question, this dramatic decline in clearcutting is the single most significant silvicultural trend on national forests in the Assessment area.

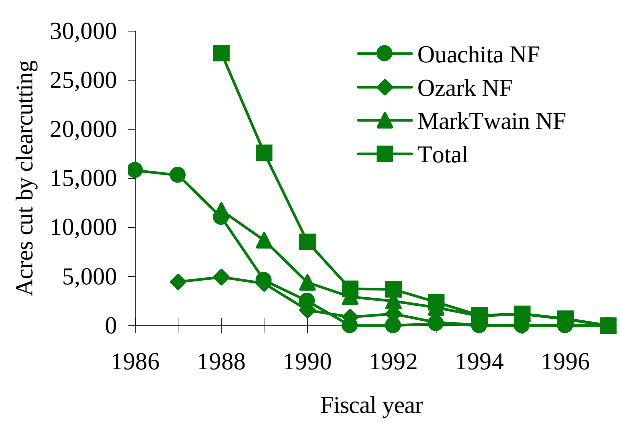


Figure 4.4—Area harvested using the even-aged clearcutting reproduction cutting method on the national forests in the Assessment area, 1986 through 1996.

During the same period, the use of several methods of reproduction cutting increased. These methods include the even-aged seed-tree and shelterwood methods and uneven-aged group selection and single-tree selection methods. The increase in these other methods is directly related to the decline in clearcutting.

Use of the seed-tree method increased over the past decade, with prominent increases in 1992 and 1993 (fig. 4.5). Reproduction cutting using the seed-tree method averaged 2,382 ac/year over the 6-year period from 1991 through 1996, which is equivalent to 8.6 percent of acres clearcut in 1998.

Although the seed-tree method has been increasingly applied, it has not been a major substitution for clearcutting because the method is a poor choice for regeneration of oak-hickory stands (see preceding discussion). Virtually all seed-tree cutting on national forest lands in the Assessment area has been in pine forests.

A slightly larger increase has occurred in the use of the shelterwood method (fig. 4.6). From 1991 through 1996, the area harvested using the shelterwood method averaged 3,157 ac/year, or 11.4 percent of the acres clearcut in 1988. The Mark Twain National Forest applied the most shelterwood cutting (57 percent of the total), averaging over 1,800 ac annually from 1991 through 1996.

National forest managers also made increased use in the 1990's of the uneven-aged group selection method (fig. 4.7). Together, the Ozark-St. Francis and Ouachita National Forests applied group selection on an average of 4,067 ac annually from 1991 through 1995, which is equivalent to 25.4 percent of the total area clearcut on those two forests in 1988.

The largest increase was in the use of the uneven-aged single-tree selection method (fig. 4.8). Together, the Ozark-St. Francis and Ouachita National Forests applied single-tree selection on an average of 8,916 ac annually from 1991 through 1995, which is equivalent to 55.7 percent of the total area clearcut on those two forests in 1988.

Thus, using the Ouachita and Ozark-St. Francis National Forests as the basis, single-tree selection was used on more than two-thirds of the uneven-aged reproduction cutting areas between 1991 and 1995. This is more likely due to its being the polar opposite of

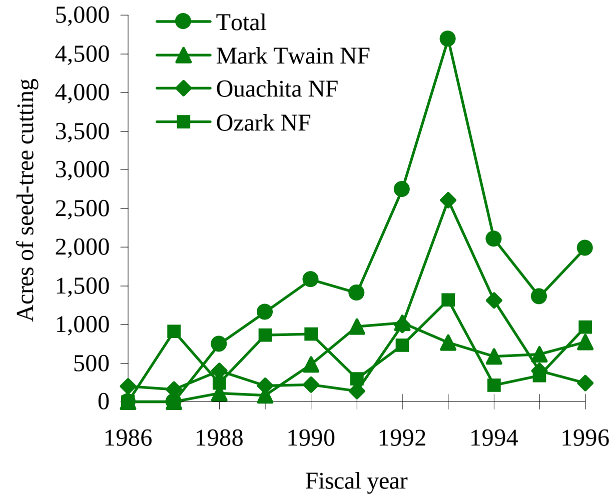


Figure 4.5—Area harvested using the even-aged seed-tree reproduction cutting method on the national forests in the Assessment area, 1986 through 1996.

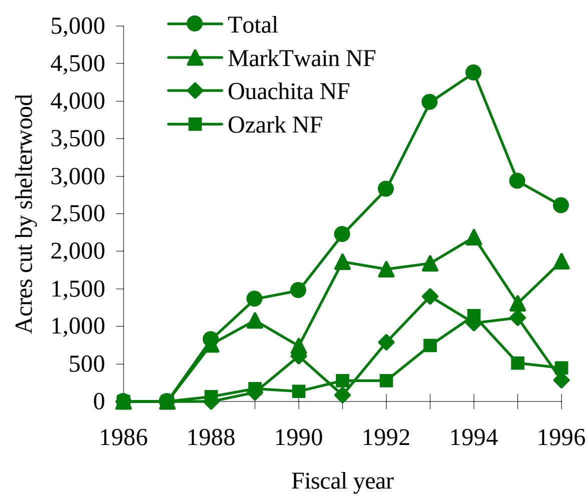


Figure 4.6—Area harvested using the even-aged shelterwood reproduction cutting method on the national forests in the Assessment area, 1986 through 1996.

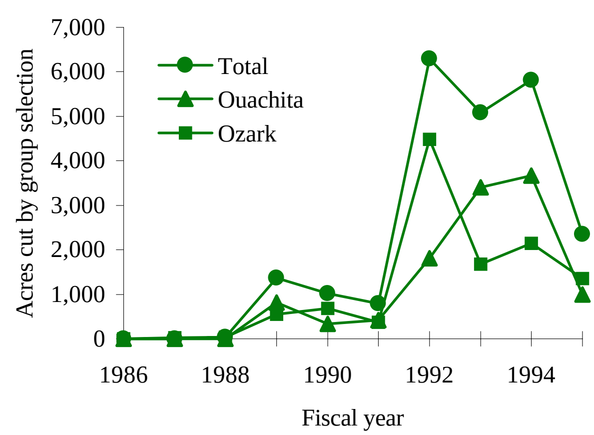


Figure 4.7—Area harvested using the uneven-aged group selection reproduction cutting method on the Ouachita and Ozark-St. Francis National Forests, 1986 through 1995.

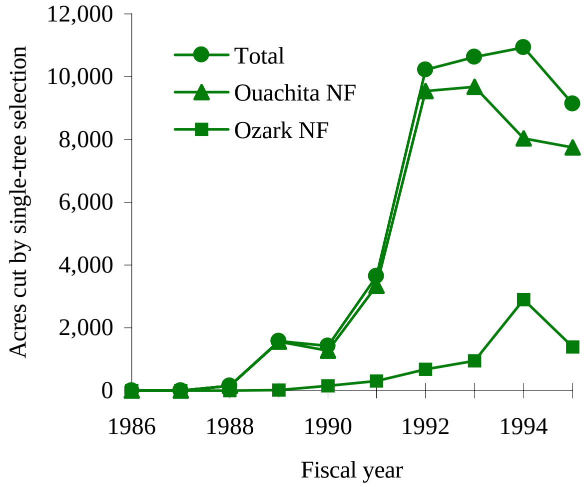


Figure 4.8—Area harvested using the uneven-aged single-tree selection reproduction cutting method on the Ouachita and Ozark-St. Francis National Forests, 1986 through 1995.

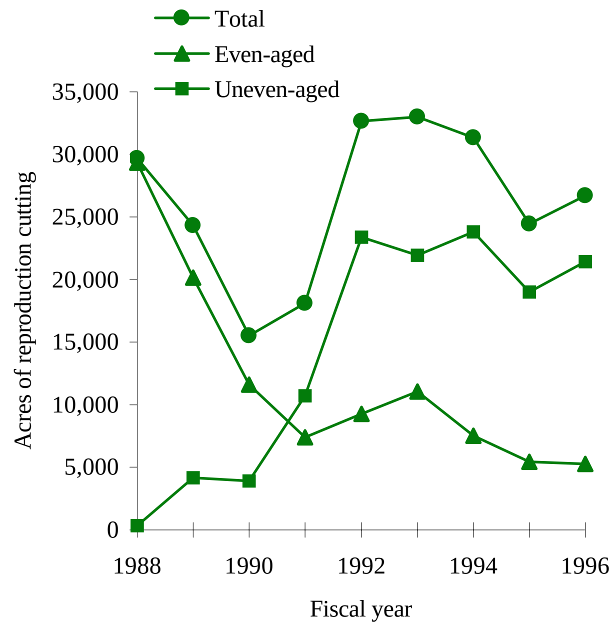


Figure 4.9—Area harvested using all even-aged methods, all uneven-aged methods, and total area harvested using all reproduction cutting methods on the national forests in the Assessment area, 1988 through 1996.

clearcutting than any innate advantages of the single-tree selection method for either pine or oak-hickory silviculture, because the research basis for application of single-tree selection in these forest types is extremely limited.

The reproduction cutting trends over the past decade can be summarized by combining the three even-aged methods (clearcutting, seed-tree, and shelterwood methods) and the two uneven-aged methods (group selection and single-tree selection methods). Data from the three national forests clearly show the decline in area subject to even-aged reproduction cutting and the increase in area subject to uneven-aged reproduction cutting over this time period (fig. 4.9). Even-aged methods declined from 29,343 ac in 1988 to 5,286 ac in 1996, a decrease of nearly 82 percent.

Conversely, the area in uneven-aged methods increased from 359 ac in 1988 to 21,437 ac in 1996—a 60-fold increase. From 1992 through 1996, uneven-aged methods averaged 21,916 ac and even-aged methods 7,724 ac (74 percent and 26 percent, respectively, of the total annual reproduction cutting on the three national forests in the Assessment area).

Reforestation

Between 1986 and 1997, reforestation on the three national forests of the Assessment area declined from 32,600 to 23,600 ac/year (fig. 4.10). The decline was 17.8 percent in the Ouachita, 43.1 percent in the Ozark-St. Francis, and 31.9 percent in the Mark Twain.

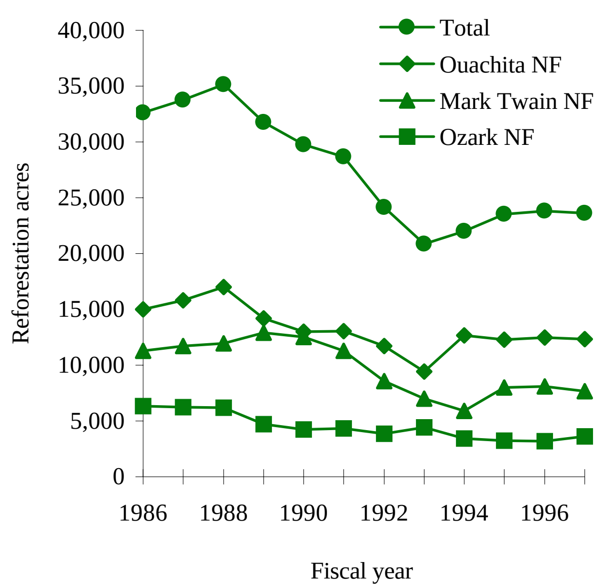


Figure 4.10—Area subject to reforestation on the national forests in the Assessment area, 1986 through 1997.

However, the acres reforested compares favorably with acres subject to reproduction cutting. Between 1988 and 1996, the cumulative area harvested by reproduction cutting was 235,874 ac, and the cumulative area reforested was 239,645 ac—indicating that the national forest managers achieved prompt reforestation of harvested lands.

In the Assessment area, reforestation is generally limited to planting of pine seedlings, natural regeneration of pine, and natural regeneration of hardwoods. The Ozark-St. Francis National Forests broke down their reforestation efforts by each of these categories, but the only clear trend is a steady decline in acres planted in pine (fig. 4.11). Generally speaking, pine planting declined from 1986 through 1997, natural regeneration of pine slightly increased, and natural regeneration of hardwoods decreased slightly. On the Ozark-St. Francis National Forests, hardwood planting is extremely rare. Experience suggests planting hardwoods is not yet practical and effective as an operational practice on national forest lands in the Assessment area.

Reforestation in the pine type on the Ozark-St. Francis and Ouachita National Forests shows two clear trends (fig. 4.12): pine planting has declined dramatically, and natural regeneration of pine has increased equally dramatically. This trend parallels the reproduction cutting trend almost exactly.

The standard reforestation prescription following clearcutting in pine stands is to reforest the site by planting pine seedlings. The decline in clearcutting is mirrored almost exactly by a decline in pine planting across the Assessment area, and the rise in natural reforestation of pine similarly parallels the increase in the use of modified seedtree and shelterwood techniques and uneven-aged reproduction cutting methods in pine stands across the Assessment area.

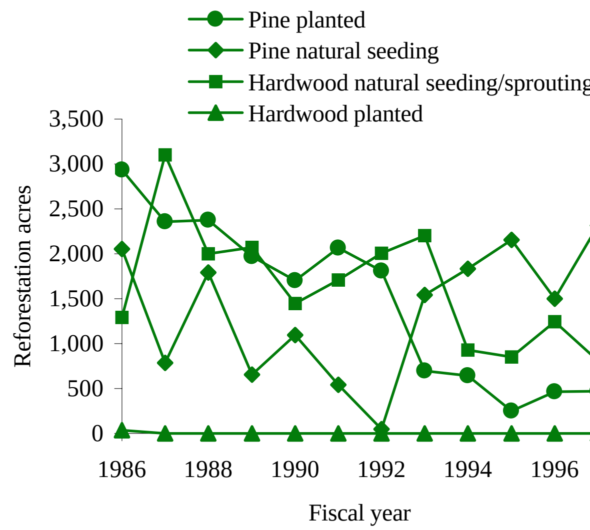


Figure 4.11—Area subject to reforestation by planting pine, natural regeneration of pine, natural regeneration of hardwoods, and planting hardwoods on the Ozark-St. Francis National Forests, 1986 through 1997.

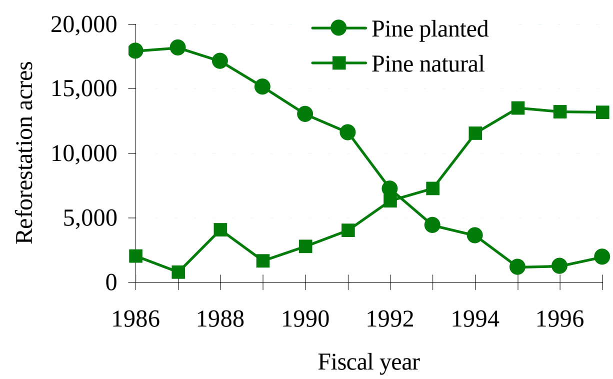


Figure 4.12—Area subject to reforestation of pine by planting and natural regeneration on the Ouachita and Ozark-St. Francis National Forests, 1986 through 1997.

Site Preparation

Trends in site preparation for the reporting forests suggest a slight decrease over time (fig. 4.13). Between 1988 and 1997, the Ouachita National Forest reported a decrease in site preparation from 22,652 ac to 17,166 ac, a decline of 24 percent. The Ozark-St. Francis National Forests reported a decrease from 7,128 ac to 2,937 ac over the same period, a decline of 58.8 percent. Thus, fewer acres are currently being site prepared than a decade ago.

The clearest trends are on the Ouachita National Forest, which reported two primary forms of site preparation: herbicide application to individual stems, which has declined dramatically, and prescribed burning, which has increased gradually (fig. 4.14). Herbicide application for site preparation declined from 12,705 ac in 1988 to 2,132 ac in 1997 an 83 percent decline over the 10-year period.

Conversely, acres burned in site preparation on the Ouachita increased from 536 ac in 1989 to 3,137 ac in

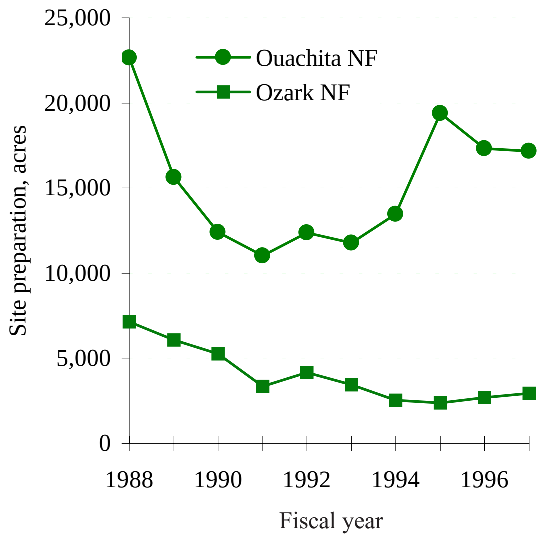


Figure 4.13—Area subject to site preparation on the Ouachita and Ozark-St. Francis National Forests, 1988 through 1997.

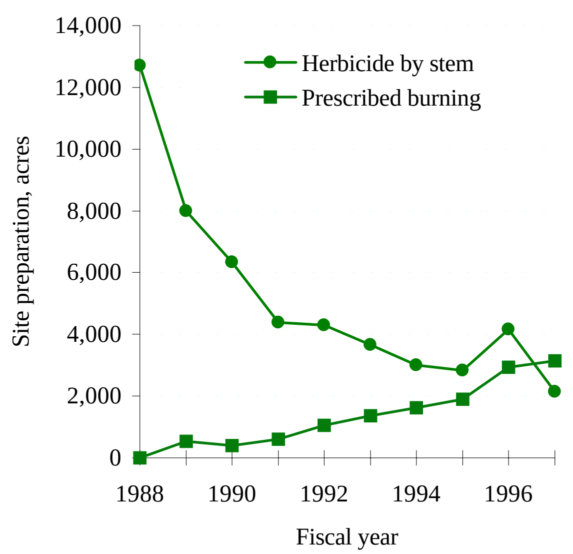


Figure 4.14—Area subject to site preparation by either herbicide application through individual stems or prescribed burning on the Ouachita National Forest, 1988 through 1997.

1997. Each year slightly more acres have been burned than the previous year, which suggests limits in using prescribed fire for site preparation have not yet been reached.

On the Ozark-St. Francis National Forests, site preparation treatments are more variable, but generally are on downward tracks. Manual felling decreased between 1988 and 1997 (fig. 4.15) but erratically, with large decreases contrasting with small increases.

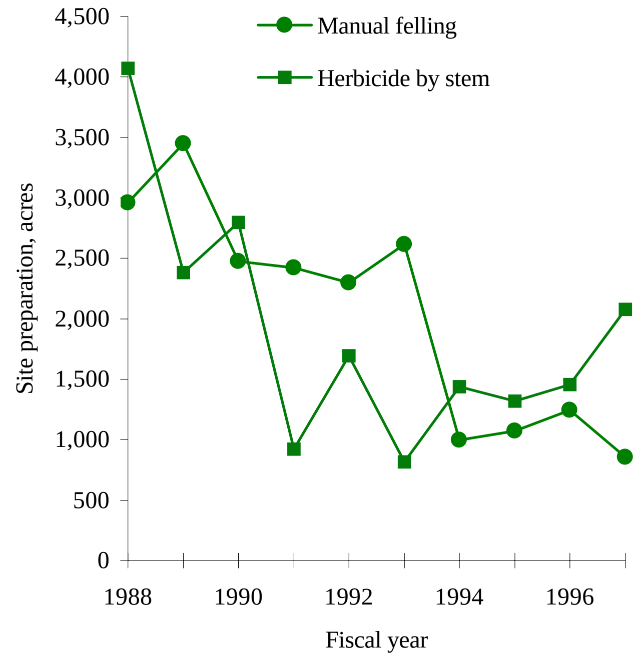


Figure 4.15—Area subject to site preparation by either herbicide application through individual stems or manual felling on the Ozark-St Francis National Forests, 1988 through 1997.

Similarly, herbicide application to individual stems has been variably applied, although acres treated in 1997 were only about half those treated in 1988.

Release

Trends in release treatments for the reporting forests suggest a marked decrease over time (fig. 4.16). Between 1988 and 1997, the Ouachita National Forest reported a decrease in release treatments from 8,164 ac to 2,409 ac, a decline of 70.5 percent. The Ozark-St. Francis National Forests reported a similar decrease of from 7,646 ac to 1,920 ac over the same period, a decline of 74.4 percent.

Thus, in one 10-year period, release treatments have declined substantially. By and large, this trend is in keeping with the increasingly prevalent philosophy of managing for mixtures of pine and hardwoods; the greater the tolerance for hardwoods in pine stands, for example, the less need there is to use release treatments to suppress the hardwoods.

Detailed consideration of specific release treatments supports this thesis. Of the two treatments reported by the Ouachita National Forest, herbicide application to individual stems declined from over 6,000 ac in 1989 to less than 1,000 ac in 1997 (fig. 4.17). Manual felling

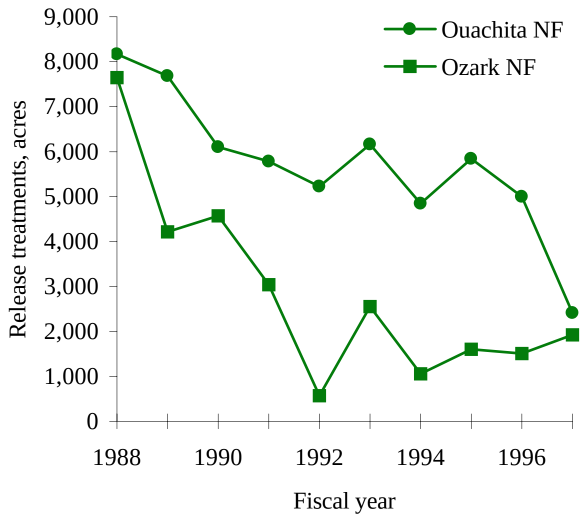


Figure 4.16—Area subject to release treatments on the Ouachita and Ozark-St. Francis National Forests, 1988 through 1997.

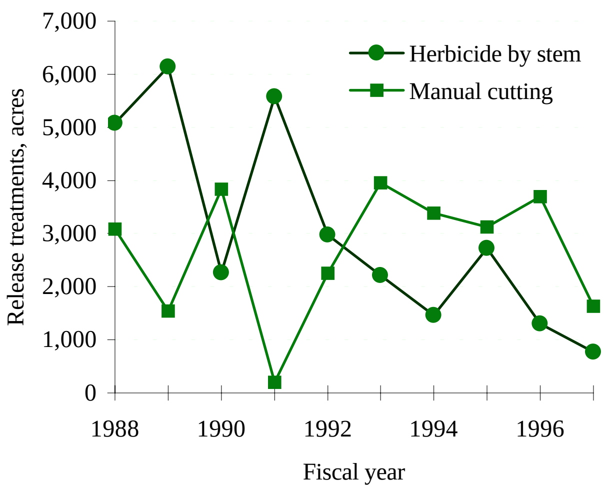


Figure 4.17—Area subject to release treatments by either herbicide application through individual stems or manual felling on the Ouachita National Forest, 1988 through 1997.

treatments rose in the early 1990's and then leveled off from 1992 through 1995, reflecting substitution of manual felling for herbicide treatments.

On the Ozark-St. Francis National Forests, the two major methods of release have declined dramatically (fig. 4.18). Unlike on the Ouachita National Forest, manual felling and herbicide application to individual stems both show a very similar pattern, suggesting that, in hardwoods (the major forest type on the Ozark-St.

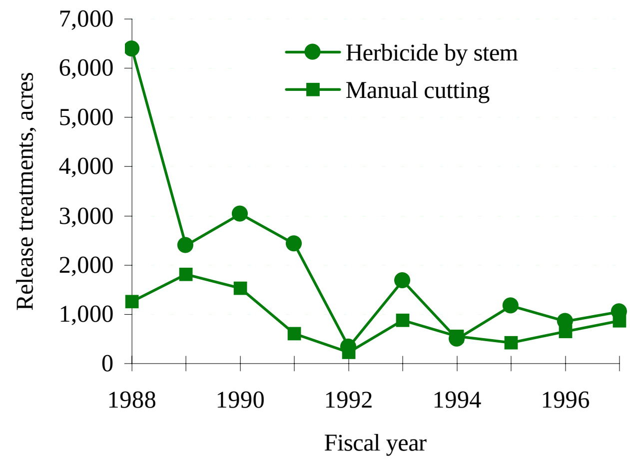


Figure 4.18—Area subject to release treatments by either herbicide application through individual stems or manual felling on the Ozark-St. Francis National Forests, 1988 through 1997.

Francis National Forests), one treatment does not seem to replace another.

Other Intermediate Treatments

Other intermediate treatments generally increased over the period studied (fig. 4.19). But nearly all of the increase was due to increased intermediate treatments on the Ouachita National Forest. Without the Ouachita National Forest's influence, intermediate treatments would be up slightly on the Mark Twain National Forest and down slightly on the Ozark-St. Francis National Forests.

The nature of the increase on the Ouachita National Forest is quickly apparent by considering the treatments reported (fig. 4.20). Use of prescribed burning as a tool for intermediate stand management has increased nearly fourfold over the past 5 years and exceeded 100,000 ac in 1997. The increase in burning is consistent with the efforts by the Ouachita National Forest to

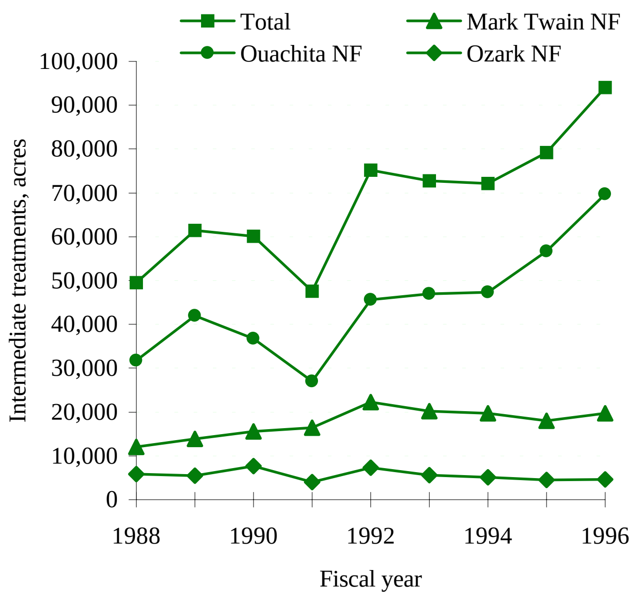


Figure 4.19—Area subject to intermediate treatments, for each of three national forests and the total for all three national forests in the Assessment area, 1988 through 1997.

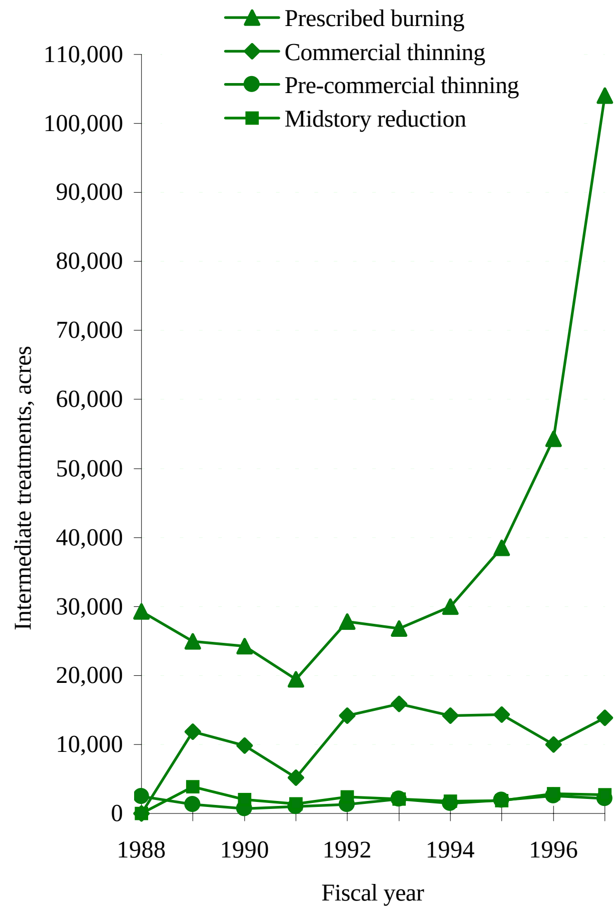


Figure 4.20—Area subject to intermediate treatments by either precommercial thinning, commercial thinning, prescribed burning, or midstory removal on the Ouachita National Forest, 1988 to 1997.

restore shortleaf pine-bluestem grass communities over extensive areas of the western Ouachitas (fire is the primary ecological tool used in this effort), sustain wildlife habitat diversity, and encourage natural regeneration in stands that are scheduled for or have already been subject to reproduction cutting. This dramatic trend screens a second important trend on the Ouachita National Forest—the gradual increase in commercial thinning, from 11,869 ac in 1989 to 13,829 ac in 1995, an increase of 16.5 percent.

The Ozark-St. Francis National Forests reported two primary forms of intermediate treatment—precommercial thinning and commercial thinning (fig. 4.21). No clear trends are evident, but precommercial thinning increased slightly from 1988 to 1997 and commercial thinning decreased slightly.

The Mark Twain National Forest reported three primary forms of intermediate treatment: commercial thinning, timber stand improvement (TSI), and wildlife habitat improvement (WHI). More acres were treated by each method in 1996 than were treated in 1988 (fig. 4.22). Commercial thinning doubled, from 2,420 ac in 1988 to 5,050 ac in 1996; in 4 of the past 6 years, more than 5,000 ac were thinned commercially. TSI treatments also more than doubled, from 3,249 ac in 1988 to 7,039 ac in 1996. Finally, WHI treatments also generally increased, from 6,346 ac in 1988 to 7,640 ac in 1996, with a peak of over 12,000 ac treated in 1993. Collectively, these treatments are typical for silvicultural interventions intended to upgrade the silvicultural and habitat conditions of oak-hickory stands.

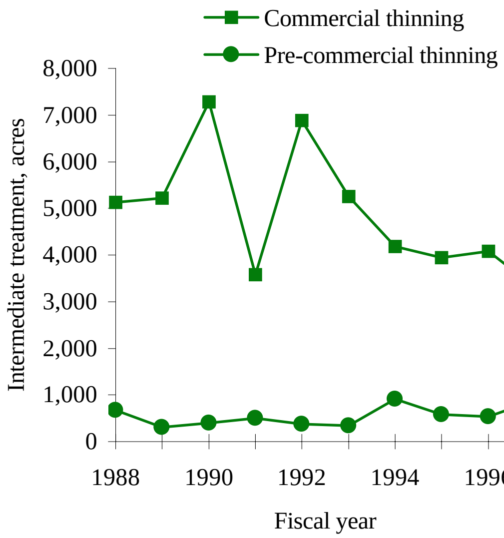


Figure 4.21—Area subject to intermediate treatments by either precommercial thinning or commercial thinning on the Ozark-St. Francis National Forests, 1988 to 1997.

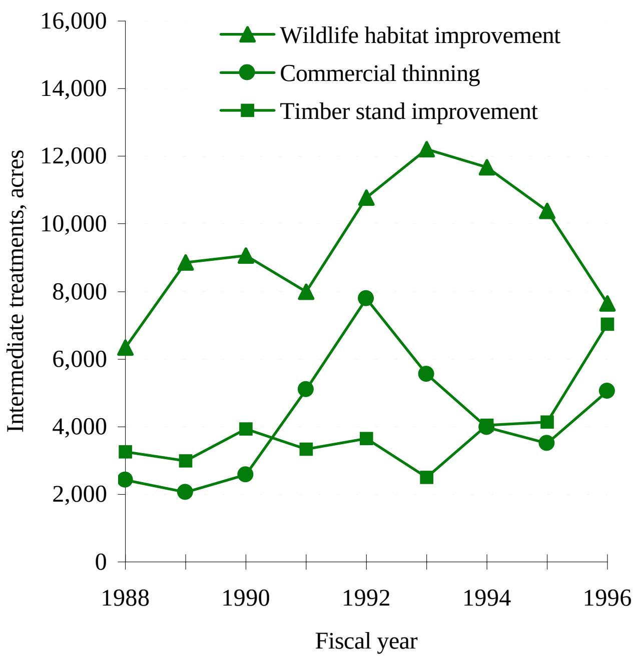


Figure 4.22—Area subject to intermediate treatments by wildlife habitat improvement, commercial thinning, or timber stand improvement on the Mark Twain National Forest, 1988 to 1996.

Implications and Opportunities

The silvicultural practices that national forest managers in the Assessment area prescribe have changed considerably since the late 1980's. Most notably, the acreage on which clearcutting and/or herbicide use occurs is down dramatically, while the acreage subject to other even-aged and uneven-aged reproduction cutting methods is up. The total area subject to reproduction cutting on all three national forests was about 30,000 ac in both 1988 and 1996. In 1988, however, nearly all of the cut area was subject to clearcutting. In 1996, most of the area on which reproduction cutting occurred was treated by uneven-aged methods, and the remainder underwent forms of even-aged harvest other then clearcutting. These shifts in national forest management have been accompanied by a reduction in timber volume: data show that volumes harvested on national forest lands declined from a peak of about 350 million board feet from 1986 through 1988 to about 200 million board feet in 1997.

Research has not yet provided definitive recommendations for use of reproduction cutting alternatives in shortleaf pine, but extensive studies are in place and preliminary results based on 5-year seedling growth will be available in summer 1999. Similarly, research has produced silvicultural recommendations for regeneration of oak using the shelterwood method but not yet for single-tree selection, at least in areas south of the Ozark Highlands section. When research results become available, they will be useful not only to Federal land managers but also to foresters advising private landowners.

Oak silviculture is considerably more complicated than pine silviculture because the regeneration ecology of oak is more involved than that of shortleaf pine. Pines are adapted to follow disturbance; after a reproduction cut, it is a rather straightforward process to conduct effective site preparation and either plant pine seedlings or catch a natural pine seedfall. On the other hand, oaks of adequate size and number must exist within the stand prior to harvest if oak is to be retained in the stand after harvest.

If landowners fail to plan ahead for development of oak advance growth, the probability of successfully regenerating oak diminishes. Generally speaking, the ownership sector with the least incentive or knowledge to plan ahead for oak regeneration is the NIPF sector. If NIPF lands are to support better stands of oak in the future, managers of State and Federal forestry programs must concentrate on how to help those landowners establish vigorous oak advance growth at least a decade prior to harvest.

Chapter 5: Plant and Animal Populations

Question 5.1: What are the current and likely future trends for populations and/or habitats for (1) federally listed threatened and endangered species; (2) other terrestrial and amphibious species with viability concerns; (3) species that are hunted; (4) neotropical migratory birds; and (5) animals that live in caves?

Thousands of plant and animal species inhabit various portions of the Ozark-Ouachita Highlands. Some are as common as white oak and white-tailed deer, 2 of several species found in all 107 counties of the Assessment area. Others, including black bear and American beech, are far more restricted in their distributions but tend to be relatively common where they do occur. Finally, the rarest plants and animals, those probably most susceptible to local, if not range-wide extinction, include seven insect species, five amphibians, and nearly two dozen plant species.

People care about different plants and animals (or groups of plant and animal species) for many reasons, including the simple pleasures of seeing them or knowing that they exist; the enjoyment of hunting or harvesting selected wild animals and plants; and the desire to conserve the diversity of life. Some people are concerned about species that pose threats to their well being or to other plants and animals they care about.

Obviously, there are many ways to categorize plants and animals that people are concerned about. For this chapter, the Terrestrial Team focused on the categories public land managers typically must address as part of their planning, habitat management, and monitoring programs: those with viability concerns, Federally listed threatened and endangered species, species that are hunted (game), neotropical migrant birds, and animals that live in caves. These 5 categories include 521 species of terrestrial and amphibious plants and animals (those that live primarily on land, not in aquatic habitats). See the companion general technical report *Aquatic Conditions* (USDA Forest Service 1999a) for discussion of similar categories of animal species that occupy streams, lakes, and other aquatic habitats in the Assessment area. Another large category, species that pose threats to forest resources in the Highlands, is discussed in the final chapter of the present report.

Key Findings

1. Of the 333 plants and animals with viability concerns in the Ozark-Ouachita Highlands, 35 are imperiled (having 20 or fewer known populations) or critically imperiled (5 or fewer known populations).
2. More than half (53 percent) of the species with viability concerns in the Ozark-Ouachita Highlands are known to occur there only on national forest lands; about one-third of these species are known to occur there only on private lands.
3. Sixteen species in the Ozark-Ouachita Highlands are federally listed as threatened or endangered.
4. Available data for game species in the Highlands show that most populations have increased or remained stable since 1970.
5. North American Breeding Bird Survey data revealed that 21 of 90 species in the Ozark-Ouachita Highlands declined significantly from 1966 to 1996. Six species showed a significant increase during the same period.

Species with Viability Concerns

Scientists designate terrestrial species with viability concerns according to global rankings of 1 to 5 (G1, G2, G3, G4, G5) and State rankings of 1, 2, or 3 (S1, S2, S3). The Federal Government lists some but by no means all of these species as threatened or endangered (see next section of this chapter for discussion). The current section addresses plant and animal species solely in terms of global rankings.

Global and State Ranks

Biologists give each species two ranks—a global (G) rank reflecting its rarity throughout the world and a State

(S) rank reflecting its rarity in the State. Following are definitions and criteria for each global rank. State ranks parallel the global ranks closely but are based on the range of each species within a State, not the complete range of the species.

- G1—Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals or acres) or because of some factor of its biology making it especially vulnerable to extinction.
- G2—Imperiled globally because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of other factors demonstrably making it very vulnerable to extinction throughout its range.
- G3—Either very rare and local throughout its range or found locally in a restricted area ("endemic"); from 21 to 100 occurrences.
- G4—Apparently secure globally, although it may be quite rare in parts of its range, especially at the periphery.
- G5—Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
- GH—Historically known, with the expectation that it may be rediscovered.
- GX—Believed to be extinct.
- GU—Not yet ranked.
- G?—There is a question about the assigned rank.
- GQ—There are taxonomic questions concerning the species or subspecific taxon.
- GT—Associated with global rank, indicating a global rarity for a particular subspecific taxon.

Data Sources

The data bases of State Natural Heritage agencies in Arkansas, Missouri, and Oklahoma were the primary sources of the spatial and quantitative data for this analysis. Members of the Terrestrial Team also contributed personal observations. The Team developed the tables included in this chapter and in the Appendix at the end of this chapter.

Patterns and Trends

At least 333 terrestrial species of plants and animals occurring in the Ozark-Ouachita Highlands are at risk because of habitat loss or other threats and thus appear on State and global lists of species with viability concerns (see Appendix tables 5.1 and 5.2 for complete listing and subset of species with global viability concerns, respectively). Nearly three-fourths of these species inhabit geologically or hydrologically isolated and/or unusual sites, including riparian wetlands, seeps, fens, prairies, rock outcrops, glades, talus, and cliffs, or communities dependent upon fire (table 5.1). Many of these communities are highly vulnerable to disruption and, therefore, their dependent species are vulnerable to habitat loss.

Two-thirds of the viability concern species occur on public lands, with 187 (56 percent) occurring on Federal lands (table 5.2). Almost all such species occurring on Federal lands in the Assessment area are found on one or more of the Highland's three national forests. Private lands are the only known sites in the Assessment area for 108 of these species.

Table 5.1— Species with viability concerns in selected habitat associations of the Ozark-Ouachita Highlands

Habitat association	Animals		Plants		Total	
		Percent		*Percent*		*Percent*
Riparian wetlands, seeps, fens	7	12	70	26	77	23
Mesic forest	9	15	50	18	59	18
Glades, talus slopes, cliffs, rock outcrops	3	5	53	19	56	17
Prairie	15	25	37	14	52	16
Fire-maintained pine/oak woodland	7	12	44	16	51	15
Bottomland hardwood forest	9	15	13	5	22	7
Nonspecific (habitat generalists)	7	12	1	0	8	2
Unknown	3	5	5	2	8	2

Source: State Natural Heritage Program databases [accessed 1997].

Table 5.2—Number of terrestrial species with viability concerns in the Ozark-Ouachita Highlands found within various land ownership categories

Ownership category	Viability concern species	Portion of all such species
		Percent
Ouachita National Forest	118	35
Ozark National Forest	70	25
Mark Twain National Forest	25	8
National forests combined[a]	175	53
Other Federal lands	26	8
All Federal lands[a]	187	56
Arkansas State lands	55	17
Missouri State lands	27	8
Oklahoma State lands	16	5
All State lands	89	27
All public lands[a]	225	68
Private lands	176	53
Private lands exclusively	108	32

[a] Species known to occur in more than one ownership category were counted only once; thus, totals cannot be derived by adding numbers of species listed in various categories in this table.
Source: State Natural Heritage program databases [accessed 1997].

Table 5.3—Ecological subsections in the Ozark-Ouachita Highlands where species with viability concerns occur

Ecological subsection	Subsection number[a]	Species
White River Hills	222Ag	86
Central Ouachita Mountains	M231Ac	72
Fourche Mountains	M231Aa	71
Springfield Plateau	222An	71
Lower Boston Mountains	M222Ab	64
Western Ouachita Mountains	M231Ab	58
Central Plateau	222Ab	52
Western Arkansas Valley	231Gc	35
Athens Piedmont Plateau	M231Ad	29
Western AR Valley Mountains	231Gb	25
Upper Boston Mountains	M222Aa	24
Eastern Arkansas Valley	231Ga	23
Springfield Plain	222Am	20
Current River Hills	222Af	14
St. Francois Knobs and Basins	222Aa	10
Elk River Hills	222Ah	8
Osage River Hills	222Ac	7
Black River Ozark Border	222Ai	5
Gasconade River Hills	222Ad	5
Meramec River Hills	222Ae	4

[a] See figure 1.1.
Source: State Natural Heritage program databases [accessed 1997].

Many viability concern species occur in more than one ecological subsection (see fig. 1.1 in Chapter 1 for map of sections and subsections), and the number of such species per ecological subsection ranges from 4 to 86 (table 5.3). The highest concentrations of viability concern species are in the White River Hills of Arkansas and Missouri, the Central Ouachita Mountains, the Fourche Mountains, and the Springfield Plateau.

Thirty-five of the terrestrial or amphibious species with viability concerns are globally imperiled (“G2,” i.e., with 20 or fewer known populations) or critically imperiled globally (“G1,” i.e., with 5 or fewer known populations) (table 5.4). About half of these species (see Appendix table 5.3) inhabit the kinds of restricted plant communities noted previously. The 12 nonaquatic animals biologists rate as having global viability concerns are either amphibians or invertebrates. Fourteen of the 35 imperiled species are known to occur only on public lands, and 11 are known to occur only on private lands (table 5.5). Ten (29 percent) of these species are known to occur on both public and private lands.

The Team analyzed the conservation status and conservation trends of the 35 critically imperiled and imperiled taxa, assigning each a conservation status of satisfactory, unsatisfactory, critical, or unknown based on the following criteria: satisfactory = 5 or more conserved populations; unsatisfactory = 1 to 4 conserved populations; critical = no conserved populations; unknown = number of populations unknown. A conserved population is one the landowner or manager (1) is aware of and (2) on a site being managed in a way likely to sustain viable habitat for the population. The 35 species were also assigned a “conservation trend” rating of stable, increasing, decreasing, or unknown. Both kinds of rankings are subjective, but the Team felt these were reasonable estimates of the conservation status and trend of vulnerable species. Federally listed threatened and endangered species were not included here, but were treated in a separate section (see subsequent discussion).

The conservation status of the 35 critically imperiled and imperiled taxa, where known, is relatively good, with 37 percent satisfactory and none critical (table 5.6 and Appendix table 5.4). However, the conservation status of 49 percent of the species is unknown. The pattern for conservation trend is similar. Those species

Table 5.4— Imperiled and critically imperiled terrestrial plant and animal species (including amphibians) in the Ozark-Ouachita Highlands[a]

Scientific name	Common name	Rank	Habitat
	Plants		
Calamovilfa arcuata	A sandgrass	G2	SS
Carex amphibola var. *globosa*	A sedge	G?T?	MF
Carex bicknellii var. *opaca*	A sedge	G5T2T3	SS
Carex fissa var. *fissa*	A sedge	G2QT?	PR
Carex gravida var. *gravida*	A sedge	G5T?	PR
Eriocaulon kornickianum	Small-headed pipewort	G2G3	RO
Galium arkansanum var. *pubiflorum*	Ouachita bedstraw	G5T2Q	WFM
Homaliadelphus sharpii	Sharp's homaliadelphus	G2G3	—
Hydrophyllum brownei	Browne's waterleaf	G1	MF
Luzula acuminata var. *carolinae*	Southern hairy woodrush	G5T?	SS
Matelea baldwyniana	Baldwin's milkvine	G2G3	WFM
Neviusia alabamensis	Alabama snowwreath	G2	RO
Platanthera praeclara	Western white fringed orchid	G2	PR
Polygonum pensylvanicum var. *eglandulosum*	Pinkweed	G5T2T4Q	SS
Polymnia cossatotensis	Heartleaf leafcup	G1	RO
Quercus shumardii var. *acerifolia*	Maple-leaved oak	G1Q	RO
Rosa foliolosa	White prairie rose	G2	PR
Sagittaria ambigua	Kansas arrowhead	G2?	SS
Scirpus hallii	Hall's bulrush	G2	SS
Scutellaria bushii	Bush's skullcap	G2G3	RO
Thalictrum arkansanum	Arkansas meadow-rue	G2	SS
Tradescantia ozarkana	Ozark spiderwort	G2G3	MF
Vertigo meramecensis	Bluff vertigo	G2	RO
	Invertebrates		
Arianops sandersoni	Magazine Mountain mold beetle	G1?	WFM
Ophiogompus westfalli	Arkansas snaketail dragonfly	G2	SS
Panorpa braueri	A panorpid scorpionfly	G1	—
Papipema eryngium	Rattlesnake master borer moth	G1	PR
Rhadine ozarkensis	A ground beetle	G1	—
Rimulincola divalis	A beetle	G1	—
Stenotrema pilsbryi	Rich Mountain slitmouth snail	G2	RO
	Amphibians		
Plethodon caddoensis	Caddo Mountain salamander	G2	MF
Plethodon fourchensis	Fourche Mountain salamander	G2	MF
Plethodon ouachitae	Rich Mountain salamander	G2G3	MF
Plethodon sequoyah	SE Oklahoma slimy salamander	G2Q	MF
Scaphiopus holbrookii hurteri	Hurter's spadefoot	G5T?	—

MF = mesic forest; WFM = woodlands, fire maintained; PR = prairie; SS = seep, fen, pond, upland riparian; RO = rock outcrop, glade, talus, cliff; — = habitat not defined.

[a] See text for definitions of imperilment and global ranks.

Table 5.5—Imperiled and critically imperiled terrestrial plant and animal species in the Ozark-Ouachita Highlands, sorted by categories of land ownership where the species are known to occur[a]

Scientific name	Common name	Taxonomic group	Global rank	Habitat
		Federal ownership		
Plethodon caddoensis	Caddo Mountain salamander	Amphibian	G2	MF
Plethodon fourchensis	Fourche Mountain salamander	Amphibian	G2	MF
Scaphiopus holbrookii hurteri	Hurter's spadefoot	Amphibian	G5T?	WFM
Papipema eryngium	Rattlesnake master borer moth	Invertebrate	G1	PR
Rimulincola divalis	A beetle	Invertebrate	G1	—
Homaliadelphus sharpii	Sharp's homaliadelphus	Plant	G2G3	—
Hydrophyllum brownei	Browne's waterleaf	Plant	G1	MF
Polymnia cossatotensis	Heartleaf leafcup	Plant	G1	RO
Quercus shumardii var. *acerifolia*	Maple-leaved oak	Plant	G1Q	RO
Rosa foliolosa	White prairie rose	Plant	G2	PR
		Federal and private		
Panorpa braueri	A panorpid scorpionfly	Invertebrate	G1	—
Neviusia alabamensis	Alabama snowwreath	Plant	G2	RO
		Federal and State		
Arianops sandersoni	Magazine Mountain mold beetle	Invertebrate	G1?	WFM
Stenotrema pilsbryi	Rich Mountain slitmouth snail	Invertebrate	G2	RO
Luzula acuminata var. *carolinae*	Southern hairy woodrush	Plant	G5T?	SS
Vertigo meramecensis	Bluff vertigo	Plant	G2	RO
		Federal, State, and private		
Plethodon ouachitae	Rich Mountain salamander	Amphibian	G2G3	MF
Ophiogompus westfalli	Arkansas snaketail dragonfly	Invertebrate	G2	SS
Calamovilfa arcuata	A sandgrass	Plant	G2	SS
Carex fissa var. *fissa*	A sedge	Plant	G2QT?	PR
Eriocaulon kornickianum	Small-headed pipewort	Plant	G2G3	RO
Galium arkansanum var. *pubiflorum*	Ouachita bedstraw	Plant	G5T2Q	WFM
Matelea baldwyniana	Baldwin's milkvine	Plant	G2G3	WFM
Tradescantia ozarkana	Ozark spiderwort	Plant	G2G3	MF
		Private only		
Plethodon sequoyah	SE Oklahoma slimy salamander	Amphibian	G2Q	MF
Rhadine ozarkensis	A ground beetle	Invertebrate	G1	—
Carex amphibola var. *globosa*	A sedge	Plant	G?T?	MF
Carex bicknellii var. *opaca*	A sedge	Plant	G5T2T3	SS
Carex gravida var. *gravida*	A sedge	Plant	G5T?	PR
Platanthera praeclara	Western white fringed orchid	Plant	G2	PR
Polygonum pensylvanicum var. *eglandulosum*	Pinkweed	Plant	G5T2T4Q	SS
Sagittaria ambigua	Kansas arrowhead	Plant	G2?	SS
Scirpus hallii	Hall's bulrush	Plant	G2	SS
Thalictrum arkansanum	Arkansas meadow-rue	Plant	G2	SS
Scutellaria bushii	Bush's skullcap	Plant	G2G3	RO

MF = mesic forest; WFM = woodland, fire maintained; PR = prairie; SS = seep, fen, riparian wetland; RO = rock outcrop, glade, talus, cliff; — = habitat not defined.
[a] See text for definition of imperilment and global ranks.
Source: State Natural Heritage program databases [accessed 1997].

Table 5.6—Summary of conservation status and conservation trend for imperiled and critically imperiled species in the Ozark-Ouachita Highlands[a]

	Species	
		Percent
Conservation status		
Satisfactory	13	37
Unsatisfactory	5	14
Critical	0	0
Unknown	17	49
Total	35	100
Conservation trend		
Stable	13	37
Increasing	1	1
Decreasing	0	0
Unknown	21	60
Total	35	100

[a] Satisfactory status means that there are at least five or more conserved populations; unsatisfactory, that one to four populations have been conserved; critical, that there are no conserved populations; see text for further explanation of conservation status and conservation trend.
Source: State Natural Heritage program databases [accessed 1997].

that have been studied show stable or increasing populations while, for 60 percent of the species, the conservation trend is unknown.

Implications and Opportunities

The importance of national forests in the Assessment area to the conservation of viability concern species cannot be overstated: appropriate management of national forest lands is critical to the conservation of biodiversity in the Ozark-Ouachita Highlands. The conservation of special habitats, expanded use of prescribed fire, and special inventory and monitoring programs are essential activities. Opportunities for partnerships among concerned citizens, landowners, and land managers are many.

Federally listed Threatened and Endangered Species

Sixteen federally listed threatened or endangered terrestrial species occur in the Assessment area:

Species	Scientific name	Status
Plants		
Geocarpon	*Geocarpon minimum*	Threatened
Harperella	*Ptilimnium nodosum*	Endangered
Mead's milkweed	*Asclepias meadii*	Threatened
Missouri bladderpod	*Lesquerella filiformis*	Endangered
Running buffalo clover	*Trifolium stolonifera*	Endangered
Invertebrates		
American burying beetle	*Nicrophorus americanus*	Endangered
Magazine Mtn. shagreen snail	*Mesodon magazinenesis*	Threatened
Reptiles		
American alligator	*Alligator mississippiensis*	Threatened
Mammals		
Indiana bat	*Myotis sodalis*	Endangered
Gray bat	*Myotis grisescens*	Endangered
Ozark big-eared bat	*Corynorhinus townsendii ingens*	Endangered
Birds		
Red-cockaded woodpecker	*Picoides borealis*	Endangered
Bald eagle	*Haliaeetus leucocephalus*	Threatened
Peregrine falcon	*Falco peregrinus anatum*	Endangered
Piping plover	*Charadrius melodus*	Threatened
Interior least tern	*Sterna antillarum*	Endangered

Except for Mead's milkweed and the American alligator, each of these species has a recovery plan in place. The most recent change in the status of these species occurred in 1995, when the U.S. Fish and Wildlife Service changed the bald eagle from endangered to threatened because of population increases. No additional proposed or candidate terrestrial species are known to inhabit the Assessment area.

Of this group of species, the most widely distributed in the Highlands is the Indiana bat (table 5.7), which occurs in caves throughout the Ozark Highlands. The Magazine Mountain shagreen snail has the most limited range of this group, being found only on the north-facing slopes of Magazine Mountain, which is in the Western Arkansas Valley Mountains subsection. This habitat is entirely in the Ozark National Forest.

Game Species

Hunting is an important recreational pursuit in the Highlands (see Chapter 5 of the *Social and Economic Conditions* report, USDA FS 1999b). Population trends of game species are important to agencies promoting hunting opportunities. State agency biologists provided data concerning densities of nine species.

Data Sources

Biologists with State wildlife agencies provided estimates of population densities in 1970 and 1996 for white-tailed deer, eastern wild turkey, black bear, gray squirrel, fox squirrel, eastern cottontail rabbit, raccoon, ruffed grouse, and bobwhite quail. Biologists used harvest and survey data where available, as well as professional judgment, to estimate densities according to

Table 5.7—Number of occurrences of endangered and threatened species in the four ecological sections of the Assessment area, their global ranks, and estimated population trends

Species	Ozark Highlands	Boston Mountains	Arkansas Valley	Ouachita Mountains	Global rank[a]	Population trend
Geocarpon	2		1		G2	Stable
Harperella				2	G2	Stable
Mead's milkweed	3				G2	Declining
Missouri bladderpod	2				G2	Increasing
Running buffalo clover	11				G3	Declining
American burying beetle		1	2	1	G1	Increasing
Magazine Mountain shagreen snail			1		G1	Stable
American alligator			1		G5	Increasing
Indiana bat	10	2	1	1	G2	Declining
Gray bat	9	2	1		G2G3	Stable
Ozark big-eared bat	2	1			G4T1	Declining
Red-cockaded woodpecker				2	G3	Stable
Bald eagle	1	1	1		G4	Increasing
Peregrine falcon					G4	Increasing
Piping plover					G3	Declining
Interior least tern			2	1	G4T2Q	Declining

[a] See text for definition of global ranks.
Source: State Natural Heritage program databases [accessed 1997].

a classification of absent, low, medium, or high (table 5.8). Population densities likely vary widely within counties, but this broad analysis relies upon estimates of county-wide average densities. Data for certain species in some counties were not available.

Patterns and Trends

White-tailed deer densities are increasing in the Highlands, particularly in Arkansas and Oklahoma. This trend is occurring across the range of white-tailed deer (deCalesta and Stout 1997). Most of the Highlands had a low population density in 1970 (fig. 5.1), but 20 counties had high densities in 1996 (fig. 5.2). Today, more than

Table 5.8—Density classes for selected game species found in the Ozark-Ouachita Highlands

	Density class			
Species	Very low	Low	Medium	High
Eastern wild turkey	< 1/mi^2	1–5/mi^2	6–15/mi^2	> 15/mi^2
Black bear	< 1/10,000 ac	< 1/ 3,000–10,000 ac	1/1,000–3,000 ac	> 1/1,000 ac
Gray and fox squirrel	< 1/15 ac	< 1/10–15 ac	1/ 3–9 ac	> 1/3 ac
Raccoon	< 1/mi^2	1–5/mi^2	5–10/mi^2	> 10/mi^2
Ruffed grouse	< 1 /mi^2	1–5/mi^2	5–10/mi^2	> 10/mi^2
Bobwhite quail	< 1/160 ac	1/80–160 ac	1/10–80 ac	> 1/10 ac
White-tailed deer	< 1/mi^2	1–15/mi^2	15–30/mi^2	> 30/mi^2
Eastern cottontail	< 1/ 40 ac	1/20–40 ac	1/10–20 ac	> 1/10 ac

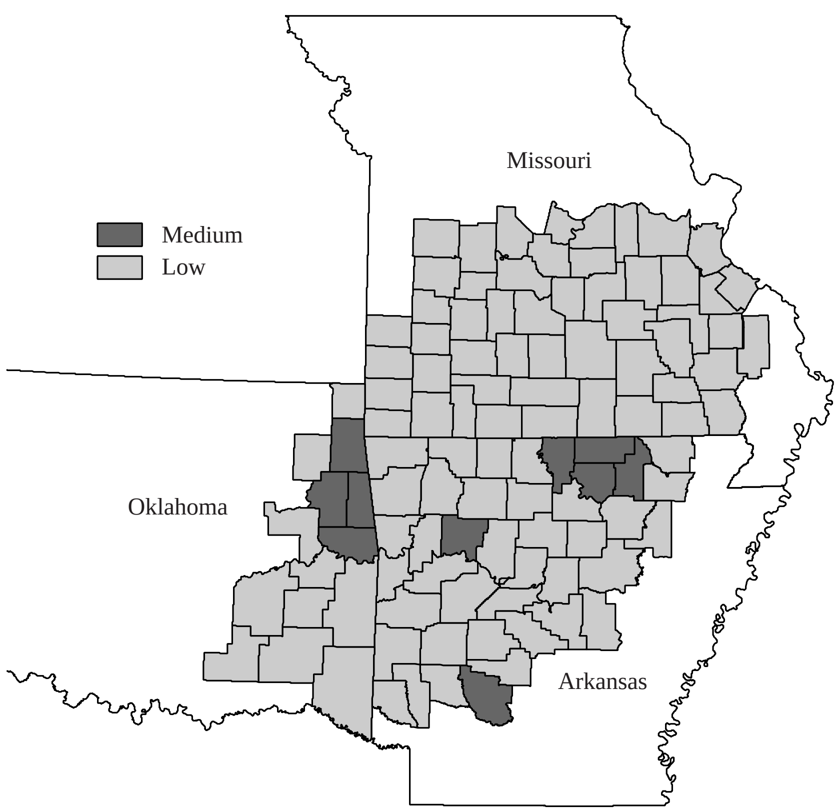


Figure 5.1—Relative deer abundance in Assessment area counties, 1970.

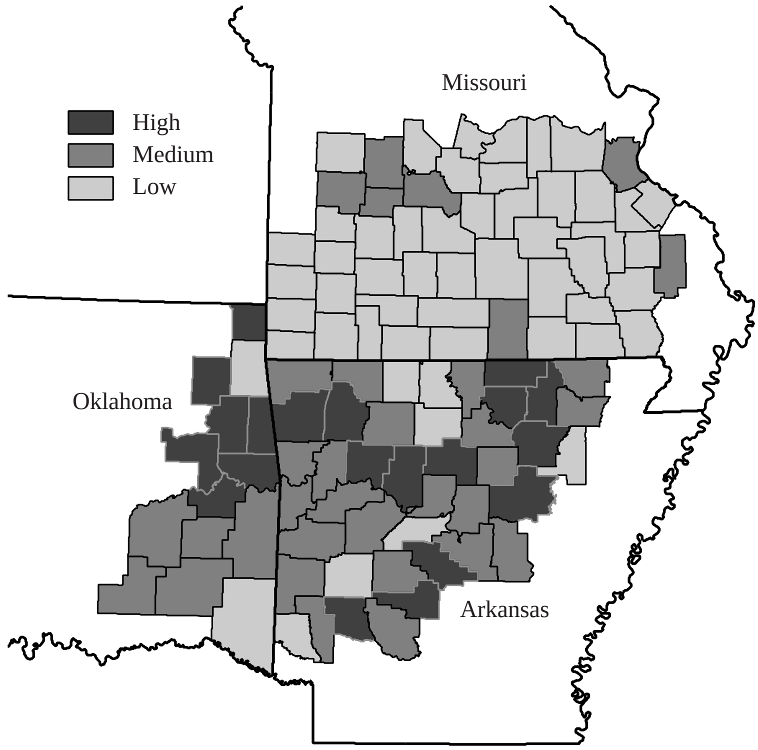


Figure 5.2—Relative deer abundance in Assessment area counties, 1996.

one half of the counties in the Assessment area support moderate to high densities of white-tailed deer.

Eastern wild turkey population densities have increased from 1970 (fig. 5.3), when most counties had low populations. By 1996, low to medium densities occurred in most of the Highlands (fig. 5.4).

Black bear are either absent, low, or very low in most of the Highlands, except in counties in Arkansas with national forest land, where the density is considered moderate. Comparing 1970 densities with 1996 densities (figs. 5.5 and 5.6), the population is expanding and increasing. At present, this species is hunted only in the Arkansas portion of the Assessment area.

Fox squirrels are associated with open woodlands and forest edges and grays are more abundant in areas of dense forest. Populations of these species fluctuate in relation to food supply, with changes in food supply having a greater impact on grays than on fox squirrels. Both species have cyclic population fluctuations. While squirrels are present in every county of the Highlands, only Missouri furnished data for gray and fox squirrels (figs. 5.7 and 5.8). Estimates of populations for these species in 1996 were very similar to those for 1970.

Efforts since the mid-1970's to reestablish ruffed grouse in the Assessment area through transplanting, habitat management, and protection on public lands have had some success in parts of the Ozarks. By 1996, grouse occurred in at least 29 counties (fig. 5.9), although population densities were low. Within the Assessment area, hunting for ruffed grouse is permissible in only a few counties in Missouri.

Bobwhite quail population densities in most counties are moderate to low. Only a few counties on the northwestern border of the Assessment area are maintaining high densities. The number of counties with lower quail densities has increased slightly since 1970 (figs. 5.10 and 5.11), which is presumably part of an overall decline of the northern bobwhite reported by Brennan (1991).

Eastern cottontail rabbit populations were stable in the Missouri counties of the Assessment area between

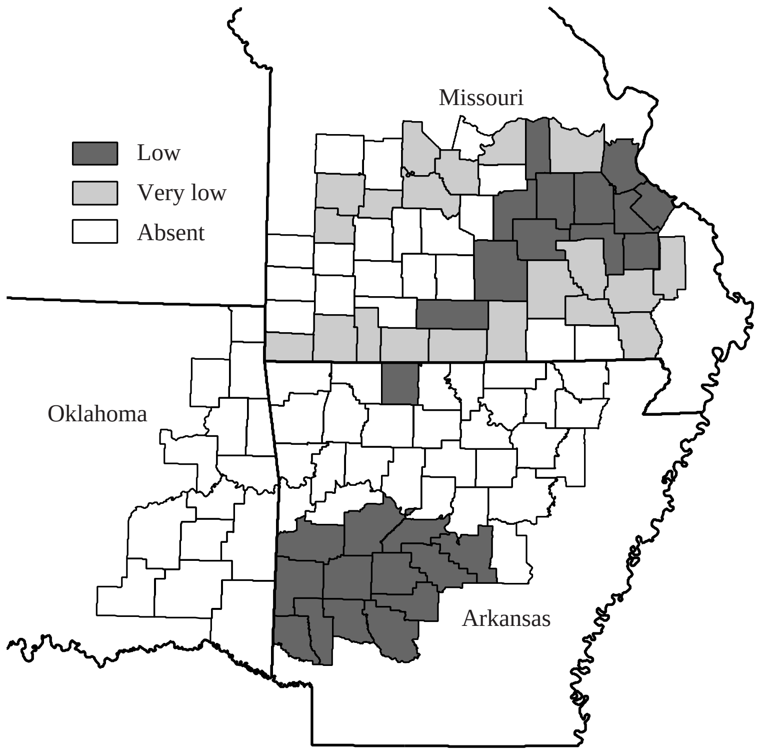


Figure 5.3—Relative eastern wild turkey abundance in Assessment area counties, 1970.

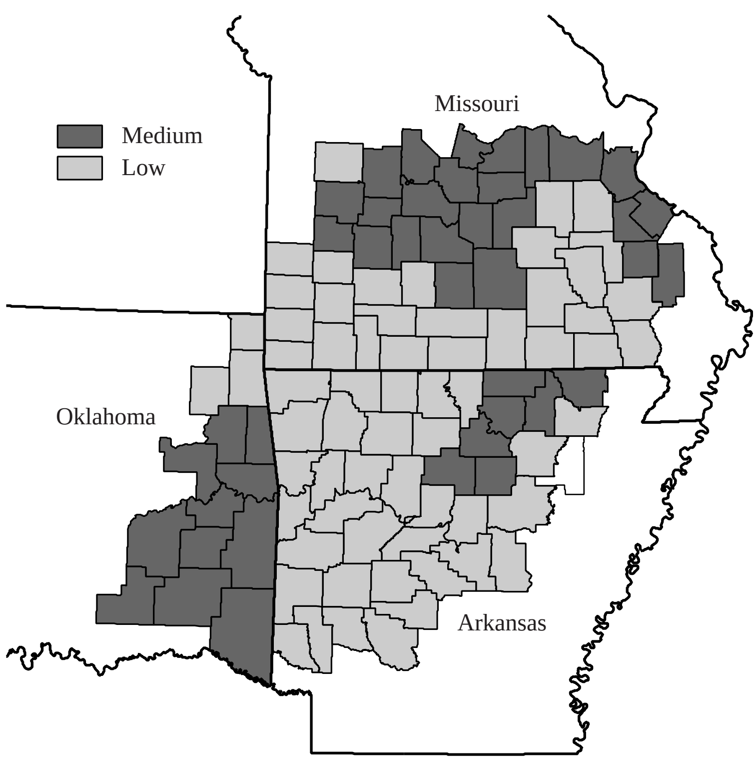


Figure 5.4—Relative eastern wild turkey abundance in Assessment area counties, 1996.

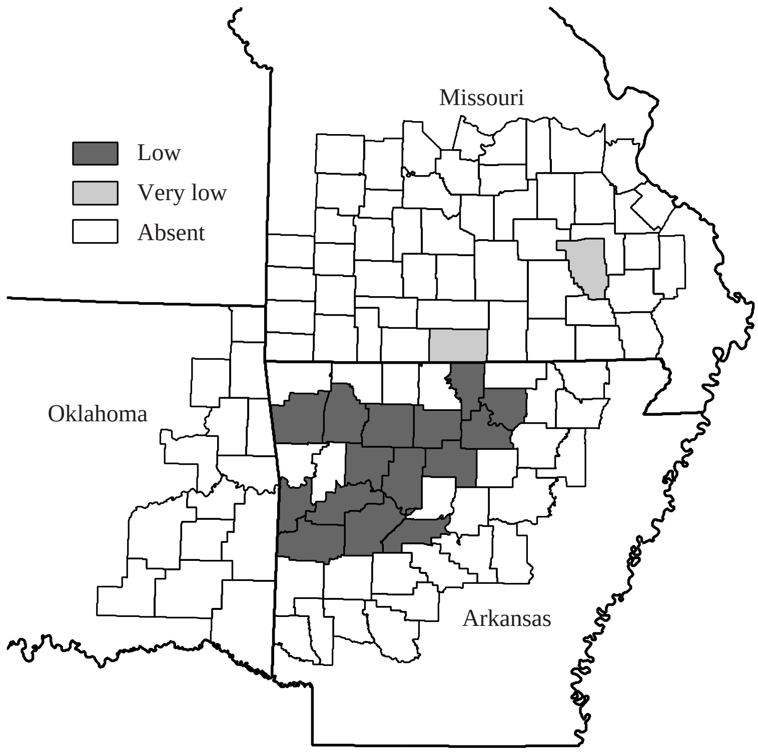


Figure 5.5—Relative black bear abundance in Assessment area counties, 1970.

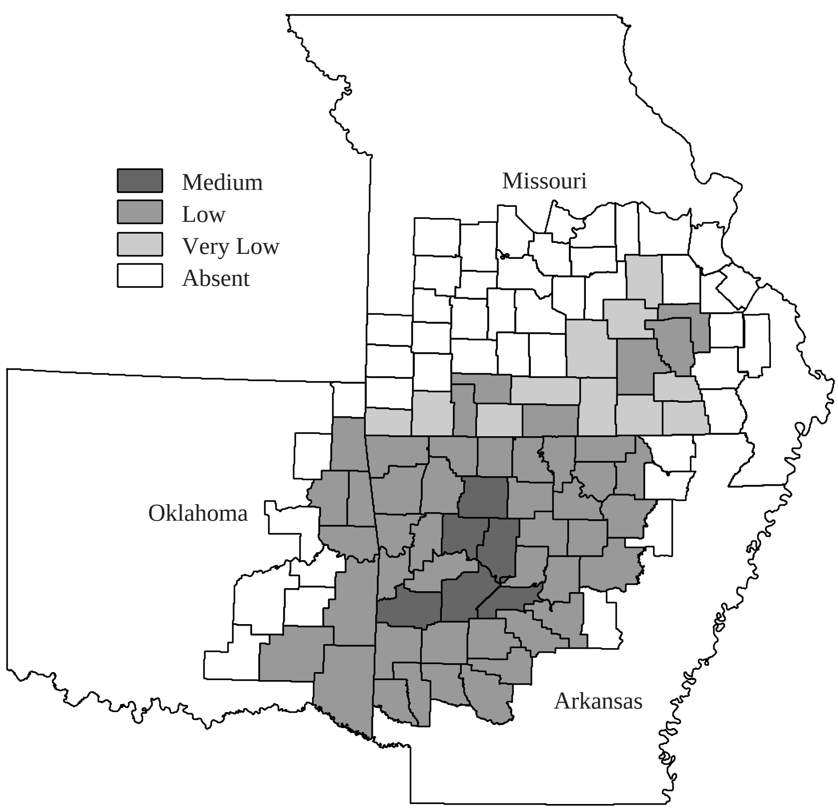


Figure 5.6—Relative black bear abundance in Assessment area counties, 1996.

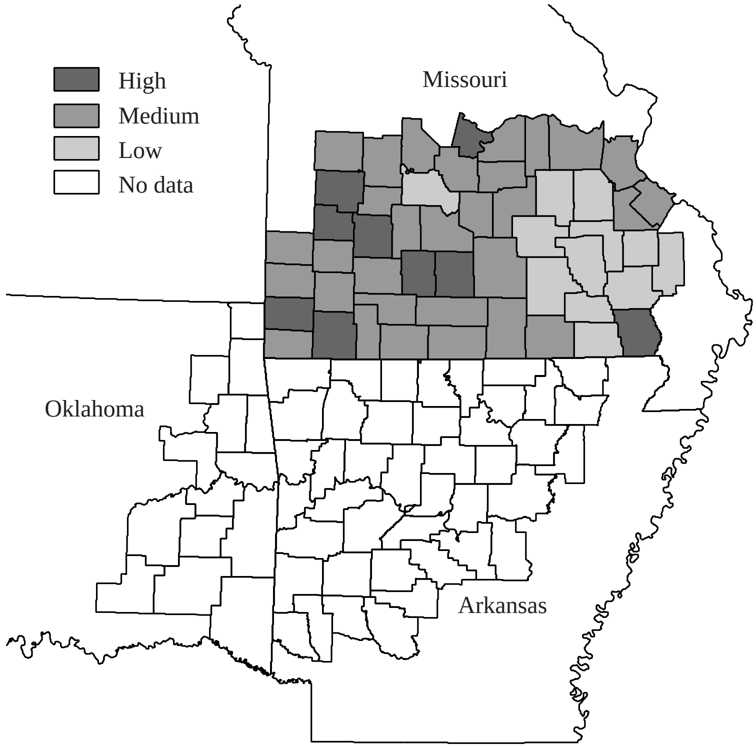


Figure 5.7—Relative gray squirrel abundance in Assessment area counties of Missouri, 1996.

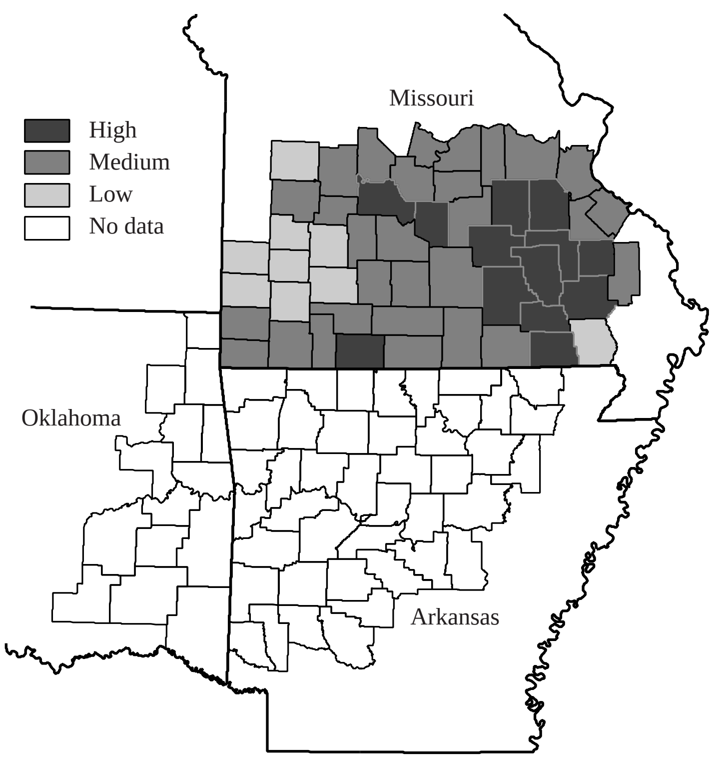


Figure 5.8—Relative fox squirrel abundance in Assessment area counties of Missouri, 1996.

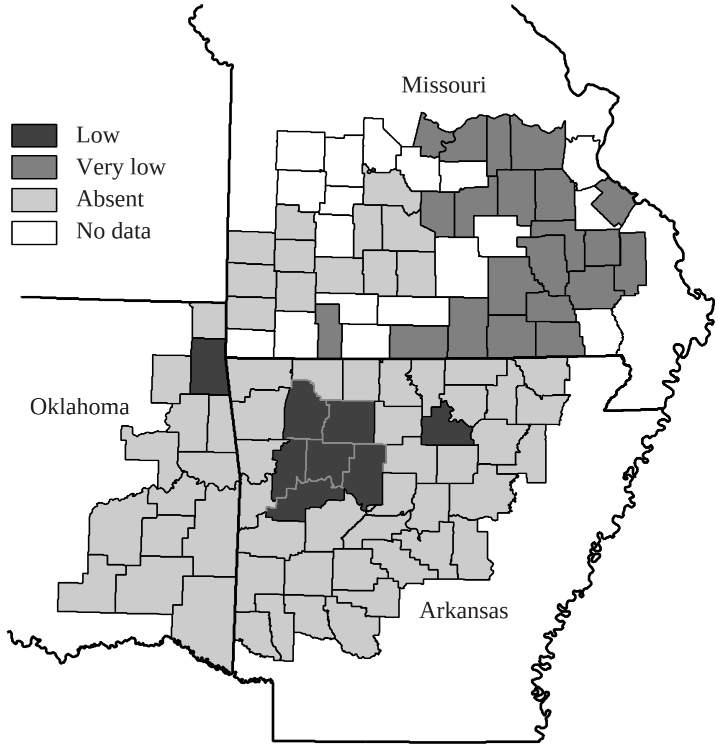


Figure 5.9—Relative ruffed grouse abundance in Assessment area counties, 1996.

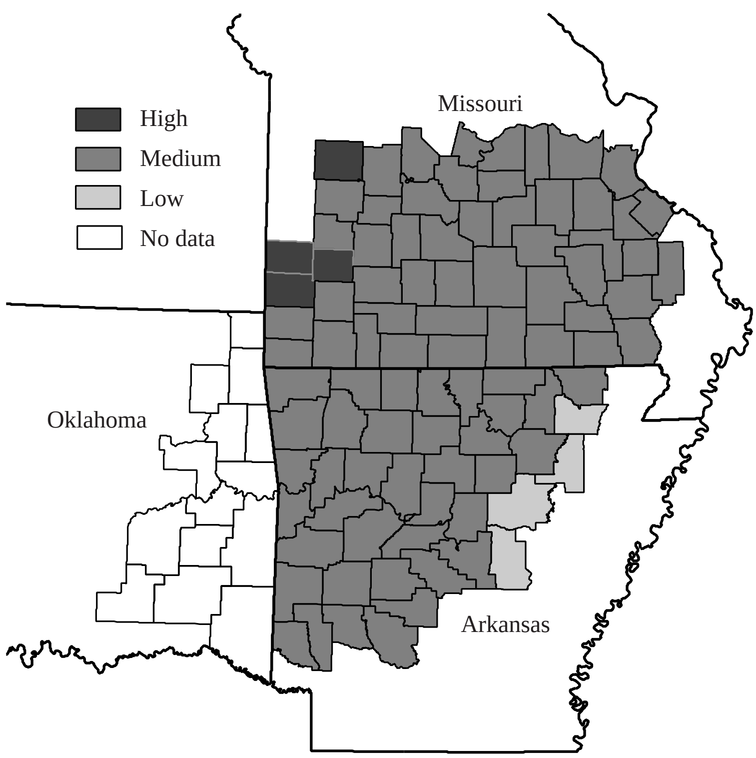


Figure 5.10—Relative bobwhite abundance in Assessment area counties of Arkansas and Missouri, 1970.

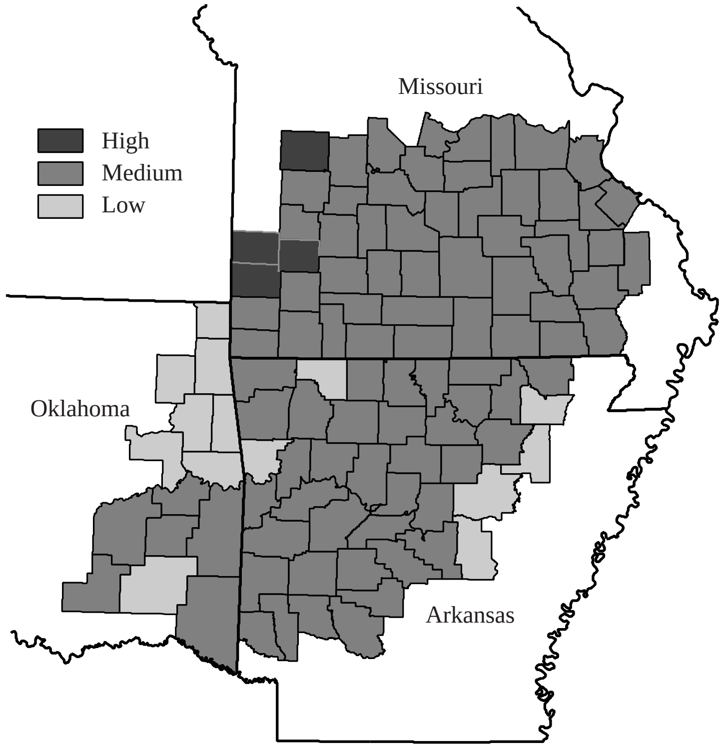


Figure 5.11—Relative bobwhite abundance in Assessment area counties, 1996.

1970 and 1996, according to the available data (fig. 5.12). Counties with higher densities tend to be on the border of the Highlands. Rabbits depend upon an abundance of escape cover interspersed with grassland communities containing a large proportion of broadleaf plants—habitat uncommon in the forested portions of the Highlands.

Raccoon densities are moderate to high throughout the Highlands (fig. 5.13). Seventeen counties had a high density in 1996. Raccoons are most abundant in floodplains, mesic forests, swamps, marshes, farmlands, and suburban residential areas. They tend toward low population density in areas with xeric woodlands and pine forests. Highland counties adjacent to agricultural areas tend to have the higher populations. Raccoon densities were not estimated for 1970.

Implications and Opportunities

The future for wild turkeys in the Assessment area is promising. Turkey densities are higher on public lands than on adjacent private forests because of past and present management programs. The expanding use of prescribed fire on the national forests of the Assessment area is likely to improve habitat conditions for this species.

Because black bear apparently are reproducing successfully in both the Ozarks and Ouachitas, they could continue to expand in the Highlands. Forest regeneration areas are very important as sources for food and denning sites, because black bears thrive within landscapes that provide a mix of young and mature forests.

The future of squirrels depends upon management practices that encourage a variety of trees, with an emphasis on mature trees of nut-producing species (Christisen 1970). Since most of the merchantable trees in the Highlands were cut by the 1920's, many hardwoods are just beginning to reach optimal mast-producing ages. Mast production, while somewhat dependent on weather, should continue to increase for decades.

Grouse populations in the Assessment area probably will always be lower than in the northern part of the grouse range. Research indicates that quality of habitat limits grouse populations more than predation and fall hunting. Favorable management programs on national

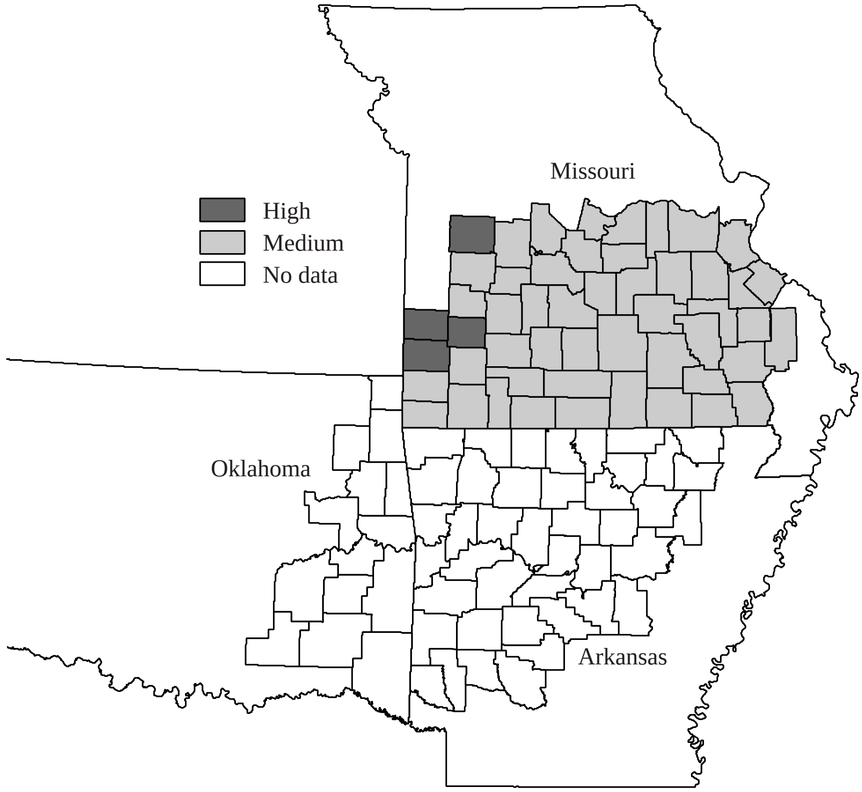


Figure 5.12—Relative rabbit abundance in Assessment area counties of Missouri, 1996.

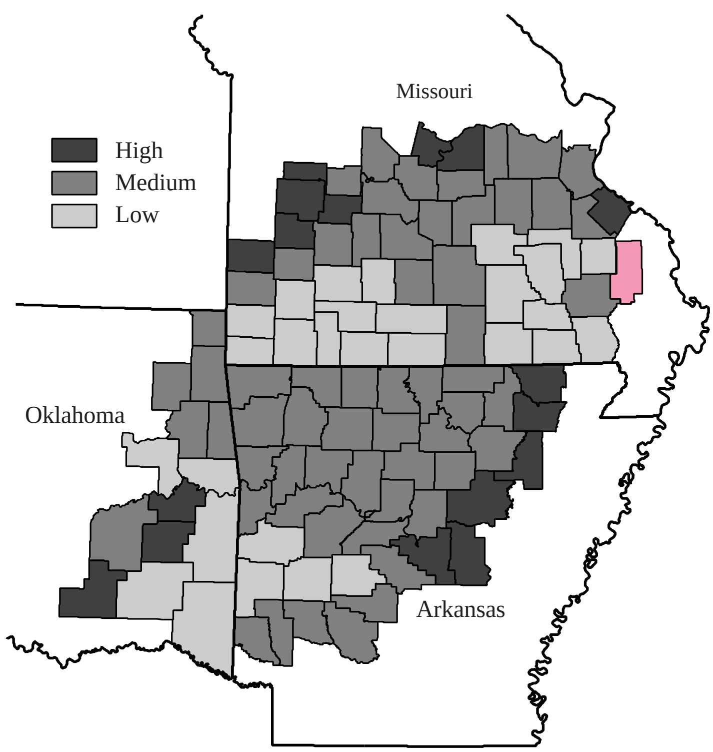


Figure 5.13—Relative raccoon abundance in Assessment area counties, 1996.

forest lands can contribute significantly to regional grouse populations because of the extensive acreage available as habitat.

Bobwhite quail populations on public lands could increase with more widespread use of prescribed burning, savanna restoration, and other enhancements. The Shortleaf Pine-Bluestem Grass Management Area on the Ouachita National Forest is an example of how a reduced forest canopy and periodic fire can support an increase in the bobwhite quail population (USDA FS 1996).

Neotropical Migratory and Resident Birds

Birds in the Ozark-Ouachita Highlands are a large and diverse group of vertebrates. The Terrestrial Team studied the status of 157 species that breed or are likely to breed in the Assessment area. Some species are the subjects of international conservation efforts. In particular, neotropical migratory birds are the focus of one of the largest international conservation efforts for non-game wildlife that are not yet endangered (Terborgh 1989, Hagan and Johnston 1992, Finch and Stangel 1993, Martin and Finch 1995).

Data Sources and Methods of Analysis

The Team analyzed data from several databases to compile three lists (table 5.9): species identified as conservation priorities for the Ozark-Ouachita Highlands by the Partner's in Flight Program (PIF); declining birds in the Ozark-Ouachita Highlands; and species that occur in the Ozark-Ouachita Highlands considered national conservation priorities. Partners in Flight is a collection of Government agencies and nongovernment organizations working to conserve birds (Rogers and others 1993). The list of priority species and declining species was developed for the Ozark-Ouachita Plateau, a region that corresponds closely to the Ozark-Ouachita Highlands Assessment area (fig. 5.14).

The PIF Priority Species were developed for physiographic regions across the United States and are based on the PIF database, which includes information on breeding landbirds within physiographic regions or States. This information includes global abundance of each species, breeding distribution, winter distribution, threats on breeding grounds, threats on wintering grounds, importance of the region or State to the individual species, and population trends (Hunter and others 1993, Carter and Barker 1993). The Team reported species that are considered conservation priorities, based on the information in the database, for the Ozark-Ouachita Plateau (Colorado Bird Observatory 1998). Species were classified as priorities by PIF if they met one or more of the following criteria:

- a species total score in the database is 23 or greater;
- a species total score is 19 to 22, with the sum of Area Importance and Population Trend equal to or greater than 8;
- it is an Audubon Watchlist species and the Area Importance score is 3 or greater;
- its Area Importance score and Population Trend scores add up to 10 (regardless of total score);
- the percentage of the population breeding in the planning unit is greater than 5 percent in planning units smaller than 2,000 square kilometers or 10 percent in areas greater than 2,000 square kilometers;
- a species is federally listed as threatened or endangered; or
- the species is of local concern as identified by PIF Technical, State or Regional Working Groups.

The Team also listed the scores for each element in the database and the total scores for species in the Ozark-Ouachita Plateau (Appendix table 5.5).

The Team identified declining species from the North American Breeding Bird Survey, which the U.S.G.S. Patuxent Wildlife Research Center coordinates (Robbins and others 1986, Sauer and others 1997). This large-scale roadside survey does not provide good information on species that are rare or not sampled well from roads but does provide the most extensive long-term abundance information for nongame wildlife. The Team analyzed data for the Ozark-Ouachita Plateau physiographic region from this survey to create a list of species with significant population declines during the period 1966 to 1996.

The Terrestrial Team also identified species on the National Audubon Society's Watchlist that may breed within the Assessment area. This list identifies birds that are at risk but do not qualify for Federal listing as threatened or endangered. The National Audubon

Table 5.9—Bird species of the Ozark-Ouachita Highlands on various lists of species with management concerns

Species	Partners in Flight score[a]	Breeding Bird Survey trend[b]	Audubon Society Watchlist[c]
Red-cockaded woodpecker	28		
Swainson's warbler	26		x
Cerulean warbler	25		x
Worm-eating warbler	25		x
Henslow's sparrow	25		x
Bachman's sparrow	25		x
Acadian flycatcher	23	-2.9	
Kentucky warbler	23		x
Louisiana waterthrush	23		
Dickcissel	23	-1.8	x
Bell's vireo	23		x
Prairie warbler	23	-4.6	x
Chuck-will's-widow	22		x
Whip-poor-will	22		
Brown-headed nuthatch	22		
Blue-winged warbler	22		
Field sparrow	22	-3.1	x
Painted bunting	22		x
Sedge wren	22		
Northern bobwhite	21	-2.6	
Hooded merganser	21		
Hooded warbler	21		
Mississippi kite	21		
Prothonotary warbler	21		x
Wood thrush	21		x
Scissor-tailed flycatcher	21		
Orchard oriole	21	-3.7	x
Brown thrasher	21	-2.9	
Eastern wood-pewee	20		x
Ovenbird	20	-3.6	
Summer tanager	20		
Yellow-billed cuckoo	20		x
Loggerhead shrike	20	-9.4	x
Yellow-throated vireo	20		
Yellow-throated warbler	20		
Rufous-crowned sparrow	20		
Common nighthawk		-8.8	
Lark sparrow		-6.4	x
Horned lark		-6.1	
Gray catbird		-3.5	x
Northern flicker		-2.9	
House sparrow		-2.8	
Pileated woodpecker		-2.6	
Eastern towhee		-2.2	
Blue jay		-1.0	
Brown-headed cowbird		-1.0	
Northern mockingbird		-1.0	
White-eyed vireo		-0.9	
Black-billed cuckoo			x
Short-eared owl			x
Chimney swift			x
Red-headed woodpecker			x
Grasshopper sparrow			x

[a] The Partners in Flight (PIF) list includes species considered a high conservation priority for the Ozark-Ouachita Plateaus; the greater the total score, the higher the conservation concern. These scores change over time. Check the Colorado Bird Observatory Web site (<http://www.cbobirds.org>) for the latest scores.
[b] Species that had statistically significant population declines from 1966 to 1996, according to the North American Breeding Bird Survey.
[c] A national list of species not yet threatened or endangered but considered of concern for conservation purposes.
Source: Sauer and others (1997), Colorado Bird Observatory (1998).

Figure 5.14—A comparison of the Ozark-Ouachita Highlands Assessment area and the boundaries of the Ozark-Ouachita Plateau physiographic region used by the North American Breeding Bird Survey (BBS) and the Partner's in Flight Landbird Database.

Society compiles the list in collaboration with scientists and PIF. The Watchlist is based on the PIF Landbird Database but provides a national perspective. Thus, the Watchlist is useful for identifying opportunities in the Ozark-Ouachita Highlands to contribute to national conservation priorities.

The Team also classified species according to the following general habitats: aquatic, developed, agriculture, grassland, savanna/glade, shrub/sapling, and forest (Probst and Thompson 1996, Dickson and others 1995, Hamel 1992). "Developed habitats" include suburban, urban, and commercial areas. "Agriculture" refers to cropland, pasture, fencerows, and farmyards. "Grassland" includes prairie and rangeland; "savanna/glade" includes semi-forested grassland habitats; "shrub/sapling" includes old fields and young regenerating forest; and "forest" includes upland, lowland, coniferous, and deciduous forest.

In addition to identifying birds breeding in the region and species that pose a management concern, the Team reviewed recent research and recommendations on the effects of habitat fragmentation and forest management practices on birds. These topics have been the subject of significant debate and investigation, particularly regarding neotropical migratory birds in the Eastern United States (Finch 1991, Hagan and Johnston 1992, Martin and Finch 1995, Thompson 1995).

Patterns and Trends

Forty-one (26 percent) of 157 species of birds that breed within the Assessment area are classified as priority species by PIF. Analysis of the North American Breeding Bird Survey reveals that 21 of 90 bird species in the Ozark-Ouachita Highlands have significantly declined in abundance during the period 1966 to 1996. Six of the species had significant population increases. Finally, 25 of the 90 species on the National Audubon Watchlist occur within the Ozark-Ouachita Highlands (table 5.9).

The three lists of birds with management concerns have some species in common but also differ in many ways. The priority species list and the Audubon Watchlist are based on similar criteria but applied at different scales (the Ozark Highlands Plateau and the United States, respectively). These two lists consist of a mix of resident, short-distance, and long-distance migrants, but are dominated by neotropical migratory birds. By contrast, the list of species in the region with population declines is a more balanced mix of resident, short-distance, and long-distance migrants.

Most bird species, including most species with management concerns in the Assessment area, primarily use forest and shrub/sapling habitats (Appendix table 5.5, fig. 5.15). Some species with management concerns inhabit savannas and glades. Half of the species on the PIF list are forest birds, although just one fifth (19 percent) of the list of declining species are forest birds. Shrub/sapling birds are a larger component of declining species (37 percent) than of those on the PIF list (25 percent). This difference exists because the PIF list is based on other factors in addition to population trends. Shrub/sapling birds exhibit some of the steepest population declines in the region, but in general are still more abundant or more broadly distributed than some forest birds with management concerns (Appendix table 5.6).

Landscape composition and pattern significantly affect the reproductive success and status of forest bird populations in the Assessment area. Productivity, source-sink status of populations (see next paragraph), and levels of nest depredation or brood parasitism (see following paragraphs) are related to landscape patterns in forest cover (Donovan and others 1995a, Robinson and others 1995, Thompson and others in press). Strong regional patterns in the productivity of some songbirds in midwestern forests occur because of the great variation in amount of forest cover (Robinson and others 1995). Reproductive rates of some forest birds are so low in some fragmented landscapes that these populations are likely sinks that cannot sustain themselves without immigration from more productive source populations (Donovan and others 1995, Robinson and others 1995, Brawn and Robinson 1996).

Interactions between local habitat factors and features of the landscape influence population size and viability of bird species. At a local or habitat patch scale, the size of the patch, the proximity to habitat edges, and the habitat type or structure can affect birds. Local management practices, including forest management practices, typically determine local habitat patch characteristics (Donovan and others 1995a, Robinson and others 1995, Thompson and others, in press). At a regional or landscape scale, the amount and distribution

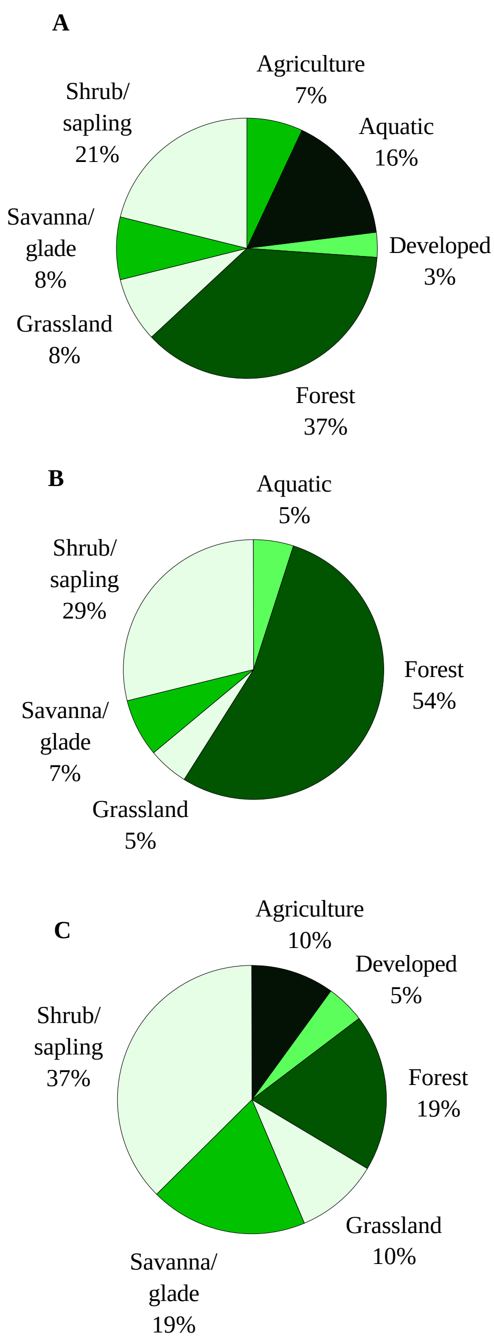


Figure 5.15—Distribution by (A) primary breeding habitat of all birds, (B) species of management concern derived from the Partners in Flight Landbird Database (PIF priorities), and (C) species with significant population declines based on the North American Breeding Bird Survey for the Ozark-Ouachita Plateau physiographic region.

of habitats affect a species abundance and viability, or reproductive success. Land uses such as agriculture, forest management, range management, and development can fragment once-contiguous habitats, shrinking the areas of deep forest, which some species require, and altering the proportion of "edge" in the landscape. Reproductive rates of birds can be so low in fragmented landscapes that these populations are "sinks" that cannot sustain themselves without immigration from more productive "source" populations (Donovan and others 1995a, Robinson and others 1995, Brawn and Robinson 1996).

Reproductive rates appear high enough in the Missouri Ozarks for this area to act as a population source for many forest birds (Donovan and others 1995, Robinson and others 1995). This is probably true for other heavily forested portions of the Assessment area, as well. However, while observed variation in reproductive rates and population modeling generally support the idea of source-sink population structure in the Highlands, there is no evidence of this in the Assessment area.

The likely reason for the relationship between the reproductive success of forest breeding birds and landscape composition is that predator and cowbird numbers are greater in landscapes where the forest is fragmented by agriculture and development. Apparently any human activities creating cowbird and predator-feeding habitat within a forested landscape will reduce nesting success. Even a single cowbird feeding area in a forested landscape can reduce nesting success over a large area because cowbirds can commute up to 4 miles between feeding and breeding sites (Rothstein and others 1984, Thompson 1994). In practice, however, mostly forested landscapes where there are few feeding opportunities for cowbirds have low numbers of cowbirds and low parasitism levels (Thompson and others, in press). Because nest predators are so diverse, regional and landscape patterns of nest predation generally are less pronounced than those for cowbird parasitism (Robinson and others 1995). Predators such as raccoons, opossums, jays, and crows that forage extensively in agricultural habitats may be a much greater problem in agricultural landscapes than in forested landscapes (Paton 1994, Marini and others 1995). Some snakes also appear to be most abundant near agricultural openings (Durner and Gates 1993).

These findings address large-scale patterns in major categories of land use, including forest, agriculture, range, and development, and may not be directly applicable to changes in forest landscapes per se. Forest management practices also affect landscape composition and pattern and local habitat structure and composition, but in different ways.

Table 5.10 and figure 5.16 indicate bird use of habitats created by different silvicultural practices in the Missouri Ozarks. Species such as blue-winged warblers, prairie warblers, yellow-breasted chats, indigo buntings, Kentucky warblers, common yellowthroats, white-eyed vireos, gray catbirds, rufous-sided towhees, and northern cardinals commonly breed in recently regenerated

Table 5.10—Abundance of neotropical migratory birds in oak-hickory and loblolly-shortleaf pine forest habitats in the Ozark Highlands

	Oak-hickory						Loblolly-shortleaf pine				
Bird species	Reg	Sap	Pole	Mat	Gs	St	Reg	Sap	Pole	Mat	Og
Whip-poor-will	U	U	U	U	U	U	N	N	N	N	?
Ruby-throated hummingbird	C	N	N	N	?	N	U	U	U	U	U
Acadian flycatcher	N	N	C	A	N	A	N	N	U	C	C
Eastern wood-pewee	N	N	U	A	N	A	N	U	P	C	A
Eastern phoebe	N	N	U	U	N	U	N	N	N	N	?
Great crested flycatcher	C	C	C	C	C	C	N	N	U	P	C
Blue-gray gnatcatcher	A	C	C	C	C	C	N	N	U	C	A
Eastern bluebird	C	N	N	N	N	N	U	U	N	N	P
Wood thrush	U	C	C	C	U	C	N	N	U	C	A
American robin	—	—	—	—	—	—	N	U	U	U	U
Gray catbird	C	C	N	N	?	N	U	U	N	U	U
White-eyed vireo	C	C	N	N	?	N	U	A	P	U	C
Yellow-throated vireo	N	N	N	U	N	U	N	N	U	A	C
Red-eyed vireo	U	U	A	A	U	A	N	U	C	A	A
Blue-winged warbler	A	C	N	N	?	N	N	N	N	N	N
Golden-winged warbler	C	U	N	N	?	N	N	N	N	N	N
Northern parula	N	N	U	C	N	C	N	N	U	U	C
Chestnut-sided warbler	C	C	N	N	?	N	N	N	N	N	N
Yellow-throated warbler	N	N	U	U	N	U	—	—	—	—	—
Prairie warbler	A	C	N	N	?	N	C	A	N	N	U
Black-and-white warbler	C	C	C	C	C	C	N	U	C	C	C
Worm-eating warbler	U	C	C	C	C	C	N	N	C	C	C
Chuck-will's-widow	—	—	—	—	—	—	U	U	U	U	U
Ovenbird	U	C	C	C	U	U	N	N	U	C	C
Louisiana waterthrush	N	U	C	C	C	C	N	N	N	P	P
Common yellowthroat	A	U	N	N	?	N	C	A	P	P	U
Kentucky warbler	A	C	U	U	A	C	N	U	C	P	P
Hooded warbler	C	C	U	U	C	C	N	U	C	A	C
Yellow-breasted chat	A	C	N	N	?	N	C	A	U	N	P
Orchard oriole	U	N	N	N	N	N	N	N	U	U	U
Summer tanager	C	C	C	A	C	C	N	N	U	C	C
Scarlet tanager	U	U	C	A	U	A	N	N	U	U	U
Indigo bunting	A	C	U	U	A	C	N	A	P	U	P
Rufous-sided towhee	A	U	N	N	C	N	N	P	C	C	P
Brown-headed cowbird	A	C	C	C	C	C	P	C	P	P	N
American goldfinch	U	N	N	N	N	N	U	U	U	U	U
Blue grosbeak	—	—	—	—	—	—	C	U	N	N	N

Reg = regeneration; Sap = sapling; Pole = poletimber; Mat = mature; Gs = group selection; St = single-tree selection; Og = old growth; U = uncommon; N = not present; ? = insufficient data; C = common or regular; A = abundant; P = present; — = does not occur in habitat.
Source: Dickson and others (1998), Thompson and others (1995).

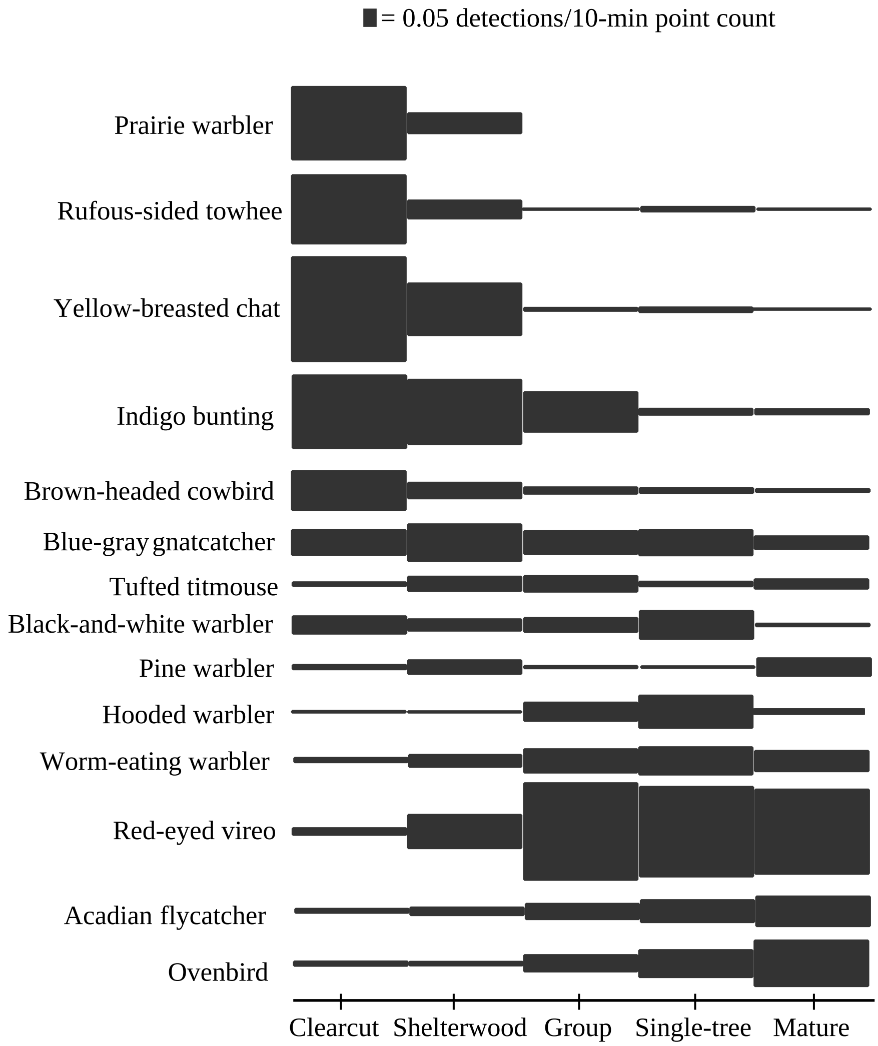


Figure 5.16—Relative abundance of breeding songbirds in habitats managed by various silvicultural practices in oak and oak-pine forests in the Missouri Ozarks (reprinted from Annand and Thompson 1997).

even-aged stands. Black-and-white, worm-eating, and Kentucky warblers are common in these stands as they mature into dense sapling stands, and ovenbirds, wood thrushes, and red-eyed vireos may also begin using them. Once even-aged stands have matured into pole- or sawtimber-sized stands, the common birds of mature forests return, including red-eyed vireos, scarlet tanagers, summer tanagers, eastern wood-pewees, wood thrushes, ovenbirds, Acadian flycatchers, pine warblers, and yellow-throated warblers. Because uneven-aged silviculture systems create stands with diverse tree sizes and small canopy gaps, many of the previously mentioned species will be present in uneven-aged stands. Species requiring large patches of young forest or shrub habitat, however, will not be present. These include blue-winged warblers, prairie warblers, yellow-breasted chats, and white-eyed vireos. Species that use or prefer small gaps, such as the hooded warbler, Kentucky warbler, and indigo bunting, will benefit from uneven-aged management. (See Dickson and others 1995 and Thompson and others 1996 for more detail on the use of managed forest habitats by forest breeding birds within the Assessment area.)

Implications and Opportunities

The list of bird species of the Ozark-Ouachita Highlands with management concerns (table 5.9) is a starting point for avian conservation. However, these species have distinct habitat requirements. Conservation efforts directed at any one species on this list will be to the detriment of at least some other species on the list. Thus, land managers and planners should plan for a diversity of habitats, including grasslands, in the Assessment area in order to conserve all of these species.

Several recent reviews of research that address forest management's effects on songbirds within the Assessment area suggest the impact of silviculture on forest songbirds depends primarily on whether even-aged or uneven-aged silvicultural systems are used (Thompson and others 1995, Dickson and others 1995, Thompson and others 1996).

Even-aged systems harvest an existing stand and result in a young even-aged stand. Over time, across a landscape, this results in a mosaic of stands or habitat of different ages. Even-aged management creates high habitat diversity at a landscape scale, but within stands or habitat patches the habitat is dominated by a single age-class of trees.

Uneven-aged silvicultural methods will maintain a range of tree sizes within a stand. Because single trees or small groups of trees are harvested at one time in an uneven-aged management system, small gaps are created in the forest canopy. These small gaps in the canopy may be too small to function as habitat for area-sensitive early successional species, e.g., prairie warbler. Consequently, uneven-aged management results in high structural habitat diversity within habitat patches (stands) but creates less diversity at the landscape scale (Thompson and others 1995).

No single silvicultural practice can be generalized as good or bad for birds. Any silvicultural system will create habitat for some species while degrading habitats for others. Land management for species conservation should consider patterns and practices at both the landscape scale and the stand scale (Freemark and others 1995, Thompson and others 1995).

Extensively forested landscapes are of greater value to forest breeding songbirds than forests fragmented by nonforest land uses. The Ozark-Ouachita Highlands are one of the most extensively forested regions in the Midwest and probably of great value to forest songbirds. How forests are managed within the region will also affect their value to individual songbird species. A diversity of forest management practices will meet the habitat needs of songbirds better than any one practice. The mix of practices will largely determine the abundance of individual species.

Cave Animals

Caves in the Ozark-Ouachita Highlands are habitat for a rich and diverse fauna. The diversity of aboveground habitats, such as forests and springs, contributes to an abundance of cave-dwelling species in the Highlands. These subterranean and surrounding forest habitats are sanctuaries for a number of State and federally listed threatened and endangered species.

Worms, leeches, snails, isopods, amphipods, crayfish, flies, pseudoscorpions, crickets, beetles, fleas, spiders, millipedes, springtails, fishes, amphibians, reptiles, and mammals occupy caves (Weaver 1992). The movement of some of these animals, especially bats, in and out of the cave, and the continual flow of water from a surface recharge area, link these communities to the surface.

Numerous solution caves riddle the Ozark Mountains. These caves form as weakly acidic groundwater seeps or flows through joints and bedding planes in the limestone and dolomite bedrock, causing the rock to slowly dissolve (Weaver 1992).

In contrast, there are no solution caves in the Ouachita Mountains due to the lack of sedimentary limestone in the region. Talus caverns and rock shelters, which are formed when large rocks fall, roll, slide, or tilt against each other, are present in the Ozarks and Ouachitas.

A few talus caverns are extensive enough to provide total darkness. These "caves" are important shelter for some animals and plants (Halliday 1982). Bear Den Caves, large talus on Winding Stair Mountain in southeastern Oklahoma, occur in an outcrop belt of sandstone. These caves have more than 1,200 feet of passageway and are the only known caves in the Ouachita National Forest (Puckette 1974–75). Abandoned mines are a third type of cave habitat in the Assessment area and provide the same specialized habitat, as do natural caves (Foti 1974). There are 27 known abandoned mines on national forests in the Assessment area (Saugey and others 1988).

Data Sources

The information in this section is from published reports and field observations by members of the Terrestrial Team.

Patterns and Trends

This section concerns caves and the management of caves within the three national forests in the Assessment area. A list of State and federally listed cave species and other sensitive cave species in or near the three forests appears in table 5.11.

Caves in the Mark Twain National Forest

There are 409 known caves on the Mark Twain National Forest, of which 306 have been nominated as significant under the Federal Cave Resource Protection Act and 140 have been mapped. These caves are habitat for five federally listed species, including the endangered gray and Indiana bats. Seven of these caves have been gated to control human disturbance.

Table 5.11—Threatened and endangered cave-dwelling species in the Ozark-Ouachita Highlands by national forest, global and State rank, and Federal and State status[a]

Common name	Scientific name	Global rank	State rank	Federal status	State status
	Mark Twain National Forest				
Gray bat	*Myotis grisescens*	G2G3	S3	E	E
Indiana bat	*M. sodalis*	G2	S1	E	E
Eastern small-footed bat	*M. leibii*	G3	S1		R
Long-eared bat	*M. septentrionalis*	G4			
Ozark cavefish	*Amblyopis rosae*	G2	S1	T	E
Southern cavefish[b]	*Thyphlichthys subterraneus*	G3	S3		WL
Central MO cave amphipod	*Allocrangonyx hubrichti*	G1G3	S1S3		R
Tumbling Creek cave snail	*Antrobia culveri*	G1	SX	C	E
Salem Cave crayfish	*Cambarus hubrichti*	G3	S2		WL
Bristly Cave crayfish	*Cambarus setosus*	G2	S2		WL
Onondaga Cave amphipod	*Stygobromus onondagaensis*	G1G3	S1S3		WL
Ozark Cave amphipod	*S. ozarkensis*	G?			
	Ozark National Forest				
Gray bat	*M. grisescens*	G2G3	S2	E	S2
Indiana bat	*M. sodalis*	G2	S2	E	S1
Eastern small-footed bat[b]	*M. leibii*	G3	S1		S1
Ozark big-eared bat	*Corynorhinus townsendii ingens*	G4T1	S1	E	S1
Rafinesque's big-eared bat[b]	*C. rafinesquii*	G3G4	S2		S2
Oklahoma salamander[b]	*Eurycea tynerensis*	G3	S2		S1
Ozark cavefish[b]	*Amblyopis rosae*	G2	S1	T	S1
Southern cavefish[b]	*Thyphlichthys subterraneus*	G3	S1		S1
	Ouachita National Forest				
Indiana bat	*Myotis sodalis*	G2	S2	E	S1
Eastern small-footed bat	*M. leibii*	G3	S1		S1

[a] See text for explanation of designations; blank spaces mean no corresponding rank has been assigned.
[b] Has never been documented as occurring on the national forest but may be present.
Source: Harvey and others (1996), Saugey and others (1989), Weaver (1992).

Caves in the Ozark National Forest

Federally and State-listed threatened and endangered cave species along with other sensitive cave species found in the Ozark National Forest are listed in Table 5.11. The endangered gray and Indiana bats and the Ozark big-eared bat use at least 10 caves in the Ozark National Forest. Two of only five known remaining hibernating colonies of Indiana bats in Arkansas occur on the Sylamore Ranger District of the Ozark National Forest. During the winter of 1995 to 1996, 1 cave contained about 400 hibernating Indiana bats, and the other contained about 350 (Harvey and Redman 1996).

Blanchard Springs Caverns, also on the Sylamore Ranger District, demonstrates the vulnerability of bat colonies to disturbance. After the Forest Service began constructing trails in the cave in 1963 and opened it to the public for guided tours in 1973, a hibernating colony of 5,000 to 7,000 gray bats dwindled to about 150 in the winter of 1978 to 1979 and dropped to only 33 bats during the winter of 1985 to 1986. Since then, the Forest Service has limited disturbance at the roost site and the bat population has increased dramatically to more than 50,000 in 1995. During the summer of 1996, there were about 34,000 bats present.

Caves in the Ouachita National Forest

Nine species of bats and six species of salamanders use caves and abandoned mines in the Ouachita Forest. Heath and others (1986) reported the occurrence of 27 vertebrate taxa using abandoned mine drifts in the Ouachita Mountains.

The discovery in 1989 of a hibernating cluster of seven Indiana bats in Bear Den Caves (Saugey and others 1989) may indicate the occurrence of this species in the Ouachita Mountains during other times of the year, although females are known to travel considerable distances from hibernacula to maternity sites (LaVal and LaVal 1980).

Implications and Opportunities

The Federal Cave Resource Protection Act of 1988 (P.L. 100-691) secures and preserves significant caves on Federal lands for the perpetual use, enjoyment, and benefit of all people and encourages cooperation and exchange of information between government authorities and those utilizing caves located on Federal lands for scientific, educational, or recreational purposes.

Inventories of threatened, endangered, rare, and sensitive cave species and new caves (as they are discovered) are important for ecosystem management on public lands. Interagency collaboration also is valuable. The Missouri Department of Conservation and the U.S. Fish and Wildlife Service plan to reestablish certain extirpated cave species, which may present opportunities for further cooperation with the Mark Twain National Forest.

Because the health of aboveground habitat affects the health of cave communities, management of connections to aboveground habitat and management in the vicinity of cave entrances is important. Controlling the use of insecticides and herbicides in the vicinity of caves also protects subsurface watersheds. Controlling access to sensitive caves in the Assessment area will further protect cave communities.

The bat fauna represents an integral component of the Ozark-Ouachita Highlands. Bats, particularly those inhabiting caves and mines, represent an extremely vulnerable faunal element (Saugey and others 1988). Most species are currently fairly widespread and have adequate populations; however, the gray bat, Indiana bats, and Ozark big-eared bat are endangered, and the southeastern big-eared bat and eastern small-footed bats are species of concern. Marginal habitats of importance to bats, such as caves and abandoned mines—alone or combined with diverse and spatially distributed forest types and age classes—appear to have contributed to the rich bat fauna of the region. Recent investigations of habitat utilization by Indiana bats in Illinois (Gardner and Gardner 1982) revealed use of living red oak, white oak, post oak, and hickory trees as roosts and use of shagbark hickory snags, all of which occur in the national forests of the Highlands, as maternity sites. Surface disturbances damaging forests and soil cover or contaminating ground water, including some agricultural, residential, and industrial development, affect the health of caves. Protection, maintenance, and enhancement of all habitat components must be considered in all phases of planning and implementation of management activities.

Appendix Table 5.1—Assessment area terrestrial plant and animal species, the viability of which is of concern to scientists, the global and State ranks of these species, and their known habitats

Scientific name	Common name	Global rank	State rank AR	State rank MO	State rank OK	Habitat
		Amphibians				
Ambystoma talpoidium	Mole salamander	G5	S2?		S1	BLH
Eurycea tynerensis	Oklahoma salamander	G3	S2		S3	SS
Hemidactylium scutatum	Four-toed salamander	G5	S2		S1	SS
Plethodon caddoensis	Caddo Mountain salamander	G2	S2			MF
Plethodon fourchensis	Fourche Mountain salamander	G2	S2			MF
Plethodon ouachitae	Rich Mountain salamander	G2G3	S2		S2	MF
Plethodon sequoyah	Southeast Oklahoma slimy salamander	G2Q			S2	MF
Plethodon serratus	Southern redback salamander	G5	S2?		S3S4	MF
Pseudocris streckeri streckeri	Strecker's chorus frog	G5T4	S1?		S4	HG
Rana areolata circulosa	Northern crayfish frog	G4T4	S1?		S4	PR
Scaphiopus holbrookii hurteri	Hurter's spadefoot	G5T?	S2?		S3	WFM
Spea bombifrons	Plains spadefoot	G5	S1		S5	PR
		Birds				
Accipiter cooperi	Cooper's hawk	G5	S1		S2	WFM
Aimophila aestivalis	Bachman's sparrow	G3	S3	S1	S2	WFM
Aimophila ruficeps	Rufous-crowned sparrow	G5	S1		S4	RO
Ammodramus henslowii	Henslow's sparrow	G3G4		S3	S1	PR
Anhinga anhinga	Anhinga	G5	S1		S1	BLH
Cistothorus platensis	Sedge wren	G3G5		S2		PR
Dendroica cerulea	Cerulean warbler	G3G4	S2		S2	SS
Dendroica pensylvanica	Chestnut-sided warbler	G5	S1		S2	WFM
Dendroica virens	Black-throated green warbler	G5	S1		S3	MF
Egretta caerulea	Little blue heron	G5	S2		S5	BLH
Egretta thula	Snowy egret	G5	S2		S5	BLH
Limnothlypis swainsonii	Swainson's warbler	G3G4	S3	S2	S1	BLH
Nyctanassa violacea	Yellow-crowned night-heron	G5	S2?		S4	BLH
Nycticorax nycticorax	Black-crowned night-heron	G5	S2		S4	BLH
Podilymbus podiceps	Pied-billed grebe	G5	S2?		S5	BLH
Quiscalus mexicanus	Great-tailed grackle	G5	S2		S5	HG
Thryomanes bewickii	Bewick's wren	G5	S2		S4	RO
		Invertebrates				
Arianops sandersoni	Magazine Mountain mold beetle	G1?	S1?			WFM
Calephelis borealis	Northern metalmark	G3G4		S1		RO
Gryllotalpa major	Prairie mole cricket	G3	S?	S2	S2	PR
Ophiogompus westfalli	Arkansas snaketail dragonfly	G2	S?	S?		SS
Panorpa braueri	A panorpid scorpionfly	G1		S1		ND
Papipema eryngium	Rattlesnake master borer moth	G1	S1		S?	PR
Rhadine ozarkensis	A ground beetle	G1	S1			ND
Rimulincola divalis	A beetle	G1	S1			ND
Speyeria idalia	Regal fritillary	G3		S3	SH	PR
Stenotrema pilsbryi	Rich Mountain slitmouth snail	G2	S1		S2	RO
		Mammals				
Corynorhinus rafinesquii	Rafinesque's big-eared bat	G3G4	S2		S1	MF
Myotis austroriparus	Southeastern myotis	G4	S2?		S1	HG

(continued)

Appendix Table 5.1—Assessment area terrestrial plant and animal species, the viability of which is of concern to scientists, the global and State ranks of these species, and their known habitats (continued)

Scientific name	Common name	Global rank	State rank AR	State rank MO	State rank OK	Habitat
		Mammals (continued)				
Myotis lucifugus	Little brown bat	G5			S1	HG
Notiosorex crawfordi	Desert shrew	G5	S1?		S3	WFM
Ochotomys nuttali	Golden mouse	G5			S1	MF
Reithrodontomy humulis	Eastern harvest mouse	G5	S1?		S1	HG
Reithrodontomy montanus	Plains harvest mouse	G5	S1?		S5	PR
Sorex longirostris	Southeastern shrew	G5	S2?			BLH
Spilogale putorius interrupta	Plains spotted skunk	G5T3T4		S1	S2	PR
Ursus americanus	Black bear	G5			S1	HG
		Plants				
Abutilon incanum	Pelotazo abutilon	G5	S1S2			RO
Acer leucoderme	Chalk maple	G5	S2S3			SS
Acer nigrum	Black maple	G5Q	S1S2			MF
Actaea pachypoda	Baneberry	G5			S1	MF
Agalinis auriculata	Auriculate false foxglove	G3	S1	S2		PR
Agalinis skinneriana	A false foxglove	G3		S3		PR
Agalinis viridis	Green gerardia	G4?			S1	PR
Aletris aurea	Golden colicroot	G5	S1S2		S1	SS
Allium stellatum	Glade onion	G5	S2S3			RO
Amianthium muscaetoxicum	Fly poison	G4G5			S1	WFM
Amorpha canescens	Leadplant	G5	S2			PR
Amorpha ouachitensis	Ouachita leadplant	G3Q	S3		S2	SS
Amsonia hubrichtii	Ouachita blue star	G3	S3		S1S2	SS
Androsace occidentalis	Western rock jasmine	G5	S1			RO
Anemone quinquefolia	Wood anemone	G5	S2			MF
Antennaria neglecta	Field pussytoes	G5			S1	WFM
Aplectrum hyemale	Puttyroot	G5			S1	MF
Aplenium x gravesii	Grave’s spleenwort	HYB	S1			RO
Arabis shortii var *shortii*	Short’s rock-cress	G5T5	S1		S1S2	SS
Arenaria benthami	Hilly sandwort	G4			S1	RO
Argyrochosma dealbata	Powdery cloak fern	G4G5	S2			RO
Armoracia aquatica	Lake cress	G4?			S1S3	SS
Artemisia annua	Annual wormwood	G?			S1	HG
Asclepias incarnata	Swamp milkweed	G5	S2			PR
Asclepias stenophylla	Narrow-leaved milkweed	G4G5	S1			RO
Asplenium bradleyi	Bradley spleenwort	G4			S1	RO
Asplenium pinnatifidum	Lobed spleenwort	G4	S1		S1	RO
Asplenium x ebenoides	Scott’s spleenwort	HYB	S1S2			RO
Aster furcatus	Forked aster	G3G4	SH	S3		RO
Aster novae-angliae	New England aster	G5			S1	PR
Aster sericeus	Silky aster	G5	S2			PR
Astragalus crassicarpus var. *crassicarpus*	Ground plum	G5T5	S2			RO
Bergia texana	Texas bergia	G5	S2			BLH
Brachyelytrum erectum	Bearded short-husk	G5			S1	MF
Brasenia schreberi	Watershield	G5			S1	SS
Brickellia grandiflora	Tassel flower	G5	S2			RO
Bromus nottawayanus	Nottaway brome-grass	G3G5			S1	SS

(continued)

Appendix Table 5.1—Assessment area terrestrial plant and animal species, the viability of which is of concern to scientists, the global and State ranks of these species, and their known habitats (continued)

Scientific name	Common name	Global rank	State rank AR	MO	OK	Habitat
			Plants (continued)			
Bryoxiphium norvegicum	Sword moss	G3?		S1		ND
Bryun miniatum	A moss	G3G4		S1		ND
Cacalia muehlenbergii	Great Indian plantain	G4	S2		S1S3	SS
Calamagrostis porteri ssp. *insperata*	Ofer hollow reed grass	G4T3	SH	S2		WFM
Calamovilfa arcuata	A sandgrass	G2	S1		S2	SS
Callirhoe bushii	Bush’s poppy mallow	G3Q	S3	S2	S3	WFM
Calopogon tuberosus	Tuberous grass-pink	G5	S2			PR
Cardamine dissecta	Dissected toothwort	G4?	S1			SS
Carex amphibola var. *globosa*	A sedge	G?T?	S1S2			MF
Carex atlantica ssp. *atlantica*	Prickly bog sedge	G5T4	S2			SS
Carex atlantica ssp. *capillacea*	A sedge	G5T5?	S2			SS
Carex bicknellii var. *opaca*	A sedge	G5T2T3	S2			SS
Carex bromoides	A sedge	G5	S2			SS
Carex careyana	Carey’s sedge	G5	S2			MF
Carex communis	Fibrous root sedge	G5	S2S3			MF
Carex crebiflora	A sedge	G4G5		S1		SS
Carex emoryi	Emory’s sedge	G5	S1S3			SS
Carex fissa var. *fissa*	A sedge	G2QT?	S1	SU	S2	PR
Carex gravida var. *gravida*	A sedge	G5T?	S2			PR
Carex hitchcockiana	Hitchcock’s sedge	G5	S1			PR
Carex interior	Interior sedge	G5	S1			RO
Carex laevivaginata	Smooth-sheath sedge	G3	S3		S2	SS
Carex latebracteata	Waterfall’s sedge	G5	S1			WFM
Carex laxiculmis	A sedge	G5	S1			MF
Carex mesochorea	A sedge	G4G5	S1			PR
Carex microdonta	A sedge	G4	S1			PR
Carex oklahomensis	Oklahoma sedge	G3?		S2	S2	PR
Carex ouachitana	Ouachita sedge	G3?			S2S3	MF
Carex pensylvanica	Pennsylvania sedge	G5	S2S3			WFM
Carex prasina	Drooping sedge	G4	S1S2			SS
Carex projecta	Necklace sedge	G5	S2			BLH
Carex retroflexa var. *texensis*	A sedge	G5T3T5		S1		WFM
Carex socialis	Social sedge	G3	S2	SU		BLH
Carex stricta	Upright sedge	G5	S1S3			SS
Carex suberecta	A sedge	G4	S2			SS
Carex swanii	Swan’s sedge	G5	S3		S1	SS
Carex virescens	Ribbed sedge	G5	S2			WFM
Carex willdenowii	A sedge	G5	S2			SS
Castenea pumila var. *ozarkensis*	Ozark chinquapin	G5T3	S3S4	S2	S2	WFM
Caulophyllum thalictroides	Blue cohosh	G5	S2			MF
Cayaponia grandifolia	A gourd	G3?Q		S1	S1	BLH
Chelone obliqua var. *speciosa*	Rose turtlehead	G4T3Q	SH	S1		SS
Cirsium muticum	Swamp thistle	G5	S1		S1	SS
Cissus incisa	Marine vine	G5	S1		S2	RO
Claytonia caroliniana	Carolina spring beauty	G5	S2S3			WFM
Clematis crispa	Blue jasmine leather-flower	G5			S1	BLH
Clematis drumondii	Drumond leather-flower	G5			S1S2	WFM
Collinsia verna	Spring blue-eyed mary	G5	S1			MF

(continued)

Appendix Table 5.1—Assessment area terrestrial plant and animal species, the viability of which is of concern to scientists, the global and State ranks of these species, and their known habitats (continued)

Scientific name	Common name	Global rank	State rank AR	State rank MO	State rank OK	Habitat
		Plants (continued)				
Cooperia drummondii	Evening rainlily	G5	S1S2			PR
Corallorhiza odontorhiza	Autumn coral-root	G5			S1	WFM
Coreopsis grandiflora var. *saxicola*	Large-flowered tickseed	G5T3T4	S3			PR
Crataegus brachyacantha	Blueberry hawthorn	G4	S2			SS
Croptilon hookeranum var. *validum*	Scratch-daisy	G5T5	S2			PR
Cyperus setigerus	Bristled cyperus	G3G5		S1		BLH
Cypripedium kentuckiense	Southern lady's-slipper	G3	S3		S1	SS
Cypripedium reginae	Showy lady's-slipper	G4	S1			SS
Dalea gattingeri	Gattinger prairie-clover	G3G4	S?		S1	RO
Delphimium newtonianum	Moore's larkspur	G3		S2		MF
Delphinium exaltatum	Tall larkspur	G3	S3			WFM
Delphinium treleasi	Trelease's larkspur	G3	S3	S3		MF
Dennstaedtia punctilobula	Eastern hay-scented fern	G5	S2			RO
Deschampsia flexuosa	Crinkled hairgrass	G5	S2S3		S1	WFM
Desmodium illinoense	Illinois tick-trefoil	G5	S2			PR
Diarrhena americana var. *americana*	American beakgrain	G3G5T?		S3	S2S3	MF
Didiplis diandra	Water-purslane	G5	S1S3		S1	SS
Dirca palusitris	Eastern leatherwood	G4			S1S2	BLH
Disporum lanuginosum	Yellow mandarin	G5	S2			MF
Dodecatheon frenchii	French's shooting star	G3	S2			MF
Draba aprica	Open-ground whitlow-grass	G3	S2	S2	S1	WFM
Dryopteris carthusiana	Spinulose wood-fern	G4	S2			RO
Dryopteris celsa	Log fern	G5	S1			MF
Dryopteris x australis	Dryopteris	HYB	S1			MF
Dryopteris x leedsi	Leed's wood fern	HYB	S1			MF
Dulichium arundinaceum	Three-way sedge	G5	S2S3		S1	SS
Echinacea paradoxa	Bush's yellow coneflower	G4	S2		S?	RO
Eriocaulon kornickianum	Small-headed pipewort	G2G3	S2		S1	RO
Erysimum capitatum	Western wallflower	G5	S2			RO
Euphorbia comutata	Wood spurge	G5			S1S2	MF
Euphorbia hexagona	Six-angle spurge	G5	S2			PR
Euphorbia longicruris	A euphorbia	G4G5	S1			RO
Euphorbia missourica	Missouri spurge	G5	S2			RO
Eustoma russellianum	Showy-prairie gentian	G5	S2			PR
Fagus grandifolia	American beech	G5			S1?	MF
Fothergilla major	Witch-alder	G3	S1			WFM
Frasera caroliniensis	Carolina gentian	G5			S1	MF
Galium arkansanum var. *pubiflorum*	Ouachita bedstraw	G5T2Q	S2		S1	WFM
Galium texense	Texas bedstraw	G4	S1			WFM
Gaura demareei	Demaree's gaura	G3G4Q			S1	WFM
Gentiana alba	Pale gentian	G4			S1	WFM
Gentiana puberulenta	Downy gentian	G4G5	S2			PR
Gentiana saponaria	Soapwort gentian	G5	S3		S1	SS
Gratiola brevifolia	Sticky hedge-hyssop	G4	S2			SS
Hedyotis ouachitana	Ouachita hedyotis	G3	S3		S1	WFM
Helianthus occidentalis ssp. *plantagineus*	Plantain-leaved sunflower	G5T5	S1			PR
Heliopsis gracilis	Pinewoods ox-eye	G5?			S1	WFM

(continued)

Appendix Table 5.1—Assessment area terrestrial plant and animal species, the viability of which is of concern to scientists, the global and State ranks of these species, and their known habitats (continued)

Scientific name	Common name	Global rank	State rank AR	State rank MO	State rank OK	Habitat
			Plants (continued)			
Heuchera parviflora var. *puberula*	Little-leaved alumroot	G5T3Q	S3			RO
Heuchera villosa var. *arkansana*	Arkansas alumroot	G4T3T4	S3			RO
Hexalectris spicata	Crested coralroot	G4?	S2		S1S2	WFM
Hieraium scabrum	Rough-hawkweed	G5	S2			WFM
Homaliadelphus sharpii	Sharp's homaliadelphus	G2G3		S1		ND
Huperzia lucidula	Shining clubmoss	G5	S2S3			RO
Hydrophyllum brownei	Browne's waterleaf	G1	S1			MF
Hydrophyllum macrophyllum	Waterleaf	G5	S2			MF
Hymenocalis caroliniana	Carolina spider-lily	G4			S1	BLH
Ilex verticillata	Winterberry holly	G5	S2			RO
Iris verna	Dwarf iris	G5	S2			MF
Isoetes melanopoda	Midland quillwort	G5			S1S2	SS
Isotria verticillata	Large whorled pogonia	G5			S1	WFM
Iva angustifolia	Narrow-leaved marsh-elder	G5?	S1			PR
Juncus subcaudatus	A rush	G5	S1			SS
Leitneria floridana	Corkwood	G3	S3			BLH
Liatris squarossa var. *compacta*	Ouachita blazing star	G5T3?	S3			RO
Lilium superbum	Turk's-cap lily	G5	S1			MF
Liparis loeselli	Yellow twayblade	G5	S1			SS
Lithospermum incisum	Narrow-leaved puccoon	G5	S2S3			RO
Ludwigia microcarpa	False loosestrife	G5	S1			SS
Luzula acuminata var. *carolinae*	Southern hairy woodrush	G5T?	S2			SS
Lyonia mariana	Stagger-bush	G5			S1S2	WFM
Magnolia acuminata	Cucumber magnolia	G5			S1	MF
Magnolia tripetala	Umbrella magnolia	G5			S1	MF
Malus coronaria	Sweet crab-apple	G5	S2S3			WFM
Marshallia caespitosa var. *caespitosa*	Marshallia	G4T4	S2		S?	RO
Marshallia caespitosa var. *signata*	Barbara's buttons	G4T4	S2		S?	SS
Matelea baldwyniana	Baldwin's milkvine	G2G3		S?		WFM
Mentha arvensis	Field mint	G5	S1			SS
Mimulus floribundus	Floribundus monkeyflower	G5	S2S3			MF
Mimulus ringens	Square-stem monkeyflower	G5	S1S2			SS
Minuartia drummondii	Drummond's sandwort	G5	S2S3			WFM
Minuartia michaxii	Rock sandwort	G5	S1			RO
Mitella diphylla	Two-leaf bishop's-cap	G5	S2			RO
Monarda stipitatoglandulosa	Ouachita horsemint	G3			S2	RO
Monotropa uniflora	Indian-pipe	G5			S1	WFM
Muhlenbergia bushii	Bush's muhly	G5	S2		S1S2	MF
Neviusia alabamensis	Alabama snow wreath	G2	S1S2	SX		RO
Osmorhiza claytonii	Hairy sweet-cicely	G5	S1S3			MF
Osmunda claytoniana	Interrupted fern	G5	S1			SS
Panax quinquefolius	American ginseng	G4			S1	MF
Pancium philadelphicum var. *tuckermanii*	Tuckerman's panic grass	G3G5		S?		SS
Parnassia grandifolia	Large-flowered grass-of-parnassus	G3G4	S3			SS
Paronychia canadensis	Forked nail-wort	G5			S1S2	WFM
Paronychia virginica var. *scoparia*	A paronychia	G4T4Q	S2			ND
Paspalum dissectum	Water paspalum	G4?			S1	SS

(continued)

Appendix Table 5.1—Assessment area terrestrial plant and animal species, the viability of which is of concern to scientists, the global and State ranks of these species, and their known habitats (continued)

Scientific name	Common name	Global rank	State rank AR	State rank MO	State rank OK	Habitat
				Plants (continued)		
Pedicularis lanceolata	Swamp lousewort	G5			S1	SS
Perideridia americana	Periderdia	G4	S2		S1S2	WFM
Phacelia gilioides	Brand phacelia	G5	S2S3		S1	WFM
Phaseolus polystachios	Wild kidney bean	G4			S1	WFM
Philadelphus hirutus	Hairy mock orange	G5	S2S3			MF
Phlox bifida ssp stellaria	Bifid phlox	G5?T3	S3	S2		WFM
Phyllanthus polygonoides	Knotweed leaf-flower	G5	S1			RO
Pilularia americana	American pillwort	G5	S2			RO
Platanthera ciliaris	Yellow-fringed orchid	G5			S1	SS
Platanthera clavellata	Small green woodland orchid	G5			S1S2	MF
Platanthera cristata	Yellow-crested orchid	G5	S1S2			SS
Platanthera flava	Southern rein-orchid	G4	S1S2		S1	BLH
Platanthera lacera	Ragged orchid	G5			S1S2	MF
Platanthera peramoena	Purple fringeless orchid	G5	S2			SS
Platanthera praeclara	Western white fringed orchid	G2		S1	S1	PR
Pogonia ophioglossoides	Rose pogonia	G5	S2		S1	SS
Polygonella americana	Jointweed	G5			S1S2	WFM
Polygonum pensylvanicum var. *eglandulosum*	Pinkweed	G5T2T4Q		S4		SS
Polymnia cossatotensis	Heartleaf leafcup	G1	S1			RO
Potamogeton natans	Floating leaf pondweed	G5			S1	SS
Potentilla arguta	Tall cinquefoil	G5	S1S2			PR
Psoralea esculenta	Indian scurf-pea	G5			S2	PR
Psoralea onobrychis	French-grass	G5			S1	MF
Pycnanthemum virginianum	Virginia mountain-mint	G5	S1S2			SS
Quercus coccinea	Scarlet oak	G5	S2S3			RO
Quercus laurifolia	Laurel oak	G5	S2S3			BLH
Quercus shumardii var. *acerifolia*	Maple-leaved oak	G1Q	S2		S1?	RO
Rhynchospora capillacea	Capillary beak rush	G1	S1			SS
Rhynchospora clorata	White-top sedge	G5	S2			SS
Ribes curvatum	Granite gooseberry	G4	S1		S1	RO
Ribes cynosbati	Prickly gooseberry	G5	S2S3		S1S2	RO
Ribes missouriense	Missouri gooseberry	G5			S1	WFM
Rosa arkansasa var. *suffultaa*	Wild rose	G5T5	S1S3			PR
Rosa foliolosa	White prairie rose	G2	S2			PR
Sagittaria ambigua	Kansas arrowhead	G2?	S1	S1		SS
Sagittaria rigida	Sessile-fruited arrowhead	G5	S1			SS
Scirpus etuberculatus	Canby's bulrush	G3G4		S1		SS
Scirpus hallii	Hall's bulrush	G2		S1	S1	SS
Scirpus polyphyllus	Leafy bulrush	G5	S2			SS
Scleria reticularis	Nutrush	G3G4	S1S2		S1S2	SS
Scleria verticillata	Low nutrush	G5	S1			SS
Scutellaria bushii	Bush's skullcap	G2G3	S2			RO
Seligeria calcarea	A moss	G3G4		S?		ND
Seligeria pusilla	A moss	G3G5		S1		ND
Sida eliottii	Elliott's sida	G4G5	S2S3			PR
Silene ovata	Ovate-leaf catchfly	G3	S2			WFM
Silene regia	Royal catchfly	G3	S2	S3	S1	PR

(continued)

Appendix Table 5.1—Assessment area terrestrial plant and animal species, the viability of which is of concern to scientists, the global and State ranks of these species, and their known habitats (continued)

Scientific name	Common name	Global rank	State rank AR	State rank MO	State rank OK	Habitat
		Plants (continued)				
Sium suave	Hemlock water-parsnip	G5	S1S3			SS
Smilacina stellata	Starry false solomon's-seal	G5	S1			MF
Smilax ecirrata	Carrion-flower	G5?	S2			MF
Smilax tamnoides	Bristly greenbriar	G5	S2			SS
Solidago auriculata	Eared goldenrod	G4	S2		S?	MF
Solidago flexicaulis	Broad-leaved goldenrod	G5			S1	MF
Solidago ouachitensis	A goldenrod	G3	S3		S1	WFM
Solidago ptarmicoides	Prairie goldenrod	G5	S1S2		S1	PR
Solidago riddellii	Riddell's goldenrod	G5	S1			SS
Spigelia marilandica	Woodland pinkroot	G5			S?	SS
Spiranthes lucida	Shining ladies'-tresses	G5	S2			SS
Spiranthes magnicamporum	Great Plains ladies'-tresses	G3G4	S1			PR
Sporobolus ozarkanus	Ozark poverty grass	G5?Q			S1S2	RO
Sporobolus pyramidatus	Whorled dropseed	G5	S2			PR
Stachys eplingii	Epling's horse-nettle	G5	S3		S1S2	SS
Stachys palustris	Hedge nettle	G5			S1	PR
Streptanthus obtusifolius	A twistflower	G3	S3			RO
Streptanthus squamiformes	A twistflower	G3	S2		S1	RO
Sullivantia sullivantii	Sullivantia	G3G4		S2		MF
Thalictrum arkansanum	Arkansas meadow-rue	G2	S2		S1	SS
Tilia caroliniana	Carolina basswood	G5			S1S2	MF
Tipularia discolor	Crippled cranefly orchid	G4G5			S1	WFM
Tradescantia longipes	A spiderwort	G3G4	S2			WFM
Tradescantia ozarkana	Ozark spiderwort	G2G3	S3	S2	S1S2	MF
Tradescantia subaspera	A spiderwort	G5	S1S3			MF
Triadenum tubulosum	Large marsh St. John's wort	G4?			S1S2	BLH
Trichomanes boschianum	Bristle-fern	G4	S2S3			RO
Trichomanes petersii	Dwarf filmy-fern	G4G5	S2			RO
Trillium flexipes	Drooping trillium	G5	S1			MF
Trillium pusillum var. *ozarkanum*	Ozark least trillium	G3T3	S3	S2	S1	WFM
Ulmus thomasii	Rock elm	G5	S2			BLH
Uvularia sessilifolia	Sessile-leaf bellwort	G5			S1	MF
Valerianella ozarkana	Ozark corn-salad	G3	S3	S2	SU	RO
Valerianella palmeri	Palmer's corn-salad	G3	S3		S1	RO
Veratrum woodii	Wood's false hellbore	G5	S1		S1	MF
Verbesina walteri	Rayless crown-beard	G3	S1		S1	WFM
Vernonia fasciculata	Prairie ironweed	G5	S1			PR
Vernonia lettermannii	Lettermann's ironweed	G3			S?	SS
Vertigo meramecensis	Bluff vertigo	G2		S1		RO
Viola canadensis var. *canadensis*	Canada violet	G5	S2			MF
Viola pedatifida	Prairie violet	G5	S2			PR
Waldsteinia fragarioides	Barren strawberry	G5	S1			MF
Woodsia scopulina var. *appalachiana*	Appalachian woodsia	G4T4	S1			RO
Zizia aptera	Golden alexanders	G5	S1S3			PR
		Reptiles				
Cemophora coccinea copei	Northern scarlet snake	G5T5	S2?		S2S3	MF
Eumeces inexpectatus	Southeastern five-lined skink	G5	S1?			HG

(continued)

Appendix Table 5.1—Assessment area terrestrial plant and animal species, the viability of which is of concern to scientists, the global and State ranks of these species, and their known habitats (continued)

			State rank			
Scientific name	Common name	Global rank	AR	MO	OK	Habitat
		Reptiles (continued)				
Eumeces obsoletus	Great Plains skink	G5	S1?		S5	PR
Eumeces septentrionalis obtusirostris	Southern prairie skink	G5T5	S1?		S4	PR
Heterodon nasicus gloydi	Dusty hognose snake	G5T3T4Q	S1?		S5	PR
Lampropeltis triangulum amaura	Louisiana milk snake	G5T4	S1?		S3	WFM
Nerodia cyclopion	Green water snake	G5	S2?			SS
Regina grahamii	Graham's crayfish snake	G5	S2?		S3	SS
Regina septemvittata	Queen snake	G5	S1?			SS
Sonora semiannulata	Ground snake	G5	S1?		S5	PR
Terrapene ornata ornata	Ornate box turtle	G5T5	S2		S5	PR
Thamnophis radix	Plains garter snake	G5	S1?		S2S3	PR

BLH = bottomland hardwood forest; MF = mesic forest; WFM = woodland, fire maintained; PR = prairie; SS = seep, fen, and riparian wetland habitats; RO = rock outcrop; glade, talus, and cliff habitats HG = habitat generalist; ND = not determined.
Source: State Natural Heritage databases [accessed 1997].

Appendix Table 5.2—Assessment area terrestrial plant and animal species with global viability concerns, showing their global ranks and known habitats

Scientific name	Common name	Global rank	Habitat[a]
	Amphibians and reptiles		
Eurycea tynerensis	Oklahoma salamander	G3	SS
Plethodon caddoensis	Caddo Mountain salamander	G2	MF
Plethodon fourchensis	Fourche Mountain salamander	G2	MF
Plethodon ouachitae	Rich Mountain salamander	G2G3	MF
Plethodon sequoyah	SE Oklahoma slimy salamander	G2Q	MF
Scaphiopus holbrookii hurteri	Hurter's spadefoot	G5T?	WFM
Heterodon nasicus gloydi	Dusty hognose snake	G5T3T4Q	PR
	Birds		
Aimophila aestivalis	Bachman's sparrow	G3	WFM
Ammodramus henslowii	Henslow's sparrow	G3G4	PR
Dendroica cerulea	Cerulean warbler	G3G4	SS
Limnothlypis swainsonii	Swainson's warbler	G3G4	BLH
	Invertebrates		
Arianops sandersoni	Magazine Mountain mold beetle	G1?	WFM
Calephelis borealis	Northern metalmark	G3G4	RO
Gryllotalpa major	Prairie mole cricket	G3	PR
Ophiogompus westfalli	Arkansas snaketail dragonfly	G2	SS
Panorpa braueri	A panorpid scorpionfly	G1	
Papipema eryngium	Rattlesnake master borer moth	G1	PR
Rhadine ozarkensis	A ground beetle	G1	—
Rimulincola divalis	A beetle	G1	—
Speyeria idalia	Regal fritillary	G3	PR
Stenotrema pilsbryi	Rich Mountain slitmouth snail	G2	RO
	Mammals		
Corynorhinus rafinesquii	Rafinesque's big-eared bat	G3G4	MF
Spilogale putorius interrupta	Plains spotted skunk	G5T3T4	PR
	Plants		
Agalinis auriculata	Auriculate false foxglove	G3	PR
Agalinis skinneriana	A false foxglove	G3	PR
Amorpha ouachitensis	Ouachita leadplant	G3Q	SS
Amsonia hubrichtii	Ouachita blue star	G3	SS
Aster furcatus	Forked aster	G3G4	RO
Bromus nottawayanus	Nottaway brome-grass	G3G5	SS
Bryoxiphium norvegicum	Sword moss	G3?	—
Bryun miniatum	A moss	G3G4	—
Calamagrostis porteri ssp. *insperata*	Ofer hollow reed grass	G4T3	WFM
Calamovilfa arcuata	A sandgrass	G2	SS
Callirhoe bushii	Bush's poppy-mallow	G3Q	WFM
Carex amphibola var. *globosa*	A sedge	G?T?	MF
Carex bicknellii var. *opaca*	A sedge	G5T2T3	SS
Carex fissa var. *fissa*	A sedge	G2QT?	PR
Carex gravida var. *gravida*	A sedge	G5T?	PR
Carex latebracteata	Waterfall's sedge	G3	WFM
Carex oklahomensis	Oklahoma sedge	G3?	PR
Carex ouachitana	Ouachita sedge	G3?	MF
Carex retroflexa var. *texensis*	A sedge	G5T3T5	WFM

(continued)

Appendix Table 5.2—Assessment area terrestrial plant and animal species with global viability concerns, showing their global ranks and known habitats (continued)

Scientific name	Common name	Global rank	Habitat
	Plants (continued)		
Carex socialis	Social sedge	G3	BLH
Castenea pumila var. *ozarkensis*	Ozark chinquapin	G5T3	WFM
Cayaponia grandifolia	A gourd	G3?Q	BLH
Chelone obliqua var. *speciosa*	Rose turtlehead	G4T3Q	SS
Cissus incisa	Marine vine	G3G5	RO
Coreopsis grandiflora var. *saxicola*	Large-flowered tickseed	G5T3T4	PR
Cyperus setigerus	Bristled cyperus	G3G5	BLH
Cypripedium kentuckiense	Southern lady's-slipper	G3	SS
Dalea gattingeri	Gattinger prairie-clover	G3G4	RO
Delphinium exaltatum	Tall larkspur	G3	WFM
Delphimium newtonianum	Moore's larkspur	G3	MF
Delphinium treleasi	Trelease's larkspur	G3	MF
Diarrhena americana var. *americana*	American beakgrain	G3G5T?	MF
Dodecatheon frenchii	French's shooting star	G3	MF
Draba aprica	Open-ground whitlow-grass	G3	WFM
Eriocaulon kornickianum	Small-headed pipewort	G2G3	RO
Fothergilla major	Witch-alder	G3	WFM
Galium arkansanum var. *pubiflorum*	Ouachita bedstraw	G5T2Q	WFM
Gaura demareei	Demaree's gaura	G3G4Q	WFM
Hedyotis ouachitana	Ouachita hedyotis	G3	WFM
Heuchera villosa var. *arkansana*	Arkansas alumroot	G5T3Q	RO
Heuchera parviflora var. *puberula*	Little-leaved alumroot	G4T3T4	RO
Homaliadelphus sharpii	Sharp's homaliadelphus	G2G3	—
Hydrophyllum brownei	Browne's waterleaf	G1	MF
Leitneria floridana	Corkwood	G3	BLH
Liatris squarossa var. *compacta*	Ouachita blazing star	G5T3?	RO
Luzula acuminata var. *carolinae*	Southern hairy woodrush	G5T?	SS
Matelea baldwyniana	Baldwin's milkvine	G2G3	WFM
Monarda stipitatoglandulosa	Ouachita horsemint	G3	RO
Neviusia alabamensis	Alabama snowwreath	G2	RO
Pancium philadelphicum var. *tuckermanii*	Tuckerman's panic grass	G3G5	SS
Parnassia grandifolia	Large-flowered grass-of-parnassus	G3G4	SS
Phlox bifida ssp stellaria	Bifid phlox	G5?T3	WFM
Platanthera praeclara	Western white fringed orchid	G2	PR
Polygonum pensylvanicum var. *eglandulosum*	Pinkweed	G5T2T4Q	SS
Polymnia cossatotensis	Heartleaf leafcup	G1	RO
Quercus shumardii var. *acerifolia*	Maple-leaved oak	G1Q	RO
Rosa foliolosa	White prairie rose	G2	PR
Sagittaria ambigua	Kansas arrowhead	G2?	SS
Scirpus hallii	Hall's bulrush	G2	SS
Scirpus etuberculatus	Canby's bulrush	G3G4	SS
Scleria reticularis	Nutrush	G3G4	SS
Scutellaria bushii	Bush's skullcap	G2G3	RO
Seligeria calcarea	A moss	G3G4	—
Seligeria pusilla	A moss	G3G5	—
Silene ovata	Ovate-leaf catchfly	G3	WFM
Silene regia	Royal catchfly	G3	PR
Solidago ouachitensis	A goldenrod	G3	WFM

(continued)

Appendix Table 5.2—Assessment area terrestrial plant and animal species with global viability concerns, showing their global ranks and known habitats (continued)

Scientific name	Common name	Global rank	Habitat[a]
	Plants (continued)		
Spiranthes magnicamporum	Great Plains ladies'-tresses	G3G4	PR
Streptanthus obtusifolius	A twistflower	G3	RO
Streptanthus squamiformes	A twistflower	G3	RO
Sullivantia sullivantii	Sullivantia	G3G4	MF
Thalictrum arkansanum	Arkansas meadow-rue	G2	SS
Tradescantia longipes	A spiderwort	G3G4	WFM
Tradescantia ozarkana	Ozark spiderwort	G2G3	MF
Trillium pusillum var. *ozarkanum*	Ozark least trillium	G3T3	WFM
Valerianella ozarkana	Ozark corn-salad	G3	RO
Valerianella palmeri	Palmer's corn-salad	G3	RO
Verbesina walteri	Rayless crown-beard	G3	WFM
Vernonia lettermannii	Lettermann's ironweed	G3	SS
Vertigo meramecensis	Bluff vertigo	G2	RO

BLH = bottomland hardwood forest; MF = mesic forest; WFM = woodland, fire maintained; PR = prairie; SS = seep, fen, riparian wetland; RO = rock outcrop, glade, talus, cliff; HG = habitat generalist; — = habitat not defined.
Source: State Natural Heritage Program databases [accessed 1997].

Appendix Table 5.3—Critically-imperiled and imperiled terrestrial plant and animal species in the Ozark-Ouachita Highlands, by habitat association, with rank

Scientific name	Common name	Taxonomic group	Global rank
		Fire-maintained woodland	
Scaphiopus holbrookii hurteri	Hurter's spadefoot	Amphibian	G5T
Arianops sandersoni	Magazine Mountain mold beetle	Invertebrate	G1?
Galium arkansanum var. *pubiflorum*	Ouachita bedstraw	Plant	G5T2Q
Matelea baldwyniana	Baldwin's milkvine	Plant	G2G3
		Seep, fen, pond, and/or upland riparian areas	
Ophiogompus westfalli	Arkansas snaketail dragonfly	Invertebrate	G2
Calamovilfa arcuata	A sandgrass	Plant	G2
Carex bicknellii var. *opaca*	A sedge	Plant	G5T2T3
Luzula acuminata var. *carolinae*	Southern hairy woodrush	Plant	G5T?
Polygonum pensylvanicum var. *eglandulosum*	Pinkweed	Plant	G5T2T4Q
Sagittaria ambigua	Kansas arrowhead	Plant	G2?
Scirpus hallii	Hall's bulrush	Plant	G2
Thalictrum arkansanum	Arkansas meadow-rue	Plant	G2
		Rock outcrop, glade, talus, and/or cliff	
Stenotrema pilsbryi	Rich Mountain slitmouth	Invertebrate	G2
Eriocaulon kornickianum	Small-headed pipewort	Plant	G2G3
Neviusia alabamensis	Alabama snowwreath	Plant	G2
Polymnia cossatotensis	Heartleaf leafcup	Plant	G1
Quercus shumardii var. *acerifolia*	Maple-leaved oak	Plant	G1Q
Scutellaria bushii	Bush's skullcap	Plant	G2G3
Vertigo meramecensis	Bluff vertigo	Plant	G2
		Prairie, grassland	
Papipema eryngium	Rattlesnake master borer moth	Invertebrate	G1
Carex fissa var. *fissa*	A sedge	Plant	G2QT?
Carex gravida var. *gravida*	A sedge	Plant	G5T?
Platanthera praeclara	Western white fringed orchid	Plant	G2
Rosa foliolosa	White prairie rose	Plant	G2
		Mesic forest	
Plethodon caddoensis	Caddo Mountain salamander	Amphibian	G2
Plethodon fourchensis	Fourche Mountain salamander	Amphibian	G2
Plethodon ouachitae	Rich Mountain salamander	Amphibian	G2G3
Plethodon sequoyah	SE Oklahoma slimy salamander	Amphibian	G2Q
Carex amphibola var. *globosa*	A sedge	Plant	G?T?
Hydrophyllum brownei	Browne's waterleaf	Plant	G1
Tradescantia ozarkana	Ozark spiderwort	Plant	G2G3
		Habitat not defined	
Panorpa braueri	A panorpid scorpionfly	Invertebrate	G1
Rhadine ozarkensis	A ground beetle	Invertebrate	G1
Rimulincola divalis	A beetle	Invertebrate	G1
Homaliadelphus sharpii	Sharp's homaliadelphus	Plant	G2G3

Source: State Natural Heritage Program databases [accessed 1997].

Appendix Table 5.4—Conservation status for imperiled and critically imperiled terrestrial species in the Ozark-Ouachita Highlands, with global and State ranks and conservation trend

Specific name	Common name	Organism type	Rank	Conservation trend
		Unsatisfactory		
Arianops sandersoni	Magazine Mtn mold beetle	Invertebrate	G1? S1?	STA
Papipema eryngium	Rattlesnake master borer moth	Invertebrate	G1 S1	UNK
Polymnia cossatotensis	Heartleaf leafcup	Plant	G1 S1	STA
Quercus shumardii var. *acerifolia*	Maple-leaved oak	Plant	G1Q S2	STA
Thalictrum arkansanum	Arkansas meadow-rue	Plant	G2 S1	UNK
		Satisfactory		
Plethodon caddoensis	Caddo Mtn salamander	Amphibian	G2 S2	STA
Plethodon fourchensis	Fourche Mtn salamander	Amphibian	G2 S2	STA
Plethodon ouachitae	Rich Mountain salamander	Amphibian	G2G3 S2	STA
Plethodon sequoyah	SE Oklahoma slimy salamander	Amphibian	G2Q S2	STA
Ophiogompus westfalli	Arkansas snaketail dragonfly	Invertebrate	G2 S?	UNK
Stenotrema pilsbryi	Rich Mtn slitmouth snail	Invertebrate	G2 S1/S2	STA
Calamovilfa arcuata	A sandgrass	Plant	G2 S1/S2	STA
Eriocaulon kornickianum	Small-headed pipewort	Plant	G2G3 S2S1	INCR
Galium arkansanum var. *pubiflorum*	Ouachita bedstraw	Plant	G5T2Q S2/S1	STA
Hydrophyllum brownei	Browne's waterleaf	Plant	G1 S1	STA
Luzula acuminata var. *carolinae*	Southern hairy woodrush	Plant	G5T? S2	STA
Neviusia alabamensis	Alabama snowwreath	Plant	G2 S1S2	UNK
Tradescantia ozarkana	Ozark spiderwort	Plant	G2G3 S3/S2/S1S2	STA
		Unknown		
Scaphiopus holbrookii hurteri	Hurter's spadefoot	Amphibian	G5T? S2?	UNK
Panorpa braueri	A panorpid scorpionfly	Invertebrate	G1 S1	UNK
Rhadine ozarkensis	A ground beetle	Invertebrate	G1 S1	UNK
Rimulincola divalis	A beetle	Invertebrate	G1 S1	UNK
Carex amphibola var. *globosa*	A sedge	Plant	G?T? S1S2	UNK
Carex bicknellii var. *opaca*	A sedge	Plant	G5T2T3 S2	UNK
Carex fissa var. *fissa*	A sedge	Plant	G2QT? S2	UNK
Carex gravida var. gravida	A sedge	Plant	G5T? S2	UNK
Homaliadelphus sharpii	Sharp's homaliadelphus	Plant	G2G3 S1	UNK
Matelea baldwyniana	Baldwin's milkvine	Plant	G2G3 S?	UNK
Platanthera praeclara	Western white fringed orchid	Plant	G2 S1	UNK
Polygonum pensylvanicum var. *eglandulosum*	Pinkweed	Plant	G5T2T4Q S4	UNK
Rosa foliolosa	White prairie rose	Plant	G2 S2	UNK
Sagittaria ambigua	Kansas arrowhead	Plant	G2? S1	UNK
Scirpus hallii	Hall's bulrush	Plant	G2 S1	UNK
Scutellaria bushii	Bush's skullcap	Plant	G2G3 S2	UNK
Vertigo meramecensis	Bluff vertigo	Plant	G2 S1	UNK

STA = stable; INCR = increasing; UNK = unknown.
Source: State Natural Heritage Program databases [accessed 1997].

Appendix Table 5.5—Breeding birds and their conservation scores from Partners in Flight[a]

Species	RA	BD	ND	TB	TN	PT	AI	Score	Habitat
Pied-billed grebe	2	1	1	2	2	3	2	13	Aquatic
American bittern	3	1	2	3	3	3	2	17	Aquatic
Least bittern	3	2	1	3	3	3	2	17	Aquatic
Great blue heron	2	1	1	2	2	1	3	12	Aquatic
Great egret	2	1	1	2	2	3	2	13	Aquatic
Little blue heron	2	1	1	3	2	3	2	14	Aquatic
Cattle egret	2	1	1	1	1	3	2	11	Agriculture
Green heron	2	1	2	2	2	3	3	15	Aquatic
Black-crowned night-heron	2	1	1	2	2	3	3	14	Aquatic
Yellow-crowned night-heron	3	1	2	3	2	3	2	16	Aquatic
Canada goose	2	1	1	1	2	3	3	13	Aquatic
Wood duck	3	1	2	3	3	2	3	17	Aquatic
Mallard	1	1	1	2	2	3	2	12	Aquatic
Blue-winged teal	2	1	1	3	2	3	2	14	Aquatic
Hooded merganser	4	2	4	3	2	3	3	21	Aquatic
Black vulture	1	1	1	2	1	3	2	11	Agriculture
Turkey vulture	2	1	1	2	1	3	3	13	Forest, agriculture
Mississippi kite	3	3	3	3	3	3	3	21	Forest, savanna/glade
Bald eagle	3	2	1	3	3	3	3	18	Aquatic
Northern harrier	3	1	1	4	3	3	2	17	Grassland, savanna/glade
Sharp-shinned hawk	3	1	1	3	2	3	2	15	Forest
Cooper’s hawk	3	1	1	3	2	3	3	16	Forest
Red-shouldered hawk	3	2	2	2	2	3	3	17	Forest, shrub/sapling
Broad-winged hawk	3	1	1	2	2	3	4	16	Forest
Red-tailed hawk	3	1	1	1	1	3	3	13	Forest, agriculture
American kestrel	2	1	1	2	1	3	2	12	Agriculture, savanna/glade
Peregrine falcon	4	1	1	4	3	3	3	19	Aquatic, grassland
Ruffed grouse	3	2	2	3	2	3	2	17	Shrub/sapling, forest
Wild turkey	3	2	2	2	3	2	3	17	Forest
Northern bobwhite	2	2	2	3	3	5	4	21	Agriculture, grassland
Sora	2	1	1	2	2	3	3	14	Aquatic
Common moorhen	2	1	1	2	2	3	3	14	Aquatic
American coot	1	1	1	2	1	3	3	12	Aquatic
Killdeer	2	1	2	2	3	3	3	16	Grassland, agriculture
Spotted sandpiper	2	1	1	2	1	3	3	13	Aquatic
Upland sandpiper	2	2	3	3	4	3	2	19	Grassland, agriculture
American woodcock	3	2	3	3	3	3	2	19	Shrub/sapling, forest
Rock dove	1	1	1	1	1	3	3	11	Agriculture, developed
Mourning dove	1	1	1	1	1	3	3	11	Savanna/glades, grassland
Black-billed cuckoo	3	2	2	3	3	3	2	18	Shrub/sapling, savanna/glade
Yellow-billed cuckoo	3	1	2	3	3	3	5	20	Forest
Greater roadrunner	3	2	2	3	2	3	2	17	Savanna/glade
Barn owl	3	1	1	3	3	3	2	16	Agriculture
Eastern screech-owl	3	2	2	3	2	3	3	18	Forest
Great horned owl	3	1	1	1	1	3	2	12	Forest
Barred owl	3	1	1	2	2	3	3	15	Forest
Long-eared owl	3	1	1	2	3	3	2	15	Forest, agriculture
Short-eared owl	4	1	1	4	4	3	2	19	Grassland, savanna/glade
Common nighthawk	2	1	1	3	2	4	2	15	Savanna/glade, grassland
Chuck-will’s-widow	3	2	3	3	3	3	5	22	Forest
Whip-poor-will	3	2	3	3	3	3	5	22	Forest
Chimney swift	2	1	3	3	3	3	3	18	Developed, forest
Ruby-throated hummingbird	3	1	3	2	2	3	5	19	Forest, shrub/sapling
Belted kingfisher	3	1	1	2	2	3	4	16	Aquatic

(continued)

Appendix Table 5.5—Breeding birds and their conservation scores from Partners in Flight[a] (continued)

Species	RA	BD	ND	TB	TN	PT	AI	Score	Habitat
Red-headed woodpecker	3	2	2	3	3	3	3	19	Forest
Red-bellied woodpecker	2	2	3	2	2	3	4	18	Forest
Downy woodpecker	3	1	1	2	1	3	5	16	Forest
Hairy woodpecker	3	1	1	2	2	3	3	15	Forest
Red-cockaded woodpecker	5	4	4	5	5	3	2	28	Forest
Northern flicker	2	1	1	2	1	5	3	15	Savanna/glade, developed
Pileated woodpecker	3	1	1	2	2	5	5	19	Forest
Eastern wood-pewee	3	1	2	3	3	3	5	20	Forest
Acadian flycatcher	3	2	4	3	3	5	3	23	Forest
Willow flycatcher	3	1	4	3	2	3	2	18	Shrub/sapling
Least flycatcher	2	1	3	3	2	3	2	16	Forest
Eastern phoebe	3	1	2	2	2	3	5	18	Forest, developed
Great crested flycatcher	2	1	3	2	3	3	4	18	Forest
Western kingbird	2	1	4	2	2	3	2	16	Savanna/glade, agriculture
Eastern kingbird	2	1	2	2	2	3	4	16	Shrub/sapling, savanna/glade
Scissor-tailed flycatcher	2	4	5	2	3	3	2	21	Grassland, agriculture
Horned lark	1	1	1	2	1	4	2	12	Grassland, agriculture
Purple martin	2	1	1	3	3	1	4	15	Aquatic, developed
Tree swallow	2	1	2	2	2	3	2	14	Savanna/glade, shrub/sapling
Northern rough-winged swallow	2	1	3	2	2	3	3	16	Savanna/glade, shrub/sapling
Bank swallow	2	1	1	2	2	3	3	14	Aquatic
Cliff swallow	1	1	1	1	2	3	2	11	Aquatic
Barn swallow	1	1	1	1	2	3	4	13	Agriculture, grassland
Blue jay	2	1	2	1	1	2	5	14	Forest
American crow	1	1	1	1	1	1	5	11	Agriculture, forest
Fish crow	2	3	4	1	1	3	2	16	Aquatic
Black-capped chickadee	2	1	1	2	2	3	2	13	Forest
Carolina chickadee	2	3	3	2	1	3	5	19	Forest
Tufted titmouse	2	2	2	1	1	3	5	16	Forest
White-breasted nuthatch	3	1	1	2	2	3	5	17	Forest
Brown-headed nuthatch	3	4	4	3	3	3	2	22	Savanna/glade
Brown creeper	3	1	1	3	2	3	1	14	Forest
Carolina wren	2	2	2	2	2	3	4	17	Forest, shrub/sapling
Bewick's wren	2	2	2	3	3	3	2	17	Shrub/sapling
House wren	2	1	1	1	1	3	2	11	Forest, developed
Sedge wren	3	3	3	4	3	3	3	22	Shrub/sapling, aquatic
Marsh wren	2	2	2	4	3	3	3	19	Shrub/sapling, aquatic
Blue-gray gnatcatcher	2	1	2	2	2	3	5	17	Forest, shrub/sapling
Eastern bluebird	2	1	2	2	2	3	5	17	Savanna/glade, agriculture
Wood thrush	2	2	4	3	4	3	3	21	Forest
American robin	1	1	1	1	1	1	3	9	Developed, agriculture
Gray catbird	2	1	3	2	2	5	2	17	Shrub/sapling
Northern mockingbird	1	1	1	1	1	5	3	13	Shrub/sapling, agriculture
Brown thrasher	3	1	3	3	2	5	4	21	Shrub/sapling
Cedar waxwing	2	1	1	2	2	3	2	13	Shrub/sapling, developed
Loggerhead shrike	3	1	1	4	3	5	3	20	Savanna/glade, shrub/sapling
European starling	1	1	1	1	1	3	3	11	Grassland
White-eyed vireo	2	2	4	3	2	2	3	18	Shrub/sapling, savanna/glade
Bell's vireo	3	3	5	4	3	3	2	23	Shrub/sapling
Yellow-throated vireo	3	2	3	3	3	3	3	20	Forest
Warbling vireo	2	1	4	2	2	3	2	16	Forest, savanna/glade
Red-eyed vireo	1	2	2	2	2	3	3	15	Forest
Blue-winged warbler	3	3	4	3	3	3	3	22	Shrub/sapling, savanna/glade
Northern parula	2	2	4	2	2	3	4	19	Forest

(continued)

Appendix Table 5.5—Breeding birds and their conservation scores from Partners in Flight[a] (continued)

Species	RA	BD	ND	TB	TN	PT	AI	Score	Habitat
Yellow warbler	2	1	1	2	1	3	2	12	Shrub/sapling
Chestnut-sided warbler	2	2	4	2	3	3	2	18	Shrub/sapling
Black-throated green warbler	3	2	3	2	3	3	2	18	Forest
Yellow-throated warbler	3	3	3	3	2	3	3	20	Forest
Pine warbler	2	3	3	2	2	3	4	19	Forest
Prairie warbler	3	3	4	3	2	5	3	23	Shrub/sapling, savanna/glade
Cerulean warbler	4	4	4	4	4	3	2	25	Forest
Black-and-white warbler	3	2	2	2	2	3	4	18	Forest
American redstart	2	1	2	2	2	3	2	14	Forest
Prothonotary warbler	3	3	4	3	3	3	2	21	Forest, aquatic
Worm-eating warbler	4	3	4	3	4	3	4	25	Forest, shrub/sapling
Swainson’s warbler	4	4	5	4	4	3	2	26	Shrub/sapling, forest
Ovenbird	2	2	3	2	3	5	3	20	Forest
Louisiana waterthrush	4	2	3	3	4	3	4	23	Forest
Kentucky warbler	3	3	4	3	3	3	4	23	Forest, shrub/sapling
Common yellowthroat	1	1	2	2	2	3	3	14	Shrub/sapling
Hooded warbler	3	2	4	3	3	3	3	21	Forest, shrub/sapling
Yellow-breasted chat	2	1	3	3	2	3	5	19	Shrub/sapling
Summer tanager	3	2	2	3	2	3	5	20	Forest, savanna/glade
Scarlet tanager	2	2	4	2	2	3	3	18	Forest
Northern cardinal	1	1	1	1	1	3	4	12	Shrub/sapling
Rose-breasted grosbeak	3	2	3	2	2	3	2	17	Forest, savanna/glade
Blue grosbeak	2	1	3	2	2	3	5	18	Shrub/sapling, savanna/glade
Indigo bunting	1	1	3	1	2	3	5	16	Shrub/sapling, savanna/glade
Painted bunting	2	4	3	4	3	3	3	22	Shrub/sapling
Dickcissel	1	2	4	4	4	5	3	23	Grassland
Eastern towhee	1	2	2	3	2	5	3	18	Shrub/sapling
Bachman’s sparrow	4	4	4	4	4	3	2	25	Savanna/glade
Rufous-crowned sparrow	3	3	3	3	3	3	2	20	Shrub/sapling, savanna/glade
Chipping sparrow	2	1	2	2	1	3	4	15	Savanna/glade, shrub/sapling
Field sparrow	2	2	2	3	3	5	5	22	Shrub/sapling, savanna/glade
Vesper sparrow	1	1	2	3	2	3	2	14	Shrub/sapling, savanna/glade
Lark sparrow	2	1	3	3	2	5	2	18	Shrub/sapling, grassland
Savannah sparrow	1	1	2	2	1	3	2	12	Grassland, agriculture
Grasshopper sparrow	2	1	2	3	3	3	2	16	Grassland, agriculture
Henslow’s sparrow	4	3	5	4	4	3	2	25	Grassland
Song sparrow	1	1	1	2	1	3	2	11	Shrub/sapling
Red-winged blackbird	1	1	1	2	1	3	3	12	Shrub/sapling, grassland
Eastern meadowlark	1	1	1	3	3	3	4	16	Grassland, agriculture
Western meadowlark	1	1	2	3	3	3	2	15	Grassland, agriculture
Great-tailed grackle	1	2	2	1	1	3	2	12	Agriculture
Common grackle	1	1	2	1	1	3	3	12	Agriculture
Brown-headed cowbird	1	1	1	1	1	5	4	14	Agriculture, grassland
Orchard oriole	2	2	3	3	2	5	4	21	Savanna/glade, agriculture
Baltimore oriole	2	2	3	3	2	3	2	17	Forest
House finch	1	1	1	1	1	3	2	10	Developed
Pine siskin	2	1	1	1	1	3	1	10	Forest, shrub/sapling
American goldfinch	2	1	1	2	1	3	3	13	Shrub/sapling, agriculture
House sparrow	1	1	1	1	1	5	3	13	Developed, agriculture

RA = relative abundance; BD = size of breeding distribution; ND = size of non-breeding distribution; TB = threats in breeding range; TN = threats in non-breeding range; PT = population trend; AI = importance of area being considered to the species.

[a] Categories are scored 1–5 based on current knowledge; the greater the total score, the higher the conservation concern. One or two general breeding habitats are identified; see text for further description. The scores change over time. Check the Colorado Bird Observatory Web site (<http://www.cbobirds.org>) for the latest scores.

Source: Colorado Bird Observatory (1998).

Appendix Table 5.6—Population trends and relative abundance of birds breeding in the Ozark-Ouachita Plateaus, as determined by the North American Breeding Bird Survey

	1966 to 1996				1980 to 1996		
Species	Trend[a]	P-value[b]	N	RA	Trend[a]	P-value[b]	N
Wood duck	11.3	0.03	19	0.16	8.3	0.17	17
Great blue heron	6.5	0.00	39	1.12	5.1	0.02	39
Green heron	-1.4	0.36	41	1.18	-3.4	0.13	39
Killdeer	0.0	0.99	39	2.09	-1.8	0.13	37
Northern bobwhite	-2.6	0.00	51	22.71	-3.9	0.00	49
Wild turkey	7.8	0.07	25	0.37	-2.9	0.48	24
Rock dove	0.2	0.87	31	3.26	-1.3	0.74	28
Mourning dove	0.0	0.97	49	13.90	2.2	0.04	47
Turkey vulture	0.0	0.98	46	2.81	3.6	0.04	43
Red-tailed hawk	-1.8	0.31	45	0.68	-2.3	0.43	43
Red-shouldered hawk	0.3	0.91	25	0.41	4.7	0.16	24
Broad-winged hawk	-0.8	0.74	19	0.16	1.3	0.87	17
Barred owl	3.7	0.18	23	0.18	5.1	0.02	20
Yellow-billed cuckoo	0.2	0.74	52	12.47	-3.0	0.01	50
Belted kingfisher	-2.0	0.30	33	0.36	3.6	0.29	28
Hairy woodpecker	-1.3	0.63	33	0.34	-2.2	0.65	28
Downy woodpecker	0.2	0.83	49	2.53	0.3	0.82	47
Pileated woodpecker	-2.6	0.00	49	2.88	-0.3	0.87	46
Red-headed woodpecker	-2.2	0.24	39	1.17	-8.2	0.03	34
Red-bellied woodpecker	-0.2	0.76	51	6.07	0.4	0.71	49
Yellow-shafted flicker	-2.9	0.07	43	1.61	-4.2	0.03	40
Chuck-will's-widow	0.5	0.69	45	2.47	0.7	0.70	41
Whip-poor-will	0.2	0.91	35	1.60	1.1	0.67	34
Common nighthawk	-8.8	0.02	15	0.22	-3.7	0.65	9
Chimney swift	-0.3	0.79	46	6.61	-0.2	0.84	44
Ruby-throated hummingbird	0.2	0.93	43	0.94	4.4	0.02	41
Scissor-tail flycatcher	0.6	0.37	26	1.57	0.7	0.56	25
Eastern kingbird	-0.4	0.61	44	5.32	-2.2	0.04	42
Great crested flycatcher	-1.6	0.17	51	5.97	0.2	0.84	49
Eastern phoebe	1.1	0.21	50	4.44	0.6	0.51	48
Eastern wood-pewee	-1.6	0.12	52	8.81	1.1	0.28	50
Acadian flycatcher	-2.9	0.08	37	1.45	0.9	0.80	36
Horned lark	-6.1	0.08	16	0.25	-10.8	0.00	12
Blue jay	-1.0	0.03	52	15.28	-1.3	0.16	50
American crow	1.9	0.00	52	41.00	1.9	0.00	50
European starling	-0.8	0.31	42	23.70	-2.6	0.03	40
Brown-headed cowbird	-1.0	0.01	51	16.77	-1.9	0.02	49
Red-winged blackbird	-0.1	0.91	46	26.30	-4.1	0.00	44
Eastern meadowlark	-1.3	0.33	47	28.32	-3.4	0.00	45
Orchard oriole	-3.7	0.01	45	3.80	-3.6	0.04	43
Baltimore oriole	-2.7	0.54	27	0.47	5.4	0.30	21
Common grackle	0.4	0.63	43	25.84	-2.1	0.10	41
American goldfinch	0.9	0.53	46	3.17	1.5	0.40	44
Grasshopper sparrow	1.1	0.75	21	0.77	-1.3	0.83	17
Lark sparrow	-6.4	0.0	30	0.82	-5.1	0.14	25
Chipping sparrow	-0.6	0.65	49	5.87	1.9	0.29	47
Field sparrow	-3.1	0.00	48	13.94	0.0	0.96	46
Eastern towhee	-2.2	0.02	41	5.61	-3.5	0.02	39
Northern cardinal	0.1	0.87	51	27.97	1.4	0.02	49
Blue grosbeak	1.0	0.48	44	4.67	-1.8	0.29	42

(continued)

Appendix Table 5.6—Population trends and relative abundance of birds breeding in the Ozark-Ouachita Plateaus, as determined by the North American Breeding Bird Survey (continued)

	1966 to 1996				1980 to 1996		
Species	Trend[a]	P-value[b]	N	RA	Trend[a]	P-value[b]	N
Indigo bunting	0.1	0.83	52	34.41	-0.4	0.49	50
Dickcissel	-1.8	0.07	40	7.57	-2.7	0.07	38
Scarlet tanager	0.5	0.86	34	2.18	1.4	0.71	33
Summer tanager	-0.4	0.66	52	7.53	-0.2	0.85	50
Purple martin	1.9	0.05	46	7.34	-0.9	0.59	44
Barn swallow	0.4	0.54	47	15.54	-2.4	0.01	45
N. Rough-winged swallow	1.2	0.52	33	1.52	-4.1	0.05	30
Loggerhead shrike	-9.4	0.00	36	0.99	-7.2	0.13	28
Red-eyed vireo	1.1	0.14	50	14.69	3.7	0.02	48
Warbling vireo	5.3	0.15	19	0.36	6.3	0.42	15
Yellow-throated vireo	-1.7	0.60	33	0.58	4.0	0.36	32
White-eyed vireo	-0.9	0.09	50	4.66	-0.5	0.65	47
Black-&-white warbler	-0.5	0.75	40	1.97	-0.4	0.88	38
Prothonotary warbler	-3.8	0.16	15	0.15	7.1	0.07	10
Worm-eating warbler	-2.3	0.61	23	0.68	7.0	0.11	21
Blue-winged warbler	4.4	0.27	18	0.60	5.0	0.22	17
Northern parula	-0.3	0.83	43	1.91	4.3	0.00	40
Yellow-throated warbler	1.8	0.57	24	0.44	-5.2	0.61	23
Pine warbler	0.1	0.94	31	6.39	1.4	0.50	30
Prairie warbler	-4.6	0.02	37	1.55	-3.8	0.08	33
Ovenbird	-3.6	0.02	29	2.86	0.6	0.87	28
Louisiana waterthrush	1.6	0.70	29	0.37	-3.2	0.56	25
Kentucky warbler	-1.4	0.37	46	3.43	-1.8	0.63	43
Common yellowthroat	-0.7	0.38	48	4.65	-2.1	0.12	46
Yellow-breasted chat	-0.6	0.15	51	11.59	-0.4	0.66	49
House sparrow	-2.8	0.00	44	24.55	-8.2	0.00	42
Northern mockingbird	-1.0	0.09	45	12.29	0.6	0.38	43
Gray catbird	-3.5	0.00	38	1.00	-5.0	0.01	33
Brown thrasher	-2.9	0.00	46	3.70	-5.1	0.00	43
Carolina wren	1.3	0.30	51	7.58	8.7	0.00	49
Bewick’s wren	-3.0	0.42	24	0.81	2.0	0.68	19
House wren	-0.2	0.94	17	0.52	1.0	0.65	14
White-breasted nuthatch	0.5	0.61	52	3.41	1.6	0.17	49
Tufted titmouse	-0.6	0.59	52	16.17	1.7	0.05	50
Carolina chickadee	-1.1	0.17	50	7.96	-1.3	0.30	49
Blue-gray gnatcatcher	-0.3	0.84	50	8.45	1.9	0.24	48
Wood thrush	-1.3	0.20	44	3.11	3.1	0.18	38
American robin	1.7	0.03	47	16.05	-0.2	0.89	45
Eastern bluebird	0.6	0.68	51	8.92	2.0	0.14	49

N = number of survey routes on which the bird species was counted; RA = mean annual abundance expressed as birds per route.
[a] Trend is the mean percent annual population change.
[b] P-values are for the test that the trend is not different than 0.
Source: Sauer (1997).

Chapter 6: Biological Threats to Forest Resources

Question 6.1: What are the current and predicted trends for insect and disease infestations or outbreaks in the Assessment area?

Certain introduced (i.e., exotic, nonnative) species of plants, animals, and other organisms threaten forest resources as competitors for living space, as disease-causing agents, or as aggressive consumers of plants. Some native species also periodically pose threats to forest resources. To assess the various threats, the Terrestrial Team sought to answer the above question.

Key Findings

1. The European gypsy moth, a defoliator of hardwood trees, has been found in the Assessment area. The outbreaks have been minor and eradication has been successful. Scientists expect a general infestation might reach the Assessment area between 2025 and 2050.
2. Red imported fire ants are invading the Assessment area from the south and are expected to continue a gradual northward expansion. Eradication is probably impossible. An integrated pest management program is the best approach to this problem.
3. The southern pine beetle is indigenous to the southern part of the Assessment area. Serious outbreaks will continue to occur in the Ouachita Mountains section. These outbreaks are cyclic and related to stand age and density of pine trees in a stand.
4. Knapweeds, invasive nonnative plants, have been present for several decades on some roadsides in southern Missouri. There are health concerns for humans and livestock related to this plant. Precautions should be taken to minimize direct contact with this plant.
5. Purple loosestrife, a serious pest in wetlands, is present in the Ozark-Ouachita Highlands and may spread.

Invasive Nonnative Insects

Data Sources

The information in this section is from published reports. (See “References” at the end of this report.) Scientists participating in the Ozark-Ouachita Highlands Assessment provided additional expertise.

Patterns and Trends

European Gypsy Moth

The European gypsy moth was introduced into the United States in 1869. A defoliator, it has caused considerable damage to forests in the northeastern part of the country and has gradually expanded its range. Scientists expect the moths’ natural expansion to reach the Ozark-Ouachita Highlands between 2025 and 2050 (USDA FS 1995b).

European gypsy moths feed on numerous trees, shrubs, and vines but prefer oaks. After European gypsy moth larvae hatch in the spring, the young caterpillars climb to the tops and extended branches of trees, from whence they ride winds for distances of up to 2 miles (mi). The airborne caterpillars land on other host plants and begin intense feeding. In the Assessment area, this occurs in late April or early May. The caterpillars feed through May and early June, going through five or six larval stages as they increase in size and appetite. They then reach the pupal stage where they transform into moths. Male moths emerge first and begin their search for females. The females do not fly, but stay very close to where they pupate, emitting a pheromone (chemical attractant) to attract male moths. After mating, the female lays an egg mass, that contains approximately 300 to 750 eggs, then dies. The next generation overwinters within the egg mass, to repeat the cycle in the spring (Doane and McManus 1981).

Spread rates for the European gypsy moth have increased from 1.8 mi/year from 1916 to 1965 to more than 12.4 mi/year from 1966 to 1990 (Liebhold and others 1992). In addition to the steady spread of the adults by wind, they can be transported in other life stages by human activities. Movements aided by humans cause isolated infestations outside generally-infested areas.

Where European gypsy moths are numerous, the larvae can defoliate trees. Their impact on a forest stand depends upon the abundance of host trees and other site and stand conditions. Defoliated trees may die, either directly as the result of defoliation or indirectly from drought, disease, or other pests. Vigorous trees can withstand one or two consecutive defoliations, but trees in poor condition can die after a single defoliation.

If left untreated, a European gypsy moth infestation causes a shift in the overstory from primary host species, such as oak, to other species. As susceptible trees die, other organisms are affected—plants dependent on the overstory for shade are stressed; and animals living in trees, feeding on the tree seeds or fruits, or browsing in the stressed understory may be adversely affected (USDA FS 1995b, Gottschalk 1990, Tigner 1992).

The European gypsy moth also affects humans. Some individuals are allergic to the hairs of the caterpillars (Anderson and Furniss 1983). Homeowners' shade trees and plantings may be lost, reducing property values. Residents lose the use of their property and recreational areas during outbreaks because of the presence of thousands of caterpillars and falling frass (droppings). Obviously, dead and dying trees diminish the aesthetic value of the landscape.

The European gypsy moth was discovered in the Assessment area near Hardy, AR, in 1982. It was eradicated in 1983 with two applications of carbaryl over 1,500 acres (ac). A separate infestation in Newton, Boone, Madison, Marion, and Carroll Counties (AR) (fig. 6.1) has been the subject of a 5-year eradication project involving aerial applications of diflubenzuron, an insect-growth regulator, spread over 600 ac of private land in 1993, and treatments with *Bacillus thuringiensis*, a biological insecticide, over 25,000 ac in 1994 and

Figure 6.1—Counties with historic European gypsy moth infestations in the Ozark-Ouachita Highlands.

18,000 ac in 1995 (Fitzgibbon 1997). A third introduction in Dent County (MO), discovered in 1995, received a ground application of *Bacillus thuringiensis* (Brown 1997). Trapping from 1995 to 1997 yielded no further evidence of European gypsy moth.

Management of the European gypsy moth in the Assessment area consists mainly of monitoring (through trapping) and eradication projects where necessary. Post-eradication monitoring of European gypsy moths in Carroll County was carried out in 1996 and 1997. Trapping in early 1998 suggests that eradication was successful. Monitoring has included an examination of the effects on neotropical migrant birds, canopy insects other than the European gypsy moth, and interactions between these groups.

Detection monitoring consists of a system of trapping in which all areas with suitable host types are checked every other year, and special sites, such as campgrounds, are checked every year. Eradication projects are considered when trapping indicates a breeding population. Federal and State agencies, including the Arkansas State Plant Board, the Missouri Departments of Agriculture and Conservation, and the Oklahoma Department of Agriculture cooperate in eradication projects, while State laws govern participation by private land owners (USDA FS 1995b).

Further introductions of this insect are likely to occur before the area of general infestation encompasses the Ozark-Ouachita Highlands. Accidental introductions during transport of lumber, outdoor furnishings, firewood, or nursery stock will likely cause small spot infestations in residential areas.

Another exotic gypsy moth, an Asian strain in which the female moth can fly, has been in the United States since 1994. The areas of infestation by Asian gypsy moths have been quarantined and are being eradicated.

Red Imported Fire Ant

The red imported fire ant, a native of Argentina, was accidentally introduced into the United States in the 1930's and was first documented in Arkansas in 1957. It is omnivorous and preys on insects and small vertebrates (Shores 1994).

Fire ants can significantly reduce local populations of arthropods. They are attracted to all kinds of foods and to low levels of electricity. When foraging, they may gnaw holes in roots and buds and, in the spring, they seek sap from trees. These ants can damage highways, roofs, joints in pavements, and electrical boxes.

More aggressive than native ants, red imported fire ants have been implicated in declines of ground-nesting birds, such as quail and turkey, because they attack newly hatched young. Red imported fire ants compete with native scavengers that feed on dead animals and fallen fruit. Fire ant mounds can cause problems for agricultural machinery (Wojcik and others 1976, Shores 1994).

Fire ants have established colonies as far north as Stone County in Arkansas and McCurtain County in Oklahoma. The infestation in Arkansas is moderate. Attempts to eradicate fire ants from generally infested areas have been unsuccessful, although eradication of isolated colonies has been somewhat successful (Shores 1994). It is probable the ant will spread accidentally through transport by potted plants, trees, sod, and cattle. Arkansas counties with quarantine programs in the Assessment area include Garland, Hot Spring, Howard, Pulaski, and Saline. Because the ant is not acclimated to freezing temperatures, colder winters in Missouri and northern Arkansas and Oklahoma may prevent the ant from invading these areas.

Asiatic Oak Weevil

The Asiatic oak weevil, native to northeastern Asia (Roelofs 1873), first appeared in the United States in 1933 in New Jersey (Triplehorn 1955). The adult weevil is greenish-gray and, with age, may become nearly black. It is about 1.5 inches (in.) long.

The insects are parthenogenic (they reproduce without fertilization). The Asiatic oak weevil feeds on the foliage of susceptible hosts by eating the intervein area, attacking the lower leaves of the host plant first. The weevil feeds on 44 or more species of woody plants, but damage to oaks—particularly oak seedlings—far exceeds damage to any other host. It can become a pest in and around households.

The range of the Asiatic oak weevil within the Assessment area is unknown. Because the Asiatic oak weevil can survive on many host plants, it is likely to spread throughout the area. However, the lack of reports of this insect in recent years indicates that native or introduced predators, parasites, or diseases are controlling the insect.

Africanized Honey Bee

The Italian honey bee, which produces most of the honey in the United States, was introduced in the 17th century. The Africanized honey bee, a more aggressive strain of honey bee, entered the United States through southern Texas in 1990.

Africanized bees defend their hives more vigorously than other honey bees. They replace or interbreed with the more docile Italian honey bees. Like the gentler strains, Africanized honey bees can escape from domestication and establish colonies in hollow trees or buildings.

The Africanized honey bee is not yet reported in the Assessment area. Perhaps overly feared, these so-called killer bees need not cause alarm, since they have rarely harmed humans. However, it is important to prevent colonies in buildings and high-use areas, such as recreation sites, and to remove such colonies if they become established. Beekeepers in South America have adjusted to Africanized honey bees, which produce more honey than many other strains of bees (except Italian honey bees) (Hubbell 1993).

Exotic Diseases

Exotic or introduced plant diseases have caused great economic impacts on agriculture and forestry. Foremost among such impacts was the Irish potato famine of 1845–1846. Among trees, the chestnut blight, white pine blister rust, and Dutch elm disease have caused significant impacts on forest ecosystems in the United States. Introduced diseases are particularly severe on native plants and may spread rapidly because the hosts have no genetically developed resistance. The following sections address significant exotic plant diseases in the Assessment area.

Data Sources

The Forest Health Protection unit of the USDA Forest Service, which maintains survey and map records, provided most of the information concerning exotic diseases for the Ozark-Ouachita Highlands Assessment. University researchers and pest specialists in State agencies provided much of the data to the Forest Service. The Forest Health Atlas at the Asheville, NC, Forest Health Protection Field Office contains the spatial data employed here. Other data and information are from published sources.

Patterns and Trends

Dogwood Anthracnose

Dogwoods, particularly the native flowering dogwood in the Eastern United States, are valuable for their fruit production, which benefit a wide variety of wildlife (Halls 1977a), and for their ornamental display of white “flowers” (technically bracts) and red berries (McLemore 1990). Dogwood anthracnose is a relatively new fungal disease of the native flowering dogwood and the Pacific dogwood in the Pacific Northwest. The disease was first seen in Washington State in 1976 (Byther and Davidson 1979) and 2 years later in New York (Hibben and Daughtrey 1988). Since then it has been confirmed in the Northwest in British Columbia, Idaho, Oregon, and Washington and in at least 17 Eastern States (fig. 6.2).

Although its origin is unknown, three factors suggest that this disease agent may be an exotic: the nearly concurrent discoveries near major seaports (Seattle and New York), indicating possible introduction sites; the severity of the disease, indicating that native dogwood populations have little natural resistance to the fungus, which in turn suggests they have not been exposed to it before; and the rapidity with which the disease seemed to spread, also indicating a lack of resistance in host species and the absence of natural competitors likely to be present if the fungus were native to the United States (Daughtrey and Hibben 1983).

The fungus affects the lower foliage of flowering dogwood trees in the early spring in the Eastern United States, causing leaf spots that are tan with purplish rims. Large dead blotches, veins, and leaf margins also occur. Leaves may die but do not fall, hanging on the tree throughout the following winter.

The fungus invades the petioles of blighted leaves and can then cause cankers on twigs, branches, and the main bole. As branches die back, epicormic shoots often develop, mostly on the main bole; these are succulent, readily infected, and the initiation point for the stem cankers that frequently occur. Dieback and stem

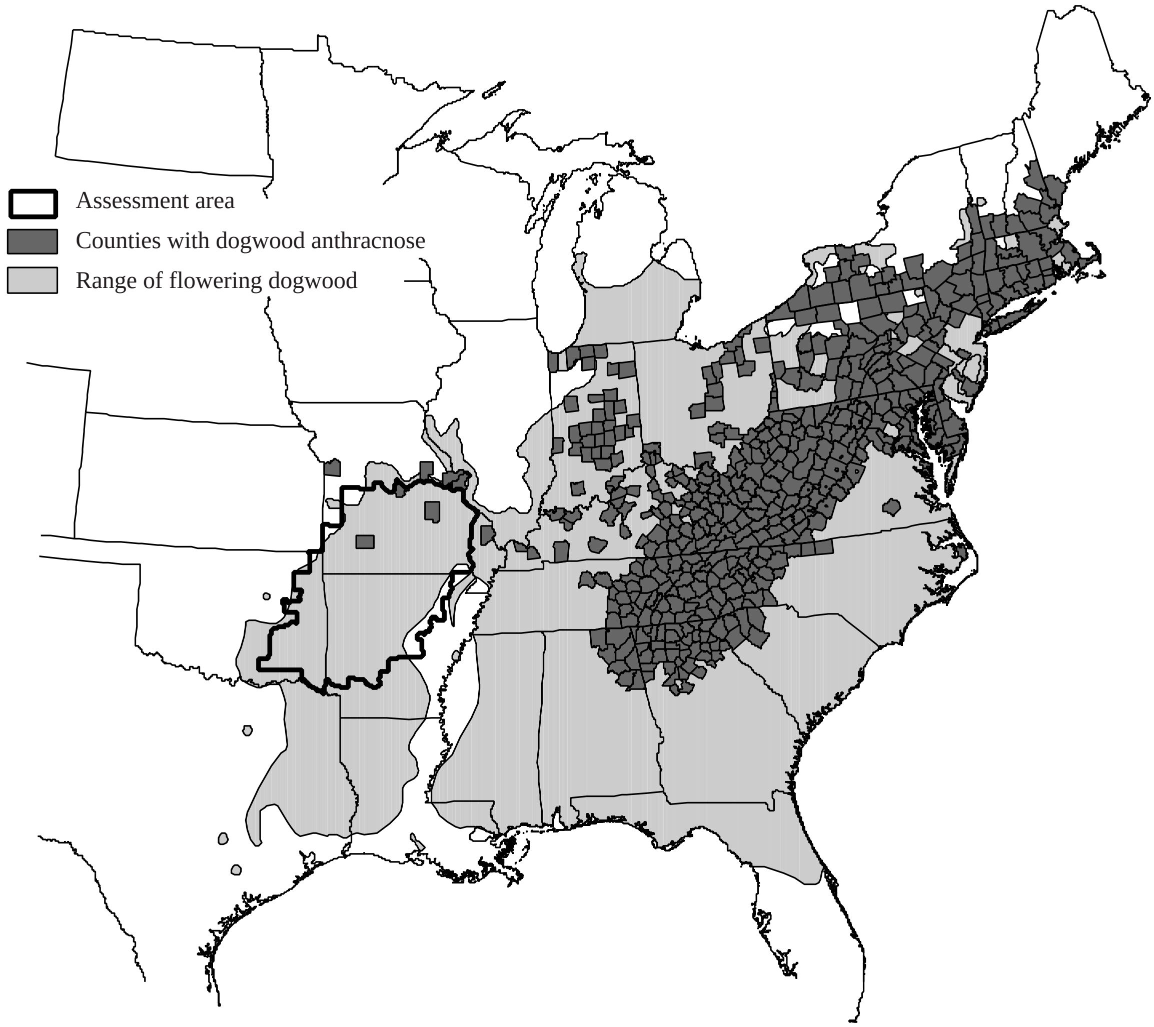


Figure 6.2—Counties with dogwood anthracnose in the Eastern United States, including the Ozark-Ouachita Highlands.

cankers eventually result in the death of the tree in some environments.

Both infection and spread of the disease is favored by moist, cool weather, which tends to occur at higher elevations, sheltered coves, and north-facing slopes. The disease is particularly severe in such environments in the Southern Appalachians (Anderson and others 1994).

By 1994, anthracnose was present on more than 12 million ac in the South (Anderson and others 1994) (fig. 6.2). The only documented anthracnose finds in the Assessment area are three counties in Missouri. However, these and finds in five other Missouri counties are all introductions on nursery stock. Eradication efforts have been employed, and no established infections are known. Detection surveys in Arkansas have not found anthracnose (Drummond 1990, 1992). Similarly, no reports are known from Oklahoma.

Dogwood anthracnose resembles other foliage and stem diseases of dogwood common in the Assessment area. Laboratory diagnosis of affected foliage or stems is necessary to positively identify the presence of the pathogen. The threat to native dogwoods in the Ozark-Ouachita Highlands is real nonetheless. An abundance of dogwoods and favorable environmental conditions exist there, although elevations are lower than where the disease has been most severe in the Appalachians

(> 3,000 feet) (Anderson and others 1994). Disease development and loss of trees could occur in the Assessment area.

There are few ways to reduce the impact of dogwood anthracnose. Methods that may be effective in park or urban situations, e.g., fungicide application, are impractical or too expensive in forest environments. Current research on prevention and treatment of dogwood anthracnose is focusing on genetic resistance. Scientists are evaluating the resistance of surviving trees in heavily damaged areas (Anderson and others 1994).

Butternut Canker

Butternut, also known as white walnut, is a small to medium-size tree that grows in scattered locations throughout the North Central and Northeastern United States (fig. 6.3). The tree grows best on streambank sites and on moist, well-drained soils. Butternut is most valued for its sweet nut, although the wood works, stains, and finishes well for small furniture and other wood products (Rink 1990). It is a useful food for wildlife, but due to its scattered occurrence, its overall importance is limited (Strode 1977).

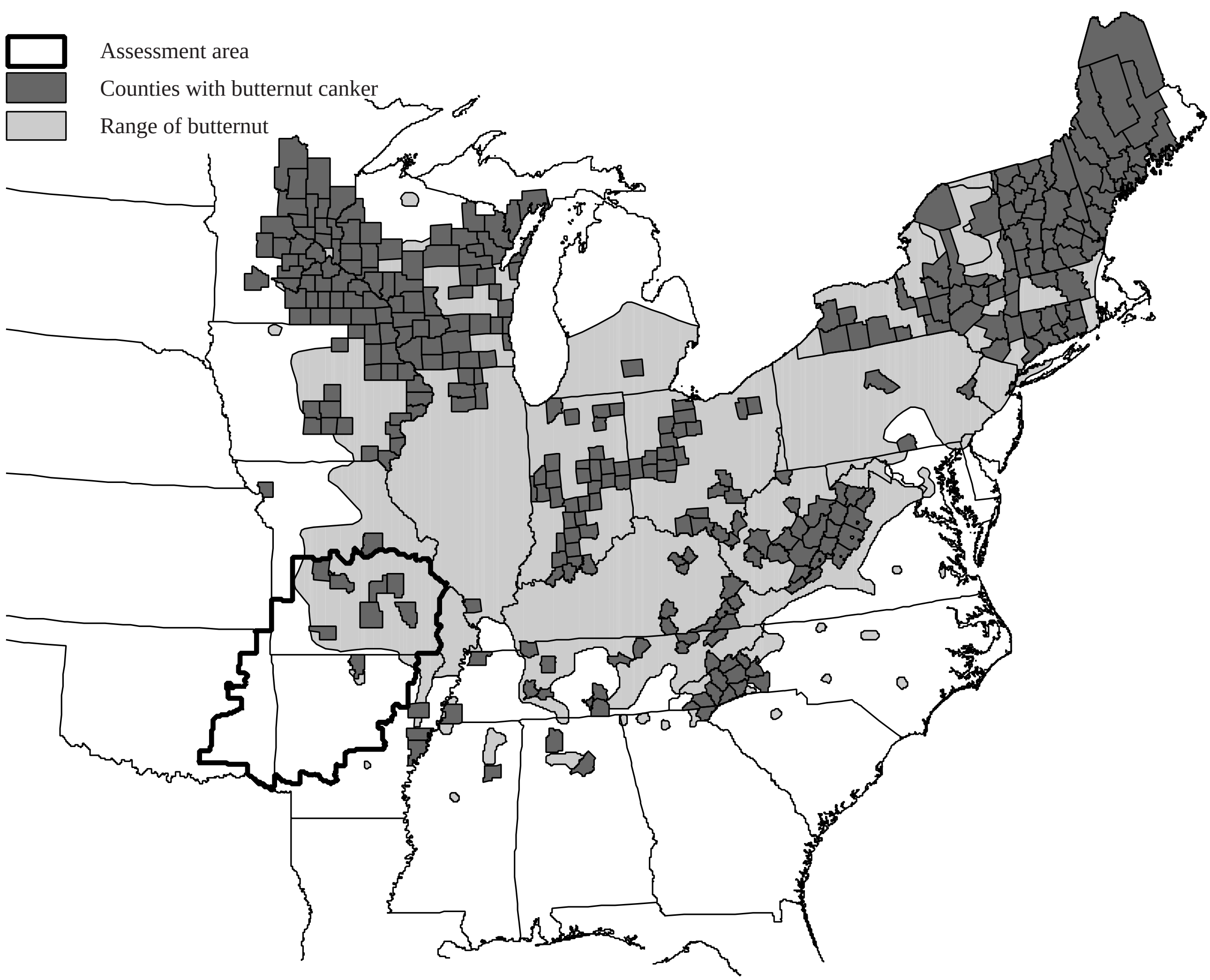


Figure 6.3—Counties with butternut canker in the Eastern United States, including the Ozark-Ouachita Highlands.

The first discovery of butternut canker was in southwestern Wisconsin in 1967 (Renlund 1971). The disease is now present in various areas throughout the natural range of the tree (fig. 6.3). In the past 20 to 30 years, this fungus-caused disease has destroyed much of the butternut resource (Ostry and others 1994). Although the origin of the disease is unknown, its severity indicates that native butternut populations have little natural resistance to the fungus, suggesting it is an introduced species (Ostry and others 1996).

The butternut canker fungus causes cankers to form under the tree's bark, killing the cambium (growing layer) and inner bark of infected areas. Buds, leaf scars, insect damage, and other wounds are the main infection points for the fungus (Ostry and others 1996).

The disease has dramatically affected the butternut resource. Reductions in forest inventories of butternut, probably due to the disease, have been dramatic over the last 10 to 15 years: 58 percent in Wisconsin, 84 percent in Michigan, and 77 percent in North Carolina and Virginia (Ostry and others 1994).

The disease is scattered over the entire range of butternut in the Eastern United States (fig. 6.3). Within the Assessment area, the tree's range covers much of southern Missouri and small parts of Arkansas (Rink 1990). The Mark Twain National Forest is within the tree's range. Because the trees occur mainly as scattered individuals in mixed forests, they are difficult to find and surveys may overlook many diseased trees.

The disease occurs in at least nine counties in Missouri and four in Arkansas. Eight of these counties are in the Assessment area; seven are in Missouri, and one is in Arkansas.

Land managers should assume that the disease is present anywhere butternut exists. The Forest Service has placed a moratorium on the harvest of healthy butternuts, but no other protection is known in the Assessment area. The U.S. Department of Interior Fish and Wildlife Service has considered listing butternut as a threatened species under the Federal Endangered Species Act, but not enough data are available to support such a decision (Ostry and others 1994).

There is probably little forest managers can do beyond observing the moratorium on harvesting of healthy butternuts. Cutting infected or dead butternuts is permissible and may help reduce local spread of the disease but is unlikely to have a significant regional effect. Silvicultural treatments in areas with healthy butternut should encourage natural regeneration (gaps in stands up to 2 ac), which will encourage growth and survival of this intolerant species. Long-term hope for restoring butternuts to their previous status may only be realized if genetically resistant individuals can be found and the resistance exploited. For such a minor forest component, it is difficult to marshal the needed scientific and economic forces. However, there is evidence that resistant trees may exist, and some researchers are studying these for potential use (Ostry and others 1994).

Dutch Elm Disease

Since 1930, the American elm tree has been devastated by one of the most well-known diseases in the world, Dutch elm disease (Stipes and Campana 1981). The fungus that causes the disease is an exotic pest, introduced to America from Europe around 1930.

The exotic European elm bark beetle is instrumental in the disease's spread in the United States, but the native American elm bark beetle also spreads the fungus. The disease spread from introduction sites in the Northeast and by the late 1970's was present over most of the United States (Stipes and Campana 1981).

Losses of elms were greatest and most alarming in cities and towns, where landscapers commonly planted the American elm as a shade tree in long rows along streets and in parks. Close-growing elms formed natural root grafts and the fungus was able to spread efficiently through the connected root systems as well as by bark beetles. Losses also occurred in forests, but because elms are typically scattered individuals in mixed forest types, they were often overlooked. Discovery of losses of other, less numerous native elms has also been overlooked (Stipes and Campana 1981).

Dutch elm disease is a vascular wilt resulting in the loss of internal water conduction in the stem of the tree, causing it to wilt and die. Most elm species worldwide are susceptible, although there is considerable variation among species.

The fungus usually enters a tree through the feeding wounds of elm bark beetles on twigs in the upper crown. It can also enter through root grafts with other infested trees. Foliage on individual branches often turns yellow, wilts, and dies, followed by the remainder of the tree's crown.

The fungus is intimately associated with elm bark beetles and sporulates in the insects' breeding galleries on the main bole of infected trees. Emerging beetles become contaminated with spores, which are transferred to new feeding wounds on twigs of healthy trees (Stipes and Campana 1981, Tainter and Baker 1996).

The American elm grows over all of the Eastern United States and Southern Canada (Bey 1990). It is present in many types of forests and occurs on a wide range of soils and sites but is most closely associated with bottomland soils or streamsides in the uplands. Dutch elm disease occurs throughout the Ozark-Ouachita Highlands. Urban areas in the Highlands have not experienced devastating losses because elms were not widely planted for shade.

In forests, elm losses have been spotty, mostly undocumented, and mostly overlooked. This situation is not likely to change. Elms will gradually become less frequent in forest stands, but extermination of American or other elm species is not likely (Stipes and Campana 1981).

Community-wide control programs have had some success in many cities in the Midwest and East, but no such programs are known to exist in the Assessment area, where cities do not have large plantings of elm. Several elm varieties or hybrids with disease resistance are now available for urban use. Active management or control of the disease in forests is impractical.

Chestnut Blight

American chestnut was one of the most prevalent and useful trees in the Eastern United States until the introduction of chestnut blight fungus from Asia in 1900. The disease spread quickly, invading most of the chestnut range in the Eastern United States by 1940 and killing most of the trees (Harlow and Harrar 1969, Tainter and Baker 1996).

Since then, the American chestnut has virtually disappeared as an overstory forest tree. The American chestnut does not occur in the Ozark-Ouachita Highlands, but chestnut blight also affects the Allegheny and the Ozark chinquapins, species related to American chestnut that are present in the Assessment area (Johnson 1988).

Chestnut blight fungus invades the cambium and inner bark of host trees, causing diffuse cankers that quickly girdle and kill the affected stems. Rootstocks of chestnuts are not infected and prolific sprouting occurs after the stems are killed. Before sprouts become tree size they are usually infected, too, so withering and sprouting become a repetitive occurrence. This pattern can deplete root reserves and eventually kill the tree.

The effects of the blight are similar in chinquapins, reducing infected individual trees to a clump of sprouts, although the Allegheny chinquapin is less susceptible and less seriously damaged than Ozark chinquapin (Johnson 1988). Within the Assessment area, the Allegheny chinquapin is widespread over central Arkansas. The Ozark chinquapin occurs almost exclusively in the Ozark and Ouachita Mountains of Arkansas, and just into eastern Oklahoma and southern Missouri. The two species may coexist in central Arkansas (Johnson 1988, Little 1977). More common within the Assessment area and more susceptible to the blight is the Ozark chinquapin, a small- to medium-size tree. Ozark chinquapin is rarely used for wood products, but the nuts are valuable wildlife food and historically have been eaten by people (Halls 1977b).

The entire ranges of Allegheny and Ozark chinquapin are affected by chestnut blight (Johnson 1988). Individual specimens of healthy Ozark chinquapin occur in some places in the Assessment area; they escaped infection or perhaps have some genetic resistance, although the latter seems unlikely given the American chestnut's lack of such resistance (Tainter and Baker 1996). The disease has affected the majority of chinquapins in the Assessment area (Johnson 1988). Continued blighting and withering of sprouts will slowly reduce the prevalence of chinquapin and debilitate rootstocks, although extermination of the species is not likely.

The Southern Region of the Forest Service has listed Ozark chinquapin as a sensitive plant because of damage from the blight. The U.S. Fish and Wildlife Service considered placing it on the list of threatened and endangered plants, but more data are needed before making that determination. No protective legal status for Ozark chinquapin is known at the State level, but the Arkansas Natural Heritage Commission lists it as a "plant species of special concern" (USDA FS 1989).

Of the national forests in the Assessment area, the disease most heavily affects the Ozark National Forest. Concern by the Forest Service resulted in the development of a proposed management guide for the Ozark chinquapin to provide as much protection for the species as possible while minimizing conflicts with management of other resources (USDA FS 1989).

The management guide proposed to fully protect Ozark chinquapins with stems 8 in. or greater in diameter at breast height (d.b.h.). In addition, the guide allows impacts to smaller stump sprouts during normal forest management activities (e.g., controlled burning or timber cutting). Although never officially adopted, the guide serves as a resource for management activities in the ranger districts.

Native Insect Threats

Data Sources

The information in this section is from published reports and from the Southern Pine Beetle Information System database maintained by the Forest Service.

Patterns and Trends

Southern Pine Beetle

The southern pine beetle is one of the most destructive insects in the South, causing the loss of pine trees over large areas. Since 1948, outbreaks have occurred in Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia. McAndrews (1926) aptly summed up the beetle's existence: "It is either abundant, killing up to 50 percent of the stands of pine over large areas and killing out groups of pine here and there throughout the country, or so rare during the intervening years that it is difficult even to make collections."

The first outbreak of southern pine beetle in Arkansas was reported in 1974. Many counties in northern Arkansas and Oklahoma have never had an outbreak of southern pine beetles, despite the occurrence of an excellent host, shortleaf pine. Drought, overstocked stands, absence of natural enemies, and stand disturbances are among the conditions that appear to be contributing factors in outbreaks, which are cyclic.

Discoloration of the crowns of trees usually indicates an outbreak of southern pine beetles. Discoloration progresses rather rapidly over the whole crown, with the fading needles soon turning to a reddish brown. Outbreaks usually affect large groups of trees, seldom as few as one or two. "Pitch tubes," small yellowish-white masses of pitch on the trunks of affected trees, are the points of beetle attack. In unusually dry weather, however, there may be no pitch, or only mere traces of it, under bark scales where the beetle bored into the tree. In this situation, the only evidence of attack may be reddish-brown boring dust lodged in bark crevices and in cobwebs on the trunk or at the base of the tree.

Removal of a piece of bark from an infested pine will reveal an array of winding galleries on the inner bark and on the wood surface, a characteristic which clearly distinguishes the presence of the southern pine beetle from any other pine bark beetle in the South. If the attack is recent, there may be some adults in the egg galleries or very tiny, whitish larvae near the galleries. In older attacks, most of the brood will be within the bark.

The adult southern pine beetle carries numerous spores of a bluestain fungus, and when an adult beetle attacks a tree, the bluestain spores are carried into egg galleries, where the spores germinate. Blue-stain fungus colonies grow into the wood of infested pines, stopping the upward flow of water to the tree crown. Lack of water causes needles to wilt and die within 2 to 8 weeks, depending on temperatures (Moser and others 1995).

The southern pine beetle may overwinter in infested pines as adults, immature adults, pupae or larvae. Beetles of overwintering broods begin to emerge and attack trees in April or May, about the time that dogwood is in full bloom. The life cycle from egg to adult requires 27 to 40+ days, depending upon the weather, and 4 to 6 generations are produced per year, with considerable overlapping. Beetle populations and beetle activity generally reach a peak in midsummer. The number of beetles may increase as much as tenfold in a single season. Activity slows as temperatures decrease. However, beetle flights and attacks do occur in winter during prolonged warm spells, even at higher elevations in the mountains.

Successful southern pine beetle attacks are dependent on two factors: the ability to mass attack pine trees, and the ability to have overlapping (multiple) generations produced at the same time in an infested stand of pine trees. Southern pine beetles usually attack the mid-trunk of a tree first, then move upward and downward. While larger trees are more commonly attacked, trees as small as 2 in. in diameter also may be infested. Natural enemies, including insect parasites, predators, diseases, and woodpeckers, rarely have a notable effect on the southern pine beetle during severe outbreaks, although they undoubtedly do exert some degree of control. The full effect of these biological control factors and the conditions under which they are most effective are unknown.

Southern pine beetle mortality has been observed during severe cold snaps, where temperatures drop suddenly and remain below freezing for several days. Mortality has also been observed during hot periods when temperatures remain above 90 ºF for several weeks. This form of control occurs most commonly at higher elevations and in the northern part of the insect's range (Kowal 1960).

After identifying and monitoring southern pine beetle outbreaks, land managers can use several techniques to control the outbreaks, including cutting and removing affected trees; cutting and leaving affected trees; cutting, piling, and burning affected trees; and chemical treatments of individual trees and small groups of trees in high value settings. The first two treatments are most commonly used because they disrupt the beetle's ability to mass attack. Felling, piling, and burning infested trees is one of the oldest control methods for southern pine beetles and can be effective, but the technique is expensive and includes the risk of the fire escaping (Swain and Remion 1974, USDA FS 1987).

Figure 6.4 indicates the incidence of southern pine beetle outbreaks in the Assessment area since 1960. The most recent outbreak in the Highlands occurred in 1995 and 1996 on the Ouachita National Forest (Haley and others 1996). In many instances, infestations of pine

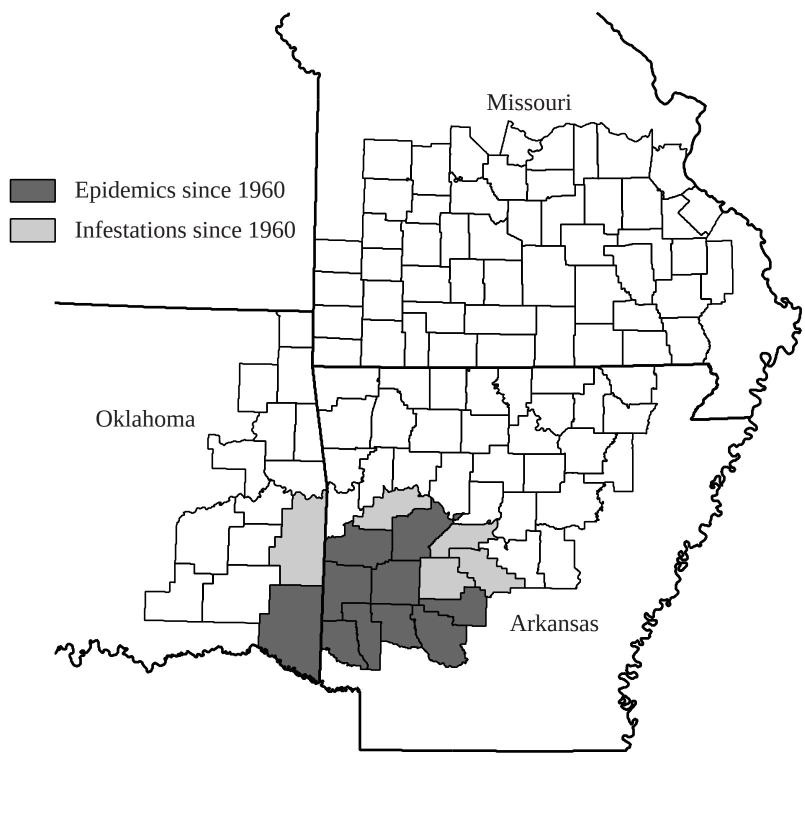


Figure 6.4—The incidence of southern pine beetle outbreaks in the Ozark-Ouachita Highlands since 1960.

engraver beetles and the black turpentine beetle were associated with these outbreaks.

The southern pine beetle is endemic in southern pine forests. Outbreaks will continue to occur in the Assessment area, primarily in the Ouachita Mountains section. It is unknown why southern pine beetle outbreaks fail to occur in some areas of Arkansas and Oklahoma where available hosts trees are present.

Research continues into methods to detect, monitor, and control outbreaks of the southern pine beetle. The Forest Service and Mississippi State University jointly obtained a patent for a natural compound, 4-allylanisole (4-AA), for use as a repellent to the southern pine beetle. This pheromone has been successful in preventing attacks by the southern pine beetles in urban settings (Hayes and others 1995). In addition, verbenone, a primary inhibitory pheromone produced by the southern pine beetle, is being used effectively to disrupt populations expansion under some conditions (Payne and Billings 1989). Neither of these compounds is registered for southern pine beetle control.

Ips Bark Beetles

The name "Ips beetle" refers to a genus of pine bark beetles. There are three principal species of Ips bark beetles attacking pine in the Ozark-Ouachita Highlands: the eastern six-spined and five-spined engravers and the small southern pine engraver.

The only insect to kill more pine trees in the South than this group of beetles is the southern pine beetle, which often attacks trees in combination with one or more of the three Ips species and/or the black turpentine beetle. It is common to find one or more species of Ips, as well as other pine-infesting beetles inhabiting various parts of the same tree. At least 16 species of pines in the United States, including the loblolly and shortleaf pine, are hosts to one or more of the Ips species.

Ips beetles usually attack weakened, dying, or recently-felled trees and fresh logging debris. Large numbers of Ips may build up when natural disturbances such as lightning storms, ice storms, tornadoes, wildfires, and droughts create conditions suitable for breeding.

Ips populations may also build up following forestry activities, such as prescribed burns that get too hot and kill or weaken pines and cutting operations that compact soils, wound trees, and leave large amounts of branches, cull logs, and stumps for breeding sites.

Like the southern pine beetle, the adult Ips beetle carries spores of a bluestain fungus. The spores are transferred into egg galleries, where they germinate. Blue-stain fungus colonies grow into the wood of infested pines, stopping the upward flow of water to the tree crown. Lack of water causes needles to die, gradually changing their color from green to yellow green to red brown. These color changes may occur in 2 to 4 weeks during the summer, but may take several months in the winter.

Several prevention or suppression techniques—including burning, chipping, debarking or burying infested portions of trees—can be effective in forested situations. During logging operations, as much of the felled tree as possible should be used, and no remaining parts of the infected tree should be left in contact with or close to other trees. Harvested timber should be removed from the cutting area as soon as possible, especially during warm weather.

Damaged portions of trees and root injuries, especially during hot, dry weather, attract Ips and black turpentine beetles. It is important to minimize damage to remaining trees from logging equipment. Soil compaction and root breakage to remaining trees can be minimized by using the lightest harvesting equipment available.

When planting and maintaining pine stands, managers should use the pine species and spacing interval best suited to the area, thin stands to maintain health and vigor, and promptly remove or destroy potential Ips breeding material. In residential areas, shade tree vigor can be maintained by watering during drought. When Ips and black turpentine beetles are associated with infestations of southern pine beetles, removal of all infested trees should occur at the same time. (Lanier 1972, Thatcher 1960, Connor and Wilkinson 1979)

Black Turpentine Beetle

The black turpentine beetle has caused extensive losses throughout the pine belt in the South, from Texas to Virginia and southward through Florida, although it has been a less serious threat in the Ozark-Ouachita Highlands. Drought, flooding, and severe stand disturbances caused by mechanized logging, fire, or other insects, such as the southern pine and Ips beetles, appear to be contributing factors.

The insect prefers freshly-cut stumps for breeding. The beetle also prefers weakened trees, such as those damaged by fire, worked for sap collection, or infested by other bark beetles. The black turpentine beetle seldom persists at a high population level for longer than 1 to 2 years. When the beetle's population is increasing dramatically, it is capable of attacking healthy trees. The beetle tends to work slowly and persistently throughout the year. Rarely do black turpentine beetle populations increase at rates high enough to be considered an outbreak.

The beetle confines its attacks to the base of the tree, with infestations almost always located in the lowest 6 feet (ft). Large pitch tubes on the bark surface are a mixture of pitch, frass, and bark boring dust; they have a reddish to white color, which quickly ages to gray. Heavily-infested trees almost always suffer secondary attacks by ambrosia beetles. These attacks also are at the base of the tree and are characterized by a fine white sawdust, which accumulates around the trunk.

Black turpentine beetle larvae feed gregariously under the bark and form large fan-shaped galleries, which may be as large as 12 in. across. The beetle's life cycle is 3 to 4 months, depending on temperature. Although development may be slowed during the cooler months, it does not go into a dormant stage.

Attacks of black turpentine beetle are usually not fatal. In trees that are killed, the needles begin to lose their normal healthy green color and fade, first to a yellowish green and finally to a reddish brown (Smith and Lee 1972). Control measures include removal of infested trees and application of pesticides on high-value sites or trees (Smith and Lee 1972). (See the previous section on Ips beetles.)

The most severe infestations in the Assessment area have been in stands of loblolly and shortleaf pine in the Ouachita Mountains section.

Walkingsticks

The walkingstick is a defoliator of deciduous trees in North America. Because of its appearance, this insect's common names include stickbug, specter, stick insect, prairie alligator, devil's horse, witch's horse, devil's darning needle, thick-thighed walkingstick, giant walkingstick, and northern walkingstick.

Nymphs hatch as early as the first of June in the southern part of the walkingstick's range. Nymphs not succumbing to cold weather move to and feed upon preferred shrubs on the forest floor until midsummer. Older nymphs and adults then move into the surrounding host trees. Young nymphs feed on low-growing plants including beaked hazel, rose, juneberry, sweetfern, blueberry, and strawberry. Older nymphs and adults prefer black oaks, basswood, and wild cherry as hosts. They also feed on hickory, locust, apple, and chestnut if those trees are in stands with the preferred hosts.

Walkingsticks reach adulthood in late July or early August. Mating occurs about 1 week later. Egg-laying continues until October or the arrival of cold weather. Each female may lay up to 150 eggs at an average rate of 3 per day. The eggs fall from trees and overwinter in leaf litter.

In the southern portion of the insect's range, most eggs hatch the following summer, but in the northern portion, hatch is delayed an additional year. Because the cycle in the northern portion of the range is 2 years, even-year and odd-year broods develop.

Because the walkingstick cannot fly, infestations are local and spread only a few hundred yards during the season. A stream, road, or other barrier often retards the spread of the insect. Heavy outbreaks of walkingsticks can completely defoliate large stands, sometimes twice in a single season. Three or four heavy infestations can kill some branches. At times, the selective feeding on black oaks by older nymphs and adults may favor the growth of white oaks or conifers in a stand of trees (Wilson 1971).

The walkingstick is present throughout the Assessment area. Severe outbreaks rarely occur below a line from southern Nebraska to Delaware, except in the Ouachita Mountains section (Wilson 1971). Major outbreaks were reported in central Missouri in 1995 and 1996. Weather, parasites, predators, and disease generally control walkingstick infestations (Wilson 1971).

Native Tree Diseases

Data Sources

Information about native tree diseases is from published sources and unpublished Forest Service reports.

Patterns and Trends

Oak Decline

Oak decline is a complex, slow-acting disease syndrome involving the interaction of (1) predisposing factors such as climatic trends, poor soil or site quality, tree age, or tree genetics; (2) inciting factors such as short-term drought, frost, or insect defoliation; and (3) contributing factors such as root disease, bark beetles, or canker or decay fungi (Manion 1981).

Decline and mortality of oaks have been reported in the Eastern United States since the early 1900's and in nearly every decade since (Ammon and others 1989). A widespread increase in the mortality and decline of oaks in the Southeast in the 1980's refocused attention on this problem (Bassett and others 1982, McGee 1984, Starkey and others 1989, Stringer and others 1989, Tainter and others 1984, 1990).

There is no single cause of oak decline, and most reports mention one or more factors. Besides drought or frost, the European gypsy moth, the two-lined chestnut borer, and Armillaria root disease are common factors (Wargo and others 1983, Starkey and others 1989, Ammon and others 1989). When mature oaks growing on average or poor sites experience drought or spring defoliation, they become weak and vulnerable to attack by secondary, opportunistic organisms. Progressive dieback of the crown usually begins and vulnerable trees may die.

In the South, the greatest influences on tree vulnerability are stand age and site conditions (predisposing factors); short-term drought or repeated European gypsy moth defoliation (inciting factors); and the two-lined chestnut borer and Armillaria root disease (contributing factors) (Starkey and others 1989). Species in the red oak group, such as scarlet oak and black oak, are more likely to die of oak decline, while white oaks are less likely. Hickories are the only species other than oaks to show decline symptoms. Patterns in hickory resemble those seen in the white oaks (Starkey and others 1989).

An evaluation in 1985 of oak decline in the South found affected stands in the Assessment area (Starkey and others 1989). Twenty-six percent of dominant and codominant trees in those stands were dead and another 4 percent had advanced decline. Oak decline is known to occur all over the Eastern United States in susceptible oak forest types.

All Southern States had some incidence of oak decline in upland hardwood forest types in a 1992 analysis of FIA data (Starkey and others 1992). North Carolina had the highest incidence (19.6 percent) while Oklahoma had the lowest. Arkansas was intermediate at 6.4 percent. Unfortunately, Missouri was not similarly analyzed since FIA data for oak decline are not available for that State. Affected plots in Arkansas were concentrated in north central and northwest Arkansas where the upland hardwood host type is most prevalent. A similar situation probably exists in southern Missouri.

The Assessment area contains approximately 19.3 million ac of hardwood forest made up of a number of forest types that could be affected by oak decline (see Chapter 3). Only a portion of this area is vulnerable to decline. High risk factors include physiological maturity (advanced age combined with an average to poor site) and a large red oak component.

Oak decline will continue to occur at various times and locations in the Assessment area. The severity and duration of decline events will vary considerably from year-to-year and site-to-site depending on climatic and local conditions. Vulnerability of oak forests will increase as they age and little reproduction cutting is performed. Oak decline may become more severe when inciting events such as drought begin the decline syndrome.

Management responses to the threat of oak decline depend on the importance of oaks as a component of particular forest areas and the costs of stand management activities. Choices range from no action to using silvicultural techniques to promote and maintain a substantial oak component in stands. Taking no action will allow decline to run its course in affected areas, with the result that oak stocking will be reduced and other species will become more abundant.

Alternatively, silvicultural techniques are available to lessen the effects of decline and maintain the prevalence of oaks. Intermediate stand treatments can be used to promote and maintain a component of young oaks, so that when decline begins or stand rotation ages are reached, reproduction cutting will be successful in replacing the oak component. (See Chapter 4 for a discussion of reproduction cutting methods and intermediate treatments.)

Even-aged methods, such as clearcutting and shelterwood, are potentially the most useful in managing decline-prone forests since they remove most or all of the vulnerable, older component of oaks in a single operation and are generally successful in regenerating oaks where sufficient advance reproduction exists. Because this process creates even-aged stands, monitoring the age and condition of overstory oaks (as well as other stand conditions) and scheduling management activities accordingly becomes relatively straightforward.

An oak component can be maintained in areas where a complex age structure (two-aged or uneven-aged) is a management objective. Advanced recruitment of young oaks must be secured prior to reproduction cutting. Oaks in the older age classes of areas managed this way will be more vulnerable to oak decline.

Oak decline may pose a greater threat on public lands, where stands tend to be older. Vulnerability to oak decline is enhanced by reduced cutting on public land, which lessens the amount of younger age classes in the landscape.

A hazard rating system that can be used on the Ozark-St. Francis and Ouachita National Forests utilizes the Continuous Inventory of Stand Conditions database. The system can identify stands most likely to be affected by oak decline.

Oak Wilt

Oak wilt is a vascular wilt disease of oaks that currently is found only in North America. The causal fungus was first identified in Wisconsin in 1942 and was fully described by the early 1950's (MacDonald and Hindal 1981, Tainter and Baker 1996), but scientists believe the disease is native to North America and was present long before 1942.

There was much concern about the disease during the 1950's and 1960's. Researchers thoroughly investigated the disease and developed control strategies, which have been implemented to various degrees in affected States (Appel and Billings 1992).

Oak wilt results when a fungus invades the vascular tissues of oaks, causing trees to wilt rapidly and die. A wide variety of oaks are susceptible, but species in the red oak group (northern red oak, scarlet oak, and black oak) are most readily killed. Oaks in the white oak group (white, post, and chestnut oaks) are infected but mortality occurs much less frequently and more slowly.

Substances produced by the fungus, as well as the tree's own defenses, combine to cause the vascular tissues to plug up and cease conducting water, resulting in wilt. Yellowing and wilting usually occur first in a branch or two and then quickly spread over the entire crown, eventually resulting in mortality. Infection "centers" develop when the fungus spreads to adjacent, susceptible trees through grafted or connected root systems.

Fungal mats develop under the bark of dead red oaks, causing a fissure to form in the covering bark. The sweet, fruity smell of these mats attracts sap-feeding beetles, which feed there. Upon leaving the mat, beetles carry spores of the oak wilt fungus. These spores are transmitted to nearby healthy trees when sap beetles feed on wounds on twigs, branches, or trunks.

Devastation of oaks in the Eastern United States never developed as researchers originally feared. This is due to a combination of stands containing many species of oaks and soils that are not conducive to multiple root grafts between susceptible trees. In central Texas, however, catastrophic losses, primarily in live oaks, have generated much interest and control efforts since the 1980's (Appel and Billings 1992). Some of the Lake States—notably Michigan, Minnesota, and Wisconsin—have experienced severe losses in urban and suburban areas and have increased control efforts in the last decade.

Oak wilt is known to occur in 21 States in the Central and Eastern United States (Rexrode and Brown 1983). The disease affects most of the Ozark-Ouachita Highlands but has not been devastating; infection centers are infrequent, usually stay small (0.5 ac or less), and die out on their own. There have been no active, coordinated control programs in the Assessment area.

Serious control efforts been made only in central Texas, central Minnesota, and a few localities in the

Lake States during the past 10 years. Control programs in most other States have been reduced to very low levels due to relatively noncatastrophic oak losses (Appel and Billings 1993).

While small, isolated patches of oaks may be killed in the Assessment area, the cost of detecting them, diagnosing the disease, and salvaging small areas of timber is usually too high to justify these actions. In addition, spread of the disease is probably little affected by control efforts. In urban and suburban areas, oak wilt may occasionally kill some trees with serious, but very localized, consequences. Here too, organized control programs are not necessary due to the very infrequent occurrence of the disease.

Invasive Nonnative Flowering Plants

Ranges of plants and animals change over time. However, landowners and forest managers are concerned about the effects of rapid invasions of organisms from other continents. Free from the parasites and predators that keep them in check in their native ecosystems, populations of nonnative species may explode when introduced into new ecosystems. Many of these alien plants and animals benefit from disturbance, gaining a toehold and then displacing native organisms, some of which may already be rare (Gilfillan 1994, Grazing Lands Forum 1993, Soule 1994, Williams 1994).

Data Sources

General references on invasive nonnative plants include Campbell (1997), Harty (1986), Hoffman and Kearns (1997), and the Natural Areas Association (1992). The information in this report comes largely from Smith (1993, 1997) and from professional biologists and botanists with field experience in managing these plants.

Patterns and Trends

The nonnative plants that the Terrestrial Team assessed typically were introduced to the Highlands for use as landscaping, wildlife cover and food, or erosion control. Many of these plants became invasive pests, since they compete with native species for growing space.

Federal and State conservation agencies were among the strongest promoters of some of these plants. For instance, State nurseries were still growing and distributing autumn olive only a few years ago (Harty 1991). Today, land managers are increasingly substituting native species for nonnative species. While intentional introductions of invasive nonnative species should decline, the costs of combating invasive plants and animals will continue.

Multiflora Rose

Formerly promoted as a “living hedge” to prevent soil erosion and benefit wildlife, this shrub is a classic example of the danger of using nonnative plants. The thorny bushes, attaining a height of 10 ft or more, spread widely by seed, ruining pastures and riparian areas and reducing land values. Land managers use herbicides, bush-hogging, grubbing, and bulldozing to control or eliminate the plant. The State of Missouri declared the plant a noxious weed in 1983. In recent years, a virus and a chalcid wasp have killed many plants, supplementing control efforts (Smith 1993).

Autumn Olive

A large shrub growing up to 20 ft tall, autumn olive has leaves with silvery undersides and produces small pulpy red fruits. In Missouri, this shrub has spread from its original conservation plantings and may become as serious a pest as multiflora rose. Threats to natural communities now outweigh its benefits to wildlife. Grubbing and herbicide applications reduce this plant where it threatens prairies and other open habitats. Native fruiting trees, including flowering dogwood, blackhaw, persimmon, and Carolina buckthorn, are alternatives to autumn olive.

Privet

This hedge-forming ornamental shrub is locally abundant in bottomland areas on the Ouachita National Forest and disturbed forest stands and urban parks in the Ouachita Mountains and Arkansas Valley. A serious invader in some parts of Missouri, it is not yet a problem in the Ozarks. Aggressive and difficult to eradicate, it spreads rapidly, forming thick stands in the woodland understory.

Mimosa

This small ornamental tree has spread to some parts of the Ouachita National Forest, displacing native fruit-bearing trees such as cherry and mast producers such as oaks and hickories. Mimosas decline and die before reaching a large size in most of the Assessment area, but they are prolific reproducers. Mimosa is not a great problem in northern Arkansas or Missouri.

Tree of Heaven

This tree spreads by seed and by suckering and invades food plots and other clearings. It is increasingly prevalent in the Ouachita National Forest and to a lesser extent in the Ozark National Forest, where it infests disturbed areas. Tree of Heaven is a common sight at old house sites in the Missouri Ozarks, but it does not appear to invade natural areas.

Kudzu

This vine is a serious pest that climbs to the forest canopy, shading out all other plants and decreasing forest productivity. It is most severe in the southern part of the Assessment area, but growing infestations of several acres in size exist as far north as Pulaski County, MO. Land managers have used herbicides, fire, grazing, and mechanical methods to control infestations in the Ozark National Forest; no treatment has eliminated the vine. Severe winters kill aboveground parts of the vine in Missouri.

Japanese Honeysuckle

Horticulturists once touted this plant for its berries, succulent foliage, and cover and food for wildlife, but Japanese honeysuckle is a serious pest in the eastern Ouachita Mountains and Arkansas Ozarks. The vine climbs high into trees, girdles saplings, and tends to shade out low-growing species. It also acts as a “ladder fuel,” carrying fires into the crowns of mature trees that otherwise would not be killed by fire. In riparian areas, mats of Japanese honeysuckle smother native species, including orchids and other wildflowers. The semievergreen leaves are able to photosynthesize before and after most native plants are growing. Early spring burning and herbicides are somewhat effective for control (Smith 1993).

Sericea Lespedeza

One of the worst nonnative pests in the Assessment area, this legume is everywhere, even within federally designated Wilderness. It invades grazing allotments and warm-season grass restorations, preventing native plants from reestablishment. Sericea has washed into streams from highway embankments and colonized gravel bars in Missouri. The foliage hardens off very early, so herbivores only eat early spring shoots. Some farmers still use the plant as a hay crop, but it requires early harvest and is subject to leaf shatter. When used for erosion control, it often prevents native plant establishment. The plant is extremely difficult to control without herbicides, but it can be shaded out (Smith 1993).

Crown Vetch

This pink-flowered legume is spreading on glades, in bottomlands, and on Mount Magazine in the Ozark National Forest. A single plant can cover a large area, shading out native plants. The national forests in the Assessment area have phased out its use on new pond banks and in other erosion control projects, but some landowners and State highway departments still use this plant as a ground cover (Smith 1993). Because the vine-like stems intermingle with desirable native vegetation, herbicide use is difficult. Mechanical removal is the only option in some areas.

Musk Thistle

This plant invades pastures, fields, and roadsides. Despite its large, attractive, nodding flower heads, Missouri and Oklahoma have declared musk thistle a noxious weed. The Mark Twain National Forest has applied herbicides directly on individual plants, and has tried chopping and digging the first-year rosettes as well as mature plants. Several weevils are available for biological control of the plants (Smith 1993). Although not on the Arkansas list of noxious weeds, musk thistle can be troublesome in improved pasture.

Tall Fescue

Valuable as a cool-season forage grass for livestock, tall fescue forms dense stands with thick mats of roots even on poor, acid soils, and it withstands trampling and overgrazing. Unfortunately this grass provides little benefit to native wildlife species and can threaten natural areas and warm-season grass restoration efforts. The national forests are gradually eliminating the use of fescue for erosion control in undeveloped areas. Wheat or rye is an alternative on many sites until native plants establish themselves. Herbicides, early burning, and overgrazing are control methods for conversion to warm-season grasses (Smith 1993).

Johnson Grass

Johnson grass is a tough competitor with native plants in disturbed areas, old fields, and roadsides. A buildup of prussic acid in its leaves after a frost can poison livestock. Missouri and Arkansas have labeled this plant, once used for pasture, a noxious weed. Control efforts can damage native grasses such as big bluestem, which Johnson grass superficially resembles (Smith 1993).

Knapweeds

One of the scourges of western rangelands, knapweeds have been present for several decades on some roadsides in southern Missouri. They are not yet serious pests in the Ozark-Ouachita Highlands. However, spotted knapweed is invading relatively undisturbed natural areas as far east as Wisconsin (Hoffman and Kearns 1997). There are health concerns for humans and livestock related to this plant. Precautions should be taken to minimize direct contact with this plant.

Sweet Clover (white and yellow)

White and yellow sweet clover are common and widespread in the Ozarks, where they invade natural areas, wilderness trails, warm-season grass restorations, prairies, and glades. Hand pulling and herbicides are used for control in particularly sensitive areas (Smith 1993).

Purple Loosestrife

This attractive plant with a wand of rose-colored flowers is one of the greatest threats to wetlands in the northern United States. Increasing in northern Missouri, the plant is the most recent addition to the State's official list of noxious weeds. The only known infestation in the Missouri Ozarks, adjacent to a riverbottom natural area, was treated with herbicide. Purple loosestrife has been present near the Ouachita National Forest, where a population has expanded along a creek over the last 3 to 4 years. Land managers hope to spot and eradicate infestations in the Assessment area before they spread.

Garlic Mustard

This biennial plant poses a threat to riparian woodlands, where it dominates the ground flora by excluding other plants. The Nature Conservancy has fought the plant for several years in its preserves in northern Missouri (Smith 1993). Garlic mustard has not been found in the Assessment area, but land managers should be alert to the possibility of its spread into the area.

Teasels

Two species of nonnative teasels are present on roadsides and in at least one riparian area in the Missouri Ozarks. This biennial plant, often confused with thistles, has the tendency to dominate open areas of forests and savannas. Biologists are concerned that they may become serious pests. Teasels do not appear to be strongly competitive in the Arkansas Ozarks or Ouachita Mountains.

Implications and Opportunities

Invasive, nonnative species present in the Assessment area but not yet widely established, such as purple loosestrife, garlic mustard, and knapweeds, should be closely monitored and eradicated as quickly as possible. In many cases, native plants can provide the same benefits without the accompanying problems of nonnative species. Virginia creeper serves the same purposes as Japanese honeysuckle; native warm-season grasses can serve in place of Sericea, crown vetch, and tall fescue. The Missouri Department of Conservation recommends several native species as alternatives to nonnative plants (Smith 1997).

A new partnership of Federal, State, and local agencies develops and promotes long-term weed management projects and provides financial support to 24 local weed management partnerships, which include national forests, State agencies, county and local agencies, private landowners, and citizen groups. (See the Web site <http://bluegoose.arw.r9.fws.gov/FICMNEWfiles/NatlWeedStrategyTOC.html>.)

Invasive Nonnative Vertebrates

Wildlife biologists regard starlings and English or house sparrows in the same way homeowners think of Norway rats and house mice. These species, like other nonnative birds and mammals, create problems in ecosystems.

Data Sources

The information in this section is from published sources and from consultations with members of the Assessment team and other wildlife biologists and natural resource managers.

Patterns and Trends

Three species of Old World birds cause problems in towns and farms throughout the Nation. Feral hogs, feral dogs, and feral cats present other problems.

Starling

The starling is a native of Europe that entered the United States in 1890, due to the intentional introduction by a hobbyist whose ambition was to introduce into the United States every species mentioned in the works of Shakespeare (Teale 1948). Starlings multiplied rapidly and spread across the country.

An abundant pest in cities, suburbs, and farmlands, the starling is a nuisance by virtue of its sheer numbers, especially where droppings are a health concern as well as an unsightly mess. Starlings join blackbirds in large roosting flocks during the winter, especially near agricultural land. Some flocks in Arkansas contain 2 to 5 million birds.

In 1980, the U.S. Fish and Wildlife Service estimated that the winter roosting population of starlings and blackbirds in Arkansas was more than 48 million (James and Neal 1986). Starlings compete with native birds, including the eastern bluebird and the purple martin, for cavity nest sites. Because the starling's breeding season is longer than that of some neotropical migratory birds, this competition has an enormous impact on migratory bird populations. Control of starlings is limited and generally ineffective.

English (House) Sparrow

Like the starling, the English sparrow displaces cavity-nesting native songbirds and crowds residential bird feeders. This species primarily occupies urban and farm areas throughout the Assessment area, nesting on buildings or in nest boxes intended for native songbirds. Temporary control measures include shooting, poisoning, trapping, and nest destruction (James and Neal 1986).

Rock Dove (Pigeons)

Another pest of urban areas, rock doves (domestic pigeons) leave unsightly and unsanitary droppings. These birds nest and roost in large flocks on bridges and cliffs along the Buffalo River in Arkansas, disrupting populations of cliff swallows (James and Neal 1986).

Feral Hog

The feral hogs in the Assessment area are descendants of domestic livestock. Not native to the United States, hogs were brought to the new world by European explorers and immigrants. Escaped or released to range freely, hogs reverted to feral status (Sealander and Heidt 1990). Their rooting habit devastates ecosystems in the Ozark-Ouachita Highlands, particularly rare wetlands and springs.

Missouri and Oklahoma recognize hogs as domestic animals and do not allow legal hunts, yet their appeal as game animals has led some persons to release feral hogs in the national forests so they can be hunted. One such herd of feral hogs was removed from the Irish Wilderness Area of the Mark Twain National Forest at great expense; these animals were infected with pseudorabies.

The McCurtain County Wilderness in Oklahoma also has experienced hog damage. Hogs in the surrounding newly acquired Ouachita National Forest lands have also tested positive for pseudorabies and brucellosis. A herd in the Arkansas Ozarks wanders from the Leatherwood Wilderness on the Sylamore Ranger District (Ozark-St. Francis National Forests) near Big

Flat to the Buffalo National River Wilderness and the Buffalo Ranger District near Jasper.

These hogs have access to a series of unique and fragile ecosystems. They compete with white-tailed deer and turkey for acorns and other foods. They root, trample, and eat their way through the nests of turkey and other ground-nesting birds. They can easily eradicate entire populations of sensitive plants. In addition, they foul water sources, ruin spring and stream structures, devastate mushroom populations, and tear up rotten logs that provide habitat for many amphibians and reptiles.

The hogs carry diseases, such as brucellosis and pseudorabies that can infect wild animals, livestock, and even humans (Stevens 1997). While there are few records of their interactions with humans, feral hogs are a hazard to visitors traveling in infested areas.

Feral Dog

Feral dog packs typically live near human communities in rural areas. These dogs are often responsible for cattle damage blamed on coyotes (Sealander and Heidt 1990). They tend to run in packs, often chasing or killing deer, turkey, and rabbit. The packs eat everything they find, including the eggs and young of ground-nesting birds, adult birds, fruit, and carrion.

Feral dogs seriously affect turkey and quail populations (Miller and Leopold 1992). These additions to the environment compete with carrion feeders such as turkey vultures and carrion beetles (including an endangered species of beetle). They also compete with bears that depend on the limited supply of fruits available each year.

Another threat of feral dogs to ecosystems in the Assessment area is their ability to interbreed with coyotes. Coyotes were known to interbreed with native red wolves when red wolves were still common in the Ozark-Ouachita Highlands. Additional degradation of the gene pool may hamper efforts to reintroduce red wolves in the area (Sealander and Heidt 1990). Control measures include informing dog owners of the importance of neutering their animals; legislation to require control of free-ranging pets, which could join feral dog packs; and aggressive pursuit of packs.

Feral Cat

Feral cats are a serious threat to birds, especially ground nesters such as quail and turkey (Miller and Leopold 1992). These cats also attack shrub-nesting songbirds, some of which are declining because of other reasons such as habitat loss and parasitism. Prolific breeders and extraordinary hunters, feral cats kill the young of any species they can reach, including opossum, mice, and rabbits. Control measures for feral cats are similar to those for feral dogs.

Implications and Opportunities

Part of the challenge of managing nonnative mammals is to inform the public about the consequences of maintaining free-range domestic animals in forests and natural areas. In addition to damaging the ecosystems of the Ozark-Ouachita Highlands, feral dogs, feral cats, and feral hogs may transmit rabies, distemper, and other diseases and parasites to humans, livestock, and pets. Private landowners and operators of game farms can stock their property with “wild boar” to serve that portion of the hunting public that wishes to pursue feral hogs.

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Glossary of Terms

abiotic: nonliving.

advance reproduction: the young trees in the understory of a forest stand that will sprout and grow when the overstory trees are cut and removed.

alluvial: composed of material—such as soils and gravels—deposited by running water.

animal unit month (AUM): The unit of measurement for the amount of forage that a cow-calf pair will consume in one month.

anthracnose: a disease causing large, irregular dead areas on leaf tissues and often cankers on twigs or stems.

areal: of, relating to, or involving an area.

artificial regeneration: planting seedlings to regenerate a forest stand.

assessment: the act of estimating or determining the significance, importance, or value of something.

average annual mortality: average annual volume of trees 5.0 in. d.b.h. and larger that died from natural causes during the intersurvey period.

average annual removals: average annual volume of trees 5.0 in. d.b.h. and larger removed from the inventory by harvesting, cultural operations (such as timber-stand improvement), land clearing, or changes in land use during the intersurvey period.

average net annual growth: average annual net change in volume of trees 5.0 in. d.b.h. and larger in the absence of cutting (gross growth minus mortality) during the intersurvey period.

basal area: the area in square feet of the cross section at breast height of a single tree, a group of trees, or all of the trees in a stand, usually expressed in square feet per acre.

basin: the entire tract of land drained by a river and its tributaries.

biotic: living or biological.

blow down: tree that has been blown down and lies on the ground.

board foot: unit of measure for timber equal to a board 1 foot square and 1 inch thick.

bole: that portion of a tree between a 1-ft stump and a 4-in. top diameter outside bark in trees 5.0 in. d.b.h. and larger.

bract: a modified or reduced leaf-like structure.

cambium: dividing tissue that produces secondary tissues (inner bark and wood).

canker: a visible dead area, usually of limited extent, in the cortex or bark or a plant.

chain: 66 feet.

chlorosis: yellowing of plant foliage.

clearcutting: the removal of all the trees on a site for the purpose of utilization and to provide for regeneration of an even-aged stand of trees, usually of a species requiring full sunlight for proper development and growth.

commercial species: tree species currently or potentially suitable for industrial wood products.

community: an assemblage of organisms interacting in an environment where they form a distinct living system with its own composition, structure, environmental relations, development, and functions.

conservation: the controlled use and systematic protection of natural resources, such as forests and waterways.

d.b.h.: diameter at breast height, usually assumed to be 4.5 ft.

diameter class: a classification of trees based on tree d.b.h. Two-inch diameter classes are commonly used by Forest Inventory and Analysis, with the even inch as the approximate midpoint for a class. For example, the 6-in. class includes trees 5.0 through 6.9 in. d.b.h.

dicennial: happening every 10 years.

dieback: dying back of twigs and branches from the terminal portions downward.

disturbance factor: any physical or biological factor responsible for change in an ecosystem.

drought: abnormal dryness, most often recognized during seasons when substantial precipitation is expected but fails to occur. Drought is associated with higher than normal surface temperatures and drier than normal atmospheric moistures.

ecological section: an area or region of land designated for study purposes that has distinct geology, landforms, soils, flora, and fauna that set it apart from surrounding geographic areas.

ecology: the branch of biology that deals with relationships between living organisms and their environment.

ecoregion: a region with distinctive, identifiable ecological attributes.

ecosystem management: an ecological approach to natural resource management to assure productive, healthy ecosystems by blending social, economic, physical, and biological needs and values.

endangered species: a species or subspecies in danger of extinction throughout all or a significant portion of its range, as rated and listed by USDI FWS.

endemic (endemism): species restricted to a particular geographic area.

epicormic: a shoot arising spontaneously from a dormant bud on the branch or stem of a woody plant.

escarpment: a steep slope or cliff formed by erosion or faulting.

even-aged management: timber management methods that result in the creation of forest stands in which all trees are essentially the same age.

exotic species: a species of plant, animal, or other organism that is not native to the locale.

extant: currently in existence.

extirpation: the loss of a species from a specific area.

Federal status: category assigned to plant and animal species by the USDI FWS: threatened, endangered, potentially endangered, or candidate. Candidate species are those for which the USDI FWS has sufficient information to initiate listing under the Endangered Species Act.

fen: a nonalluvial wetland fed by water seepage and generally characterized by the absence of an overstory canopy.

feral: having escaped from domestication and become wild.

fire-dependent: the characteristic of requiring periodic fire as part of the ecosystem.

fire-tolerant: the characteristic of tolerating periodic fire in the ecosystem but not requiring fire as part of the ecosystem.

floodplain: low, relatively flat land adjoining inland and/or coastal waters that is subject to periodic flooding.

forb: an herbaceous plant other than grass.

forest fragmentation: the breaking up of large, contiguous forested tracts into smaller or less contiguous tracts.

Forest Inventory and Analysis (FIA): a USDA Forest Service research program that periodically conducts a forest inventory for each State. See the following Web site for more information: <http://www.srsfia.usfs.msstate.edu/wo/wofia.htm>.

forest land: land at least 10 percent stocked by forest trees of any size, or formerly having had such tree cover, and not currently developed for nonforest use. The minimum area considered for classification is 1 acre. Forested strips must be at least 120 ft wide.

forest type: a classification of forest land based on the species forming a plurality of live-tree stocking. Major eastern forest-type groups are:

white-red-jack pine—forests in which eastern white pine, red pine, or jack pine, singly or in combination, constitute a plurality of the stocking. (Common associates include hemlock, birch, and maple.)

spruce-fir—forests in which spruce or true firs, singly or in combination, constitute a plurality of the stocking. (Common associates include maple, birch, and hemlock.)

longleaf-slash pine—forests in which longleaf or slash pine, singly or in combination, constitute a plurality of the stocking. (Common associates include oak, hickory, and gum).

loblolly-shortleaf pine—forests in which loblolly pine, shortleaf pine, or other southern yellow pines, except longleaf or slash pine, singly or in combination, constitute a plurality of the stocking. (Common associates include oak, hickory, and gum.)

oak-pine—forests in which hardwoods (usually upland oaks) constitute a plurality of the stocking but in which pines account for 25 to 50 percent of the stocking. (Common associates include gum, hickory, and yellow-poplar.)

oak-hickory—forests in which upland oaks or hickory, singly or in combination, constitute a plurality of the stocking, except where pines account for 25 to 50 percent, in which case the stand would be classified oak-pine. (Common associates include yellow-poplar, elm, maple, and black walnut.)

oak-gum-cypress—bottomland forests in which tupelo, blackgum, sweetgum, oaks, or southern cypress, singly or in combination, constitute a plurality of the stocking, except where pines account for 25 to 50 percent, in which case the stand would be classified oak-pine. (Common associates include cottonwood, willow, ash, elm, hackberry, and maple.)

elm-ash-cottonwood—forests in which elm, ash, or cottonwood, singly or in combination, constitute a plurality of the stocking. (Common associates include willow, sycamore, beech, and maple.)

maple-beech-birch—forests in which maple, beech, or yellow birch, singly or in combination, constitute a plurality of the stocking. (Common associates include hemlock, elm, basswood, and white pine.)

nonstocked stands—stands less than 10 percent stocked with live trees.

game species: those species that are hunted.

gap-phase dynamics: the process by which single overstory trees or small groups of trees in a mature forest are gradually replaced by seedlings and saplings in the understory.

glade: an opening in the forest canopy characterized by herbaceous vegetation.

global ranks: ranks assigned to plant and animal species by The Nature Conservancy and State heritage programs based on the number of occurrences of each species and denoted by "G" and a number (1-5) or a letter code: **G?**, **G_Q_**, **G_T_**, **G1**, **G2**, **G3**, **G4**, and **G5**. Two G, T, or S rankings together (e.g., G2G3) indicate the range in uncertainty about the status of the taxa. Also see **State ranks** and Chapter 5 of this report**.**

gross growth: annual increase in volume of trees 5.0 in. d.b.h. and larger in the absence of cutting and mortality.

ground water: generally, all subsurface water (as distinct from surface water); specifically, that part of the subsurface water in the saturated zone (a zone in which all voids are filled with water) where the water is under pressure greater than atmospheric.

group selection: an uneven-aged harvest and regeneration system that periodically removes small groups or clusters of trees from several small portions of the stand.

growing season: the portion of the year when soil temperatures 19.7 in. below the soil surface are higher than biologic zero (5 °C). For ease of determination, this period can be approximated by the number of frost-free days.

growing stock: the volume of sound wood in cubic feet in trees that are at least 5.0 in. in diameter at breast height (d.b.h.), from a 1-ft stump to a minimum 4.0 ft in top diameter (outside bark) of the central stem or to the point where the central stem breaks into limbs.

growing-stock volume: the cubic-foot volume of sound wood in growing-stock trees at least 5.0 in. d.b.h. from a 1-ft stump to a minimum 4.0-in. top diameter outside bark of the central stem.

hardwoods: dicotyledonous trees, usually broadleaf and deciduous.

soft hardwoods—hardwood species with an average specific gravity of 0.50 or less, such as gums, yellow-poplar, cottonwoods, red maple, basswoods, and willows.

hard hardwoods—hardwood species with an average specific gravity greater than 0.50, such as oaks, hard maples, hickories, and beech.

herbicides: chemicals used to kill unwanted plant pests.

hibernaculum (plural: hibernacula): any structure that protects an organism during winter; in this volume, the term refers to caves in which bats and other animals spend the winter months.

historic: relating to or existing in times of written history; within the Assessment area, the historic period is considered to begin with the expedition of Hernando de Soto in the 1540's.

improvement cutting: treatment applied to stands past the sapling stage to remove trees of undesired or inferior species, quality, or condition that are competing with desired trees.

indicator species: a species of plant or animal whose presence or absence indicates the general health of the community upon which the species is most dependent.

Interior Highlands: that region of the South-Central United States that contains the Ozarks Plateaus Province and Ouachita Province; more or less equivalent to the Ozark-Ouachita Highlands.

intermediate treatments: the set of treatments applied to stands where the desired species are larger than saplings but not old enough for reproduction cutting. Intermediate treatments include: thinning, release, improvement cutting, salvage cutting, prescribed burning, fertilization, and pruning.

introduced species: species that has been intentionally or accidentally released in a locale by humans.

isopod: an aquatic crustacean with a flat, oval body having seven pairs of walking legs.

land area: the area of dry land and land temporarily or partly covered by water, such as marshes, swamps, and river floodplains (omitting tidal flats below mean high tide), streams, sloughs, estuaries, and canals less than 200 ft wide, and lakes, reservoirs, and ponds less than 4.5 acres in area.

land cover type: descriptive term for the dominant vegetation (e.g., oak-hickory forest) or other predominant land cover (e.g., water or urban/developed) of a given area.

land use: particular function to which a region is being put, e.g., agricultural or forested.

live trees: all living trees. All size classes, all tree classes, and both commercial and noncommercial species are included.

mast: the fruit of flowering trees used by wildlife for food (e.g., acorns).

mesic: describing sites with a moderate amount of moisture.

National Resources Inventory (NRI): a statistically based, nationwide inventory of land uses and natural resource conditions and trends (e.g., erosion potential) on rural, non-Federal lands.

native species: species that is within its known historical range and for which there is no evidence of humans having artificially introduced it.

natural regeneration: the naturally occurring processes in trees that result in new seedlings and sprouts.

necrosis: death of host tissue.

neotropical migratory birds: birds that migrate to the neotropics (South and Central America and the Caribbean) during the winter but breed and nest in North America.

nest predation: the placement by a female bird of one or more eggs in the nest of another bird species, which then hatches and (typically) feeds the chick of the "nest predator." The "victim" expends energy raising the young of another species.

nonforest land: land that has never supported forests and land formerly forested where timber production is precluded by development for other uses.

North American Breeding Bird Survey: annual survey of breeding birds coordinated by the National Audubon Society.

old-growth stand: a stand of trees characterized by a diversity of tree species in several size classes, advanced age, downed logs and snags, large canopy trees, tree fall gaps, undisturbed soils, and other plants and animals that prefer old growth.

other forest land: forest land other than timberland and productive reserved forest land. It includes available and reserved forest land that is incapable of producing annually 20 cubic feet per acre of industrial wood under natural conditions because of adverse site conditions such as sterile soils, dry climate, poor drainage, high elevation, steepness, or rockiness.

outbreak: explosive growth of an insect population or disease organism, typically resulting in damage to or death of a large number of trees and/or other organisms.

ownership: the property owned by one ownership unit, including all parcels of land in the United States.

national forest land—federal land that has been legally designated as national forests or purchase units and other land under the administration of the USDS Forest Service, including experimental areas and Bankhead-Jones Title III land.

forest industry land—land owned by companies or individuals operating primary wood-using plants.

nonindustrial private forest (NIPF) land—privately owned land excluding forest industry land or forest industry-leased land.

corporate—owned by corporations, including incorporated farm ownerships.

individual—all lands owned by individuals, including farm operators.

other public—an ownership class that includes all public lands except national forests.

miscellaneous Federal land—Federal land other than national forests.

State, county, and municipal land—land owned by States, counties, and local public agencies or municipalities or land leased to these governmental units for 50 years or more.

Paleozoic age: the second era of geologic time (Cambrian Period through Permian Period) that began approximately 545 million years B.P. and ended 248 million years B.P.

Partners in Flight (PIF): a collection of government agencies and nongovernment organizations working to conserve birds.

pathogen: a parasite that causes disease.

pheromone: chemical attractant used by an animal.

physiography: the study of the surface features of the land.

PIF list: list of bird species identified as conservation priorities by Partners in Flight.

PIF priority species: bird species identified as conservation priorities by Partners in Flight. Species are classified as priorities if they meet one or more of seven criteria.

pixel: the basic unit or picture element that makes up a digital image.

poletimber: trees 5.0 to 8.9 in. d.b.h. for softwoods and 5.0 to 10.9 in. for hardwoods.

population density: the number of individuals of a species per unit area.

prehistoric: relating to or existing in times predating written history. This term generally refers to those North American cultures in existence prior to A.D. 1540.

prescribed burning: the use of fire to achieve forest or land management objectives.

province: in the context used in the report, a geographic area having particular geologic and landform characteristics.

pruning: the removal of lower branches of young trees to develop stems free of knots.

pulpwood: trees in the poletimber size class that are harvested for use.

P-value: probability.

rare: a classification reflecting a species' scarcity in a given area. Rare plants and animals (and eventually communities) are assigned rarity ranks according to The Nature Conservancy's global ranking system.

regeneration cutting: a cutting that provides conditions necessary for the establishment of a new stand of forest trees.

release treatments: treatments that free desired trees from competing vegetation in stands not yet past the sapling stage. Release treatments include chemical applications, mechanical methods, and prescribed burning.

removals: the net volume of growing stock trees removed from the inventory by harvesting or cultural operations such as timber stand improvement (e.g., thinning), land clearing, or change in land use.

reproduction cutting: cutting treatment that imitates a natural disturbance and is designed to promote regeneration of young trees.

restoration: the process of reintroducing the natural actions (e.g., periodic fire) required by a community in order to reestablish critical components of the community.

riparian: describing lands adjacent to streams and lakes.

rotation age: the age at which an even-aged stand of trees is scheduled for harvest or regeneration cutting (the actual age depends on management objectives, the tree species involved, and local site conditions).

rotten trees: live trees of commercial species not containing at least one 12-ft saw log or two noncontiguous saw logs, each 8 ft or longer, now or prospectively, primarily because of rot or missing sections, and with less than one-third of the gross board foot tree volume in sound material.

rough trees: live trees of commercial species not containing at least one 12-ft saw log or two noncontiguous saw logs, each 8 ft or longer, now or prospectively, primarily because of roughness, poor form, splits, and cracks, and with less than one-third of the gross board foot tree volume in sound material; and live trees of noncommercial species.

salvage cutting: removal of trees that have succumbed, or are in danger of succumbing, to the actions of disturbance.

saplings: live trees 1.0 to 5.0 in. d.b.h.

savanna: an assemblage of woody vegetation having a scattered distribution with an understory dominated by grasses and forbs maintained by recurring fire; height and diameter growth of canopy-layer trees may be stunted by environmental factors (i.e., weather, shallow soils) or within established averages for the species.

saw log: a log meeting minimum standards of diameter, length, and defect, including logs at least 8 ft long, sound and straight, with a minimum diameter inside bark for softwoods of 6 in. (8 in. for hardwoods).

sawtimber: trees with a 9 in. d.b.h. and larger for softwoods and 11 in. d.b.h. and larger for hardwoods.

sawtimber volume: growing-stock volume in the saw-log portion of sawtimber-size trees in board feet (International ¼-inch rule).

secondary forest succession: the normal growth and development of a forest stand that begins immediately after a disturbance when new trees and other plants begin to grow or older ones resprout.

seedlings: trees less than 1.0 in. d.b.h. and greater than 1 ft tall for hardwoods and greater than 6 in. tall for softwoods.

seedtree: an even-aged silvicultural harvest and regeneration system that removes most of the mature stems. A number of trees (generally, 4 to 10 per acre, singly or in groups) are retained to provide seeds to establish the new stand.

seep: a place where groundwater oozes slowly to the surface, often forming a pool; a small spring.

shelterwood: an even-aged silvicultural harvest and regeneration system that gradually removes most or all trees in a series of partial cuttings, which resemble heavy thinning. Regeneration establishes under the protection of partial canopy cover.

silvics: the study of forests, especially the ecological relationships that govern particular tree species.

silvicultural: of or relating to the culture of trees or forests.

silviculture: the element of forestry that deals with the establishment, development, reproduction, and care of forest trees.

single-tree selection: an uneven-aged silvicultural harvest system that removes selected trees to create canopy gaps. Trees selected for removal may be healthy or diseased, depending on the goals of the landowner.

softwoods: coniferous trees, usually evergreen, having leaves that are needles or scalelike.

yellow pines—loblolly, longleaf, slash, pond, shortleaf, pitch, Virginia, sand, spruce, and Table Mountain pines.

other softwoods—cypress, eastern redcedar, white-cedar, eastern white pine, eastern hemlock, spruce, and fir.

source-sink status: description of the reproductive status of a species that it is reproducing successfully enough in some portions of the landscape to serve as the "source" of new individuals for other portions in which reproduction is poor or entirely lacking ("sink"). For example, the reproductive rates of birds can be so low in fragmented landscapes that these populations are "sinks" that cannot sustain themselves without immigration from more productive "source" populations.

special concern: a term used by some States for certain native species determined to require monitoring and/or special management.

sporulate: to form spores.

springtail: small, wingless insect with strong leaping abilities.

State ranks: ranks assigned to the species by State heritage programs based on number of known occurrences of each species in the State. The ranks (**S1** through **S5**) are the same as **global ranks**, which are described in detail in Chapter 5 of this report.

S1: Critically Imperiled—Critically imperiled species in a State because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the State. Typically, there are five or fewer occurrences of a critically imperiled species or there are very few remaining individuals or acres in which they occur.

S2: Imperiled—Imperiled species in a State because of rarity or because of some factor(s) making it very vulnerable to extirpation from the State. Typically, there are 6 to 20 occurrences of an imperiled species or there are few remaining individuals or acres in which they occur.

S3: Vulnerable—Vulnerable species in a State because it is rare or uncommon. Typically, 21 to 100 occurrences of the species are found only in a restricted range (even if abundant at some locations); or because of other factors making the species vulnerable to extirpation.

SH: Historical—Element occurred historically in the State (with an expectation that it may be rediscovered), perhaps having not been verified in the past 20 years, and is suspected to be present still. Naturally, an element would be SH without such a 20-year delay if the only known occurrences in a State were destroyed or if it had been extensively and unsuccessfully looked for. The SH rank should be reserved for elements for which some effort has been made to relocate occurrences, rather than simply ranking all elements not known from verified extant occurrences with this rank.

SX: Extirpated—Element is believed to be extirpated from the State (or province or other subnational unit).

stocking: the degree of occupancy of land by trees, measured by basal area or the number of trees in a stand and spacing in the stand, compared with a minimum standard, depending on tree size, required to fully utilize the growth potential of the land.

talus: a sloping mass of rocky fragments, usually with little or no vegetation.

taxa: two or more taxonomic groups or entities.

taxon: a taxonomic group or entity; the name applied to a taxonomic group in a formal system of nomenclature.

taxonomy: classification of organisms into categories according to their natural relationships.

thinning: the harvesting of some immature trees of desired species so that other immature trees with better developmental potential might thrive.

threatened species: a species or subspecies that is likely to become endangered throughout all or a significant portion of its range and listed as such by the USDI FWS.

timberland: forested land that is capable of producing crops of industrial wood at a rate of at least 20 cubic feet/acre per year and has not been withdrawn from timber production. (Some forest lands are not classified by the FIA as timberland because they are unproductive and some—such as national parks and wildernesses—because, by law, they are off limits to harvesting.)

tolerance: the ability of a species to develop and attain maturity under the influence of various degrees of shading. Trees said to be shade-tolerant do well in shady environments. Shade-intolerant species require a minimum solar exposure to robustly mature.

topography: the configuration of a surface (usually the Earth's surface) including its relief and the position of its natural and artificial features.

township: federally mandated division of land encompassing 36 square mi and consisting of 36 sections.

tree: woody plants having one erect perennial stem or trunk at least 3 in. d.b.h., a more or less definitely formed crown of foliage, and a height of at least 13 ft (at maturity).

uneven-aged management: timber management method that results in forest stands characterized by trees of many ages or sizes intermingled singly or in groups.

vascular: relating to tissues within a tree that carry water, carbohydrates, and minerals up and down the tree.

watershed: the area of land above a given point on a stream that contributes water to the volume of a body of surface water; also referred to as hydrologic unit or drainage basin.

wetlands: those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (U.S. ACE 1987). Wetlands generally include (1) swamps, marshes, bogs, and similar areas; and (2) lands that are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface of the land and is covered by shallow water. For purposes of this classification, wetlands must have one or more of the following attributes: (1) at least periodically, the land predominantly supports hydrophytes (plants dependent on saturated soils or a water medium); (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

wilderness: a Congressionally-designated area that provides opportunities for solitude and primitive, unconfined recreational experiences. There are no constructed facilities such as campgrounds, picnic areas, or interpretive sites, and motorized and mechanized vehicles are prohibited. See **Wilderness Act.**

Wilderness Act: The Federal Wilderness Act of 1964 established the National Wilderness Preservation System, declared it the policy of the United States to "secure . . . the benefits of an enduring resource of wilderness" and provided guidelines for managing wilderness areas. The Wilderness Act prohibits motorized and mechanized vehicles as well as recreation facilities such as campgrounds, picnic areas, and interpretive sites in wilderness areas.

wildfire: any fire that is not burning for a prescribed management purpose or being managed as a prescribed fire.

wind-throw: the toppling of live trees by strong winds.

woodland: an assemblage of woody vegetation having a scattered distribution more dense than savanna and less dense than forest; height and diameter growth of canopy-layer trees may be stunted or within established averages for the species.

xeric: describing sites without significant moisture, very dry sites.

Glossary of Abbreviations and Acronyms

ac: acre(s)

A.D.: (anno Domini) refers to the number of years after the birth of Christ

AUM: animal unit month

AVHRR: Advanced Very High Resolution Radiometer

B.P.: years before the present date

d.b.h.: a measurement of the diameter of a tree at breast height (4.5 ft from the groung)

FIA: Forest Inventory and Analysis

FS: Forest Service

ft: foot or feet

GAP: Gap Analysis Project

GIS: Geographic Information System

GLO: General Land Office

in: inch(es)

NIPF: nonindustrial private forest

NOAA: National Oceanic and Atmospheric Administration

NRI: National Resources Inventory

OK BTF: Oklahoma Biodiversity Task Force

PIF: Partners in Flight

P.L.: Public Law (Federal)

P-value: probability

RCW: red-cockaded woodpecker

TNC: The Nature Conservancy

USDA: United States Department of Agriculture

USDA FS: USDA Forest Service

USDA FS SFES: USDA Forest Service, Southern Forest Experiment Station

USDA FS SRS: USDA Forest Service, Southern Research Station

USDA NRCS: USDA Natural Resources Conservation Service

USDI: United States Department of the Interior

USDI FWS: USDI Fish and Wildlife Service

USDI GS BRD: USDI Geological Survey, Biological Resources Division

USGS: USDI Geological Survey

List of Tables

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U.S. Department of Agriculture, Forest Service. 1999. Ozark-Ouachita Highlands Assessment: terrestrial vegetation and wildlife. Report 5 of 5. Gen. Tech. Rep. SRS-35. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 201 p.

This publication provides citizens, private and public organizations, scientists, and others with information about terrestrial animals, plants, and biological communities in and near the national forests in the Ozark-Ouachita Highlands: the Mark Twain in Missouri, the Ouachita in Arkansas and Oklahoma, and the Ozark-St. Francis National Forests in Arkansas. The document examines the status and trends of vegetation, plant and animal populations, forest management, and biological threats to forest resources in the Highlands.

Keywords: Biological threats, ecological classification, forest management, plant and animal populations, silviculture, vegetation cover.

The Forest Service, U.S. Department of Agriculture, provides leadership in the management, protection, and use of the Nation's forests and rangelands. The Agency takes an ecological approach to the implementation of multiple-use management, providing sustained yields of renewable resources such as water, forage, wildlife, wood, and recreation. The Forest Service has embraced ecosystem management as its operating philosophy and is committed to the preservation of wilderness, biodiversity, and landscape beauty as well as the protection of the basic resources of soil, water, and air quality.

The Forest Service is responsible for the 191.8-million-acre National Forest System, with its 155 national forests and 20 grasslands in 44 States, Puerto Rico, and the Virgin Islands. In addition, the Agency works with State land management organizations to help private landowners apply good natural resource management practices on their lands. The International Program of the Forest Service enables the Agency to share its technical expertise and managerial skills with other nations. The Research and Development Program of the Forest Service conducts extensive research to enhance and protect productivity on all of America's forests and rangelands, with special attention to long-term natural resource issues of national and international scope.

This report is one of five that documents the results of the Ozark-Ouachita Highlands Assessment. Three of the remaining reports examine *Air Quality*, *Aquatic Conditions*, and *Social and Economic Conditions*, respectively, and the fourth provides an overall summary.