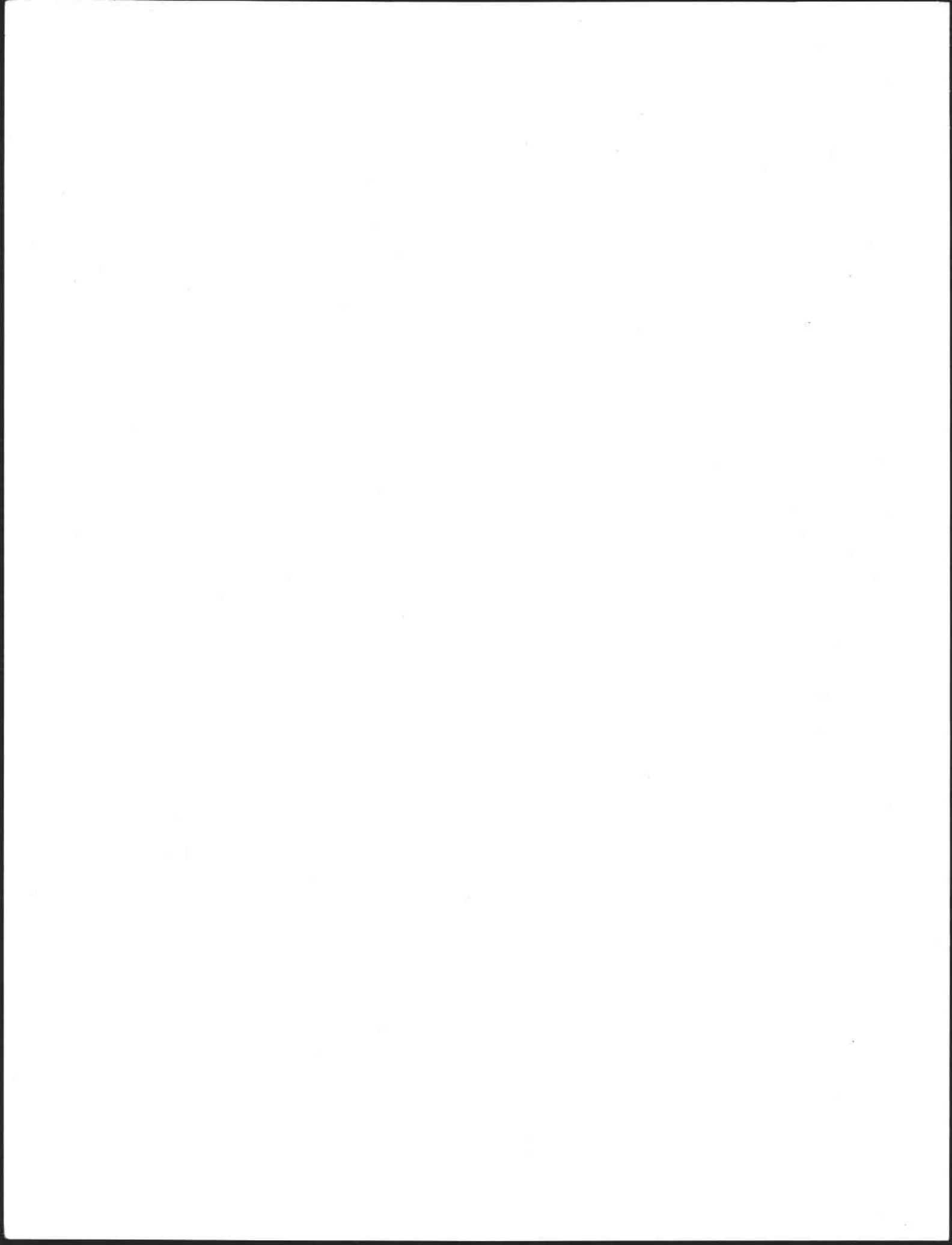


Restoration of Old Growth Forests in the Interior Highlands of Arkansas and Oklahoma

Proceedings
of the
Conference



Ouachita National Forest ● Ozark - St. Francis National Forests
Arkansas Natural Heritage Commission ● Oklahoma Natural Heritage Inventory
Winrock International Institute for Agricultural Development



**Restoration of Old Growth Forests
in the Interior Highlands
of Arkansas and Oklahoma**

Proceedings of the Conference
Winrock International, Morrilton, AR
September 19-20, 1990

Editors
Douglas Henderson
L. D. Hedrick

Ouachita National Forest
Winrock International Institute for Agricultural Development

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**Ouachita National Forest
Ozark-St. Francis National Forests
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Foreword

Old-growth forests are unlike any other. They differ dramatically from younger forests in both ecology and appearance. They have distinctly different benefits for wildlife habitat, ecological function, aesthetic perception, spiritual value, and high-quality wood products. Old-growth forests offer a valuable ecological insight into long-term sustainable uses of forested lands. And they are disappearing or have disappeared from North American landscapes.

For the past decade, there has been continuous and contentious debate concerning the fate of remaining old-growth forests in the Pacific Northwest, especially in Washington, Oregon and northern California. This debate has now been elevated to the highest levels of government. At this writing, the ultimate fate of those old-growth forests is unclear. However, the debate itself has served a valuable purpose. Previously unasked ecological questions have been raised and these in turn have stimulated research efforts to provide answers. Through it all, public awareness about, and appreciation for, old-growth forests have increased enormously.

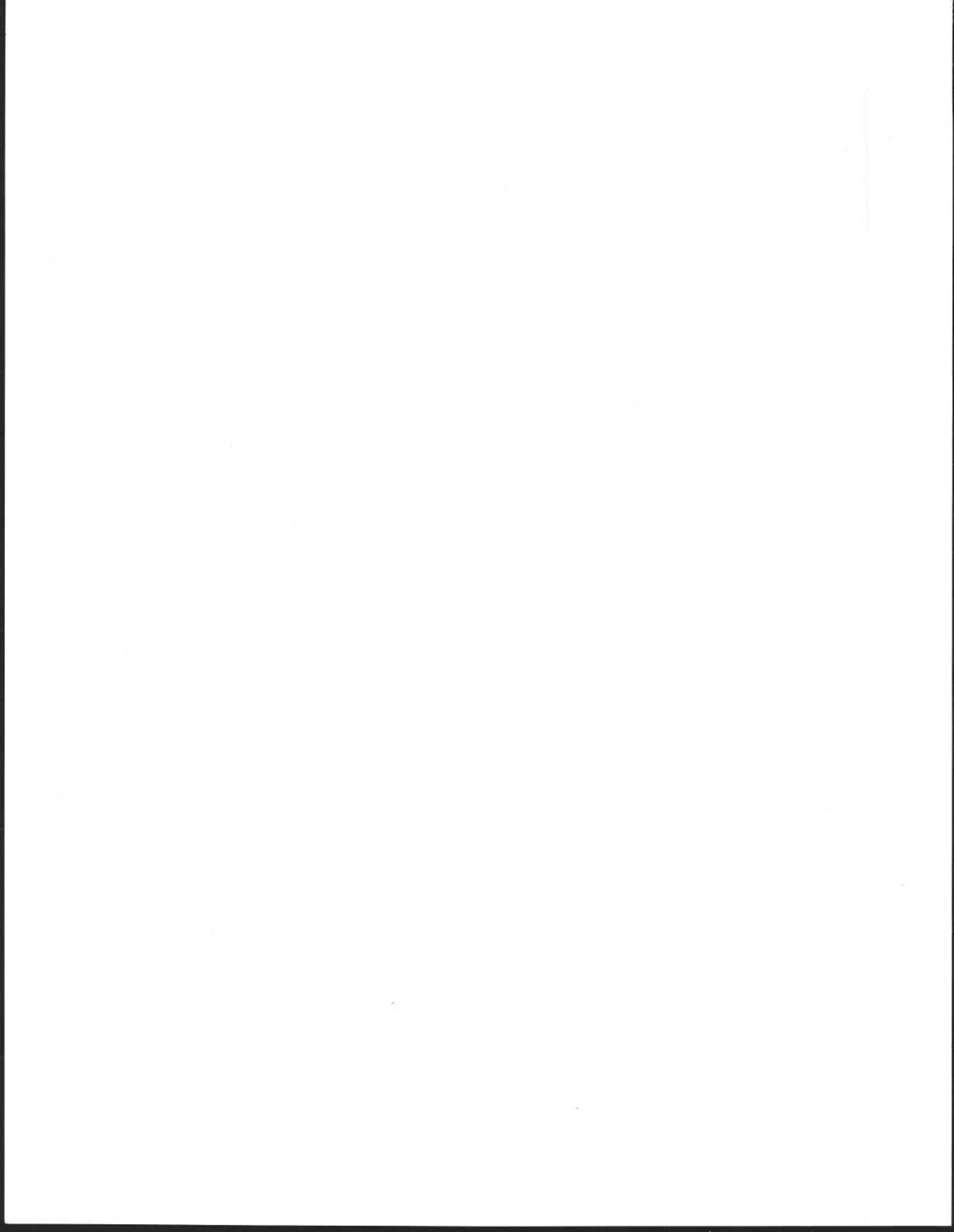
But what of the eastern U.S., where little or no old-growth forests remain? Here the question is not what pieces to retain, but rather what pieces to restore and, once having restored them, how to ensure their maintenance. The very idea of restoration presupposes that knowledge about old-growth forests exists: that we possess an adequate understanding about how such forests developed and persisted over geologic time, that we know the optimal parcel sizes for maintaining functional integrity, and how best to arrange these restored parcels on the landscape. Indeed, much information does exist in the specialized fields of paleoecology, paleobotany, community ecology, landscape ecology, the wildlife sciences, and forestry. However, we know of no prior effort to organize information from these disciplines into a synthetic paradigm specifically for the restoration of old-growth forests in the East.

The desire to survey and share available information from these varied scientific fields to create such a restoration paradigm for old-growth forests in the Interior Highlands of Arkansas and Oklahoma was the driving force behind the present endeavor. The goal, of course, is to have an adequate number and arrangement of old-growth stands representative of the major forest types on these landscapes. Toward that end, this conference and these proceedings are dedicated.

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Economically Sustained Yield Versus Ecologically Sustainable Forests¹

Chris Maser²

Introduction

The language of the "Multiple Use Sustained Yield Act of 1960," although of good intent, is based on an economic assumption that is totally at odds with ecological reality. The assumption is that biological processes in the forested portion of the ecosystem remain constant while we humans strive to maximize whatever forest product or amenity seems desirable. The central-European errors over the past several hundred years (Plochmann 1989) illustrate well the results of ignoring ecological reality while attempting to maximize short-term profits from a system that ultimately is controlled by ecological laws.

Obviously, we must change our thinking and our actions in managing forests for the long run. Forests are not the endless producers of commodities and amenities that we have heretofore assumed them to be.

The critical point is that before we can change our European, utilitarian paradigm that forces us to view the forest and all it contains simply as commodities to be endlessly exploited, we must devise a new paradigm. In this new paradigm, we must view the forest as a living organism with which we cooperate and through such cooperation are allowed to harvest products as the ecological capability of the forest permits.

To this end, I discuss the traditional, European, utilitarian view of the forest, including some of the historical errors of this view. I contrast biological capital with economic capital and discuss native forests and old-growth forests in terms of ecological sustainability. Finally, I examine the concept of sustainability and offer updated definitions of some words, which will allow us to evolve a new paradigm for forests and forestry – one better in keeping with the view of the entire earth as a living organism.

¹ This paper was presented at the Conference on Restoring Old Growth Forests in the Interior Highlands of Arkansas and Oklahoma, held at Winrock International, Morrilton, Arkansas, September 19-20, 1990.

² Department of Forest Sciences, Oregon State University, Corvallis, OR 97331. This paper was prepared when the author was with the Environmental Monitoring Systems Laboratory, Environmental Protection Agency; the paper does not, however, reflect the views of the U.S. Environmental Protection Agency, and no official endorsement should be inferred.

An Awareness

The only constant in the universe is change, but change is the one process that we in Western civilization seem to resist the most. Change is a continual process, be it an expanding universe, an aging forest, or a shifting economy. An issue is a point of debate, discussion, or dispute; a matter of public concern; a culminating point leading to a decision. Any issue that becomes a focal point of public concern and debate is based on change in some circumstance.

This alteration in circumstance at first necessitates, and finally precipitates, a change in perception, which ultimately precipitates a change in action. In dealing with change, lies the challenge to the future of humanity, a challenge we must accept, face, and deal with, or perish.

An awareness of disastrous consequences, of unwise historical choices, should encourage us to change the way we do things so that we may alter an outcome. Before we can alter the outcome of any historical trend, however, we must ask fundamentally different questions than heretofore have been asked. Foresters are not asking such questions (Perlin 1989), but rather accept a European mode of plantation management that we call "forestry," a practice based on the soil-rent theory (Plochmann 1989).

The soil-rent theory calculates the species of tree with the highest monetary return and the financial rotation with the highest internal rate of return on a given site. Said another way, by holding everything as a constant, except the age at which the trees are harvested, the age at rotation, one can calculate that age of harvest or rotation that will give the highest rate of return on the economic capital invested. The soil-rent theory -- a classic, liberal, economic theory -- is a planning tool devised by Johann Christian Hundeshagen in the early 19th century for use in maximizing profits as the general objective of economic activities (economically-sustained yield)³, which, since its adoption by foresters, has become the overriding objective for forestry worldwide. Therefore, the practice of forestry is based on economic concepts that have nothing whatsoever to do with the ecology and ecological sustainability of forests (Maser 1988). We are merely repeating the mistakes already recorded in the annals of history (Perlin 1989, Plochmann 1968, 1989), namely that "renewable," natural resources are considered to be infinite and that conservation (carrying into the future) of these inherited, natural resources is considered to be economically unsound. This latter

³ Economically-sustained yield is the volume of wood fiber to be cut annually as predetermined by the economic targets of timber industry rather than by the ecological capability of the forest ecosystem to produce that volume on a sustainable basis. Thus far in our history, an economically-sustained yield has meant a physically-sustained cut of available native forest.

concept, for instance, is based on the notion that if a 400-year-old tree dies, falls over, and rots in the forest rather than having been sent to the sawmill, it is an economic "waste," a notion which in turn is used to justify practicing the economics of liquidation/extinction of our inherited native forests through short-term economic expediency.

Historical Errors in Forestry

Forestry "management" has been and still is based on at least five flawed assumptions that stem from the soil-rent theory (Plochmann 1968, 1989). First, we assume that once the native forests are liquidated, they can be replaced by plantations, which are forever renewable on a continual plant-cut cycle. Here the problem is that our thinking and therefore our models are linear, but the cyclic forest occupies a sphere vastly different from both our thinking and our models.

Second, we either fail to realize or refuse to accept that all our "management" is directed towards what we see aboveground and that we cannot alter the aboveground without simultaneously altering the belowground. We do not manage -- or even think about or plan for -- belowground processes. Thus we either fail to understand or refuse to accept that each tree, each stand of trees, each forest is a mirror reflection of the soil's ability to grow that particular tree, stand, or forest **just once!**

Third, forest productivity rests on four ecological factors -- the depth and fertility of the soil on which the forest grows, the quality and quantity of the precipitation reaching the forest, the quality of the air infusing the forest, and the amount of solar energy meeting the forest. But we make the mistake of assuming that these factors are constants and therefore fail to include them in our economic and planning models. Even if we try to build them into our ecological models, we do so only in a linear mode. We therefore think and act as though soil, water, air, and sunlight are constants and as though the only variable we manipulate is the tree we plant.

But these ecological factors are indeed variables! Soil, for example, is eroded in two ways, chemically and physically. We do both. We pollute our waters and our air with chemicals. Air pollution directly affects the forest by altering the quality of the soil and water as well as the quality and quantity of the sunlight that drives forest processes. The chemicals we dump into the air also alter the climate and thus the environment in which the forest grows. The quality and quantity of soil, water, air, and sunlight with which a forest interacts and on which a forest is interdependent are all variables and must be so treated.

The fourth error is the conscious simplification of the only part of the forest we see, that which is aboveground -- an error we make as a short-term, economic expedient toward our primary objective, producing wood fiber. In this sense, we not only eliminate as much biological diversity as possible, such as "undesirable" species of plants and animals, but also eliminate as much "undesirable" genetic diversity as

possible. We deem this to be good forestry because we either do not realize or refuse to accept that the forest we see aboveground is in large measure a faithful reflection of the health of the belowground, biological processes and their ability to grow that stand of trees.

The fifth error is clinging to the idea that for an economic endeavor to be healthy it must be ever-expanding. Thus we attack the world's renewable, natural resources from an ecologically-exploitive point of view, which produces increasingly finite limits on most, if not all, "renewable" resources.

The timber industry, particularly in areas where considerable native forest remains, operates in a perpetual expansionistic mode, and as a result, the world's forested resource is rapidly shrinking. Perpetual expansion involves liquidating the native forest and ultimately exhausting the soil (Plochmann 1989). The forests' death knell is sounded by the ever-increasing push for more and more intensive plantation management based on linear, industrio-economic thinking. So the question becomes one of whether an economically-sustained yield is possible in the face of the exhaustion of the soil and the probable collapse of the ecosystem.

Biological Capital Versus Economic Capital

The native, old-growth forest has three prominent characteristics: large live trees, large snags, and large fallen trees (Franklin et al. 1981, Maser 1989, Maser et al. 1988). The large snags and large fallen trees become part of the forest floor and eventually are incorporated into the forest soil, where myriad organisms and processes make the nutrients stored in the decomposing wood available to the living trees. Furthermore, the changing habitats of the decomposing wood encourage nitrogen fixation to take place by free-living bacteria (Harmon et al. 1986, Maser et al. 1988). (Nitrogen fixation is the conversion of atmospheric nitrogen to a form useable by living organisms, such as a tree.) These processes are all part of nature's rollover accounting system, which includes such assets as large dead trees, genetic diversity, and biological diversity, all of which count as reinvestments of biological capital in the growing forest.

Intensive, short-term, plantation management disallows reinvestment of biological capital in the soil and therefore in the forests of the future, because such reinvestment has come to be seen, erroneously, as economic waste. We therefore plan the total exploitation of any part of the ecosystem for which we see a human use and we plan the elimination of any part of the ecosystem for which we cannot see a human use. With this myopic view, we have created the intellectual extinction of nature's diversity through humanity's planning system, which inevitably leads to biological extinction of species and their functions within the ecosystem.

After the native forest is liquidated, we may be deceived by apparently successful growth of a first-rotation plantation, which lives off the stored, available nutrients and processes embodied in the soil of the liquidated native forest (Maser et al. 1988, Spies

and Cline 1988). Without balancing biological withdrawals, investments, and reinvestments, both biological interest and principal are spent and so both biological and economic productivity must eventually decline. The dysfunctional "managed forests" (plantations) of Europe – biological deserts compared to their native forests – bear testimony to such shortsighted folly (Plochmann 1968, 1989).

Replacing a mature, native forest with a plantation or applying fertilizer are neither biological reinvestments nor economic reinvestments in either the forest or the soil; they are economic investments in "crop trees!" The initial outlay of economic capital required to liquidate the inherited forest, plant seedlings on bared land, and fertilize the young stand is an economic investment in the intended product. But a forest does not function on economic capital; it functions on **biological capital** – the decomposing wood of large fallen trees and genetic and biological diversity.

Native Forests and Ecological Sustainability

In our burgeoning, product-oriented society, one of the most insidious dangers to native forest – that which has experienced minimal disruptive, human intrusion – be they old or young, is the sadly mistaken perception that there is no value in maintaining an area for its **potential**. By potential, I mean its research value as an ecological blueprint of what an ecologically-sustainable forest is, how it functions, its educational value, its spiritual value, or any other value that does not turn an immediate, visible, economic profit. This short-sightedness is understandable considering that: (1) whereas the Native North Americans viewed the land and all it contained as a "Thou," which is holy and is to be revered, and therefore lived in harmony with the land, Europeans viewed the same land and all it contained – including the indigenous peoples – as an "it," which is simply an object to be exploited (Buber 1970, Campbell with Moyers 1988), (2) we in Western civilization focus predominantly on utilizable **products** from the ecosystem rather than on the **processes** that produce the products, (3) renewable "natural" products are largely manifested aboveground whereas many of the processes that produce the products are invisible belowground, (4) we therefore think about and manage what is visible aboveground and tend to ignore the crucial biological processes below the surface of the soil, and (5) short-term economic gain is the driving force behind management of renewable, natural resources and our society.

When these points are taken together, they form the foundation of Western economic culture. Reared with this historical background, most people find it difficult to really understand the risks to humanity's future, which accompany the violation of remaining natural areas either in principle or in fact. Although this may seem a bold statement, consider that, in addition to representing a collection of native species of both plants and animals with a given amount of genetic diversity, each protected area of native forest, whether old or young, also represents a repository with a portion of the world's healthiest ecological processes and their attendant functions.

For example, the native, temperate coniferous forests of the Pacific Northwest are still relatively "healthy," whereas both the temperate coniferous forests and plantations of central Europe are dying, and far more is known scientifically about forests of the Pacific Northwest and how they function than is known about European forests (Franklin et al. 1981, Harmon et al. 1986, Harris 1984, Maser et al. 1988). So a system of natural areas of native forest in the healthy Douglas-fir (*Pseudotsuga menziesii*) region of the Pacific Northwest is a repository for ecological processes that, although different in specifics, are similar in principles to those of the dying forests and the dying Norway spruce (*Picea abies*) plantations of central Europe (Blaschke and Bäumler 1986, Durrieu et al. 1984, Plochmann 1986, 1989). By analogy, rather than a historical transplant of a particular species to reintroduce it into an area from which it has been extirpated, we have the potential to perform "global process-information transplants" through ecological knowledge that is and can be gleaned from and maintained through benchmark areas that represent nature's blueprint -- natural areas -- whether or not today's economists and industrialists can see anything but "economic waste" in saving them.

Areas of native, old-growth forest are even more important now than ever before, because today we face the possibility of a generalized global warming -- the "greenhouse effect." Such a historically-unprecedented warming would mean that forests must be adaptable -- both plants and animals, which constitute the interrelated, often symbiotic, biological processes of life. The problem for humanity is that no one knows which species or which individuals within a species will be able to adapt to such changes. What is known, however, is that native species are much more likely to be able to adapt than exotics, even of the same species, brought in from other areas. As stated by Hoyt (1990), "In wilderness [native species] lies a genetic bank account we have been drawing on for generations only now are we trying to find out what's left." In this sense, adaptability equates to resilience in the face of sudden, dramatic, perhaps irreversible change.

Part of the process of maintaining ecological resilience is setting aside an ecologically-adequate system of natural areas of native forest, including old growth, as an unconditional gift of potential knowledge for the future. In so doing, present and future generations have a repository not only of species, which more often than not are region-specific, but also of processes, which more often than not are world-wide in principle and application.

From such repositories, in addition to monitoring human-caused changes and maintaining habitat for particular species, it will be possible to learn how to maintain, restore, and sustain biological processes in various portions of the ecosystem. In this sense, reserves of native forest, including old growth, are the parts catalogs and the maintenance manuals not only for forests of the present but also for forests of the future.

Here I think we need to pause and carefully consider what the great historian, Arnold Toynbee (1958), learned when he asked the critical question of why 26 great

civilizations fell. He concluded that **they could not or would not change their direction, their way of thinking, to meet the changing conditions of life.** On page 298, Toynbee says of history, "We cannot say [what will happen] since we cannot foretell the future. We can only see that something which has actually happened once, in another episode of history, must at least be **one of the possibilities** [emphasis mine] that lie ahead of us." For us, the adults of the world, to grasp this lesson in terms of the children of today and of tomorrow and beyond, we must ask ourselves, "Can society continue to afford the environmental costs of the economics of extinction?" Have we become so myopic that we are willing to risk losing the ability to have sustainable forests by pursuing the short-sighted, short-term, economic windfall to be had by cutting the remaining native forests, including the remaining commercially-available old growth?

In this context, it is imperative to understand that humanity has not "reforested" a single acre, because no one has planted and grown a forest on purpose. What we and the rest of the world have done and are doing under the guise of "forestry" is trading our forests in on simplistic, economic plantations. And forests and plantations are **not synonymous!**

Old-growth Forests and Ecological Sustainability

There are many valid reasons to save the remaining commercially-available old-growth forests from extinction, as many, perhaps, as there are for saving tropical forests. One is that our forests, such as those of the Pacific Northwest, are beautiful and are unique in the world (Waring and Franklin 1979). Another is that the old trees inspire spiritual renewal in many people and are among the rapidly-dwindling, living monarchs of the world's forests. They are unique, irreplaceable, and finite in number, and they exist precisely once in forever. We can perhaps grow large trees over two or three centuries, but no one has yet done that on purpose. If they do, such trees will not be nature's trees; they will be humanity's trees. And although they may be just as beautiful as those created by nature, they will be different in the human mind. A third reason is that a number of organisms, such as the spotted owl (*Strix occidentalis*), the northern flying squirrel (*Glaucomys sabrinus*), and the red-cockaded woodpecker (*Picoides borealis*), either find their optimum habitat in these ancient forests or require the structures provided by the live, old trees, the large declining trees, the large snags, or the large fallen trees, to survive (Franklin et al. 1981, Harris 1984, Meslow et al. 1981, Thomas et al 1990). A fourth reason is that each old-growth tree is a "carbon sink," a storehouse of immobilized carbon, the storage of which reduces the carbon dioxide in the atmosphere and thereby has a positive influence on the greenhouse effect (Harmon et al. 1990). And a fifth reason is that old-growth forests are the only living laboratories through which we and the future may be able to learn how to create sustainable forests – something no one in the world has so far accomplished.

As a living laboratory, old-growth forests serve four vital functions. First, they are our link to the past, to the historical forest. The historical view tells us on what the

present is built, and together the past and the present tell us on what the future is projected. Because the whole forest cannot be seen without taking long views both into the future and into the past, to lose the remaining commercially-available old-growth forests is to cast ourselves adrift in a sea of almost total uncertainty with respect to the creation and sustainability of future forests and plantations. We must remember that knowledge is only in past tense; learning is only in present tense, and prediction is only in future tense. To have sustainable forests and plantations, we need to be able to know, to learn, and to predict. Without significant amounts of old-growth forests, which are allowed to function in the absence of direct, human intervention, we eliminate learning, limit our knowledge, and greatly diminish our ability to predict.

Second, we did not design the forest, so we do not have a blueprint, parts catalog, or maintenance manual with which to understand and repair it. Nor do we have a service department in which the necessary repairs can be made. Therefore, how can we afford to liquidate the remaining commercially-available old-growth forest that acts as a blueprint, parts catalog, maintenance manual, and service station -- our only hope of understanding the sustainability of our simplified plantations?

Third, we are playing "genetic roulette" with plantations of the future. What if our genetic engineering, our genetic cloning, our genetic streamlining, our genetic simplifications run amuck, as they so often have around the world? Native forests, be they old or young, are thus imperative because they -- and only they -- contain the entire genetic code for living, healthy, adaptable forests.

Fourth, intact segments of the old-growth forest from which we can learn will allow us to make the necessary adjustments in both our thinking and our subsequent course of management to help assure the sustainability of forests and plantations. If we choose not to deal with the heart of the old-growth forest issue -- sustainable forestry, we will find that reality is more subtle than our understanding of it and that our "good intentions" will likely give bad results.

There are many valid reasons to save the remaining commercially-available old-growth forests, but there is only one reason that I know of for liquidating them -- short-term economics. Economics, however, is the common language of Western civilization. Is it not therefore wise to carefully consider whether saving substantial amounts of well-distributed old-growth forests is a necessary part of the equation for maintaining a solvent timber industry?

Can we really afford to liquidate our remaining commercially-available old-growth forests? I have often heard that, "We can't afford to save 'old-growth,' it's too valuable and too many jobs are at stake." Here, I submit, we must be careful, because scarcity not only increases the economic value of the remaining commercially-available old-growth forests but also increases the ecological value of these same forests. In the face of this scarcity, cutting most of the remaining commercially-available old-growth forests will serve only a small proportion of the immediate

generation of humans, whereas protecting most or all of the remaining commercially-available old-growth forests will serve all individuals within all generations to come (Perlin 1989). Therefore we must be exceedingly cautious lest economic judgment isolates us from the evidence that, without ecologically-sustainable forests, we will not have an economically-sustainable forest industry, and without an economically-sustainable forest industry, there will be human communities in which we cannot have a sustainable economy.

Thus, if we liquidate the remaining commercially-available old-growth forests – our living laboratories – and our plantations fail, as plantations are failing over much of the world (Plochmann 1968, 1989), there will be no forest industry (Perlin 1989), and we will have further impoverished our souls and those of future generations through the myopic drive for short-term profits. Unless our minds and our hearts are set on maintaining an ecologically-sustainable forest, each succeeding generation will have less than the preceding one, and their choices for survival will be equally diminished.

Sustainability, The Concept

We cannot have an economically-sustainable yield of any forest product, such as wood fiber, water, soil fertility, wildlife, or genetic diversity until we first have a ecologically-sustainable forest, one in which the biological divestments, investments, and reinvestments are balanced in such a way that the forest is self-maintaining in perpetuity. Sustainability is additive. We must have a sustainable forest to have a sustainable yield, we must have a sustainable yield to have a sustainable industry, we must have a sustainable industry to have a sustainable economy, and we must have a sustainable economy to have a sustainable society. When sustainability is put in purely economic terms, the additive economic relationship of the biological yield becomes clear. We must first practice sound "bio-economics" (the economics of maintaining a healthy, sustainable forest), before we can practice sound "industrial-economics" (the economics of maintaining a healthy, sustainable forest industry), before we can practice sound "socio-economics" (the economics of maintaining a healthy, sustainable society). It all begins with a solid foundation – in this case, a healthy, ecologically-sustainable forest.

Today's "forest practices" are counter to sustainable forestry because, instead of training foresters to manage forests, we train plantation managers to manage the short-rotation, economic plantations with which we are replacing our native forests. Forests have evolved through the cumulative addition of structural diversity, which initiates and maintains process diversity, complexity, and stability through time. We are reversing the rich building process of that diversity, complexity, and stability by replacing native forests with plantations designed only with narrow, short-term, economic considerations.

Every acre on which a native forest is replaced with a plantation is an acre that is purposely stripped of its biological diversity, its ecological sustainability, and is

reduced to the lowest common denominator -- simplistic economics. The simplistic economics of the soil-rent theory -- be it in forestry or agriculture -- has not proven to be ecologically sustainable anywhere in the world in the medium and long term. Thus, the concept of a "plantation," a strictly simplistic, economic concept, has nothing whatsoever to do with the ecological sustainability of a forest. Under this concept, native forests are replaced with plantations of genetically manipulated trees accompanied by the corporate-political-academic promise that such plantations are better, healthier, and more viable than are the native forests that evolved with the land over millennia.

"Sustainable" means producing industrio-economic outputs as the land gives us the ecological capability of the forest to do so in perpetuity. In turn, this necessitates balancing product withdrawals with bio-economic reinvestments in the health of the forest. It means maximizing the health of the forest and optimizing the harvest of all forest products and amenities.

To accomplish ecological sustainability, we must shift our historical paradigm from that of the exploitive colonial mentality -- "use it until it collapses then someone else can deal with it," to the paradigm of trusteeship. Much as we might wish it otherwise, humanity is not in control of nature. So, if humanity is to survive, we must become trustees of our natural resources -- in the original sense of the word "resource," a reciprocal relationship between humanity and the earth. As I think about the word resource, it occurs to me that the very structure of the word -- re and source -- means reciprocal relationship, to use something from the earth and then to be the source of its renewal. Today's dictionaries, however, define "resource" as "the collective wealth of a country or its means of producing wealth, any property that can be converted into money." Yet, if we go back to the original sense of the word "resource," we will find that the ecological sustainability of our forests lies embodied in a word that we blithely use but do not fully understand.

Finally, how would we be thinking about our forests if the "Multiple Use Sustained Yield Act" had been conceived of and written as the "Multiple Use Sustainable-Yield Act" or even as the "Multiple Use Sustainable-Forest Act?"

Suggested Definitions

It may be unusual to close a paper with definitions, but words, collectively language, are the basic tool through which we convey our perceptions to each other. And today's use of words in the English language is often imprecise. Thus, after a great deal of thought and much discussion with colleagues, I suggest the following definitions in an attempt to help us say what we mean and mean what we say, because words we use determine the actions we perform, which in turn determine the options we bequeath the generations of the future.

Ecologically sustainable forest -- one in which the biological divestments, investments, and reinvestments are balanced in such a way that the forest is self-maintaining in perpetuity.

Economically-sustained yield -- the volume of wood fiber to be cut annually as predetermined by the economic targets of industry rather than by the ecological capability of the forest ecosystem to produce that volume on a sustainable basis. Thus far in our history, an economically-sustained yield has meant a physically-sustained cut of available native forest. Consider, for example, that the first record of logging in what is now the Willamette National Forest, in western Oregon, was in 1875 and that 90% of the timber cut there during the first three decades of this century was readily accessible and occurred below 4,000 feet elevation. Every increase in the technology of logging and the utilization of wood fiber has speeded the exploitation of forests; thus from 1935 through 1980, there has been a geometric increase on the Willamette National Forest of 4.7% per year in the annual volume of timber cut, which means a doubling of volume cut every 15 years. By the 1970's, 65% of the timber cut on the Willamette National Forest occurred above 4,000 feet elevation, and because the average tree harvested is progressively younger and smaller, the increase in annual acreage cut has been five times greater than the increase in volume cut during the last 40 years (Harris 1984).

Forest -- the most complex, terrestrial ecosystem, characterized by a predominance of trees.

Forestry -- the profession that embraces the science, art, and business of managing the forest ecosystem in a manner that assures the maintenance and sustainability of biological diversity and productivity for perpetual production of amenities, services, and goods for human use.

Plantation -- a simplified and specialized area under cultivation as an economic crop of cultivated trees.

Plantation management -- the profession that embraces the science, art, and business of growing a plantation of trees as an agricultural crop to reap the greatest economic returns on the least economic investment in the shortest possible time.

Reforestation -- the purposeful, scientific simulation of nature's forest as it evolved through the cumulative addition of structural diversity, which initiates and maintains process diversity, complexity, and stability through time.

Scientific forest management -- the strict application of factual information to the art and business of managing the forest ecosystem in a manner that assures the maintenance and sustainability of biological diversity and ecological productivity for perpetual production of amenities, services, and goods for human use.

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Late-Quaternary Vegetation History of the Interior Highlands of Missouri, Arkansas, and Oklahoma¹

Hazel R. Delcourt and Paul A. Delcourt²

Abstract

We review the Late-Quaternary history of changes in vegetation in the Interior Highlands, a region which includes the Ozark Plateaus of central and southern Missouri, northern Arkansas, and northeastern Oklahoma, as well as the Ouachita Mountains of central Arkansas and southeastern Oklahoma. Our analysis is based upon radiocarbon-dated records of fossil pollen grains, spores, and plant macrofossils from karst sinkhole lakes, bogs, oxbow lakes, and springs within stream terraces located within these physiographic regions, in addition to other paleoecological sites distributed across southeastern North America. Plant-fossil data from these sites demonstrate that the composition of forests has changed dramatically over the past 20,000 years since the last full-glacial maximum (the Late Wisconsinan). In the Interior Highlands of Missouri, Arkansas, and eastern Oklahoma, full-glacial forests were dominated by spruce (*Picea*) and jack pine (*Pinus banksiana*), with few deciduous forest elements. Twenty thousand years ago, the ecotone between boreal-like coniferous forest and temperate deciduous forest was located in north-central Louisiana and probably extended eastward across Mississippi, Alabama, and Georgia at about 34°N latitude.

In the southeastern Ozark Plateaus, tree populations of jack pine, spruce, and fir (*Abies*) declined in importance generally after about 14,000 years ago, as species of oak (*Quercus*), black ash (*Fraxinus nigra*), elm (*Ulmus*), hornbeam (*Ostrya/Carpinus*), and hickory (*Carya*) immigrated successively from more southerly latitudes during the late-glacial interval from about 14,000 to 10,000 years ago. Prairie established in eastern Oklahoma and elsewhere in the eastern Great Plains as early as 12,000 years ago, and this climatically controlled vegetation constituted a phytogeographic barrier to the westward dispersal of deciduous forest species as well as to the northern expansion of boreal conifers.

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During the Holocene, after 10,000 years ago, warm and dry climatic conditions favored expansion of prairie, oak savanna, and oak hickory forest in the Interior Highlands.

Warm-temperate swamp species today characteristic of riparian corridors and pond margins, including buttonbush (*Cephalanthus occidentalis*) and tupelogram (*Nyssa*), became established during the late Holocene interval, after about 4000 years ago. Shortleaf pine (*Pinus echinata*), a commercially important species within the forests of eastern Oklahoma, northern Arkansas, and southeastern Missouri, also immigrated into those regions after 4000 years ago. The presettlement old-growth forests of the Interior Highlands thus consisted of newly formed plant communities that were still in the process of change in response to changing late-Holocene climate.

Introduction

Interpreting the structure, composition, and dynamics of presettlement old-growth forests as a prelude to restoring some of their characteristics through management of present-day forests requires a long-term perspective on vegetation history that takes into account the development of forest communities on the time scale of millennia. The long life spans of many forest trees result in dynamics of species migrations and forest community development which require hundreds to thousands of years to occur (Davis 1983; Delcourt and Delcourt 1987a). Forest community responses occur not only in response to short-term, localized, and high-frequency disturbances such as wind throw and wildfire (Runkle this volume, Pickett and White 1985), but they are also fundamentally controlled by longer-term and broader-scale changes in regional climate, hydrology, and geomorphology (Delcourt et al. 1983; Delcourt and Delcourt 1987a, 1988, Bartlein et al. 1986, Webb 1988). In recent years, paleoecological research has demonstrated that the responses of both plant and animal species to regional and global climatic changes are individualistic, resulting in a major reshuffling of species composition to form new combinations during times of environmental change (Davis 1983, 1986, Graham 1986). A paleoecological perspective is thus of fundamental importance in determining the trajectory and rate of vegetational change through time (Jacobson et al. 1987), as well as for anticipating the rates and directions of change in species composition that may occur as a result of the global climatic changes projected for the next several hundred years (Delcourt and Delcourt 1987b, Davis and Zabinski 1991).

Across the Interior Highlands, a region which includes the Ozark Plateaus of central and southern Missouri, northern Arkansas, and northeastern Oklahoma, as well as of the Ouachita Mountains of central Arkansas and southeastern Oklahoma, late-Quaternary plant-fossil studies (figure 1, table 1) are few in number relative to those studied in formerly glaciated landscapes where kettle lakes are abundant (Delcourt and Delcourt 1985).

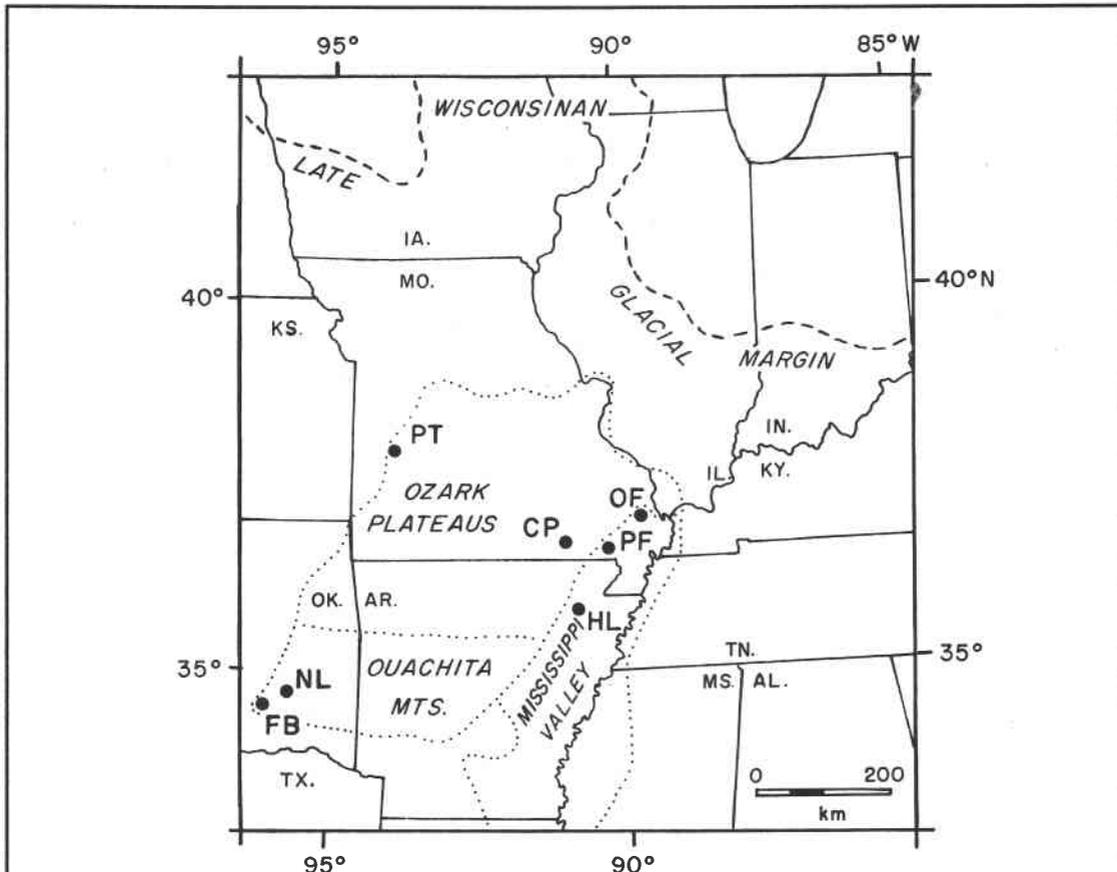


Figure 1. Location map of radiocarbon-dated paleoecological sites discussed in text. The dotted lines correspond with the boundaries of major physiographic regions. Paleoecological sites are designated as follows: CP, Cupola Pond; FB, Ferndale Bog; HL, Hood Lake; NL, Natural Lake; OF, Old Field; PT, Pomme de Terre Springs; PF, Powers Fort Swale.

This is in part due to the general perception of the scarcity of appropriate study sites in the Interior Highlands (Delcourt and Delcourt 1985). However, sites studied within this region include peat lenses buried within stream terraces of western Arkansas that were some of the first Holocene vegetation records to be studied within North America (Sears 1935). Springs emanating from stream terraces along the Pomme de Terre River in the Ozark Plateaus of western Missouri are internationally recognized for their records of Pleistocene megafauna as well as plant fossils (Mehring et al. 1968, King 1973, King and Lindsay 1986). In recent years, several long, continuous records that span the transition from Pleistocene to Holocene climatic conditions have been obtained from karst sinkhole ponds such as Cupola Pond within the southeastern Ozark Plateaus (Smith 1984). In the Ouachita Mountains of eastern Oklahoma, Ferndale Bog, perched on a sandstone ridge, has been studied recently (Albert and Wyckoff 1981; Bryant and Holloway 1985) and has revealed a continuous record of vegetation history extending back through the entire Holocene interglacial

Table 1. Radiocarbon-dated paleoecological sites discussed in text.

Site name, state	Code	Latitude North	Longitude West	Time range	Depositional Environment	Pollen analyst	Publications
Cupola Pond, MO	CP	36°48'	91°06'	Full-glacial to late-Holocene	Karst sinkhole	E. N. Smith, Jr.	Smith 1984
Ferndale Bog, OK	FB	34°25'	95°49'	Late-glacial to late-Holocene	Spring-fed bog	L. Albert R. Holloway	Albert and Wyckoff 1981 Bryant and Holloway 1985
Hood Lake, AR	HL	35°42'	90°55'	Late-glacial to late-Holocene	River swale	H. Delcourt	Delcourt et al. (in press)
Natural Lake, OK	NL	34°39'	95°24'	Late-Holocene	Oxbow lake	L. Albert	Albert and Wyckoff 1981
Old Field, MO	OF	37°06'	89°48'	Early- to late-Holocene	River swale	J. King	King and Allen 1977
Pomme de Terre Springs, MO (Boney, Jones, Koch and Trolinger)	PT	38°07'	93°22'	Middle Wisconsinan to late-glacial	Springs in river terraces	P. Mehringer J. King	Mehringer et al. 1968 King 1973, King and Lindsay 1976
Powers Fort Swale, MO	PF	36°36'	90°35'	Full-glacial to late-Holocene	River swale	P. D. Royall	Royall et al. 1991

interval, with a basal radiocarbon date of 11,800 years Before Present (yr B.P.) Natural Lake, an oxbow lake located near Ferndale Bog but within a valley underlain by shale, provides a plant-fossil record extending through the last several thousand years of the late-Holocene interval and which contrasts with that from Ferndale Bog because of differences in both topographic setting and underlying substrate (Albert and Wyckoff 1981).

In this paper, we review the history of changes in vegetation over the past 20,000 years in the Interior Highlands, as recorded in the particular study sites thus far analyzed by Quaternary paleoecologists (figure 1, table 1). We then place these changes in a regional context that includes changes in the composition and distribution of major vegetation types, their mutual ecotones, and the individualistic migrations of tree species through the time span of the last transition from glacial to interglacial conditions, as well as continuing through the present, or Holocene, interglacial interval up to the time of EuroAmerican settlement.

Pleistocene Vegetation of the Western Missouri Ozarks

Jim King (1973, King and Lindsay 1976) excavated a number of artesian springs within stream terraces of the Pomme de Terre River, western Missouri (figure 1). The spring deposits were rich in organic remains including the bones of many species of Pleistocene vertebrates as well as abundant plant fossils. The oldest finite radiocarbon dates obtained on organic matter from the spring deposits were in the range of 34,000 to 39,000 yr B.P.; thus, Trolinger Spring, Koch Spring, and Jones Spring all dated from the Mid-Wisconsinan time of cool climatic conditions that preceded the onset of maximum glacial-age cold climates (King 1973). Boney Spring deposits dated from about 27,500 yr B.P. to an estimated 13,500 yr B.P. (King 1973).

Boney Spring thus spans in time the transition to the Late-Wisconsinan glacial maximum at about 24,000 yr B.P., represents biotic conditions throughout the Late-Wisconsinan "full-glacial" interval, and spans the transition from full-glacial to "late-glacial" climatic conditions after 16,500 yr B.P. when the Laurentide Continental Ice Sheet began its northward retreat across the Midwest and climates warmed south of the Late-Wisconsinan glacial margin (figure 1).

The plant-fossil sequences from the spring deposits of the Pomme de Terre River Valley record two major changes in regional vegetation of the western Missouri Ozarks over the interval from approximately 40,000 yr B.P. to 13,500 yr B.P. Open parkland of jack pine (*Pinus banksiana*) covered the region from at least 40,000 yr B.P. until the beginning of the full-glacial interval about 24,000 yr B.P. (King and Lindsay 1976). Evidence for the predominance of jack pine during Mid-Wisconsinan time was found at all spring sites in the form of abundant pine pollen grains in the size range of jack pine; in addition, cone scales of jack pine were identified (King 1973). This past vegetation was interpreted as an open parkland on the basis of the abundant fossil pollen of sedges (Cyperaceae), grasses (Gramineae), chenopods (Chenopodiaceae/

Amaranthaceae), ragweed (*Ambrosia* type) and asters (Compositae) preserved in the spring deposits along the Pomme de Terre River.

During the full-glacial interval, boreal spruce (*Picea*) forest replaced jack pine parkland in the western Missouri Ozarks. Boreal tamarack (*Larix*) was also present locally, based on remains of its cones recovered from full-glacial deposits of Boney Spring (figure 2, King 1973, King and Lindsay 1976).

Spruce continued to dominate the fossil-pollen assemblages at Boney Spring until after 16,500 yr B.P. By 13,500 yr B.P., however, in addition to spruce pollen were substantial percentages of pollen of temperate deciduous trees and shrubs, including oak (*Quercus*), willow (*Salix*), alder (*Alnus*), ash (*Fraxinus*), elm (*Ulmus*), hazel (*Corylus*), and hornbeam (*Ostrya/Carpinus* type) (figure 2, King 1973, King and Lindsay 1976). Late-glacial forests were thus composed of an admixture of boreal conifers and cool-temperate hardwoods.

King (1973) interpreted the replacement of jack pine parkland by spruce forest during full-glacial times as a response of the vegetation to increasingly wet and cold climatic conditions. During the late-glacial interval, beginning about 16,500 yr B.P., climatic warming was reflected by increases in the pollen percentages of temperate deciduous forest species.

King (1973) and King and Lindsay (1976) concluded that the warm-temperate oak-hickory forests today characteristic of the western Missouri Ozarks must have formed there during postglacial times.

Late Pleistocene and Holocene Vegetation of the Southeastern Missouri Ozarks

The paleoecological study of plant fossils from lake sediments of Cupola Pond, Ripley County, Missouri (Smith 1984) represents the first examination of the only late-Quaternary site in the Ozark Plateaus of Missouri known to span continuously the time interval that includes full-glacial conditions, the transition through the late-glacial interval, and the entire Holocene interglacial interval (figure 3). Cupola Pond is contained within a karst sinkhole collapsed on a high ridge between the Current and Jacks Fork Rivers, at 244 meters elevation. Interpretations of late Pleistocene and Holocene changes in vegetation and climate of the southeastern Ozarks of Missouri are based upon analysis of pollen and plant-macrofossil samples from a 12-meter sediment core from Cupola Pond which has radiocarbon dates extending back to 17,100 yr B.P. (Smith 1984).

The pollen diagram from Cupola Pond (figure 3) illustrates that during the full-glacial interval, from at least 17,100 yr B.P. to about 15,350 yr B.P., forest communities were co-dominated by northern Diploxylon pine (with measurements of fossil pollen grains

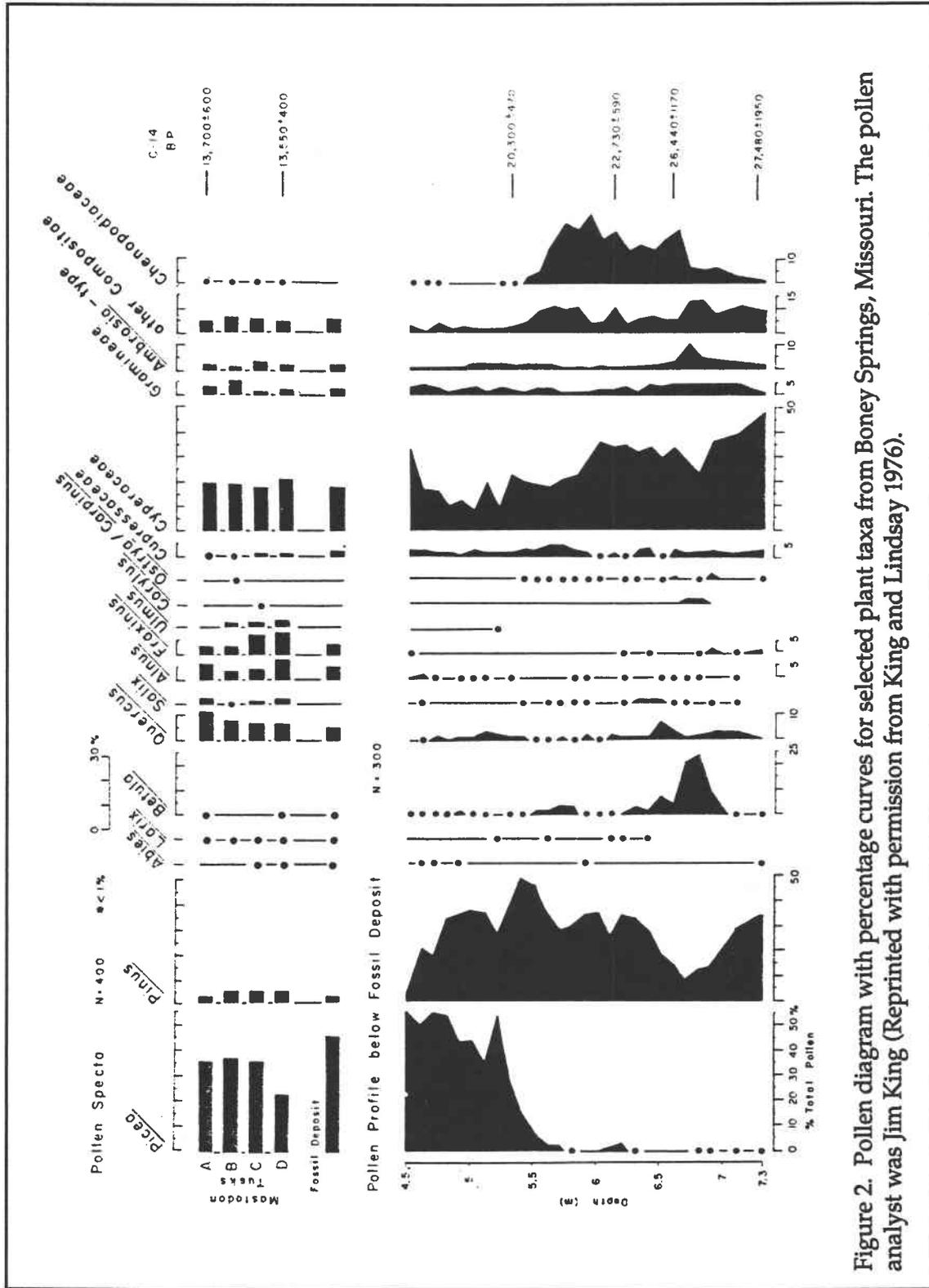
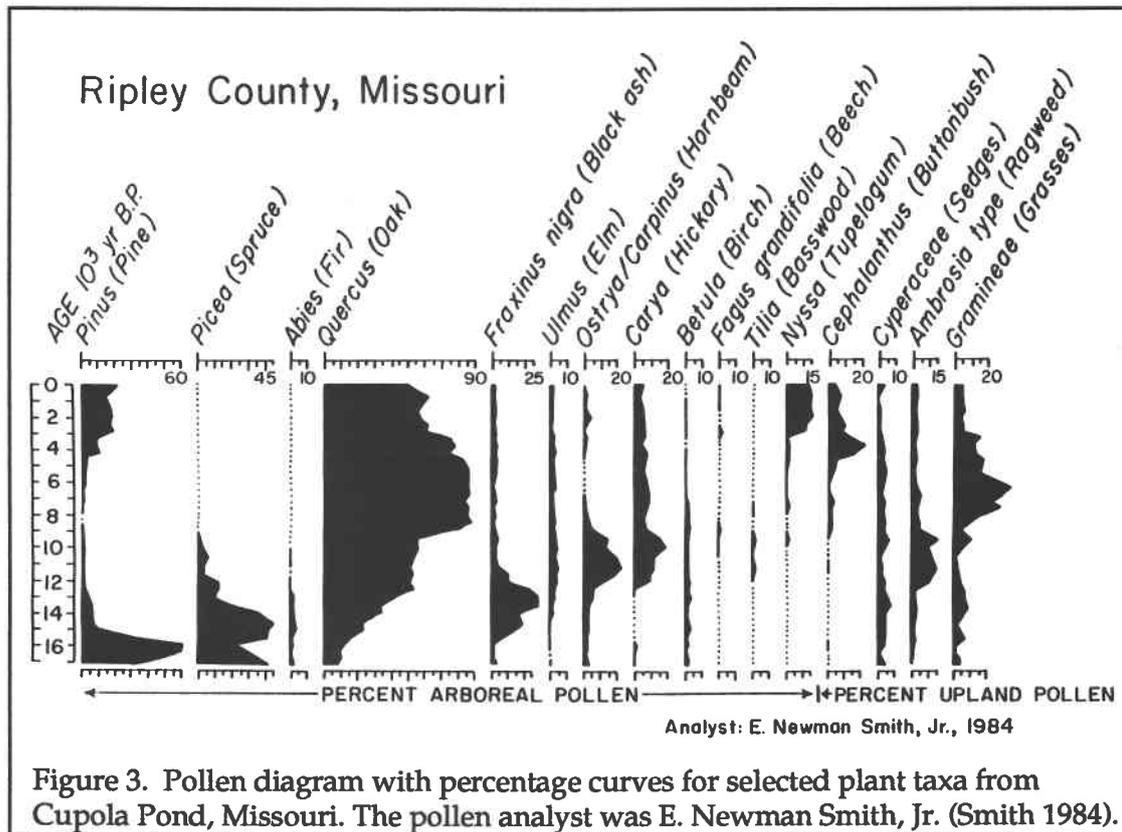


Figure 2. Pollen diagram with percentage curves for selected plant taxa from Boney Springs, Missouri. The pollen analyst was Jim King (Reprinted with permission from King and Lindsay 1976).

indicating that they represent populations of either jack pine or red pine [*Pinus resinosa*] or both pine species) and spruce (*Picea*); fir (*Abies*) was also present. During the full-glacial interval, as much as 10% of the tree pollen was of oak. Traces of other deciduous tree pollen were also recorded, including black ash (*Fraxinus nigra* type), hornbeam, and birch (*Betula*) (figure 3).



Smith (1984) interpreted this as evidence that small populations of cool-temperate deciduous trees may have survived the full-glacial interval in the southeastern Missouri Ozarks.

After 15,350 yr B.P., percentages of oak increased rapidly, followed by ash and then by elm, hornbeam, and hickory (figure 3). This pattern of sequential arrival and rapid increase may be interpreted as successive waves of immigration and establishment of tree species in response to late-glacial climatic warming across the Interior Highlands. A large increase in representation of the herb ragweed (*ambrosia* type) between 12,000 yr B.P. and 10,000 yr B.P. indicates that the forests that developed during the transition from late-glacial to Holocene conditions were open-canopy in structure.

Oak and hickory dominated the forests on the watershed of Cupola Pond after 10,000 yr B.P. Hickory, however, declined in abundance by about 8,000 yr B.P. and percentages of grasses (Gramineae) increased, indicating that oak-hickory forests were

replaced at least locally by an open oak savanna. Oak savanna persisted along the eastern Ozark Border until about 4,000 yr B.P. (Smith 1984). The mid-Holocene time of maximum warmth and dryness reflected in the pollen record from Cupola Pond occurred from approximately 8,000 yr B.P. to 4,000 yr B.P. (Smith 1984; this corresponds well with the "Hypsithermal Interval" recorded elsewhere in the Midwest as an eastward expansion of prairie at the expense of closed forest (Wright 1968, 1976).

In the late-Holocene interval, after 4,000 yr B.P., warm and humid climatic conditions are indicated by increases in percentages of pollen both of warm-temperate upland trees such as shortleaf pine (*Pinus echinata*) and of bottomland trees and shrubs including tupelogram (*Nyssa*) and buttonbush (*Cephalanthus occidentalis*) at Cupola Pond (figure 3; Smith 1984). With the late-Holocene decline in representation of prairie elements and the establishment of populations of warm-temperate trees and shrubs on the watershed of Cupola Pond, the paleoecological evidence indicates that the forest communities in the region of southeastern Missouri therefore have assembled with their present composition only in the past four thousand years.

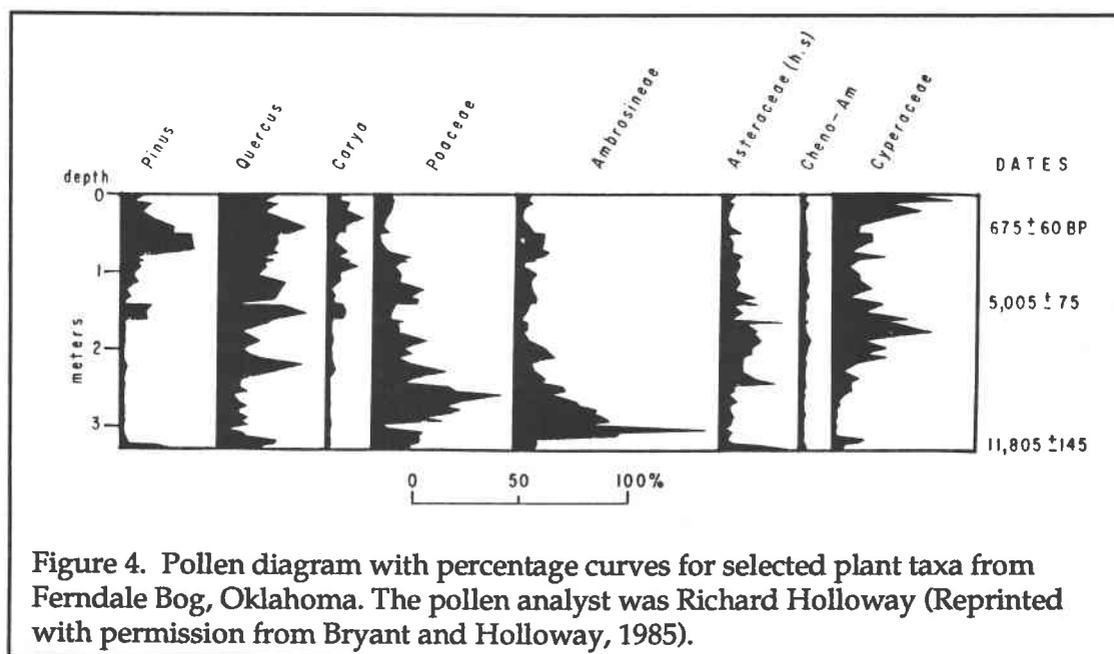
Holocene Vegetation of the Ouachita Mountains of Southeastern Oklahoma

Two late-Quaternary paleoecological sites, Ferndale Bog and Natural Lake, have been studied from the region of the Ouachita Mountains of southeastern Oklahoma (Albert and Wyckoff 1981, Bryant and Holloway 1985).

Ferndale Bog is a small peat bog located near the crest of a sandstone ridge at about 265 meters elevation in Atoka County, Oklahoma (Albert and Wyckoff 1981). Sediment cores from Ferndale Bog (figure 4) have been dated back to 11,800 yr B.P. (Bryant and Holloway 1985). Only small traces of spruce pollen occur in the oldest sediments from Ferndale Bog, indicating that by about 12,000 yr B.P. spruce trees were growing no closer than 160 kilometers from the site. High pollen percentages of grass (Poaceae in figure 4), ragweed (Ambrosineae in figure 4), and other herbs in the aster family (high-spine Asteraceae in figure 4), along with pollen of chenopods (Cheno-Am in figure 4), in the earliest sediments from Ferndale Bog indicate that prairie vegetation was established in southeastern Oklahoma by the time of the transition from late-glacial to Holocene climatic conditions (Bryant and Holloway 1985). Bryant and Holloway (1985) suggest that late-glacial replacement of coniferous woodland by grassland in the western Ouachita Mountains implies that the higher elevations of the eastern Ouachita Mountains were probably an effective migration corridor for boreal coniferous trees and other boreal plant species, at least locally, during the late-glacial interval.

High percentages of pollen of grass and other herbs persisted in the Ferndale Bog record until after 5,000 yr B.P. (Albert and Wyckoff 1981, Bryant and Holloway 1985).

During the late-Holocene interval, percentages of grass pollen and other herbs decreased, and there were substantial increases in the representation of southern pine, oak, and hickory after 5,000 yr B.P. (figure 4). Establishment of oak-hickory-pine forest in southeastern Oklahoma thus occurred after the peak of warm, dry climatic conditions that marked the Hypsithermal Interval of the mid-Holocene interglacial.



Natural Lake is an oxbow lake located in a stream valley overlying a shale substrate at an elevation of about 150 meters in Pushmataha County, Oklahoma. The pollen record from Natural Lake dates from approximately the past 2,500 years and is similar in broad outline to that from Ferndale Bog for the late-Holocene interval (Albert and Wyckoff 1981). At Natural Lake, however, percentages of southern pine pollen are lower than at Ferndale Bog, and Natural Lake sediments contain more pollen of elm and ash than do late-Holocene samples from Ferndale Bog (Albert and Wyckoff 1981). These differences may reflect a more mesic forest composition in the shale valley surrounding Natural Lake and a more xeric forest growing on sandstone uplands surrounding Ferndale Bog.

Late-Quaternary Regional Vegetation Changes

A number of recent synthesis articles and books are available that summarize late-Quaternary changes in vegetation and climate in map form for portions of the North American continent and which form the basis for placing the vegetation history of the Ozark Plateaus and the Ouachita Mountains in a broader regional perspective (Delcourt and Delcourt 1981, 1985, 1987a, Davis 1981, 1983, Bryant and Holloway 1985, Jacobson et al 1987, Webb 1988). The maps contained in these syntheses

summarize data from a broad array of late-Quaternary paleoecological sites. The maps reveal changes in broad vegetation types and their ecotones, or boundaries (Delcourt and Delcourt 1981, 1987a) as well as changes in the locations of population centers and range margins for individual plant taxa (Davis 1983, Delcourt and Delcourt 1987a, Jacobson et al. 1987, Webb 1988).

During the Late Wisconsinan full-glacial interval, boreal coniferous forest occupied much of the landscape across eastern North America south of the margin of the Laurentide Continental Ice Sheet and extending southward to about 34°N latitude (Wright 1981; Delcourt and Delcourt 1981, 1987a). Boreal coniferous woodland stretched across the Great Plains. The Interior Highlands of the Ozark Plateaus and the Ouachita Mountains was covered by boreal forest in which conifers were dominant, with pure stands of spruce trees to the northwest and a boreal mixture of spruce and jack and/or red pine farther to the southeast.

Populations of cool-temperate deciduous trees survived the full-glacial interval in the loess hills or Blufflands at Memphis, Tennessee (Delcourt et al. 1980) as well as in north-central Louisiana (Kolb and Fredlund 1981) and to the south along the Gulf Coastal Plain. Temperate deciduous forest, however, was confined to the southeastern coastal plain region east of Texas (Bryant and Holloway 1985, Delcourt and Delcourt 1987a). The Central Mississippi River Valley was occupied by boreal coniferous forest at least as far south as eastern Arkansas (Royall et al. 1991, Delcourt et al. in press) and was therefore a major phytogeographic barrier that separated and isolated populations of deciduous forest species on the Gulf Coastal Plain to the east and to the west of the Mississippi River.

With climatic amelioration of the late-glacial interval beginning in the Interior Highlands as early as 16,500 yr B.P. to 15,500 yr B.P. (King 1973, Smith 1984), tree populations of spruce and jack pine declined, and boreal conifers were rapidly replaced by newly establishing deciduous forest trees such as oak, ash, hornbeam, and hickory. To the west, with the late-glacial dieback of boreal conifers, prairie became predominant across the Great Plains. To the north of the Ozark Plateaus, boreal forests died out without establishing continuous migration corridors to Canada; instead, the eastern Canadian boreal forest of the late-Holocene interval was established by plant populations that survived the full-glacial interval east of the Mississippi River (Wright 1968, King 1973). Disjunctions in the ranges of species of boreal plants between today's boreal regions of Canada and the Interior Highlands of the Ozarks and Ouachitas (Steyermark 1959) originated during the late-glacial interval (King 1973).

Very few paleoecological records exist to substantiate the distribution and abundance of oak and hickory species during the full-glacial interval (Delcourt and Delcourt 1987a). From existing plant-fossil information, it has been interpreted that populations of oaks, hickories, and other species that today comprise the dominant plant communities of the extensive eastern deciduous forest were in full-glacial time very restricted in both the area they occupied and in their population density (Delcourt

and Delcourt 1987a). From small full-glacial refuge areas in the southeastern coastal plains, temperate deciduous forest spread northward rapidly following the first climatic warming of the late-glacial interval. Deciduous forests dominated by species of oak and hickory, however, did not become a really extensive across the Ozark Plateaus and the Ouachita Mountains until between 12,000 yr B.P. and 10,000 yr B.P. (Delcourt and Delcourt 1987a). With a population source area located primarily to the west of the Mississippi River, many of the endemic taxa of deciduous forest species in the Interior Highlands may have arisen as new species in the present, or Holocene, interglacial interval, established from founder populations that spread to the highland areas of Missouri, Arkansas, and eastern Oklahoma in the late-glacial interval (King 1973, Delcourt and Delcourt 1987a).

The mid-Holocene interval, spanning from about 8,000 yr B.P. to 4,000 yr B.P. (Albert and Wyckoff 1981, Smith 1984), was characterized by warm, dry climatic conditions and the spread of xeric prairie and savanna vegetation eastward from the Great Plains to the eastern Ozarks and Ouachitas. Farther east, in the Central Mississippi Alluvial Valley, warm-temperate bottomland hardwood forests of sweetgum (*Liquidambar styraciflua*), bald cypress (*Taxodium distichum*), and tupelogum (*Nyssa*) became established in the early Holocene, as evidenced by low but continuous pollen percentages at sites such as Powers Fort in southeastern Missouri and Hood Lake in northeastern Arkansas (Delcourt et al. in press, Royall et al. 1991), as well as at Old Field in southeastern Missouri (King and Allen 1977). During the mid-Holocene interval, at Old Field, the local peatland was dominated by marsh grasses (Gramineae, possibly including cane [*Arundinaria gigantea*]) and other wet-meadow herbs. At Powers Fort Swale (Royall et al. 1991, Delcourt et al. in press), bald cypress, sweetgum, oak, ash, and hickory increased in representation during the early and mid-Holocene intervals.

Chenopods, ragweed, and grasses increased as well, indicating lowered water levels in the swale during the mid-Holocene interval (Delcourt et al. in press). The pollen record from Hood Lake reflects a change from high water levels and open marsh during the early Holocene to a more dry oak-hickory-bottomland hardwoods forest during the mid-Holocene interval, as the stream hydrology changed from a regime of permanently flowing water to a regime of ephemeral, intermittent flow with pools of water becoming isolated and persisting throughout the year only in remnant basins such as Hood Lake and Powers Fort Swale (Delcourt et al. in press).

After about 4,000 yr B.P., regional climates became more humid and populations of many warm-temperate plant species increased around the margins of ponds and spread along riparian corridors. Pollen records from the southeastern Ozark Plateaus of Missouri (figure 3, Smith 1984) as well as from the Central Mississippi Alluvial Valley (Delcourt et al. in press, Royall et al. 1991) record increases in populations of wetland shrubs such as buttonbush (*Cephalanthus occidentalis*) as well as in bottomland trees such as tupelogum and bald cypress. Late-Holocene increases also occurred in the populations of southern pines as they expanded northward across the uplands from the southern Ouachita Mountains (Albert and Wyckoff 1981, Bryant and Holloway 1985) to the southern Ozark Plateaus (Smith 1984). The late-

Quaternary pollen records available from the Interior Highlands thus indicate that many of the plant species previously considered to be floristic relicts from the Tertiary Period of several million years ago (Steyermark 1959) must have survived glacial intervals of the Pleistocene farther south in Gulf Coast refuges and have re-colonized the Interior Highlands only during relatively brief intervals such as the present Holocene interglacial (King 1973).

Conclusions

Presettlement vegetation of the Interior Highlands was dominated by modern plant communities that began to assemble only in the Holocene interglacial interval. Boreal elements of the flora that persist along protected rock bluffs and springs are relicts of the late Pleistocene, when boreal forests covered the upland landscape. Warm-temperate species that were long thought to be holdovers from the Tertiary Period are Holocene immigrants whose populations expanded only in the past 4,000 years. The species-rich oak-hickory forests are a forest type that emerged no more than 10,000 to 12,000 years ago and whose composition and structure continued to change throughout the entire Holocene interglacial interval in response to continental-scale changes in climate and hydrology.

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Natural Disturbance Regimes and the Maintenance of Stable Regional Floras¹

James R. Runkle²

Abstract

The nature of the disturbance regime affecting a forest will determine many aspects of that forest, including the species which can occur there. A model developed here for closed forests looks at disturbances affecting the overstory (stems exposed to direct light and with low rates of turnover) and understory (stems shaded and with higher rates of turnover) separately. Parameters necessary to describe the overstory regime are given first: contrast between disturbed and undisturbed conditions, average disturbance rates, distribution of disturbance rates in time and space, severity of disturbances, recovery rates and mechanisms, and the frequency of repeat disturbances. Next are discussed several factors which affect the understory directly but affect the overstory only through their effect on the understory: shrub competition, ground fires, grazing, and drought. Many species require specific patterns of both overstory and understory disturbance to maintain themselves in a forest. As those disturbance regimes change, so will likely species composition.

Key words: Interior Highlands, disturbances, oaks, *Quercus*, overstory, understory

Introduction

The flora and vegetation of a region often remain remarkably stable for periods much longer than the lifespan of an individual tree: Community attributes such as species diversity, species lists, biomass, and stem size-class structure often keep the same average values for several tree generations. Change is frequent at individual locations but factors affecting which tree gains the canopy after its predecessor dies are relatively constant, enabling roughly the same species to occur with the same relative importance over long time periods. No single species always reaches the canopy in every tree replacement episode. Rare species survive by reaching the canopy following sequences of events which, though infrequent, occur often enough to maintain reproducing populations of those species.

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This paper introduces a scheme for examining some of the factors that determine which species will reach the canopy. For a forest or regional flora to be at equilibrium these factors should have similar probability distributions of values over time. These factors, with their probability distributions, comprise a disturbance regime. Runkle (1985) described several of the key parameters of such a disturbance regime which affect mesic forests of the eastern deciduous forest, particularly in relation to overstory disturbances. This paper recapitulates that scheme and expands it to include understory disturbances. It then shows how the two sets of disturbances (to the canopy and to the understory) interact to explain more about forest dynamics than can either alone.

Assumptions

In most mesic forests, space is limiting. Tree crowns fit together tightly with little space between them. The only time space in the canopy and thus access to direct light is available is when a canopy tree dies and relinquishes its space. After space is relinquished by one dominant individual a period of rapid growth occurs for previous suppressed or new individuals, one or more of which eventually again fill the space.

Trees die in different ways. How they die determines in part which individuals of which species will replace them. Therefore, to maintain the same species composition over long time periods it is necessary for the pattern of tree death to remain constant for that time period. A change in the disturbance regime will undoubtedly produce a change in the vegetation and probably the flora too.

Disturbance regimes are characterized not just by average values of their parameters but also by the variance of their parameters. For example, most forests are affected by disturbances of many different sizes. What is important for the maintenance of the flora is that the balance of large and small disturbances remains more or less constant over time so species requiring either can persist.

I will simplify forest structure by considering it to be composed of only two size classes: An overstory and an understory. The overstory is the layer of the forest which receives direct light; overstory stems grow relatively rapidly and turnover (stem death and replacement) is low. The understory does not receive direct sunlight; growth is slow and turnover of stems is high. The overstory and understory can be considered to be acting independently under the normal (e.g., undisturbed) course of events. The overstory changes little as the dominant tree in a location slowly grows. The understory changes more rapidly as stems germinate, grow to some species- or habitat-specific size and then die to be replaced by others.

What unites the dynamics of the overstory and understory two size classes is that a disturbance to the overstory favors those saplings in the understory at the right time and the right place. If the understory is in perfect equilibrium in species and size-

classes, the timing of the overstory disturbance does not matter. However, if the understory varies in its vegetation from time to time then an overstory disturbance at one time may release a different set of stems than would happen if the overstory disturbance occurred at some other time. The goal of studying understory disturbance and seedling/sapling demography (dynamics) is then to determine how often and under what conditions a given type of understory vegetation will be released following a given type of overstory disturbance.

Description of the Overstory Disturbance Regime

Many different types of overstory disturbances have occurred in the forests of the Interior Highlands in the past. These disturbances undoubtedly have been important in determining the structure and species composition of the present forests. Small, individual tree gaps occur (personal observation). Fires, both ground and crown, have occurred frequently and have had major impacts (Braun 1950, Foti and Glenn this volume, Tucker this volume), though at present, fire occurrence rates are lower than in the Coastal Plain pine forests (Nelson and Zillgitt 1969). In addition, large windstorms and tornadoes (Fujita 1976) have been noted in the area (Fountain this volume) and may explain the common occurrence of even-aged stands (Turner 1935). The frequency of damaging tropical storms is very low but the frequency of glaze storms is fairly high (Nelson and Zillgitt 1969). Severe droughts occasionally occur (Hinckley et al. 1979).

Knowing that such disturbances occur is a good beginning toward understanding the disturbance regime. It also is necessary to know more specifically how often disturbances of different types occur and what effect each type has on the vegetation. The following scheme, taken largely from Runkle (1985), identifies some of the particular questions to ask about each type of disturbance in order to evaluate its importance to the vegetation.

Contrast between disturbed and undisturbed conditions

In many forests the areas where trees have died are sharply and obviously different from adjacent non-disturbed areas: The distinction between closed canopy and canopy gap or opening is pronounced. In some forests the distinction is not as pronounced: Canopy trees are scattered; much light penetrates everywhere. For the latter forests a different approach than the one below may be necessary.

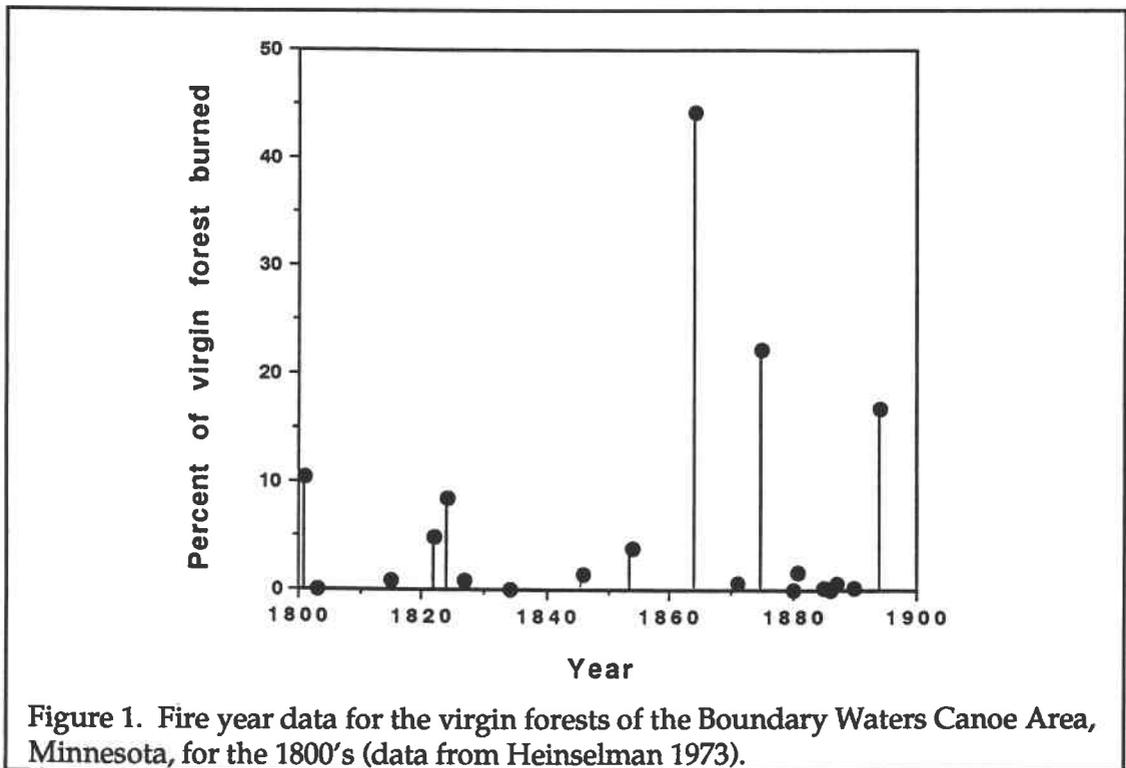
Average disturbance rates

Average disturbance rates seem remarkably constant over a wide range of forest and disturbance types at about 1% per year (table 1). This constancy of average rates matches well a corresponding similarity in tree longevities over a variety of forest types. It also argues that the distribution of disturbance over time and space is more important than average tree mortality.

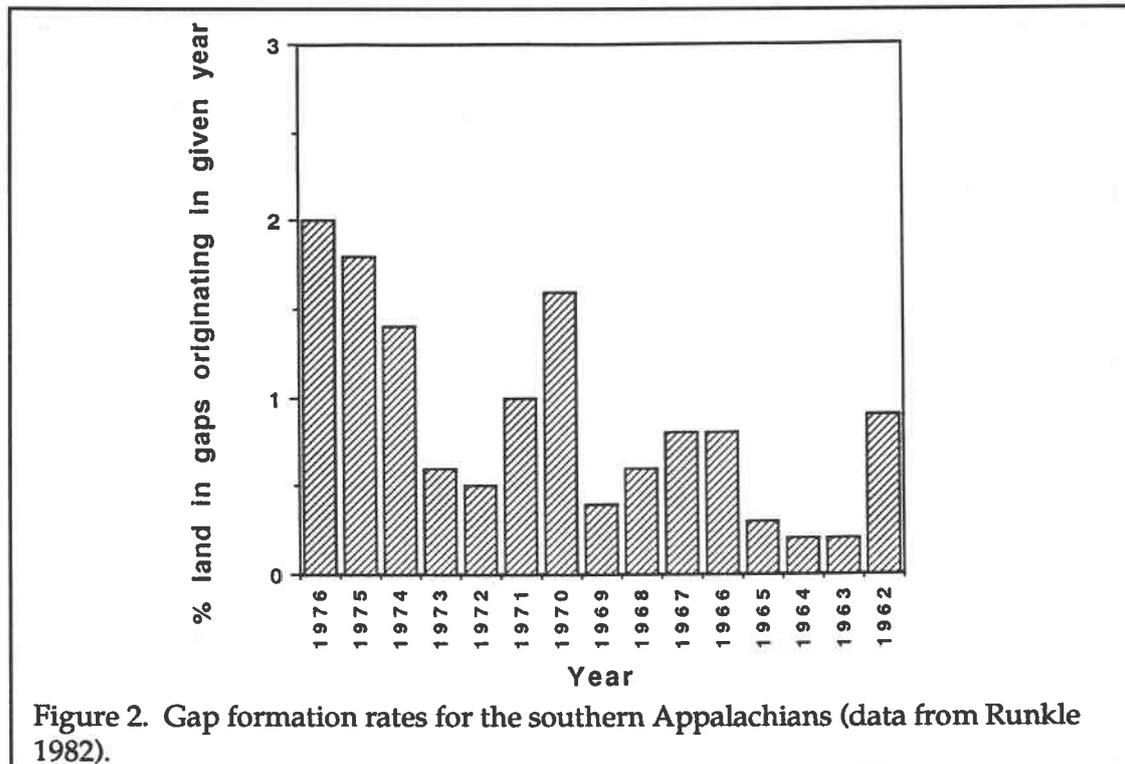
Table 1. Average disturbance rates (%/year) for different forests.		
Rate	Forest	Reference
1.0	Northern Minnesota	Heinselman 1973
0.6-0.78	Upper Michigan	Lorimer and Frelich 1989
0.5	Pennsylvania beech-hemlock	Runkle 1982
0.8	Ohio beech-maple	Runkle 1982
1.2	Southern Appalachian coves	Runkle 1982
0.3-0.8	Japanese beech forests	Nakashizuka 1987
0.2-1.7	Various tropical forests	Brokaw 1985

Distribution of disturbance in time and space

Forests do vary in the distribution of their disturbance. Heinselman's (1973) work on the pine forests of northern Minnesota documents a situation where disturbance is highly clumped (figure 1). In most years very little mortality occurs. In the other years, however, mortality can be very high: Almost half the total study area was



affected in a single major fire year. In contrast, moist forests in the southern Appalachians show a much more constant level of low but steady mortality: Every year a few trees die; in no year do a great many trees die (figure 2).



Both situations are common though to different degrees in different places. A recent literature survey (Runkle 1990) concluded that in the interior mesic portions of the eastern deciduous forest, gap-dominated disturbance regimes prevail. Around the edges, there seems to be an increased incidence of large-scale disturbances such as major wind-related blowdowns and extensive fires. Although I found few good references for the Interior Highlands, except for those cited earlier, I anticipate that large-scale disturbances in general should be important there.

These differences are expected to have major effects on the kinds of species which dominate their respective forests because of the well known relationship between opening size and the physical environment and, therefore, the likely species composition. This relationship is one basis for the variety of silvicultural systems developed by foresters to favor different sorts of species (Smith 1962; U.S. Forest Service 1973, 1978). Table 2 provides representative data showing how light and soil moisture levels vary with opening size and how tree growth rates also respond. Even small variations in size of disturbance may be sufficient to allow different species to persist in the stand: In an old growth stand at Hueston Woods, Ohio, the four main

species varied in importance according to opening size for gap sizes (canopy openings) only about 500 m² at the largest (Runkle 1990).

Table 2. Climate and growth responses to gap size in Illinois.			
D/H ¹	% full light, clear day, coves ²	Available soil moisture (%) 4th summer, North aspect ²	White oak growth (cm/yr) Avg for 6 yr, North aspect ²
0.25	--	--	
0.50	20	2.2	27
0.75	28	--	
1.00	55	6.0	34
1.50	62	--	
2.00	95	10.8	53

¹ D/H = gap diameter/tree height
² Conditions at gap centers

Source: Minckler, Woerheide and Schlesinger 1973.

Severity of the disturbance

Disturbances also can vary in their severity, i.e. the degree to which vegetation has been damaged and ecosystem properties disrupted. In mild disturbances only overstory individuals are affected and the forest recovers rapidly. In more severe disturbances, overstory and understory stems may both be affected and recovery is slower and may favor different species. Where all traces of the previous vegetation have been removed and soils are greatly affected, as in agriculture, recovery to a forest like that before disturbance is often a very slow process.

Recovery rates and mechanisms

In forests which I have studied, recovery involves a race between the branch growth of canopy trees bordering an opening and the height growth of small stems in the opening. Small gaps close primarily by branch growth; large ones by height growth. For gap sizes commonly encountered in the Southern Appalachians (mostly <300 m²) most saplings require at least two disturbance episodes to reach the canopy (Runkle 1985, Runkle and Yetter 1987). Some forests may be dominated by species which grow either especially rapidly by height growth or canopy extension; other forests by particularly slow-growing species. In some forests injured trees usually die within a few years; in others, injured trees may sprout or grow even faster than uninjured

trees. These different patterns of regrowth should produce different opportunities for different species and therefore should be reflected in the average species composition of the forest.

Repeat disturbances

Repeat disturbances occur when an area is affected by a new disturbance before all effects of an older disturbance have disappeared, e.g. when a tree falls beside an already existing treefall gap before its canopy has been reestablished. Such events occur fairly often (Runkle and Yetter 1987). The reason is not that trees by a gap are more likely to die than other trees. The reason is that small gaps have so many neighbors that it is very likely that at least one will die during even fairly short time periods, say a decade. The state of the understory (species and size classes present) at the time of the new disturbance will partly determine how recovery from the disturbance proceeds.

Disturbance and Dynamics of the Understory

Changes in the understory are important because overstory disturbance usually releases the pre-existing understory: Incumbents prevail! For example, in my study of gaps in the southern Appalachians the best predictor of the vegetation of a gap during my second sample was the vegetation present in the first sample (6 or 7 years earlier): There was no evidence that gap vegetation fluctuated greatly or that new stems were able to invade and gain dominance (Runkle and Yetter 1987). A species or individual more successful at maintaining its importance in the undisturbed understory is therefore more likely to reach the canopy following a disturbance to the overstory.

Sapling longevities are an important index of their relative success though not the only one. Successful species are those for whom saplings are almost always available to respond to overstory disturbance. Shade or understory tolerance is one way to be available (e.g. sugar maple, *Acer saccharum*). Buried or newly dispersed seed represents a successful strategy if overstory or understory disturbances tend to eliminate tolerant saplings. The approach taken in analyzing overstory disturbance can also be applied to the understory. However, I would like here first to document understory mortality rates and then to discuss a few types of disturbances which are likely to be especially important to the understory.

Unfortunately, few studies have documented mortality rates over a wide range of stem sizes. These studies support the hypothesis that understory stems show much larger rates of mortality than overstory stems in the same location. In the most extensive study, Buchman (1983) and Buchman and Lentz (1984) summarized thousands of permanent plot tree records for the major forest tree species of the Great Lake states. For each of the 19 species studied larger stems usually had lower mortality rates than smaller stems. For example sugar maple had an annual mortality

rate of 7% for stems 1.3 to 3.8 cm dbh (diameter at breast height), 3% for stems 3.8 to 6.3 cm dbh, and < 2% for all larger size classes. Parker et al. (1985) measured mortality between 1926 and 1976 in an old-growth forest in Indiana and found overall mortality to decline consistently from trees 10 to 19.9 cm dbh to trees 50 to 59.9 cm dbh. Similar mortality rates and patterns were found by Smith and Shifley (1984) for trees in Indiana and Illinois.

Several factors influence the composition of the understory at any particular time. Of these factors several types of disturbances will be briefly discussed below. Conditions such as average weather or soil properties will not be discussed. Disturbances, by definition, lead to changes in the understory which allow a variety of species to exist. Lack of disturbance tends to favor a more restricted set of species.

Shrubs can compete with tree seedlings and saplings for understory resources. Factors which influence shrub cover therefore can have a great influence on which tree species, if any, will be available when an overstory disturbance occurs. Several examples of the importance of shrubs have been published.

- Niering and Goodwin (1974), working on old fields in Connecticut, demonstrated that a well established shrub cover could effectively resist invasion by tree species for at least 15 years. Some of their areas of dense shrub cover were naturally established; some were created by selectively removing trees.
- Rhododendron (*Rhododendron maximum*) in the southern Appalachians often occurs as dense thickets. Tree regeneration within such thickets often is noticeably different than tree regeneration elsewhere. Oosting and Bourdeau (1955) showed that the composition of a stand in a rhododendron differed from that in an adjacent stand without rhododendron (figure 3). Phillips and Murdy (1985) found that total tree regeneration was lower in plots with high levels of rhododendron than in plots with less rhododendron. They also found that different species were affected differently. Therefore, rhododendron could act to change the composition of the canopy by affecting which species of saplings were most abundant. Palmer (1987) also demonstrated that rhododendron has an inhibitory effect on tree establishment: Most seedlings in rhododendron thickets were found in spatially rare microsites such as rocks, logs, and paths.
- Some Japanese beech (*Fagus crenata*) forests have a dense undergrowth of *Sasa*, a type of bamboo. Nakashizuka and Numata (1982) suggest that most successful tree reproduction occurs only during the years of mass *Sasa* death, which occur after mass *Sasa* reproduction.
- Work in Wisconsin suggests that an important ecological limitation to the shelterwood system as a method of increasing northern red oak (*Quercus rubra*) regeneration in the region is that such cutting increases the shrub layer which in turn inhibits the growth and establishment of tree seedlings (Johnson and Jacobs 1981).

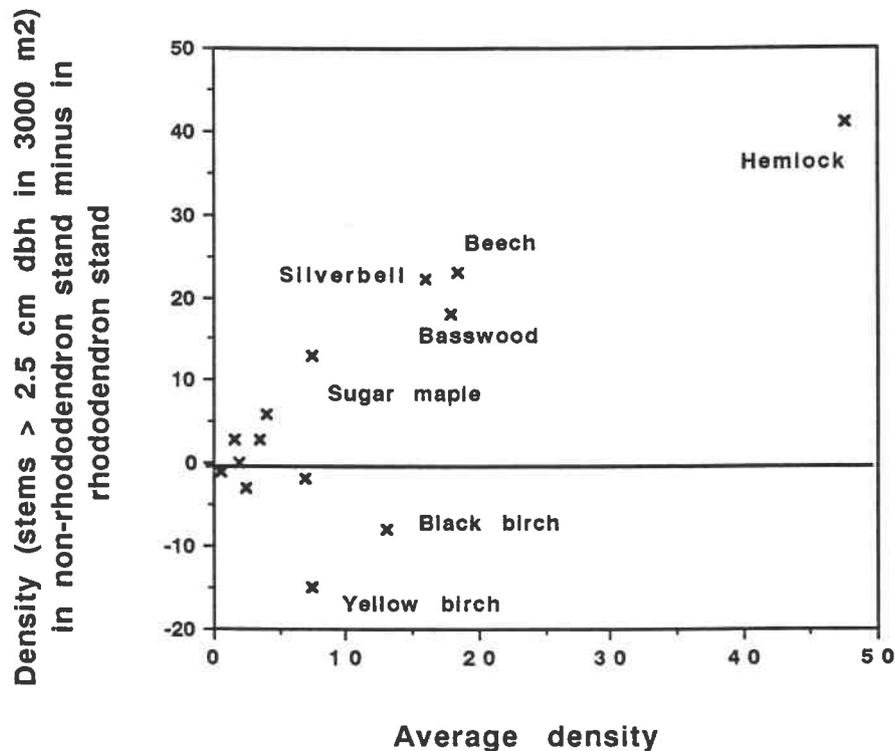


Figure 3. Density differences between plots with and without rhododendron in the Joyce Kilmer Natural Area, North Carolina (data from Oosting and Bourdeau 1955). Species listed are hemlock (*Tsuga canadensis*), beech (*Fagus grandifolia*), silverbell (*Halesia carolina*), basswood (*Tilia americana*), sugar maple (*Acer saccharum*), black birch (*Betula lenta*), and yellow birch (*B. lutea*). Lesser species not listed on the figure by name are *Liriodendron tulipifera*, *Fraxinus* spp., *Magnolia acuminata*, *M. fraseri*, *Aesculus octandra*, *Acer rubrum*, *Ilex opaca*, and *Cornus florida*.

In all four of these situations the shrubs play an important role in the composition of the overstory by affecting the success of species in the understory. The interaction of shrub population dynamics and sapling demography is very important to the community.

Fire can have major effects on community composition and structure. Some fires directly influence the overstory and lead to rapid changes in dominant individuals and species. Many fires, including many fires reported from the Interior Highlands, are ground fires, directly affecting only the understory. These fires still may be crucial in determining the long-term nature of the forest by selecting which species are most likely to reach the canopy. Several articles have associated the presence of oaks as

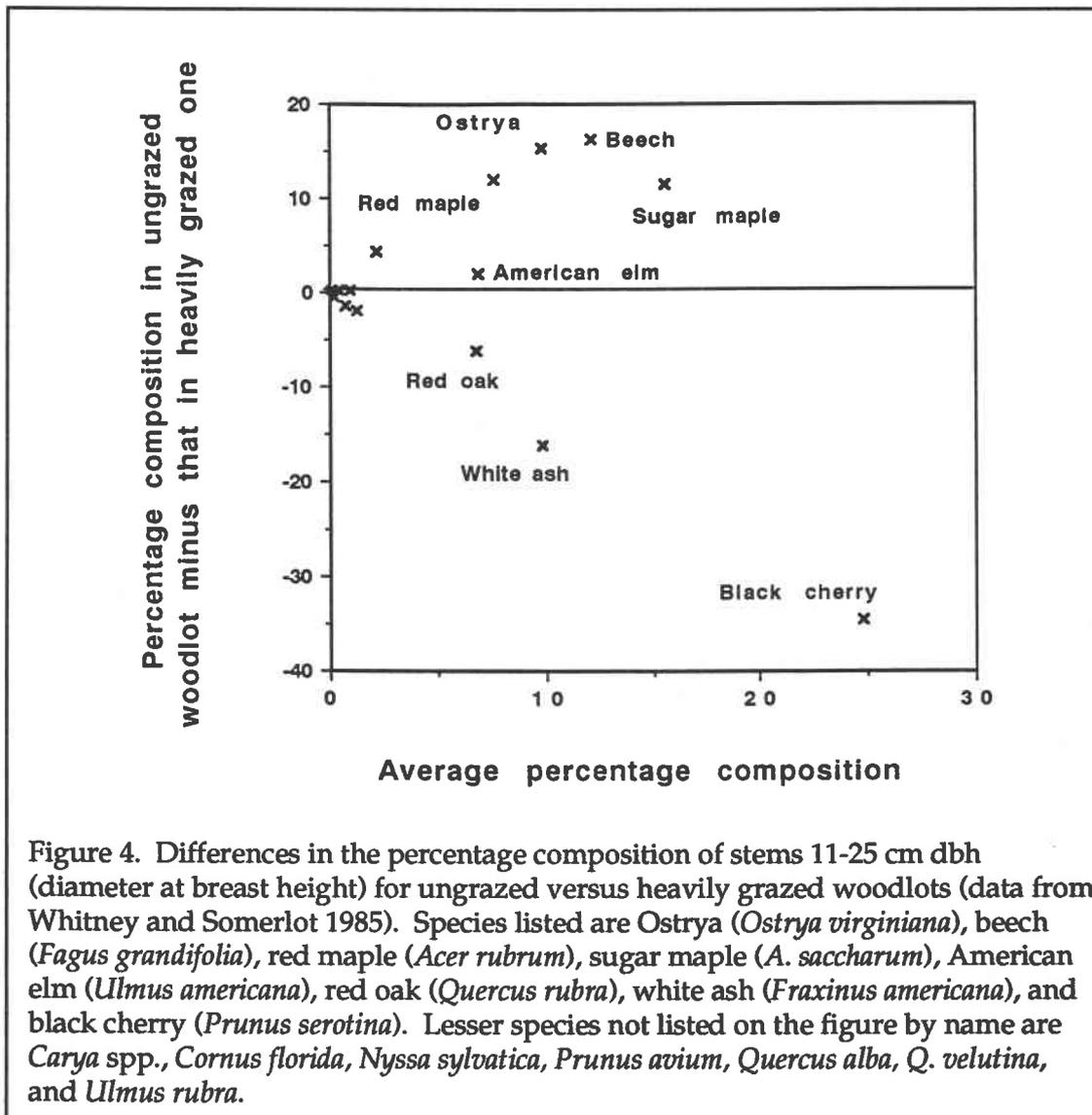
forest dominants in several parts of the eastern forest with the existence of frequent fires of low to moderate intensity, which affect the understory but not, directly, the overstory. These articles include Lotan et al. (1981) for the eastern deciduous forest in general, Whitney and Somerlot (1985) for oak forests in Ohio, Abrams (1986) for gallery forests on the Konza Prairie in Kansas, Rouse (1986) for northeastern forests, Crow (1988) for northern red oak throughout its range, and Van Lear and Waldrop (1989) for oak forests in the southern Appalachians. Reich et al. (1990) found that low-intensity controlled surface fires in Wisconsin decreased the abundance of red maple (*Acer rubrum*) in the understory while the density of *Quercus ellipsoidalis* remained unchanged. On the other hand Huntley and McGee (1982) found no increase in oak following prescribed burns in northern Alabama. Decreasing understory fires results in the establishment of other species, first in the understory and ultimately in the overstory, e.g. hackberry (*Celtis* spp.), redbud (*Cercis canadensis*), and elm (*Ulmus* spp.) in Kansas (Abrams 1986) or American beech (*Fagus grandifolia*), sugar maple, and basswood (*Tilia americana*) in northern deciduous forests (Spurr and Barnes 1973).

The complexity of the relationship between fire and forest is shown by the 20-year study of Lewis and Harshbarger (1976) on prescribed burning in the South Carolina Coastal Plain. Six burning treatments were followed, varying in fire frequency (annual, biennial, periodic, unburned) and season (summer, winter). Each treatment produced somewhat different vegetation responses, though with broad overlap. Burning could either perpetuate sprouting species (shrubs, oaks) or eliminate them, depending on the season of the burn and the frequency of burning. Determining the exact patterns of burns in the Interior Highlands will obviously be important in understanding the origin of the vegetation and how to modify or maintain it.

Grazing by large animals can have many effects on the understory (e.g. Spurr and Barnes 1973, Patric and Helvey 1986). Stems can be eaten or broken off. Roots can be trampled. Soils can be compacted and their hydrological properties affected. Some regard grazing as a complete disaster for woodland: "Around the world, grazing by livestock has probably been more important than any other factor in reducing the productive capacity of uncultivated land" (Spurr and Barnes: 234). In contrast, Patric and Helvey (1986) argue that the ill effects of grazing have been exaggerated and that even though soil infiltration rates are decreased they still are sufficient to cope with almost all naturally occurring precipitation events.

It is certain that grazing can have significant effects on the species composition of a forest, first by affecting the understory and eventually by affecting the overstory. For example, increased deer browsing has been implicated in the decrease of hemlock (*Tsuga canadensis*) and increase of sugar maple in different northern hardwood forests (Bjorkbom and Larson 1977, Anderson and Loucks 1979, Butt 1984, Frelich and Lorimer 1985). Grazing by livestock in midwest woodlots also has had large impacts on the vegetation. During periods of heavy grazing no tree regeneration occurs; if maintained, grazing eventually leads to the formation of a thick sod layer which will continue to inhibit tree establishment even after grazing is discontinued (Den Uyl et al. 1938). Usually, however, excluding grazers from an area produces a dense thicket

of woody regrowth which eventually thins after 20 or so years, usually dominated by different species than are in the overstory (Putman et al. 1989). In particular, light seeded species like ash (*Fraxinus* spp.), cherry (*Prunus* spp.), elm, and sugar maple are favored at the expense of heavy seeded species like beech or oak (Den Uyl et al. 1938, Dambach 1944, Whitney and Somerlot 1985). A period of grazing followed by a release from grazing therefore can cause a woods to change in composition from oak-dominated to domination by species such as white ash (*F. americana*) and black cherry (*P. serotina*) (Whitney and Somerlot 1985). Figure 4 shows differences in species composition between an undisturbed woodlot in Ohio and a heavily grazed one for the size classes corresponding to the years of grazing (Whitney and Somerlot 1985). In the Missouri Ozarks sugar maple has been increasing in the understory, far



surpassing oak regeneration, even in forests presently dominated by oak. Nigh et al. (1985) attributed this condition to a reduction in the activities, chiefly fires and grazing, which historically have resulted in site disturbance. They think it likely that the persistence of these conditions will result in profound shifts in species composition in future forests of the region.

Drought and other weather phenomena also can directly affect the understory without obviously affecting the overstory. Even though oaks as a group are drought resistant, oak species vary in their drought resistance as seedlings and that variation may play an important role in their distribution across a landscape (Bourdeau 1954). Therefore droughts can cause changes in understory composition and those changes can affect the ability of different species to later reach the overstory.

These disturbance factors can affect the understory in at least two ways. 1) They can act non-selectively to lower the density of all stems. Although all stems may be affected, species usually harmed by competition from other species can benefit from this effect: Something which hurts all stems is particularly harmful to the species which would have made up the majority of those stems. The group of species most likely hurt are those which usually saturate the understory through their relatively shade tolerant sapling stage, e.g. sugar maple. Likely beneficiaries are those species able to grow rapidly from seeds, small saplings, or an extant root system when an overstory disturbance occurs, passing through the dangerous sapling stages rapidly. An example may be white oak (*Quercus alba*) or the oaks in general. 2) Factors might act selectively, directly harming some species more than others. Some species are more sensitive to fire or more palatable to grazers than other. Some store relatively more resources in underground parts than others and so can respond more quickly to a disturbance. Oaks seem to use both methods to be relatively resistant to grazing and fire in the first place and to recover quickly from them if they are harmed.

Parameters characterizing understory disturbance therefore include the following: 1) impact on overall understory density, irregardless of impact on specific species; 2) selectively among species; 3) patchiness in time and space (whether due to random or topographic variations); 4) correlation or synchronization with overstory disturbance.

Conclusion

Plants of all sizes die and are replaced. The impact of the deaths varies, however, with the size of the plant. In a forest, stems of species with the potential to reach the canopy can be divided into two classes: An overstory of stems which receive direct light and typically live for a long time and an understory of stems growing slowly and dying relatively rapidly thus continually changing in exact composition of species and size-classes beneath the relatively unchanging canopy. Canopy individuals do eventually die, however, though often not predictively for understory stems. Their

death provides the flush of resources required by at least some understory stems to reach the canopy themselves. Because the occurrence of the overstory disturbance is not predictable and change in the understory continually occurs, the effect of a given overstory disturbance will vary.

However, on a broad scale of time and space, the two levels of disturbance and species responses to them interact in such a way that the overall composition of the forest is relatively constant. Some species possess growth strategies appropriate for normal conditions: These species dominate the forest. Still, other species require more unusual sets of conditions and so occur more rarely in the forest. Other species require conditions which rarely if ever occur, at least too rarely to maintain an adequate reproducing population in the area, and so are not found there.

To understand the dynamics of the forest and how all elements of its flora are able to persist, it is necessary to understand the disturbance regimes of both the overstory and the understory and how they interact.

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The Ouachita Mountain Landscape at the Time of Settlement¹

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Abstract

The vegetation of the Ouachita Mountain region at the time of settlement is described using historical narrative descriptions and quantitative study of General Land Office (GLO) land survey field notes of ca. 1840. Historic accounts describe the forests as similar to, but typically more open than those of the present. Extensive prairies were described in the western Ouachita Mountains. Openness of forest was often ascribed to frequent fire, either human (native American or settler) caused or natural. A single modern fire frequency study demonstrated frequent fire occurrence on a site in Hot Springs National Park ca. 1800. Data indicate that human-set fires may have altered, but did not replace, the natural fire regime. Analysis of GLO data using GRASS/GIS shows that *Pinus echinata* was generally dominant on slopes underlain by sandstone or novaculite, while *Quercus* species dominated on more level sites underlain by shale. *P. echinata* occurred primarily on moderately steep, south- or northwest-facing sites. *Q. alba* was most abundant on north-facing aspects, *Q. velutina* on west-facing, and *Q. stellata* on gentle slopes. These patterns differ from those of today in that *P. echinata* is not generally described as dominant on northwest aspects, and *Q. stellata* is usually found on steep slopes. Density and basal area in 1840 were lower than those of existing old-growth forests of the Central Hardwood Forest region. Red-cockaded woodpeckers occur today in an area which had abundant pine in the original forest.

Introduction

A knowledge of vegetation patterns at the time of settlement (18th to mid-19th century) is needed to appropriately manage old-growth forests in the Ouachita Mountain region. Knowledge of vegetation at that time aids in the identification of

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current old growth areas and selection of appropriate management techniques. It also provides a useful baseline for evaluating the effects of management on natural systems. Differences between structure and function of existing and original forests, and between effects of management techniques and natural disturbance processes may be estimated using information on pre-settlement vegetation.

The purpose of this study is to describe the original plant community mosaic of the Ouachita region. Using historical documents, both the structure of vegetation and the disturbance processes operating at the time of settlement (with emphasis on fire and windstorm) are documented. Using field notes of General Land Office surveyors, pre-settlement distributions of dominant species are analyzed with respect to topography.

Study Area

The Ouachita Mountains cover an area approximately 380 km east to west by 100 km north to south in western Arkansas and southeastern Oklahoma; elevations range from 100 m to 900 m (Croneis 1930). Although the Arkansas River Valley has sometimes been included in the Ouachita Mountain Physiographic Province (Croneis 1930, Fenneman 1938), we consider these as separate regions (Foti 1976, Pell 1983, Omernik 1986). General descriptions will refer to the more limited area.

The Ouachita Mountain region has ridge and valley topography. Marine sediments deposited during the early Paleozoic era were folded into ridges by continental collision during later Paleozoic (Croneis 1930, Hatcher et al. 1989). Erosion has been the dominant geological force for the last 300 million years. Ridges typically run east-west, having long north-facing and south-facing slopes. However, complex folding, faulting, and erosion have resulted in variations in slope and aspect. Typical surface rocks include sandstone, shale, and a hard siliceous rock, novaculite; limestone and other calcareous rocks are encountered frequently in the southern Ouachitas (Croneis 1930). Maximum average annual precipitation in the Ouachita Mountains is over 150 cm/yr (near Rich Mountain as a result of orographic lifting of moist south winds from the Gulf of Mexico) and minimum average annual precipitation is less than 100 cm/yr (Ark. Dept. of Planning 1973). South-facing slopes are warmer and drier than north-facing slopes because of increased insolation. Valleys are subjected to cold air drainage, and peaks are exposed to high winds and colder winter temperatures (Palmer 1924).

The typical vegetation pattern of Rich Mountain and Blackfork Mountain is "...a rather open forest..." dominated by *Pinus echinata* on the south slopes of mountains, and a mesic forest dominated by several species of *Quercus* and *Carya*, *Acer rubrum*, *A. saccharum*, *Castanea pumila* and others on north-facing slopes (Palmer 1924). Near the tops are open rocky glades, prairies, and there may be forests of small trees, seldom over eight or ten meters tall, with gnarled and twisted trunks and branches (Palmer 1924). These topographic variations result from differences in insolation (Johnson 1986).

In the Crystal Mountain area, *Pinus echinata* is dominant on south-facing slopes, and is controlled by steepness (Mayo and Raines 1986). On south-facing slopes, *Quercus alba* is dominant on lower slopes, *Q. marilandica* on mid-slopes, and *Q. stellata* on upper slopes (Mayo and Raines 1986). On north-facing slopes, *Q. rubra* and *Q. alba* are dominant with *Nyssa sylvatica* and *Carya tomentosa* (Mayo and Raines 1986).

The vegetation patterns at Hot Springs National Park (HSNP) are similar to those of the Crystal Mountain area but are influenced by the orientation of the pitch of strata (Palmer 1926). *Pinus taeda*, "sandy bogs" and lowland species occur in this area along streamsides and in the Ouachita River bottoms (Palmer 1926). No differences in soil or geology were found among various forest community types occurring in Hot Springs National Park; rather, slope and exposure determined soil moisture and affected species distributions (Dale and Watts 1980).

Based on fire scars on trees in transects through representative forest types, fuel loadings and topographic conditions, the fire return interval at any point in HSNP was estimated as 41.4 years, but has recently increased to 1200 years through fire suppression (Johnson and Schnell 1985). On an average site in the park, the fire-return interval was 27 years/ha (Johnson and Schnell 1985). On south, southwest, west, and northwest aspects, the mean fire-return interval was 20.5 years/ha, and on other aspects it was 33.4 years/ha (Johnson and Schnell 1985). There were not enough old trees to provide precise estimates of pre-settlement fire-return intervals. However, the oldest tree sampled, a *Pinus echinata* on a south-facing slope, experienced fires in 1788, 1798, 1806, 1811, 1817, 1829, 1847, 1857, 1873, 1889, and 1929 (Johnson and Schnell 1985). From 1788-1817 the mean fire-return interval was 7.25 years. In interpreting these figures, it should be understood that fire scars overestimate the return interval because low intensity fires do not often produce scars (Johnson and Schnell 1985).

Methods⁴

Historical descriptions

We reviewed primary historical sources for descriptions of vegetation and natural disturbances in the Ouachita Mountains and vicinity prior to the 20th century. The sources were limited to published accounts that have been cited in the scientific and/or historical literature.

⁴ Nomenclature throughout follows Smith (1988).

Land survey notes

General Land Office (GLO) notes of the original land survey of the Ouachitas in the late 1830s and early 1840s provide qualitative and quantitative data on forest composition at that time. Direction and distance from each section and quarter-section corner to two or four bearing trees was measured and species were identified (Bourdo 1956). Diameter of each tree at breast height (dbh) was also measured. Location of additional line trees and qualitative descriptions of the topography, soil, forest, and undergrowth along each mile line surveyed were also recorded.

Data from the GLO were analyzed along a north-to-south 73 km transect in western Arkansas and in two rectangular study areas (figure 1). The transect line across the mountains (TRANS1) provided a regionally representative sample including 318 trees. Bee Mountain (BEE MTN) was selected because digitized elevation data was available for that area in 30 m cells. This level of detail allowed for characterization of the physiographic position (slope and aspect) of individual trees. The BEE MTN sample included 621 trees in 156 km² (1-1/2 townships). This site lies on the border of the Ouachita Mountains and the Arkansas River Valley, but primarily has the character of the Ouachitas.

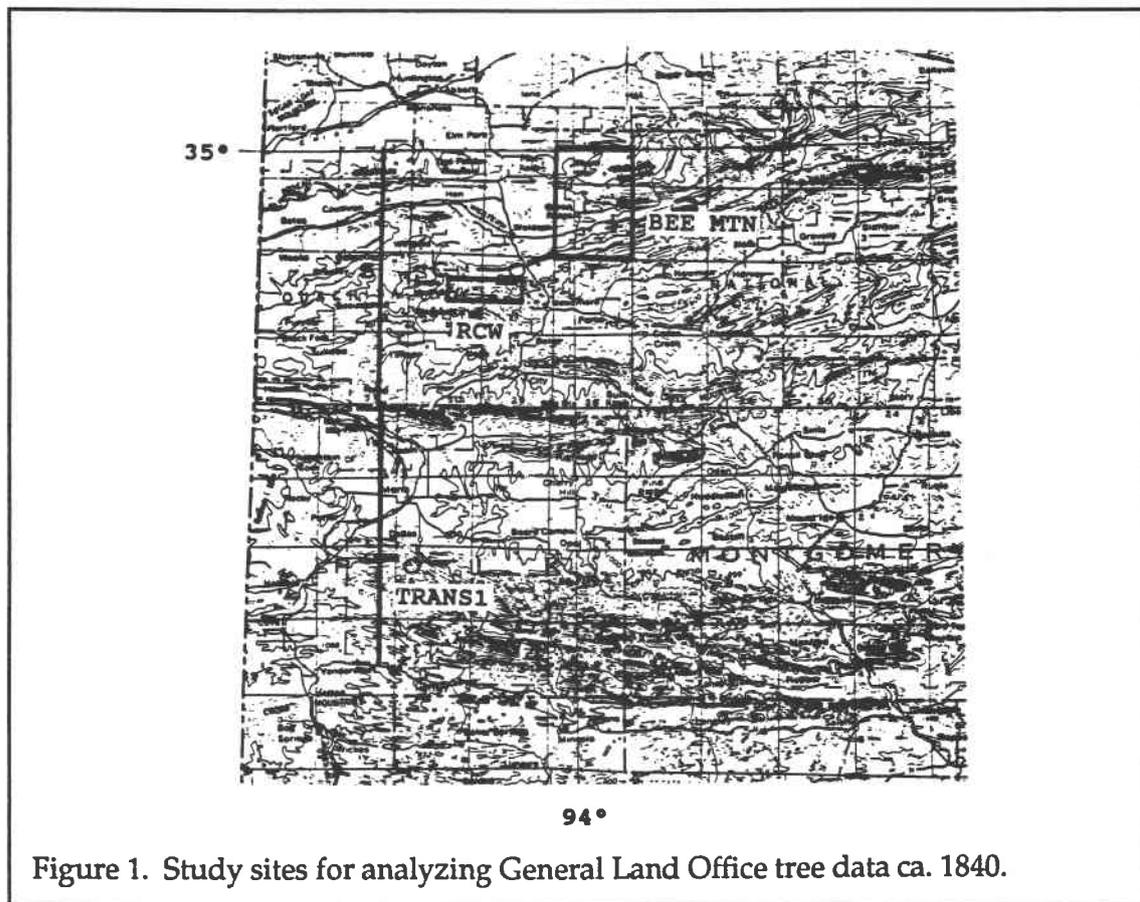


Figure 1. Study sites for analyzing General Land Office tree data ca. 1840.

The red-cockaded woodpecker site (RCW) supports several clans of this species (Ouachita National Forest file data). This may indicate that the original, as well as present, vegetation was distinctive. In the RCW site of 34.7 km², 195 trees were sampled.

Data were treated as point-centered quarter samples and used to calculate density and basal area, along with relative indices of each, for each species after the method of Cottam and Curtis (1956). Relative density and relative basal area were averaged to obtain species' importance values.

Trees were analyzed using GRASS Geographic Information System (GIS) (U.S. Army Construction Engineers Research Laboratory, Champaign, IL). Surveyor notes were digitized by obtaining the Universal Transverse Mercator (UTM) coordinates for each section corner and surveyors' direction and distance from the corners to each bearing and line tree along the ensuing mile. Using elevation data that already existed in the system, trees were sorted by slope and aspect. The proportion of the study area occupied by each combination of slope and aspect, and species frequency on that physiographic position, were calculated. Significant deviations from random species distributions across these topographic categories were tested using the Chi-square statistic (Goran et al. 1987) and used to define slopes and aspects positively or negatively associated with each species. Using the GIS, these areas were mapped for *Pinus echinata*.

Fire regime

Monthly thunderstorm occurrence data were obtained from the National Weather Service for Little Rock, Texarkana, and Fort Smith, AR (NOAA 1980) and lightning-set fire data were obtained from the Arkansas Forestry Commission (AFC file data) and the Ouachita National Forest (ONF file data). These data were compiled over various intervals. Therefore, the data sets were combined by summing the total number of fires or thunderstorms in all sets by month. The totals were then rescaled to create a fire and a thunderstorm index for graphical comparison.

Plat maps of 42 townships in the Arkansas Ouachitas (a rectangle of 30 km by 140 km) were examined for records of prairies, fires or windstorms, all of which were commonly mapped.

Results

Historical descriptions

In the late 1720s, Le Page du Pratz of Natchez set out with an Indian escort to travel through Louisiana, "...from the Natchez to the St. Francis..." (Du Pratz 1774). His narrative contains numerous references to the landscape and to the effects of fire:

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, by two or three leagues in breadth, more or less, according as the wind sets, and is higher or lower [a league is variously 2.7-5.4 km, usually estimated at about 5 km]. In the second place, this season is the most commodious for travelling over those countries; because, by means of the rain, which ordinarily falls after the grass is burnt, the game spread themselves all over the meadows, and delight to feed on the new grass, which is the reason why travelers more easily find provisions at this time than at any other (du Pratz 1774, p. 134).

The following passage indicates that the country was open, for the parties to be able to see each other's signals at a distance of "a league":

Every day, at nine in the morning, at noon, and at three in the afternoon, we made a smoke...in order to know, whether the scouts followed each other, and whether they were nearly at the distance agreed on (du Pratz 1774, p. 135).

Moving up the Ouachita River, he:

...travelled over a charming country...highly delighted with the sight of fine plains, diversified with very extensive and highly delightful meadows. The plains were intermixed with thickets...and interspersed with hills, running off in gentle declivities, and with valleys, thick set, and adorned with woods... (du Pratz 1774, p. 135ff).

At this point in the narrative, du Pratz described gypsum (found today in the lower Cretaceous deposits near the southern margin of the Ouachitas) and crystal (found within the Ouachitas), showing that he was in fact in the Ouachitas.

Later he reiterated:

The lands we find in going up the Black [Ouachita] River...in general may be considered as one very extensive meadow, diversified with little groves, and cut only by the Black River and little brooks, bordered with wood up to their sources (du Pratz 1774, p. 169).

Dunbar and Hunter led an expedition to the hot springs in 1804 and 1805 (Rowland 1930). They described cane along the margin of the Ouachita River within the Ouachitas, with the hills sometimes barren. Between Gulpha Creek and Hot Springs the forest was dominated by oak species with few pines (Rowland 1930, p. 272). "Pine woods" were also described in this area. Species of *Quercus*, *Carya*, and *Vitis* were mentioned as being on Hot Springs Mountain (Rowland 1930, p. 278).

Edwin James, botanist for the Stephen Long expedition to the Rocky Mountains in 1819-1820, described the Ouachita Mountains between present-day Dardanelle and Hot Springs as covered with small and scattered trees or as nearly treeless (James

1823). *Quercus* species and *Castanea pumila* were found on sandstone with pine forests on novaculite (James 1823, p. 287). However, not all of the area James described was barren. Dense forests of *Quercus*, *Fraxinus*, and *Acer saccharum* were found along the bases of mountains east of Hot Springs (James 1823, p. 297).

Thomas Nuttall (1819) described large prairies in the valleys between the Red River and Fort Smith in the Ouachita Mountains of what is now eastern Oklahoma, as well as "pine ridges" and "oak ridges". On the lower Kiamichi, Nuttall described an area of bushes and half-burnt trees (Nuttall 1819, p. 162). Along that river were "...horrid, labyrinthine thickets and cane-brakes [with] very little prairie" (Nuttall 1819, p. 162). The hills were covered in *Pinus*. An open, hilly prairie with thickets of *Smilax* along streams was described at the junction of Jack Fork and Kiamichi rivers (Nuttall 1819, pp. 162-163). He also described dwarf *Quercus alba* forests like those currently found on the crest of Rich Mountain.

Featherstonhaugh experienced an "immense conflagration" between ridges of the Ouachita Mountains in late November (Featherstonhaugh 1844, p. 36). These areas were dominated by stunted oaks and "open wooded country" (Featherstonhaugh 1844, p. 38). Effects of a tornado were also noted (p. 104ff). In his opinion, Indian fires somewhat thinned the forests but did not destroy them and "...now that Indians have abandoned the country, the undergrowth is rapidly occupying the ground again" (p. 164ff). Fire and tornados were also mentioned by Gerstacker (1881). He referred to "frequent fires in the forest" (p. 217) but said of the sources of the Ouachita, "...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). According to Gerstacker, tornados "...will sweep a district of a mile in width and several miles in length, leveling everything in their path." After a time they became "impenetrable" thickets of "blackberries, thorns and creepers" important for wildlife such as bear (p. 273).

Land survey notes

Vegetation of study sites. Comparison of species compositions of the three study sites shows that the compositions of the BEE MTN site and the RCW site were similar, but TRANS1 crossed more habitats and included more species (table 1). Species abundance differed among all sites (table 2). BEE MTN and RCW were dominated by *Pinus echinata*, with RCW having a greater *P. echinata* component (55% vs. 38%). Three *Quercus* species co-dominated the BEE MTN site with *P. echinata* (table 2). *Pinus echinata*, made up a smaller proportion (25%) and both *Quercus alba* and *Q. velutina* had highest importance values on TRANS1 (table 2). *Quercus stellata* had its highest importance on the BEE MTN site (table 2).

Table 1. Species recorded by GLO surveyors in 1830's and 1840's in study areas in the Ouachita Mountains. Vernacular names used by surveyors, with probable scientific names.

Species	TRANS1	BEE MTN	RCW
Pine (<i>Pinus echinata</i>)	X	X	X
Post Oak (<i>Quercus stellata</i>)	X	X	X
Black Oak (<i>Q. velutina</i> , poss. <i>Q. falcata</i> , <i>Q. shumardii</i> , <i>Q. rubra</i>)	X	X	X
White Oak (<i>Q. alba</i>)	X	X	X
Blackjack (<i>Q. marilandica</i>)	X	X	X
Hickory (<i>Carya</i> spp.)	X	X	X
Spanish Oak (<i>Q. falcata</i>)	X	X	
Black Gum (<i>Nyssa sylvatica</i>)	X	X	
Red Oak (prob. <i>Q. falcata</i>)	X		
Sweetgum (<i>Liquidambar styraciflua</i>)	X	X	
Elm (<i>Ulmus</i> spp.)	X	X	X
Dogwood (<i>Cornus florida</i>)	X	X	
Beech (<i>Fagus grandifolia</i>)	X		
Maple (<i>Acer</i> spp.)	X		
Mulberry (<i>Morus rubra</i>)	X		
Ash (<i>Fraxinus</i> spp.)	X		
Cottonwood (<i>Populus deltoides</i>)	X		

Table 2. Importance Values (Relative Abundance + Relative Basal Area)/2 of tree species on three sites in the Ouachita Mountains ca. 1840. See Table 1 for scientific nomenclature.

Species	TRANS1	BEE MTN	RCW
Pine	23.60	38.22	54.66
Post Oak	14.55	25.11	19.47
Black Oak	26.01	17.47	8.46
White Oak	24.63	14.11	13.75
Blackjack	0.96	2.84	1.91
Other	10.22	2.22	1.74

The GIS display of species distribution showed more *Pinus echinata* on the northern half of TRANS1 than on the southern half. This is consistent with the mile summary notes of the surveyors (e.g. "mostly oak and pine" vs. "mostly pine"). This pattern may be related to geology. *Pinus echinata* abundance is reduced on the Stanley Shale

Formation along the southern portion of TRANS1 and is greater on the Atoka Formation toward the north.

While the surficial geology of Stanley Shale is predominantly shale, the Atoka Formation consists of alternating beds of sandstone and shale and ordinarily the sandstone is exposed (Croneis 1930, p. 117). Therefore, the distribution of *P. echinata* on TRANS1 may be explained by the common association of pines with sandy sites (Foti 1974). Density of trees was similar on TRANS1 and BEE MTN (100/ha); however, basal area was greater on TRANS1 than on BEE MTN because of greater average diameter (table 3). The RCW site had higher basal area than the other sites (almost 67% higher than BEE MTN); there was almost as much basal area of *Pinus echinata* on the RCW site as in the total forest of the BEE MTN site (table 3).

Table 3. Density and basal area of tree species in three sample areas in the Ouachita Mountains ca. 1840. See Table 1 for scientific nomenclature.						
Species	TRANS1		BEE MTN		RCW	
	#/ha	m ² /ha	#/ha	m ² /ha	#/ha	m ² /ha
Pine	16.3	2.45	33.8	3.56	59.1	8.42
Post Oak	19.3	1.56	28.0	2.27	42.7	2.72
Black Oak	26.5	3.70	18.6	1.43	14.2	1.06
White Oak	26.1	2.72	14.1	1.09	27.4	2.07
Blackjack	0.4	0.03	3.1	0.17	1.1	0.03
Other	11.5	1.19	2.4	0.11	3.3	0.11
Totals	100.1	11.67	100.0	8.63	150.0	14.41

There was mention of mesic forests on north slopes on TRANS1, e. g., two corners on north-facing slopes used *Q. alba*, *Q. falcata*, *Nyssa sylvatica*, and *Fagus grandifolia* as bearing trees. Density at these corners was 83 trees/ha, which is lower than the site average.

Undergrowth was generally described on all sites as "oak bushes". Other species that were mentioned included hickory (*Carya*), dogwood (*Cornus*), chinkapin oak (*Quercus muehlenbergii*), post oak (*Q. stellata*), blackjack (*Q. marilandica*), and black oak (*Q. velutina* or possible *Q. shumardii*). Cane (*Arundinaria gigantea*) was mentioned only along major rivers. Vines and briars were seldom mentioned. Grass was not mentioned within the study sites. However, there were several references to "no undergrowth" in the RCW and BEE MTN sites that may have meant only that there was no woody undergrowth (i.e., there was grass undergrowth), because this comment was once made in the same mile that a "prairie" was mapped.

Examination of plat maps of 42 townships revealed that prairies were mapped only within and near BEE MTN. No major burned areas, and only one tornado path was found on the maps.

GIS analysis of species distribution at BEE MTN

The highly-detailed digital elevation data that were available for the Bee Mountain site made possible more extensive GIS analysis of the distribution of species by topographic or physiographic position. Relationships described below are those determined to be statistically significant (Chi-square $p < .05$).

More *Pinus echinata* were found on southern and northwestern aspects and on 17°-24° slopes than if the species were distributed at random. Fewer than expected occurred on southeast, northeast, and no aspect, and on 0°-8°, 49°-61°, and 85°-90°.

When slope and aspect were analyzed simultaneously, many more *P. echinata* than expected occurred on 17°-24° north-facing and northwest-facing slopes, and fewer than expected on slopes of the same steepness facing west (table 4). There were also more *P. echinata* than expected on 9°-48° south-facing slopes (table 4). Therefore, the typical *P. echinata* site may be described as having been a moderate to steep south-facing or northwest-facing aspect. *Quercus stellata* was found most frequently (50% of trees) on slopes of less than 16°, while only 5% of the trees were on slopes steeper than 40°. There was little relationship to aspect other than fewer than expected *Q. stellata* on northeast aspects.

When sites were sorted by slope and aspect simultaneously, *Q. stellata* on less than 8° slopes were concentrated on north, northwest, west, and south aspects, while trees on 9°-16° slopes were primarily on southwest and southeast aspects (table 5).

Quercus alba were found mainly (63% of trees) on north, northeast, and northwest aspects. There were fewer *Q. alba* than expected on south and southwest aspects, and 9°-16° and 33°-40° slopes.

When slope and aspect were considered simultaneously, there were more *Q. alba* than expected on gentle to steep northwest-facing and on east-facing 41°-48° slopes than if the species were randomly distributed (table 6).

Examining relationships with slope and aspect separately, there were more *Quercus velutina* trees than expected on west-facing aspects and fewer than expected on south-facing aspects. There were many more *Q. velutina* trees than expected on slopes of less than 8°. Combining slope and aspect in the analysis, there were more trees than expected to occur on northwest, southwest and west slope less than 8°, and on 25°-32° west-facing slopes (table 7).

Table 4. *Pinus echinata* distribution by slope and aspect.

	85°-90°									
	62°-84°									
S	49°-61°									
L	41°-48°		-				x			
O	33°-40°	+								
P	25°-32°						+			
E	17°-24°	+	x	X	-					
	9°-16°		+				+	-		
	0°-8°		-						-	
		E	NE	N	NW	W	SW	S	SE	O
		A S P E C T								
Legend:										
- fewer trees than expected, Chi-Sq 2.5-5.										
+ somewhat more trees than expected, Chi-Sq 2.5-5.										
x more trees than expected, Chi-Sq 5-10.										
X many more trees than expected, Chi-Sq >10.										
All relationships significant (p<.05).										

Table 5. *Quercus stellata* distribution by slope and aspect.

	85°-90°									
	62°-84°									
S	49°-61°									
L	41°-48°									
O	33°-40°		+							
P	25°-32°									
E	17°-24°									
	9°-16°				-		+		+	
	0°-8°			X	x	+		x		
		E	NE	N	NW	W	SW	S	SE	O
		A S P E C T								
Legend:										
- fewer trees than expected, Chi-Sq 2.5-5.										
+ somewhat more trees than expected, Chi-Sq 2.5-5.										
x more trees than expected, Chi-Sq 5-10.										
X many more trees than expected, Chi-Sq >10.										
All relationships significant (p<.05).										

Table 6. *Quercus alba* distribution by slope and aspect.

	85°-90°									
	62°-84°									
S	49°-61°									
L	41°-48°	X								
O	33°-40°			X	x					
P	25°-32°		+			X				
E	17°-24°						+			
	9°-16°									
	0°-8°							+		
		E	NE	N	NW	W	SW	S	SE	O
		A S P E C T								
Legend:										
- fewer trees than expected, Chi-Sq 2.5-5.										
+ somewhat more trees than expected, Chi-Sq 2.5-5.										
x more trees than expected, Chi-Sq 5-10.										
X many more trees than expected, Chi-Sq >10.										
All relationships significant (p<.05).										

Table 7. *Quercus velutina* distribution by slope and aspect.

	85°-90°									
	62°-84°									
S	49°-61°									
L	41°-48°									
O	33°-40°									
P	25°-32°									+
E	17°-24°									
	9°-16°									
	0°-8°				+	+	+			
		E	NE	N	NW	W	SW	S	SE	O
		A S P E C T								
Legend:										
- fewer trees than expected, Chi-Sq 2.5-5.										
+ somewhat more trees than expected, Chi-Sq 2.5-5.										
x more trees than expected, Chi-Sq 5-10.										
X many more trees than expected, Chi-Sq >10.										
All relationships significant (p<.05).										

Present-day fire regime

The historic record, already cited, includes numerous mentions of fire in the landscape, some attributed to humans, and others of uncertain origin. Data on present-day lightning-set fires show a high peak in August (with an average of 26 fires), with high numbers also in July and September (figure 2). This differs from the average monthly thunderstorm number, which had a broad peak centered in July (figure 2). Fires, but not thunderstorms, were also frequent in April (figure 2).

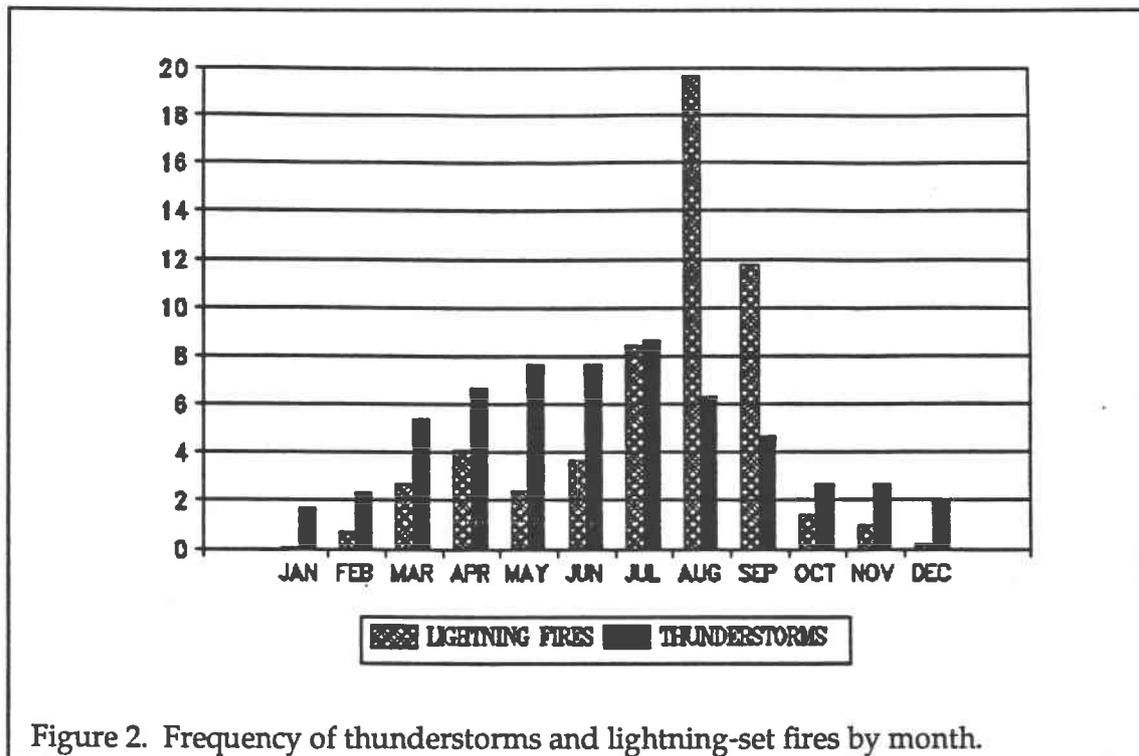


Figure 2. Frequency of thunderstorms and lightning-set fires by month.

Discussion

The historical literature and the GLO notes demonstrate that the Ouachita Mountain region supported at the time of settlement a diversity of plant communities distributed in relationship to topographic and microclimatic factors. Each of the three study sites was dominated by a distinct assemblage of species with a distinct forest structure. Furthermore, examination of individual corner data and surveyors' mile notes show considerable geographic variation even within each of the study sites.

In comparing sites, *Pinus echinata* was virtually ubiquitous in the pre-settlement forests of the Ouachitas, but it varied greatly in dominance. Hardwoods, primarily oaks, were a major component on most sites, especially at the southern end of the TRANS1 sample. This was apparently caused by dominance of oaks on shale substrates and pine on sandstone.

Red-cockaded woodpeckers are currently located in an area (the RCW site) that had an abundance of pines in the pre-settlement forest. This area was probably superior habitat in the past and has remained so since.

Microsite distributions of individual dominant tree species documented by land survey records were generally consistent with present-day patterns. *Pinus echinata* was on south aspects and intermediate slopes, *Quercus velutina* was on west aspects, and *Q. alba* was found on north and east aspects over a wide range of slopes.

The large numbers of *P. echinata* found on northwest aspects in pre-settlement vegetation is not noted in current literature. This may have been caused by unusual local climatic conditions or disturbance regimes, or may be a characteristic of *P. echinata* distribution that has been overlooked.

The GLO distribution of *Quercus stellata* is particularly intriguing. It was strongly associated with gentle slopes and flats in the pre-settlement forests. This is inconsistent with current descriptions of its distribution which place it on steep slopes (Foti 1974, Mayo and Raines 1986, Moore 1972). This change may be a result of present-day reduced fire frequency, which has allowed less fire tolerant species to dominate the gentle slopes. Former, increased fire frequency on the level valley floors would have allowed this fire-tolerant species to dominate.

The basal areas and stem densities in the land survey data (8.6-11.6 m²/ha and 100-150 stems/ha) were less than those in old growth forests of the Central Hardwood Forest (25-35 m²/ha and 161-427 stems/ha - Parker 1989). This implies that old growth did not exist widely in this region, or that its structure was substantially different from eastern forests. It may also result from a bias in the surveyors' selection of young, and perhaps more distant bearing trees that were more likely to survive than closer, older trees. The historical literature supports the view that the forest was more open at the time of settlement and that fire contributed to that low density.

Although the GLO survey notes documented forests with a relatively low density and basal area, consistent with frequent burning, the forest was not typically open savanna. The density of 100 trees/ha on two sites was well above the density of 47 trees/ha proposed by Anderson and Anderson (1975) as a criterion for savanna. Nevertheless, it must be emphasized that the figures obtained in this study were of large areas and studies scaled locally would be more sensitive for identifying savanna sites.

Modern lightning-fires indicate most fires occur in August, with many in adjacent months, which is consistent with early accounts of fire. In addition, the historical literature maintains that people, both native Americans and settlers, frequently set fires. However, the frequency of fires at any one place was not enough to eliminate hardwoods, but was apparently enough to influence vegetation composition and

structure. The timing of late summer and fall fires may have reduced their effectiveness in killing fire-sensitive species.

Since lightning-set fires and the fires referred to in the historic record occurred at approximately the same time (lightning-set: Jul-Sept; historic: Sept-Nov) it seems clear that humans were not imposing a new disturbance regime, but rather were modifying the natural regime by increasing the frequency, reducing the intensity, or shifting the timing to later in the Autumn when the ability of fires to kill vegetation would be reduced. Therefore the native Americans probably did not produce the overall vegetation patterns seen at and before the time of settlement, but rather modified and emphasized the patterns that resulted from the climatic fire regime.

Data developed in this study are of value in identification of old-growth communities in the Ouachita region, in guiding management of those areas, and in providing perspective on more "naturalistic" management of general forest land. It aids identification by documenting landscape patterns, species composition, site relationships, etc. It can guide old-growth management by documenting the structure of the original forests and the physical processes that shaped those forests, both of which should be maintained in old-growth management. Finally, the study can aid in developing management plans for the general forest area by identifying sites where species were likely to occur in high or low abundance under "natural" conditions. A GIS can dramatically aid this process by displaying or mapping these sites for incorporation into management plans. Forest management plans that attempt to have least impact on natural communities should relate to these patterns. Such a map can be refined to include overall species composition and the variation in compositions found on a given site so that management plans can be tailored to provide maximum landscape scale (gamma) biodiversity.

Further analysis of the existing data set will be undertaken to more clearly define both within-site and between-site variation. In addition, we recommend that all GLO records for the Ouachitas be digitized, analyzed, and incorporated into the Ouachita National Forest planning process. At the same time, existing stand conditions should be digitized for comparison. Besides the obvious management and identification value of such data, future studies can also use existing old growth forest and remaining witness or bearing trees to test the analysis and predictions based on historical field data.

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Pre-settlement Vegetation of the Ozark National Forest¹

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Abstract

Evidence gathered from examination of early Government Land Office (GLO) survey records and other historical sources indicates that the composition of pre-settlement vegetation on the Ozark National Forest (ONF) probably was not dissimilar to that now present. The structure of pre-settlement vegetation, however, is more difficult to determine. Pre-settlement vegetation types of the Ozarks region either described in or interpreted from early records include prairies, glades, pine forest, mixed pine-hardwoods forest, and several kinds of hardwoods forest. Today hardwoods occupy the majority of the forests on the Ozark National Forest, primarily in the form of some phase of oak or oak-hickory forest type. The remainder consists of shortleaf pine (*Pinus echinata*) and shortleaf pine-oak types. Glades, often dominated by eastern red cedar (*Juniperus virginiana*) or white cedar (*Juniperus ashei*), and prairie openings interrupt the forest cover locally. Reduced incidence of fire may have contributed to increased cover by members of the sugar maple (*Acer saccharum sensu lato*) complex, eastern red cedar, and understory vegetation in general but that is not known with certainty.

Introduction

A better understanding of the structure and composition of pre-settlement vegetation on the Ozark National Forest is highly desirable. Finding a way to determine the character of that original forest, though, is difficult. Examination of various historical records has shown that none provides a full account of pre-settlement vegetation in the Ozarks region. Few explorers penetrated the Ozarks of Arkansas prior to settlement. In Missouri, on the other hand, several skilled observers traveled widely in the Ozarks region before settlers arrived in numbers. Few of the early explorers had the necessary training or background to give a good assessment of the vegetation of the Ozarks. The surveyors who ran the original landlines surveys, though, left copious notes which generally are of high quality.

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Historical Record

Important among the early explorers into Northwest Arkansas were Nuttall (1819), Schoolcraft (1821, 1853), Featherstonehaugh (1835), Lesquereux (1860), and Harvey (1875-1885). Nuttall barely entered the area occupied by the Ozark National Forest, because his journey was almost totally confined to the Arkansas River and areas south of the river. Featherstonehaugh, Schoolcraft, and Lesquereux each visited areas near to if not on the Sylamore Ranger District but none left observations in either sufficient accuracy or detail to be of much value in a reconstruction of 19th century vegetation. Harvey was a faculty member at Arkansas Industrial University, Fayetteville, where he conducted an on-going field study of Arkansas vegetation during the 10-year period of 1875-85.

Harvey's early observations were among the best of all observers to that time and it is unfortunate he was not earlier on the scene. He wrote (1883): "North of the Arkansas River a great many deciduous trees grow with the pines. The percentage of pine increases as you go South, but there are no forests exclusively pine in the State." Harvey also stated, "...in Arkansas pine largely replaces pine, which would insure a continued supply," suggesting an edaphic subclimax condition for pine forest types.

The 1880 federal census report (Sargent, 1884) included an inventory of standing timber reserves in the U.S. and specifically for the state of Arkansas, giving a detailed account of pine reserves by county. Also included was a state map showing the distribution of prairies and forests having commercial value. The map, dated 1881, was attributed to C. S. Sargent, but it almost certainly was based on the work of F. L. Harvey. Harvey, according to oral tradition passed down from early Arkansas botanists, was trained in "forestry" although just what that meant in the post-Civil War period of his training is not known. Harvey had a major interest in tree species, traveled widely, and did field work throughout the state during the period of 1875-85. He was active in professional circles in the East, corresponding regularly with leading botanists of the period and publishing numerous papers on Arkansas plants.

Steyermark (1959) provided a detailed vegetational history of the Ozarks region, although most of his observations were directed toward Missouri rather than Arkansas. He championed the idea that pre-settlement vegetation in the Ozarks was little different from that of today, at least in Missouri.

Government Land Office survey notes

Field notes of the original Public Land Survey are among the most valuable of all records giving insight into pre-settlement vegetation of Arkansas. Hutchison (1988) gave a useful account of how the field notes from Illinois surveys could be used in reconstructing pre-settlement vegetation patterns.

Congressional acts of 1811-12 provided bounty lands for service in the War of 1812, and Arkansas had 1 of the 3 military reserves used to process the claims. One

principal meridian was established in 1815 and the earliest GLO land district in the state was established at Little Rock in 1821 (Eakle and Cerny, Eds., 1984). Surveying on lands now in the Ozark National Forest apparently did not begin, though, until the late 1820's. Field notes and plats for the entire state are on file in the State Land Survey Office, Little Rock. Copies of the field notes pertinent to the National Forest also are on file at the pertinent Ranger District office.

Vegetation information from GLO records

Examination of the GLO records clearly indicate that the Ozarks region, at least in Arkansas, was vegetated in pre-settlement times by a mosaic of types not dissimilar from those now present. The early surveyors distinguished vegetation types still present: prairies, glades, and forest communities. All were indicated in field notes and often delineated on the plats. Comparison of numerous sites across the Forest generally indicates a fairly close similarity between GLO records and present communities with the exception of former prairie areas. The map of Sargent (1884) showed that extensive prairies occurred locally in northwest Arkansas with major concentrations found in Benton and Washington counties. Examination of the GLO records has shown close agreement with Sargent's map. Most of this map probably was compiled from the work of F.L. Harvey (if not by he himself).

Unfortunately, less than 100 acres remains of the original prairies in those counties and practically nothing remain on the Ozark National Forest other than remnant species long-persisting after habitat destruction. Within the boundaries of the Ozark National Forest, significant prairie acreages occurred only on the Wedington unit of the Boston Mountain Ranger District. Prairies there formed something of a ring around the present-day Wedington Unit with small prairie acreages included on the Unit. Dry-mesic prairies dominated by bluestem grasses (*Andropogon spp.*) occurred, often over residual chert, on both the Wedington and Sylamore units. Other small prairie acreages occurred on the Buffalo and Pleasant Hill Ranger Districts as well as on the Magazine Ranger District. No indication of prairies on the Bayou Ranger District has been found but probably they occurred there also.

Glades are defined as rocky barrens dominated by a herbaceous flora with sparse woody vegetation. In the GLO records many of the areas described as "barrens" probably correspond to glades. Glades were well represented in GLO records. Examination of the GLO records for the Buffalo, Sylamore, and Wedington units indicates the early surveyors found glades in abundance. Those on the Buffalo and Sylamore units typically were dominated by cedar, either eastern red cedar or white cedar. Typically, the glades intergraded with either prairie or thin woods, making their recognition a subjective call and often probably were not broken out clearly in the notes despite their apparent occurrence.

GLO records indicate the following forest types were well represented in pre-settlement vegetation patterns on lands presently within the Ozark National Forest: mesic communities dominated by either beech-maple (*Fagus-Acer*) or a more complex

mixture of hardwood species, white oak-hickory (*Quercus alba-Carya*), red oak-hickory (*Q. rubra/falcata-Carya*), black oak-hickory (*Q. velutina-Carya*), xeric oak communities dominated by either blackjack oak (*Quercus marilandica*) or post oak (*Q. stellata*) or both, shortleaf pine or pine-hardwoods types, and possibly others.

Generalizations derived from historical sources

Bass (1981) said "Logging in the Ozarks had begun by 1879 although fewer than 10 steam sawmills then operated within the Cherokee Reservation. Following construction of the railroads this number increased and by 1890, the lumber industry was established." The railroad line from Little Rock to Fort Smith was operating in 1874 and the need for railroad ties undoubtedly created local demands for oak timber. In all probability, though, much of that demand was provided by mills located close to the line and it was not until considerably later that more mills were established further and further into the forest. It is said that Newton County timber remained little impacted by the lumber industry until after 1900 (Lackey, 1950). Railroad ties constituted one of the most important early uses of hardwood and resulted in the removal of the largest and best of at least oak timber. It does not seem unreasonable to suspect that removal of the large old oak trees from mixed pine-oak stands served to convert those areas to predominantly pine stands.

The question of how much pine was "originally" in the Ozarks has been a subject of much debate over many years. Sargent's map of 1881 indicates a broad area of north-central Arkansas with significant quantities of standing pine timber. This distribution can not be completely explained solely by edaphic factors. Also, while those areas were settled by 1880, there is no indication the settlers had effected significant timber removal. Attempts to relate railroad tie and stave production to the significant pine acreages also seem to fall short.

The question remains as to whether the areas with indicated pine reserves were essentially virgin pine stands or whether they were a result of some type of disturbance, either natural or by man. It should be noted that the 1880 Federal census report for Arkansas (Sargent, 1884) said:

The pine forests are almost intact. Settlements made for agricultural purposes have been confined to bottom lands, and only during the past few years has pine lumber been manufactured in the state, except to supply a very limited local demand. Recently, however, comparatively small quantities of lumber manufactured at numerous railroad mills, principally established south of the Arkansas River, have been shipped north and south out of the state.

It should be noted that examination of the GLO records clearly indicates the presence of pine in the western counties, but the Sargent map does not indicate commercial supplies in those counties.

Discussion of GLO record strengths and weaknesses

The GLO survey records constitute the only quantitative data available from any of the early 19th century documentation. The bearing trees can be treated statistically in much the same way data from the time-honored quarter-point method of vegetation sampling have been used. Therefore, the GLO records are well suited to interpretation of species composition but probably are less well suited to community structure. Attempts to use GLO records to reconstruct structure of virgin forest communities, in my opinion, should be approached with caution and should take into account the following:

(1) Selection of bearing and witness trees by the surveyors was subjective. The current *Manual of Surveying Instructions* (Bureau of Land Management, 1973) is the result of numerous revisions and is based on a combination of both statutory law and actual survey practices. Bearing trees normally were selected within a distance of 3 chains of the corner. Trees were selected, where possible, with a view to the length of their probable life. Sound trees, not matured, were preferred and it was considered better to avoid marking fully matured trees, especially those showing any signs of decay or unusually large size. Ordinarily trees of 25-40 cm (10-16 inches) in diameter are (and were) preferred by surveyors. One does not know if the bearing trees as recorded accurately represent the diameter and spacing of dominant tree species. Examination of the records for known stands with high site indices indicates that bearing trees often are similar in size to trees in stands with much lower site indices. This suggests the surveyor did indeed choose bearing trees that were healthy and of less than mature size. The goal was to select trees that would stand for a long time into the future and that were sound enough to support the extensive blazing and marking operations.

(2) There is little way to assess the importance of fire from the GLO records. Not once in GLO records for the Ozarks have I seen direct reference to fire. Numerous authors have promoted the idea that fire was an integral part of the development of the vegetation of the Ozarks region. Steyermark (1959) discussed much of the evidence. Stahle et al. (1985) derived a 450-year drought reconstruction for Arkansas and gave data to support regular periods of severe drought over the period. This would suggest periods during which competition for moisture resulted in death of many trees in the forest: if not mature trees certainly young ones. Any resulting open spaces should have provided habitat for grasses and the opportunity for regular ground fires. Stahle et al. postulated that 10 droughts equal to or more than 10 years in length (years 1555, 1570, 1595, 1670, 1765, 1835, 1850, 1875, 1900, and 1915) had occurred in the period of 1531-1980. They indicated the period of 1549-1577 may have been the worst June drought period for Arkansas in the past 450 years. The interface between forested areas in the Ozarks and prairies and plains to the west undoubtedly has been a dynamic ecotonal zone over the past several thousand years. A clear understanding of the relationships between prairie, fire, and Ozarks forests, though, remains to be demonstrated.

(3) The incidence of tornado damage was assessed by the surveyors but other types of natural disturbance were rarely indicated in the survey notes. Several instances have been seen in the GLO records where mention was made of entering a "hurricane" while running the landlines. Hurricane was a term used to describe the windthrow of trees following a tornado. A number of streams in the Ozarks are called Hurricane Creek because of past major damage from a tornado. The role of insect damage and/or disease in creation of openings and secondary succession in pre-settlement vegetation is not known. Similarly, any role(s) played by either native Americans or large herds of wandering bison, particularly on the more western portions of the Ozark National Forest, is not known.

(4) There often is some degree of confusion in knowing what was meant by the surveyors' general vegetation descriptions. What, for example, is the difference between prairies and barrens? Glades and barrens? From evidence seen to date it looks as though some surveyors used the term "barrens" synonymously with what today is usually called a "glade." Some barrens, though, appear to have been very dry and others very wet. Similarly, the difference between "slough" and "pond" is not always clear. The upland perched wetland systems commonly known as "upland swamps" or "natural ponds" appear to be used interchangeably with the term "slough" in at least a few cases.

(5) Today's surveyors say it is much more difficult to make good time in surveying than it was in the original surveys. The length of time it took the surveyors to run their lines in comparison with the same task today indicates conditions may have changed. The land surveyor for the Ozark National Forest, is convinced that there was less underbrush present in pre-settlement times, which allowed the surveyors of the time to make rapid progress. He says it took 30 days to do an average township, regardless of how rugged the terrain, and that there is no way the job could be done in that time today due to the amount of underbrush (H. Humerickhouse, personal communication). The GLO records generally do not adequately assess the undergrowth and there appear to be considerable differences in the descriptions from one surveyor to another.

(6) Particularly on more mesic sites, the presence of lower strata (both herbaceous and woody) is important in differentiating communities. Unfortunately, GLO records are not very helpful in this respect. Through much of the Boston Mountains region, for example, the distinctive umbrella magnolia (*Magnolia tripetala*) often serves to indicate a mixed mesophytic community which possibly has a relictual relationship with the mixed mesophytic communities several hundred miles to the east. Thus far, no mention has been seen in the GLO records of umbrella magnolia. Beech (*Fagus grandifolia*) is another component of the mixed mesophytic community but it often occurs to the exclusion of umbrella magnolia and under those conditions seems to represent a different community. When only beech is indicated in the GLO records it is difficult to know which community was present. Similarly, sugar maple/Florida maple (*Acer saccharum/A. floridanum*) may be expanding its occurrence from the pre-settlement condition. Throughout the Ozarks region we see young maple trees on

slopes that do not appear to be mesic enough to have supported maple historically. GLO records suggest that "sugar trees" were more localized along streams and on very mesic sites than is the case presently. Whether or not young trees were found on slopes as is the case today is unknown. Eastern red cedar may be more abundant than in the past. Some studies have pointed to the reduction in fire as the reason, although Steyermark (1959) has argued there probably has been little change in red cedar distribution. In view of the fact there was a probable bias against using cedar as a bearing tree unless there was nothing else present, though, it is hard to make real comparisons.

(7) Much has been written about the park-like nature of most virgin hardwood forest in the eastern states (Braun and others, 1950). Many have assumed that much of the original forest in Arkansas was composed of widely spaced trees of large size and characterized by a closed canopy. Examination of the data from GLO records does not allow one to confirm this.

(8) Examination of the GLO records clearly shows that some surveyors recorded much more information than others. The directions provided to the surveyors by the government outlined the minimal requirements for adequate field notes. Some surveyors did just that and others gave considerably more information. It is those surveyors who wrote down more than was required who often give additional insight into the character of the vegetation. Those are the townships in which more reliable estimates of pre-settlement vegetation structure can be made.

Conclusions

Determination of what the pre-settlement vegetation in the Ozarks region was like remains a largely unanswered question. Numerous glimpses into historical documentation suggest it may have been much different from that of today. Much more work remains to be done, particularly in a systematic analysis of GLO data and comparison with vegetation occurring on the sites today. Many of us may be surprised to learn what old growth in the Ozarks really looked like in pre-settlement times. Some of our long-held ideas may fall when better information becomes available.

An old hickory tree that was cut on the Ozark National Forest in the past year may be instructional. Recorded as a 25 cm (10-inch) bearing tree in the 1845 survey, by 1990 it was slightly over 30 cm (12 inches) in diameter. There undoubtedly were many, many trees of massive dimensions in the original forest. On the other hand, there may have been just as many or more that were nothing out of the ordinary either in terms of size or habitat. Until we do a better job of analyzing available documentation we just don't know.

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Pre-settlement Birds and Mammals of the Interior Highlands¹

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Abstract

Birds and mammals present in pre-settlement times (ca. early 1800s) within the Interior Highlands of Arkansas and Oklahoma are identified based upon remains from archeological sites, accounts of early explorers and travelers, and from published works on birds and mammals from Missouri, Arkansas, and Oklahoma.

Geese and ducks were common, as were trumpeter swans, accipiters, passenger pigeons, Carolina parakeets, and most woodpeckers. Wild turkeys were ubiquitous and greater prairie-chickens were extremely common, but numbers dwindled by the turn of the century due to unregulated hunting and habitat changes, as did those of the once-common ruffed grouse. Although undoubtedly common during pre-settlement times, species of passerines (songbirds) and smaller mammals, such as bats, mice, and rats, were almost unrecorded by early travelers. Composition of both groups has probably changed little since settlement.

Some larger mammals, such as elk, wolves, mountain lions, and bison, were common in pre-settlement times, but populations disappeared soon after settlement due to over-harvesting and persecution. Beaver, black bear, river otter, and white-tailed deer were also common, and their populations also declined following settlement due to over-harvesting, but they are common in areas of the Interior Highlands again today due to successful restocking programs.

Introduction

The Interior Highlands of the United States encompass the Ozark Plateau in the southern half of Missouri, northern Arkansas, and northeastern Oklahoma, the

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Ouachita Mountains in western Arkansas and southeastern Oklahoma, and slivers of Illinois and Kansas. Oak-hickory forests of the eastern deciduous forest reach their best development and greatest diversity in this region (Braun 1950). The largest areas of oak-hickory forests without pine occurred in southern Missouri and northern Arkansas (Shelford 1963). From early accounts, much of the Ozarks and Ouachita Mountains were forested at the time of settlement in the early 1800s (Steyermark 1959). White oak (*Quercus alba*) forests occurred in more mesic situations on the Ozark Plateau and shortleaf pine (*Pinus echinata*) forests dominated the Ouachita Mountains and parts of the Ozarks of Missouri and Arkansas (Sargent 1884, Dale 1986). Few uncut stands still exist, and much of the Ozarks today is covered in secondary vegetation in various stages of succession (Braun 1950). Also, prairies existed within the Ozark Plateau, especially along the western border, and along the Arkansas River in Arkansas (Sargent 1884, Transeau 1935, Schroeder 1982).

Prior to 1800, most inhabitants of the Interior Highlands were Native Americans. Settlement from the east began after the Louisiana Purchase of 1803 and human populations in Missouri and Arkansas increased greatly after statehood in 1821 and 1836, respectively. Populations in the Ozarks increased further during the "logging boom" of the late 1800s and early 1900s, when most of that region was stripped of trees (see Smith and Petit 1988). Logging operations early in this century also removed most old trees in the Ouachita Mountains, the last extensive tracts of virgin timber that remained in eastern United States (Smith 1986).

By all accounts, the pre-settlement Interior Highlands were a hunting and fishing paradise (Sutton 1986), but rapid settlement and subsequent habitat alteration profoundly affected animals of that region. In many cases, it is not possible to directly assess those impacts because the pre-settlement fauna was poorly known. For example, the first scientific collections of fish in Arkansas were made in the 1850s (Robison and Buchanan 1988) and herpetological studies in Missouri did not begin until the late 1800s (Johnson 1987). However, recent archeological excavations in Arkansas and Oklahoma have yielded remains of many pre-settlement birds and mammals (Sabo et al. 1982). Early travelers also made remarks about birds and mammals that they saw. Based on those sources, many pre-settlement birds and mammals can be identified in the Interior Highlands, allowing an attempt to assess effects that settlement had on those species.

Sources of Information

Archeological sites

Archeological sites occupied in and near the Interior Highlands prior to settlement (table 1) have yielded bones of some birds (table 2) and many mammals (table 3). Faunal lists from prehistoric sites are, of course, biased towards those animals that were hunted and used by early inhabitants. This analysis combines information that, in some cases, spans several thousand years (table 1), so that one should not conclude

Table 1. Archeological sites in or near the Interior Highlands of Arkansas and Oklahoma that contained remains of birds and mammals. Numbers at left are used in Tables 2 and 3.

Site name	Location	Dates of occupation	Source
Arkansas			
1. Ozark Bluffs	Northwest Arkansas	500 - 1400 AD	Cleland (1965)
2. Albertson	Benton Co.	200 - 1700 AD	Dickson (in press)
3. Goldsmith Oliver 2	Little Rock	1500 - 1700 AD	Scott and Jackson (1990)
4. Hardman	Clark Co.	1450 - 1700 AD	Styles and White (1990)
5. Ink Bayou	Pulaski Co.	900 AD	Colburn (1987)
6. Toltec Mounds	near Little Rock	500 - 900 AD	Hoffman (1980), Rolingson (1982)
7. Sliding Slab Shelter	near Booneville	2650 BC - 1200 AD	Marrinan (1981)
8. Alexander	Conway Co.	700 - 900 AD	Styles et al. (1985)
9. Rush	Buffalo National River	900 AD	Scott (1990)
10. Ridge House	Washington Co.	1800 AD	Jurney (1978)
11. Ten Mile Rock	Washington Co.	pre-1600 AD	Medlock (1978)
Oklahoma			
12. Wister Lake	LeFlore Co.	300 BC - 1200 AD	Galm (1978)
13. Curtis Lake	LeFlore Co.	292 BC - 1400 AD	Galm (1978)
14. Bug Hill	Pushmataha Co.	1000 - 1600 AD	Byrd (1983)
15. Scott and Wann Sites	Wister Valley	2500 BC - 700 AD	Galm and Flynn (1978)
Missouri			
16. Rodgers Shelter	Benton Co.	9000 BC - 1500 AD	McMillan (1971)

Table 3. Species of mammals found in archeological sites in and near the Interior Highlands based on frequency of occurrence rather than taxonomic order. Numbers in legend refer to sites in Table 1 (continued).

Common name	Scientific name	Arkansas										Oklahoma					Mo		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
Bobcat	<i>F. rufus</i>	X	X																
Badger	<i>Taxidea taxus</i>									X						X			
Long-tailed Shrew	<i>Sorex sp.</i>									X									
Least Shrew	<i>Cryptotis parva</i>															X			
Big Brown Bat	<i>Eptesicus fuscus</i>															X			
Jack Rabbit	<i>Lepus sp.</i>															X			
Flying Squirrel	<i>Glaucomys volans</i>		X																
Marsh Rice Rat	<i>Oryzomys palustris</i>								X										
Prairie Vole	<i>Microtus ochrogaster</i>																X		
Rat	<i>Rattus sp.</i>										X								
Red Wolf	<i>Canis rufus</i>													X					
Red Fox	<i>Vulpes vulpes</i>														X				
Long-tailed Weasel	<i>Mustela frenata</i>															X			
Eastern Spotted Skunk	<i>Spilogale putorius</i>																X		
Small mammals					X													X	

that all birds (table 2) and mammals (table 3) mentioned here from a particular site coexisted at that site or that they occurred during present day climatic conditions. Original sources (table 1) should be consulted to find exact dates of occurrence and relationships of fauna to paleoclimates.

Early travelers and explorers

People traveling with the expedition of De Soto, which entered what is today Arkansas in 1541, were the first to mention animals of the region (Wilmer 1859). Over the next 250 years, a number of explorers, trappers, and travelers visited the region, many of whom recorded wildlife that they saw (Nice 1931, Deaderick 1941, Ganier 1973, Griffiee 1986). Fort Orleans was established in 1724 and a trading post was established in 1763 at the confluences of the Mississippi and Missouri rivers, both primarily for trading deer and beaver furs (McKinley 1960, Schwartz and Schwartz 1981). That trading post later became known as St. Louis. Records of furs shipped in the early 1800s from Arkansas Post (Plaisance 1952, Bearrs and Brown 1971), at the confluences of the Arkansas, White, and Mississippi rivers, and by A. P. Chouteau, who operated a trading post in the early 1800s near present-day Muskogee, Oklahoma (Foreman 1926, Lecompte 1972), provide insight into pre-settlement abundances of furbearers.

After the Louisiana Purchase of 1803, a number of important expeditions and travelers visited the Interior Highlands. President Thomas Jefferson sent William Dunbar, a friend from Natchez, Mississippi, to explore the Ouachita Mountains in 1804 (President of the United States 1807, Deaderick 1941, Foti 1976). The famous Lewis and Clark Expedition, which had the stated purpose of assessing abundance and distribution of furbearers in the Louisiana Territory (Wishart 1979), passed through Missouri in 1804. Schoolcraft (1821) was the first to write in detail about his travels through the Ozarks of Missouri and Arkansas, which occurred in 1819. The naturalist Thomas Nuttall (1821) also traveled through much of western Arkansas and eastern Oklahoma in 1819. An expedition lead by Major Stephen H. Long to map the Louisiana Territory for the U.S. Army traveled through Missouri and Arkansas several times (James 1905). Thomas Say was the naturalist on that expedition. Unfortunately, his manuscript describing animals encountered was stolen by deserting soldiers and was never recovered (Deaderick 1941). In 1835, G. W. Featherstonhaugh, a geologist, traveled along the eastern edge of the Interior Highlands on a trip from Missouri to Texas, recording much about animals that he encountered (1844). Frederick Gerstäcker, a German adventurer, spent 1839 to 1841 hunting a wide variety of animals throughout Arkansas, later publishing accounts of those hunts in a book "Wild Sports in the Far West" (1859).

Other general sources

General historical perspectives on abundance and distribution of birds and mammals exist for both Missouri (McKinley 1960) and Arkansas (Holder 1951, Griffiee 1986). Foti (1976) discussed expeditions in the early 1800s in Arkansas and provided a map

showing routes taken by those mentioned in the previous section. Sabo et al. (1982) presented an overview of the archaeology of the regions of the Ozark National Forest.

Five books have been written concerning birds of Arkansas (Howell 1911; Wheeler 1924; Baerg 1931, 1951; James and Neal 1986). James (1974) and Smith and Petit (1988) also are important sources of information about past distributions and abundances of birds within the region. Widmann (1907) and Nice (1931) discussed pre-settlement distributions of many bird species for Missouri and Oklahoma, respectively. Books also have recently been published concerning mammals in Arkansas (Sealander and Heidt 1990), Missouri (Schwartz and Schwartz 1981), and Oklahoma (Caire et al. 1989).

The Pre-settlement Avifauna

Early accounts of birds in the Interior Highlands focused on game species, making it possible to estimate abundances of those birds prior to settlement. Other groups, such as herons, pelicans, vultures, and owls, were mentioned with such frequency that they must have been common during appropriate seasons at the time of settlement (Widmann 1907, Nice 1931). Hawks, and possibly kites (Widmann 1907), also were reported in early accounts, but only the red-tailed hawk (scientific names listed in table 2) is still commonly found within the region (Smith and Petit 1988). Shorebirds were numerous in prairie regions during migration in pre-settlement times (Schroeder 1982). For example, flocks of lesser golden-plovers (*Pluvialis dominica*) were reported to have covered the ground for acres in Missouri in 1834 and woodcocks (*Scolopax minor*) and snipes (*Gallinago gallinago*) were common game species in the mid-1800s (McKinley 1960). However, populations of all shorebirds, with the possible exception of killdeer (*Charadrius vociferus*) (Smith and Petit 1988), have declined within the region due to the slaughter of shorebirds in the late 1800s (McKinley 1960).

Almost nothing was recorded concerning songbirds prior to settlement of the Interior Highlands. Smith and Petit (1988) concluded that many birds associated with deciduous forests in the Ozarks that are common today probably also were common at the time of settlement. Assessing former status of passerines in the Ouachita Mountains is more difficult since earliest reports are from this century (e.g., Baerg 1927, Deadrick 1938).

Swans. Swans were reported by travelers in the early 1880s in Oklahoma (Foreman 1926, Nice 1931), the Ozarks of Missouri (Schoolcraft 1821) and Arkansas (Deadrick 1941), and in the Ouachita Mountains (President of the United States 1807, Deadrick 1941). They also were a motif on pre-settlement clay pots (see James and Neal 1986) and found in the Rodgers Shelter (table 2). According to most (Widmann 1907, Nice 1931), those reports were of trumpeter swans (*Cygnus buccinator*), a species with a very restricted range today.

Geese. Geese were reported by several early travelers (Schoolcraft 1821, Featherstonhaugh 1844, Foreman 1926, Schroeder 1982) and did appear in one archeological site (table 2). Both Canada and snow (*Chen caerulescens*) geese were migrants and possibly winter residents within the region. Canada geese apparently bred in Missouri in pre-settlement times (Widmann 1907) and probably in Arkansas, at least in the eastern part (Corning 1929).

Ducks. By all accounts, ducks were common in fall, winter, and spring in the Interior Highlands (Schoolcraft 1821, Featherstonhaugh 1844, Foreman 1926, Griffie 1986), particularly in marshy areas in prairies (Schroeder 1982, Bolen et al. 1989). The wood duck, the only breeding species, was a common motif on pre-settlement clay pots (see James and Neal 1986). A variety of ducks have been found in archeological sites, mallard (or American black duck) being found most often (table 2). Mallards continue to be the most abundant wintering duck within the region (Nice 1931, James and Neal 1986).

Eagles. Both Schoolcraft (1821) and Gerstacker (1859) shot "eagles", but neither specified which species. Bald eagles (*Haliaeetus leucocephalus*) were probably common at the time when bison were abundant in eastern Oklahoma (Nice 1931) and they formerly nested in the Missouri Ozarks (Wilson 1984). James (1974) attributed their subsequent decline to loss of habitat and persecution by hunters. Golden eagles (*Aquila chrysaetos*) apparently were more common in former times within the region (Widmann 1907, Nice 1931). Wheeler (1924) reported a golden eagle nest in the Ozarks.

Accipiters and Falcons. Mentioned in early accounts as "blue darters" for their speed and "blue devils" for their habit of raiding farmyards, sharp-shinned (*Accipiter striatus*) and Cooper's (*A. cooperii*) hawks probably bred within the Interior Highlands at the time of settlement, although recent nesting records are rare (James and Neal 1986). At the turn of the century, Widmann (1907) thought that density of sharp-shinned hawks in Missouri had not been affected by settlement, and that persecution of all hawks by farmers was due to Cooper's hawks removing young chickens from farmyards. Baerg (1951) considered Cooper's hawk to be "relatively common in northwestern counties" of Arkansas.

Ospreys (*Pandion haliaetus*) also formerly nested along bluffs of all major rivers in Arkansas and Missouri, but were rare by 1910 (Widmann 1907, James 1974). Peregrine falcons (*Falco peregrinus*) also nested along river bluffs in Missouri prior to settlement, but had become rare by the turn of the century (Widmann 1907). The last recorded nesting in Arkansas was along the Little Red River in 1888 (Howell 1911).

Galliformes. Ruffed grouse (*Bonasa umbellus*) were probably common in the Ozarks prior to settlement (Widmann 1907, Smith and Petit 1988). Due to over-hunting, grouse were declining in some areas of Missouri by 1835, but also increasing in other areas opened by settlers (McKinley 1960). However, they were rare by the turn of the century in both Missouri and Arkansas (Widmann 1907, Howell 1911). No evidence

exists that they occurred in eastern Oklahoma (Nice 1931) or in the Ouachita Mountains of Arkansas (D. James, personal communication). Ruffed grouse have been successfully reintroduced in Missouri (Lewis et al. 1968) and a reintroduction project is continuing in Arkansas (Widner et al. 1988). Greater prairie-chickens were once extremely common on prairies within the Interior Highlands (Schwartz 1945, James and Neal 1986), on open ridges within the Ozarks (Bennitt 1939), and in eastern Oklahoma (Nice 1931). Populations declined rapidly in the latter part of the 1800s (Bennitt 1939). Birds were rare in Arkansas by the turn of the century (Howell 1911), and the total population in Missouri was estimated to be 12,500 birds at that time (Schwartz 1945). Schwartz (1945) attributed the decline to market hunting, indiscriminate killing of adults and young, plowing of prairies, and increased cultivation of land. James (1974) argued that reintroduction in Arkansas would be futile because remaining prairie patches were too small.

By all accounts, wild turkey were ubiquitous and extremely common at the time of settlement (Widmann 1907, Nice 1931, James and Neal 1986). They also were the most frequently encountered bird species in archeological sites (table 2). Populations were declining by 1835 in some parts of Missouri due to over-hunting, but turkeys were still plentiful in other areas in 1850. Populations increased in Missouri Ozarks as a result of a reprieve from hunting during the Civil War (McKinley 1960), but turkeys were nearly extirpated from the Arkansas Ozarks by the turn of the century (Howell 1911). Successful translocation projects have restored the turkey to most of its former range in the Interior Highlands (James et al. 1983).

Although found in archeological sites (table 2) and mentioned by early travelers (e.g., Schoolcraft 1821:44), Northern bobwhite probably became more numerous as a result of agricultural activities during the 1880s (Baerg and Warren 1949, McKinley 1960). Nonetheless, populations declined in Missouri and Arkansas by the turn of the century (Widmann 1907, Howell 1911), most likely because of unregulated hunting.

Passenger Pigeon. Passenger pigeons probably did not breed in the Interior Highlands, but they could be very common in winter (James and Neal 1986). Remains of passenger pigeons have been found in many archeological sites in and around the Interior Highlands (table 2) and pigeons were commonly reported by early travelers (e.g., Featherstonhaugh 1844, Schroeder 1982). Passenger pigeons fed substantially on hard mast crops during fall and winter and were thought to be nomadic. "Flight years" occurred several times during the mid-1800s in Arkansas, such as in fall of 1841, when the Arkansas Gazette reported that 900 pigeons were killed with 15 shots outside Little Rock on 27 October and 110 pigeons were killed with one shot on 3 November. The last reliable record for the species in Arkansas was of a bird shipped to market in Little Rock from Cabot at Christmas in 1899 (Schorger 1955).

Carolina Parakeet (*Conuropsis carolinensis*). By most accounts, Carolina parakeet was locally common in the Interior Highlands in the early 1800s and bred in both Missouri (Widmann 1907, McKinley 1960) and Arkansas (McKinley and James 1984). Large raucous flocks were reported by early travelers (e.g., Featherstonhaugh

1844:346). Parakeets apparently ate fruit and at times were considered orchard pests (McKinley 1960). Parakeets nested in hollows of old trees (Widmann 1907) and McKinley (1960) suggested that cutting of such trees, particularly for honey, may have contributed to the demise of the species. Baerg (1951) reported that parakeets were persecuted by humans, killed for their feathers, hunted by farmers and fruit growers, and trapped and sold as caged birds.

Carolina parakeets apparently made a last stronghold in western and northwestern Arkansas until around 1885 (McKinley and James 1984). The last sighting of a Carolina parakeet in southern Missouri was in 1905 (Widmann 1907). Based on the apparent need for hollow old trees, Carolina parakeets may have been the first old-growth species to disappear due to logging of the Interior Highlands.

Woodpeckers. Woodpeckers have been found in several archeological sites (table 2) and were used as a motif on clay pots (see James and Neal 1986). All species of woodpeckers probably were common in the Interior Highlands in pre-settlement times (Smith and Petit 1988), and all remain fairly common today, with the exception of red-cockaded woodpecker (*Picoides borealis*). Now restricted to a few mature shortleaf pine stands in the Ouachita Mountains, all active sites in the Interior Highlands of Arkansas occur in the Ouachita National Forest in Scott and Polk counties (Neal and Montague 1992) and all remaining active sites in Oklahoma occur in the McCurtain County Wilderness Area (MCWA) except for one in Pushmataha County (Wood 1977, Masters et al. 1989). The species once occurred in the Ozarks in virgin shortleaf pine forests of both Arkansas (James and Neal 1986) and Missouri (Woodruff 1908, Eddleman and Clawson 1987), but red-cockadeds disappeared from those regions with the logging of those pine forests. Unlike other woodpeckers, red-cockadeds nest only in live trees infected with red heart disease caused by the fungus *Phellinus pini*. Many logged trees from virgin forests of the Ouachita Mountains pictured in Smith (1986) clearly had red heart disease, suggesting that many suitable nest trees were available prior to logging. Red-cockaded woodpeckers have been reported from at least 52 sites within the Arkansas Ouachitas, but only 14 sites are presently active (Neal and Montague 1992); similar numbers also have been documented in McCurtain County and surrounding counties in Oklahoma (Wood 1977, Masters et al. 1989). The logging boom in the Ouachitas between 1910 and 1950, during which most virgin pine stands were removed (Smith 1986), caused an initial decline of red-cockaded woodpeckers, and additional losses have occurred as the result of fire suppression. Natural fires once maintained dominance of pine and an open, park-like condition in certain stands, making the habitat suitable for red-cockadeds. Fire suppression allowed hardwoods to invade those formerly open pine woodlands, making them unsuitable for this woodpecker (Neal and Montague 1992). Present-day virgin pine-oak woodland in the MCWA once included large areas of pure open stand of pine (see Bruner 1931), but fire suppression in the MCWA allowed a dense hardwood midstory to develop, which contributed to a significant decrease in woodpecker numbers in that area (Masters et al. 1989).

Although present in bottomland forests of eastern Arkansas (James and Neal 1986), eastern Oklahoma (Nice 1931), and extreme eastern Missouri (Widmann 1907), no valid records appear to exist for ivory-billed woodpecker (*Campephilus principalis*) within the region (Tanner 1942).

Passiformes. Some passerines associated with pine woods, such as brown-headed nuthatch (*Sitta pusilla*), are found today primarily south of the Arkansas River, although they formerly occurred further north in southern Missouri (Widmann 1907). Bachman's warbler (*Vermivora bachmanii*), a species present in southeastern Missouri in the late 1880s (Woodruff 1908), may have disappeared with the loss of extensive "canebrakes" (*Arundinaria gigantea*) (Remsen 1986). Willow flycatcher (*Empidonax traillii*), a prairie specialist in this region, was first collected by Audubon in 1822 in Arkansas. After being nearly extirpated from the state during this century (James and Neal 1986), there are recent nesting reports from a degraded prairie in northwestern Arkansas, where the flycatcher was reported nesting at least 40 years ago (see Baerg 1951). Other species dependent on early successional vegetation or post-fire succession, such as blue-winged warbler (*Vermivora pinus*) and Bachman's sparrow (*Aimophila aestivalis*), probably initially benefited from settlement and clearing of land, although their populations remain at low levels today. Other species associated with forest edge and agricultural lands, such as meadowlarks, robins, cowbirds, and blackbirds, are now much more common than at pre-settlement times (James and Neal 1986).

The Pre-settlement Mammalian Fauna

All early travelers in the Interior Highlands remarked on the abundance of large mammals, particularly elk (scientific names listed in table 3), bears, deer, wolves, panthers, bison, beaver, and otters (Schoolcraft 1821, Nuttall 1821, Featherstonhaugh 1844, Gerstäcker 1859, Griffiee 1986). The fur trade flourished during the early 1800s. At Arkansas Post, one company shipped 930 bear skins, 680 kg of beaver skins, and 500 bales of deer skins in 1806 (Plaisance 1952). Bison skins fetched 75 cents in 1817, although bison were hunted mainly for fat at that time (Bears and Brown 1971). From trading posts in eastern Oklahoma and southwestern Missouri, A. P. Choutaeu shipped 17,572, 17,617, and 22,727 kg of deer skins in 1823, 1824, and 1825, respectively, as well as many skins of beaver, otter, raccoon, wolf, and bear (Lecompte 1972). Such exploitation could not continue for long. Schoolcraft (1821) remarked that game was mostly gone from the northeastern Ozarks by 1818. The "fur era" for central Missouri was over by 1822, and concerns were raised about decreasing number of deer in 1823, due to hunting for skins (McKinley 1960).

Large carnivores were greatly feared and persecuted by early settlers. McKinley (1960) reported that the first bounty law was passed in 1816 by the territorial legislature of Missouri, effective 1817. For adult "wolves" (coyotes and gray wolves) and "panthers" (mountain lions) taken within 16 km of settlements, \$2.00 certificates that could be used as legal tender were offered; the bounty on "wildcats" (bobcats)

was 50 cents. That bounty law was repealed effective 1 April 1819, but another act was passed in 1825 to encourage killing of wolves. In 1837, a statewide bounty was offered on wolves, but it was repealed in 1845. From 1840 to 1842, the state of Missouri paid out \$7,629 in wolf bounties. Another state-wide coyote-wolf bounty law was passed in 1855.

Many large mammals disappeared very quickly after settlement of the Interior Highlands in the early 1800s, including an endemic race of ocelot (*Felis pardalis albescens*) that may have occurred in the extreme southern part of the Interior Highlands (Sealander and Heidt 1990). Based on faunal lists from archeological sites (table 3), it appears that most small mammals that are common today also were present in pre-settlement times. However, as with songbirds, few early travelers mentioned anything about the smaller mammals, such as bats, squirrels, mice, voles, and shrews, that they encountered.

Rabbits. Eastern cottontails and swamp rabbits were probably common during pre-settlement times. Eastern cottontails were frequently found at archeological sites (table 3) and they are abundant in the Interior Highlands today. Also found at several archeological sites (Table 3), swamp rabbits have declined in abundance due to draining of swampy areas, clearing of floodplains, and damming of rivers (Caire et al. 1989).

Black-tailed Jack Rabbit (*Lepus californicus*). A number of species that are associated with prairies and open plains, such as jack rabbits, have been more common in the western Interior Highlands during past warmer climatic periods, but they also may have benefited more recently from clearing of forests. In Missouri, jack rabbits were formally plentiful, but populations have been declining in recent years (Schwartz and Schwartz 1981). Jack rabbits apparently are not known from the Oklahoma Ouachitas (Caire et al. 1989).

Plains Pocket Gopher (*Geomys bursarius*). Found in many archeological sites (table 3), gophers apparently were numerous at the time of settlement, e.g., gopher mounds hindered the early plowing of prairies in Missouri (McKinley 1960). They now are absent from southern Missouri (Schwartz and Schwartz 1981), uncommon in the Oklahoma Ozarks (Caire et al. 1989), and found only in a few small prairies remaining in northwest Arkansas.

Squirrels. At least 19 13-lined ground squirrels (*Spermophilus tridecemlineatus*) were recorded from the Conard Fissure in Newton County, Arkansas (Brown 1908). The presence in the Conard Fissure of this prairie ground squirrel, as well as antelope and other mammals more typical of arid western environments, reflects climate change during the Holocene. Hypsithermal conditions prevailed in the Interior Highlands between 8700 and 5000 years ago, bringing with it the spread of prairie grasslands and faunal associates (Sabo et al. 1982:58, and references therein). Ground squirrels apparently were present up to about 1000 years ago (Guiday and Parmalee 1971), and have recently expanded in range once again into tongues of prairies that extend into

the western Ozarks, due to clearing of land for agriculture (Schwartz and Schwartz 1981).

Remains of both gray and fox squirrels are common in archeological sites (table 3), and both species are common throughout the Interior Highlands today.

Beaver. Found in almost all archeological sites (table 3), beavers were reported as very common throughout the Ozarks and Oklahoma in the early 1880s (Schwartz and Schwartz 1981, Caire et al. 1989). However, they were all but eliminated by 1900 from the entire region due to extensive trapping that began in the late 1700s and continued in the 1800s. Only a few colonies remained, particularly in remote Ozark watersheds. Restocking and translocation programs in this century have reestablished beavers throughout the region.

Building of dams by beavers and subsequent formation of ponds behind dams had a strong influence on the landscape (see Schwartz and Schwartz 1981) and the distribution of many other animals (e.g., McDowell and Naiman 1986, Reid et al. 1988). Since the Interior Highlands were not glaciated, beavers were the main source of pond formation in pre-settlement times and probably functioned as a keystone species (sensu Paine 1966) by increasing habitat and species diversity. Beavers also can have a profound influence on vegetation structure and on the process of succession itself, particularly on flood plains and riverbanks (e.g., Barnes and Dibble 1988).

Muskrat. Probably common in pre-settlement times (table 3), the muskrat is one of the most abundant furbearers in Missouri and Arkansas today, due to the increase in farm ponds this century (Schwartz and Schwartz 1981). The highest density today in Oklahoma also occurs in the Ozark region (Caire et al. 1989).

Coyote. Based on the rare occurrence of bones in archeological sites (table 3), western Arkansas is considered to be the eastern edge of the historic range of coyote prior to settlement (Nowak 1978). Abundance probably fluctuated with climatic conditions, being greatest during long-term dry periods (Gipson 1978) and, more recently, following clearing of forests (Sealander and Heidt 1990). Bones from some sites exhibit characteristics intermediate to those of coyotes and red wolves, suggesting that hybridization was occurring prior to settlement (Gipson 1978).

Gray Wolf (*Canis lupus*). Gray wolves were common in the Interior Highlands in the early 1800s (Gipson 1978), but they disappeared very rapidly following settlement (Schwartz and Schwartz 1981). Few historical accounts exist from Oklahoma during the 1800s, although 6 specimens were collected in the northeast corner of the state in 1902 (Caire et al. 1989).

Red Wolf. Red wolves also were common in the woods of the Interior Highlands at the time of settlement, but were extirpated from much of their former range by 1900 (Gipson 1978). Gipson (1972) attributed that decline to clearing of land, over-

exploitation of prey species by humans, predator control programs, and, eventually, availability of mates.

Dog. Domestic dogs, often termed "Indian dogs", also were common at the time of settlement (Gipson 1978), as they have been found in many archeological sites (table 3). Those dogs commonly hybridized with wolves and coyotes (Gipson 1978).

Red Fox. The time period in which red foxes actually appeared in the southeastern United States is a matter of debate; they were not common in archeological sites within the region (Table 3). Nonetheless, circumstantial evidence suggests that they may have been common within the region at the time of settlement (see Zumbaugh and Choate 1985), possibly due to clearing of forests that allowed populations of preferred prey (small rodents and rabbits) also to increase (Schwartz and Schwartz 1981). Highest densities in Oklahoma today occur within the Ozark region (Caire et al. 1989).

Gray Fox. Although found in many archeological sites (table 3), gray fox abundance at the time of settlement is unclear (Zumbaugh and Choate 1985). Population densities today are highest within the Ozark region in all three states within the region.

Black Bear. Black bears were important to early residents of the Interior Highlands and were a valuable commodity to early settlers of Arkansas (Smith et al. 1991). Bears were numerous in the early 1800s (McKinley 1960, Schwartz and Schwartz 1981, Smith et al. 1991) and thousands were killed annually by commercial hunters during French and Spanish occupation of Arkansas and Missouri (Holder 1951). In fact, the number of bear skins stretched to dry in front of a house was a status symbol (Schoolcraft 1821). Nuttall (1821) and Gerstäcker (1854) recorded observations concerning bears (also see Sutton 1986), and legends of big bears in Arkansas in the early 19th century (Bangs 1846) figured prominently in the mythology of the American frontier. At that time, Arkansas may have had the largest populations of black bears in North America (Dellinger 1942). Arkansas was unofficially known as "The Bear State" prior to the General Assembly of 1923 (Holder 1951). Over-exploitation from unregulated hunting and habitat alteration due to lumbering and agricultural activities (e.g., Smith 1986, Smith and Petit 1988) caused the near elimination of bears from Arkansas by 1940. But, even as early as the 1830s, there were reports that bear populations in Arkansas were declining (Featherstonhaugh 1844, Gerstäcker 1854). Bear populations also declined in Missouri and Oklahoma by 1850 and only a few remained by 1880 (McKinley 1962, Schwartz and Schwartz 1981, Caire et al. 1989). Today more than 2,500 black bears exist within the Ozark and Ouachita regions and adjacent areas because of a restocking effort that began in 1958 (Smith et al. 1991). Although probably found as far east as central Oklahoma (Caire et al. 1989), there is no evidence that grizzly bears (*Ursus arctos*) occurred in the Interior Highlands.

Raccoon. Found in almost all archeological sites (table 3), raccoons were probably common at the time of settlement. Although populations declined in the early part of this century (Schwartz and Schwartz 1981), raccoons are an abundant furbearer throughout the region today. Schwartz and Schwartz (1981) suggested that preservation of suitable den trees is the most important aspect of management for this species.

Badger. Badgers were one of the few animals that probably were not common prior to settlement (Schwartz and Schwartz 1981). They were all but eliminated from the region by the turn of the century due to plowing of prairies, poisoning of burrowing rodents (their main prey), and poisoning and trapping of badgers themselves (Schwartz and Schwartz 1981). Widely scattered populations of badgers exist today within the region (Schwartz and Schwartz 1981, Sealander and Heidt 1989), with a few badger records from eastern Oklahoma, but none from the Oklahoma Ouachitas (Caire et al. 1989).

River Otter. Otters were probably common at the time of settlement (Polechla 1987), although extensive trapping of otters and beavers had begun in the mid- to late 1700s (Holder 1951). Numbers declined during the 1800s due to trapping and hunting, so that otters were rare by the turn of the century throughout the region (Holder 1951, Schwartz and Schwartz 1981, Sealander and Heidt 1990). Populations have slowly increased in Arkansas since the middle of this century (Holder 1951, Polechla 1987).

Mountain Lion. Mountain lions also were present at the time of settlement throughout the Interior Highlands, but populations declined very quickly, primarily due to persecution. Further decline and possible extirpation may have followed the decline of their main prey item, white-tailed deer. It is unclear whether cougars or "catamounts" still exist within the region.

Elk. Found in many archeological sites (table 3), elk were common prior to settlement (e.g., Schroeder 1982). However, they disappeared very quickly, being scarce in Missouri by 1830 (Schwartz and Schwartz 1981) and extirpated from Arkansas by 1840 (Sealander and Heidt 1990). Several hundred elk exist today along the Buffalo National River in Arkansas due to a reintroduction started in the early 1980s.

White-tailed Deer. Found in every archeological site (table 3), deer were abundant prior to settlement. Schwartz and Schwartz (1981) estimated that 500,000 deer may have been present in Missouri in the early 1800s, and one report mentioned that 700 deer were killed in one drive in 1808 (McKinley 1960). However, due to the over-harvesting mentioned earlier, populations dwindled by the turn of the century, so that there were only 500 deer in Oklahoma in 1917 (Caire et al. 1989), 395 deer in Missouri in 1925 (Schwartz and Schwartz 1981), and less than 500 deer in Arkansas in 1930 (Holder 1951). Due to restocking efforts begun in 1925 in Missouri and in the 1930s and 1940s in Arkansas (Holder 1951), deer are again abundant within the Interior Highlands.

Bison. Bison were common prior to settlement in Oklahoma (Caire et al. 1989), present in the Oklahoma Ouachitas (Nuttall 1821) and in Arkansas (Sealander and Heidt 1990), but probably never abundant in Missouri (Schwartz and Schwartz 1981). Bison disappeared very rapidly, being nearly gone from Arkansas by 1830 and Missouri by 1840. Foraging by bison has been shown to have a positive effect on plant species diversity (e.g., Krueger 1986) and bison also can greatly influence vegetation structure by the creation of "wallows" (e.g., Polley and Collins 1984).

Pronghorn Antelope (*Antilocarpa americana*). Although they ranged into central Oklahoma and at one time may have out-numbered bison in abundance (Caire et al. 1989), pronghorns apparently did not occur in the Interior Highlands at the time of settlement. However, bones of antelope are present in some older archeological sites (e.g., Rodgers Shelter [McMillan 1971], Ten Mile Rock [Medlock 1978], Albertson [Dickson 1991]) documenting their presence in the region during the Hypsithermal period.

Conclusions

A great diversity of birds and mammals inhabited the Interior Highlands 200 years ago, but nearly all large birds and mammals have been adversely affected by settlement since that time. A few animals, such as elk and bison, disappeared very quickly, while most declined throughout the 1800s as the human population within the Interior Highlands continued to grow. In addition to obvious effects of habitat alteration due to logging of virgin forests and draining and plowing of prairie areas, swans, ruffed grouse, prairie chickens, turkey, black bears, elk, deer, and bison declined due to over-harvesting and unregulated hunting. Beavers, badgers, and otters also declined due to overharvesting by trappers. Hawks, eagles, falcons, Carolina parakeets, small mammals such as gophers, wolves, badgers, and mountain lions declined mainly from persecution by early settlers. Although initially affected by logging of pine, red-cockaded woodpecker populations may be declining further due to recent fire suppression.

Although the evidence is sketchy, many smaller birds and mammals, such as ducks, forest songbirds, and squirrels, seem to have been relatively unaffected by settlement of the Interior Highlands, and some, such as coyotes and birds associated with edge and agricultural land, have increased in abundance due to settlement.

Regrowth of forests in both the Ozarks and Ouachita Mountains is again providing suitable habitats for species that require mature forests. Restocking and reintroduction projects during this century have restored populations of ruffed grouse, turkey, beaver, otter, black bear, elk, and white-tailed deer in many areas of the Interior Highlands. Some have been very successful, such as the reintroduction of black bear, which is probably the most successful reintroduction of a large carnivore in the world (Smith et al. 1991). Others, such as reintroduction of ruffed grouse (Widner et al. 1988) and elk in Arkansas, seem to be having some success, and

trumpeter swans are now reappearing in winter in Arkansas as a result of establishment of a breeding population in the northern Great Plains. However, it is unclear whether those animals will become as common as they were in pre-settlement times. Nonetheless, those reintroductions suggest that populations of most pre-settlement birds and mammals can be maintained in the Interior Highlands through management practices that provide suitable habitats including old-growth forests.

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Old Growth Stands of the Ouachita National Forest¹

Roger D. Fryar²

Abstract

Assessing old growth stands on the Ouachita National Forest requires (1) defining old growth characteristics, (2) identifying representative forest cover types, (3) estimating the extent of cover types, (4) determining stand locations and, (5) assessing the relative condition of stands with respect to age, size classes and density. Mapping of older stands for adjacency and landscape connectivity can greatly assist in planning efforts to manage for old growth. The Ouachita National Forest currently relies primarily on a database, Continuous Inventory of Stand Condition (CISC II), to facilitate answering questions about older stands. This database contains information regarding forest cover type, age, general location and condition of stands. The advent of Geographic Information Systems (GIS) that can interact with the CISC II database will allow resource managers further opportunity to analyze stands as they occur on forested landscapes and automatically update and display mapping. Other sources of information for assessing old growth are the Continuous Forest Inventory plot data (CFI) and a recently completed project whereby older stands were manually mapped for each ranger district on the forest.

Introduction

Definitions of what constitutes old growth on the Ouachita National Forest are now being formulated. Examples of original old growth stands are essentially nonexistent. Generally, today's mature growth is represented by stands having relatively larger and older trees with little evidence of human disturbance. Conceptual models must therefore rely on historical records and ecological knowledge.

Based upon historical accounts, typical pine old growth was characterized by open-canopied "parklike" stands with relatively low numbers per acre of large diameter overstory trees and herbaceous understory vegetation. This pyrogenic model would fit many of the descriptions given by early explorers and adventurers of the vast pine stands of pre-settlement times (USDA Forest Service 1990a). For mixed stands of pine and hardwood and for predominantly hardwood forest types, definitions are more difficult because of the lack of historical descriptions. Generally it is believed that old

¹ This paper was presented at the Conference on Restoring Old Growth Forests in the Interior Highlands of Arkansas and Oklahoma, held at Winrock International, Morrilton, Arkansas, September 19-20, 1990.

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growth mixed and hardwood forest types would have occurred on more northerly aspects and along stream courses. These stands might have had less evidence of a fire history and therefore contained many cavity trees with standing dead snags and downed woody debris (Martin this volume).

Methods

CISC II database

Resource managers on the Ouachita National Forest systematically inventory and record information for individual stands within a given area. These data are contained in the CISC II database. The intervals for updating data vary, but occur at least once every 10 years. Inventories include field-gathered data and information based on photo interpretation.

CISC II databases are retained at the ranger district and supervisor s office level and can be easily accessed for analysis.

A coding system allows resource specialists to enter data for a wide variety of conditions including forest cover type, tree size (height and diameter), age, basal area of woody components, midstory composition, general condition of trees, and identify wildlife and silvicultural needs. The basic geographic unit in CISC II is for a single compartment which administratively encompasses approximately 1000 to 1500 acres of land. Database queries can be used to compare and analyze sets of compartments to find total acres in a particular forest type and stand condition in a specific project area.

Queries of this database were run to ascertain acreages by forest type, age, land classification and ranger district.

Manual mapping

A recent project designed to manually map older stands on the Ouachita National Forest was completed during the summer of 1990.

This project required each ranger district to map older stands using data taken from CISC II records. Mapping was done on a scale of 1:24000. This work has since been transferred to a smaller scale (one-half inch to the mile) administrative map.

This mapping project currently provides a means of showing landscape connectivity, biogeographic corridors and adjacency of older stands on all lands of the Ouachita National Forest.

Mapping work was reviewed to determine relative locations of older stands over the forest.

Continuous forest inventory (CFI)

The Forest Inventory and Analysis (FIA) research work unit of the Southern Forest Experiment Station collects data on an approximate 10-year cycle to provide assessments of forest resources in seven southern states and Puerto Rico. These data include measurements taken on permanent plots of tree species in various size classes. A custom run of data for plots on the Ouachita National Forest was analyzed to determine diameter distribution by species groups and volumes of pine and hardwood on the Forest. Figure 6 shows these data in graphic form.

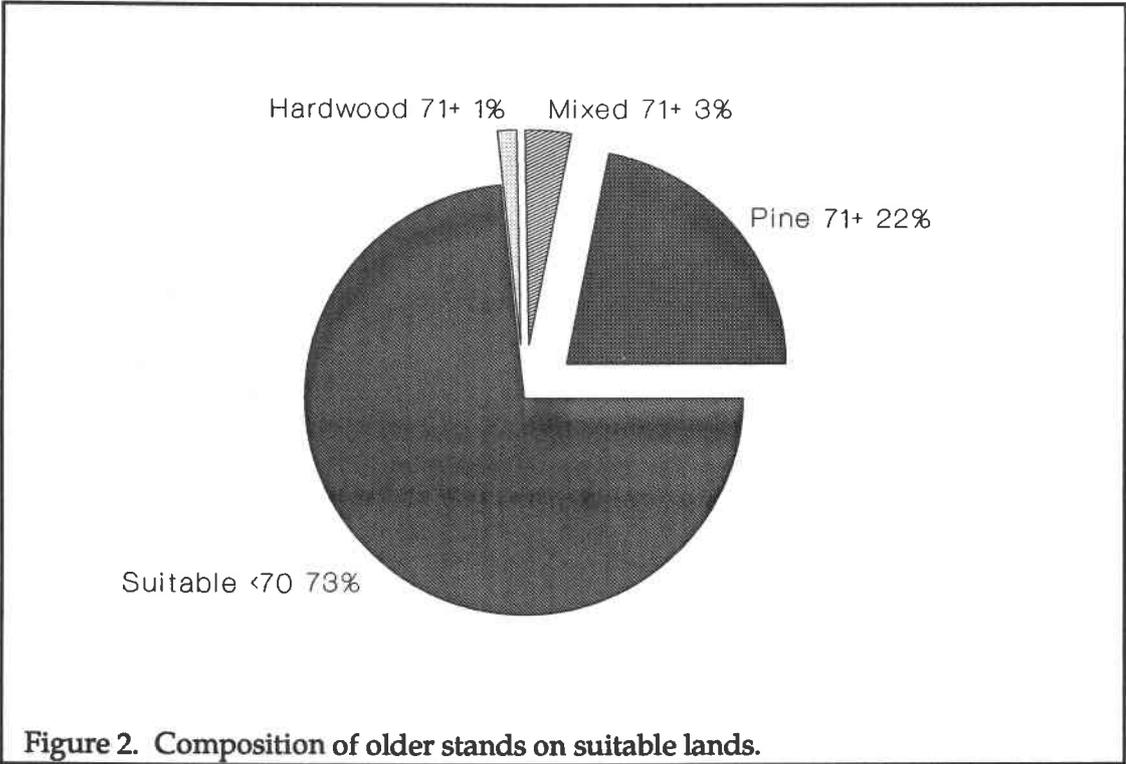
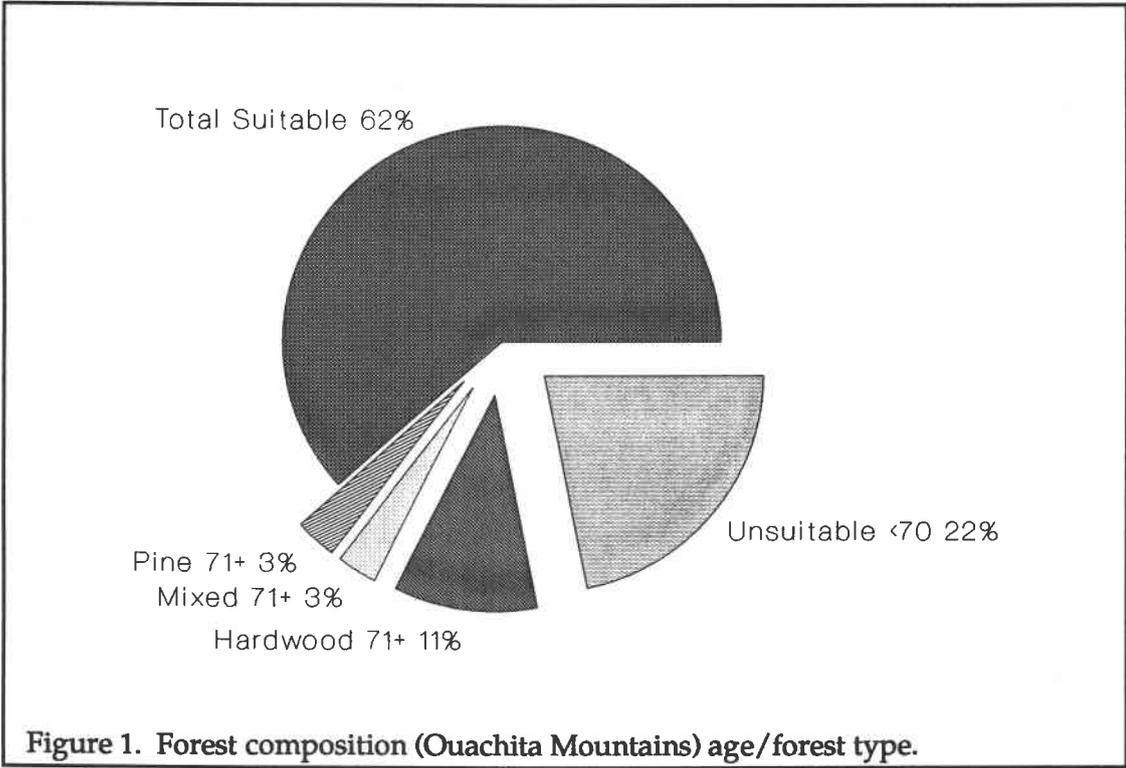
Results

CISC II analysis

Summaries of CISC II data for current stand conditions of the Interior Highlands portion of the Ouachita National Forest reveal that 528,084 acres of forest are comprised of stands that are 70 years old or older. Of this sum, 264,673 acres are pine, 81,714 acres in mixed pine and hardwood, and 181,697 acres are in hardwood types (table 1, figures 1 and 2).

Forest type	Acres >71 years old	Percent of total
Suitable acres		
Pine	215,754	13.5
Mixed	33,678	2.1
Hardwood	13,762	0.9
Subtotal	263,194	16.5
Unsuitable acres		
Pine	48,919	3.1
Mixed	48,036	3.0
Hardwood	167,935	10.5
Subtotal	264,890	16.6
Total	528,084	33.1

Forestwide, stands on the Ouachita are skewed toward older age classes. There are 23,318 acres 100 years old or older; 872,756 acres are 60 years old or older while only 254,301 acres are less than 20 years old (figure 3).



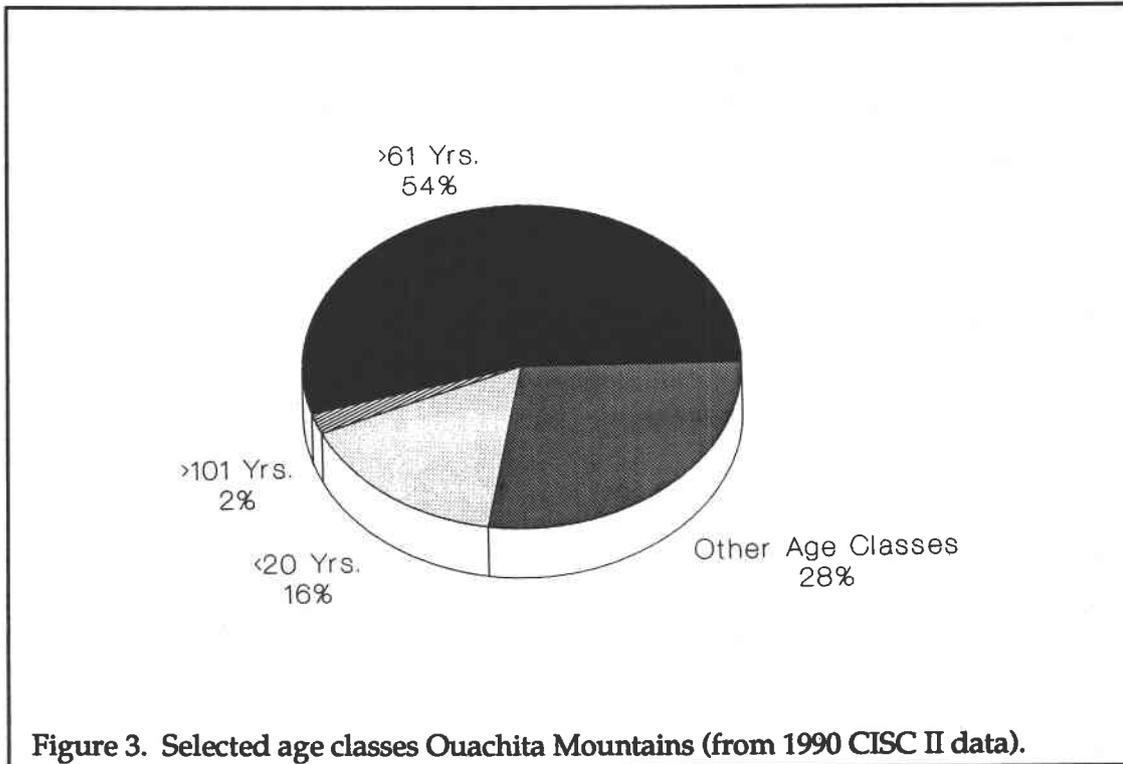


Figure 4 is a graph depicting age class distribution by 10-year age classes for 11 ranger districts.

Older stands (71 years) are not distributed uniformly over the forest but all districts have a representative amount (figure 5).

Land suitability analysis

The intensity of management for a given stand is dependent on its land suitability classification.

There are 20 management areas identified in the Forest Plan (USDA Forest Service 1990b), the management prescriptions ranging from essentially custodial care, e.g., Management Area #4 - Research Natural Areas and National Natural Landmarks, to moderate intensity management emphasis such as for Management Area #14 - Ouachita Mountains, Lands Suitable for Timber Production. Lands are broadly categorized as suitable and unsuitable based on potential uses for timber production. Suitable lands are those that, in general, can be managed for timber production utilizing a wide range of practices and intensities.

Areas may be classed as unsuitable lands because of multiple use objectives, administrative problems, physically limiting factors such as access or because of economic

considerations. These stands generally will not be subject to timber harvesting or other timber management activities.

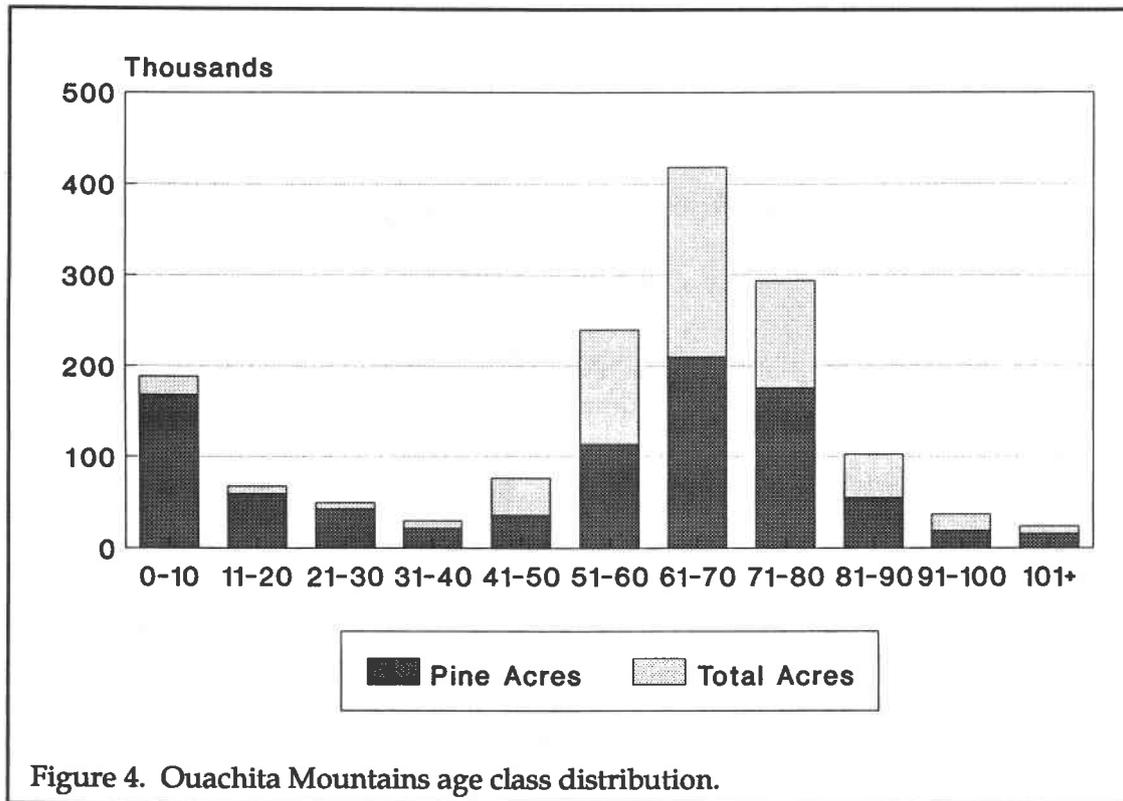


Figure 4. Ouachita Mountains age class distribution.

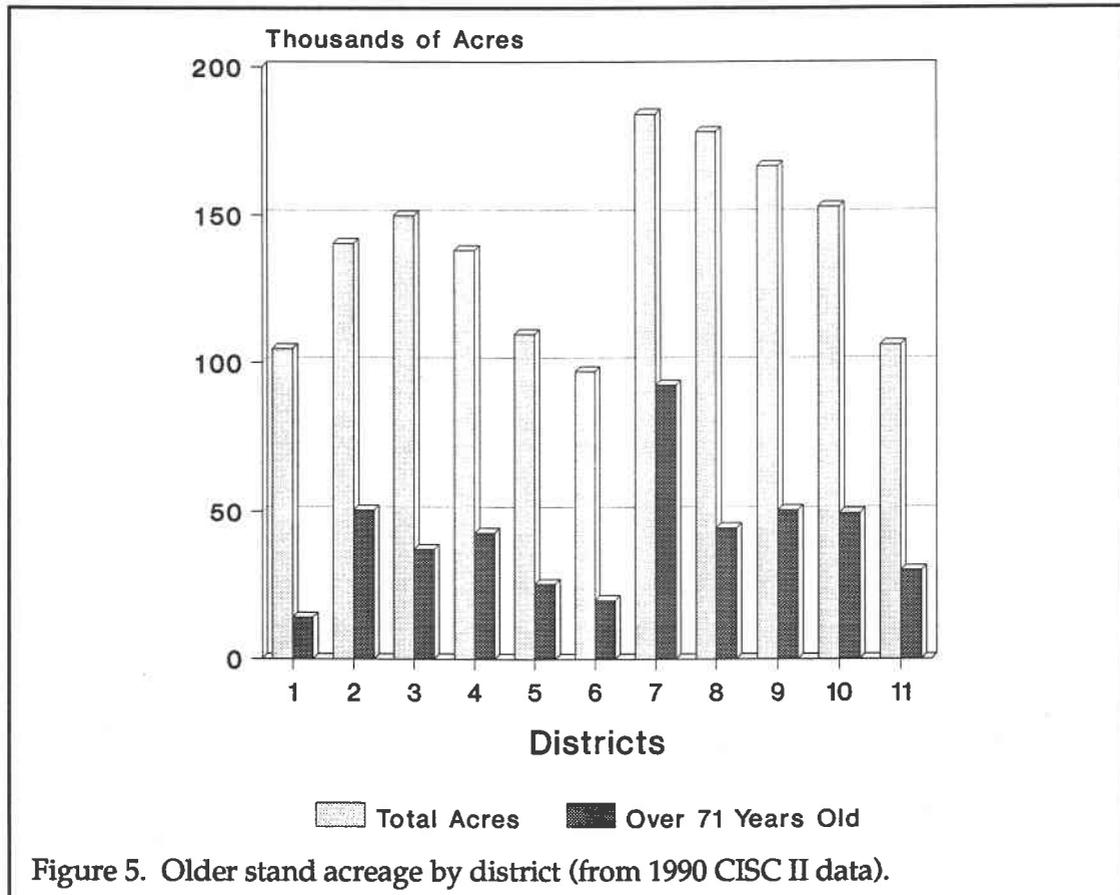
Table 1 and figures 1 and 2 show the percentages of suitable and unsuitable acres by forest cover types and older age classes. Approximately, 62% of the forest is classed as suitable. Of the remaining 38%, 22% is less than 70 years old.

Approximately 3% of the unsuitable land is pine cover type older than 70 years. Two percent is mixed pine/hardwood type 70 years and 11% is hardwood cover type 70 years. On suitable lands, 73% of the acreage is 70 years old. For stands 70 years in age, 22% is pine, 3% is mixed pine/hardwood and 2% is hardwood 70 years in age.

Continuous forest inventory (CFI)

Other information about stand characteristics can be extrapolated and summarized from CFI plot data.

Figure 6 shows the forestwide diameter distribution of softwoods and hardwoods and relative volumes. This graph was generated using a core table of data subset from CFI plots.



Discussion

Results of the CISC II queries indicate that age class distribution on the Ouachita National Forest is skewed toward relatively older age classes. There is an abundance of acreage in cover types of pine, mixed pine/hardwood and hardwood 70 years of age or older. A relatively small amount of the forest is 100+ years old. Older stands exist on all ranger districts with some districts having proportionally more than others.

Available data on stands inventoried as part of the CFI program indicate that forest-wide, diameter distribution is represented by a range of size classes skewed toward smaller diameters and that softwood volumes represent the vast majority of total timber on the forest. Fire control efforts have undoubtedly given rise to an increase in hardwood midstories and understories in older pine cover types (USDA Forest Service 1990b). Other studies have indicated that a significant non-pine woody component occurs in the majority of even-aged pine plantations on the Ouachita National Forest (Fryar and Clerke 1988). These conditions could account for the current diameter distribution. The implications of the CFI data reflecting a preponderance of

smaller diameter hardwood stems would indicate that vegetation management strategies, particularly prescribed burning, would be needed to reduce these components in older pine stands where restoration of old growth characteristics was desired. Future stand management of plantations could require treatments to reduce hardwood components to ensure old growth characteristics prevail.

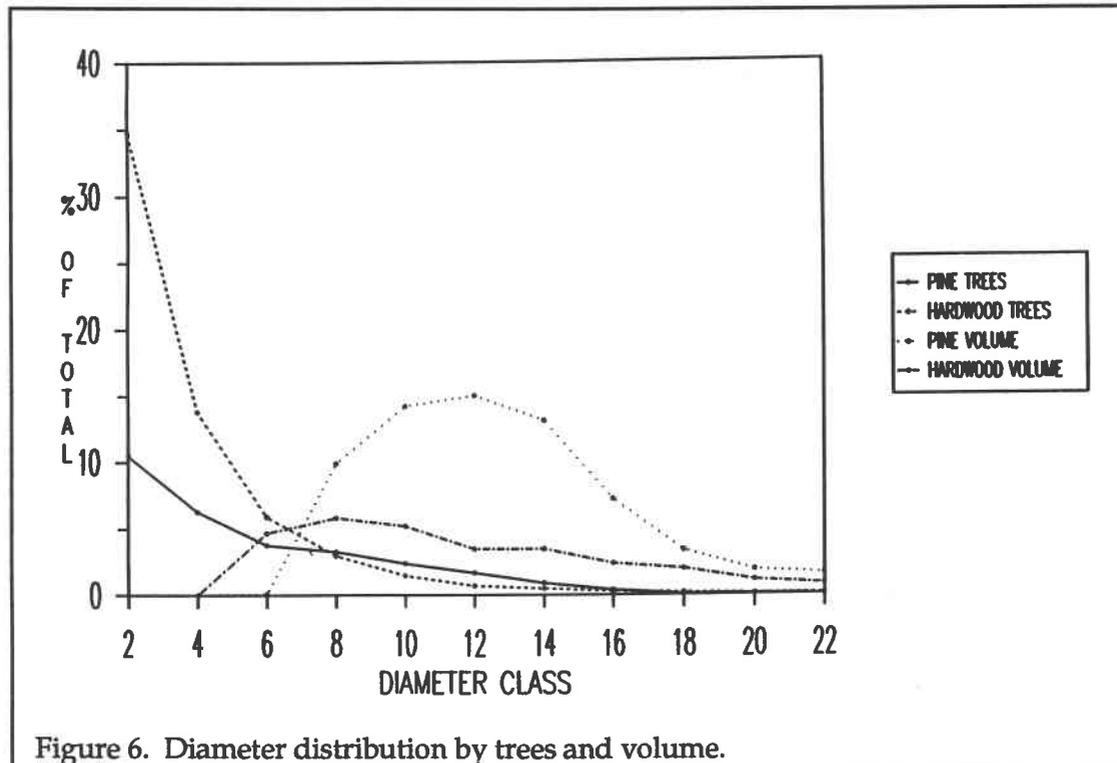


Figure 6. Diameter distribution by trees and volume.

One implication of the land suitability analysis is that a majority of the older pine stands occur on suitable acres. Management emphases for this landbase permit a wide range of practices and intensities to be employed to meet resource objectives. Management of these lands is usually focused on their potential uses for timber production. It is possible that some of these stands would need to be retained and harvesting be deferred as old growth restoration projects are implemented. On unsuitable lands, hardwood forest types less than 70 years old predominate. Management emphases on this landbase would tend to allow these forest types to persist to become stands with old growth characteristics.

The recently completed manual mapping project of older growth stands on the Ouachita National Forest is providing a tool for resource managers by identifying the location of older stands and visually displaying adjacency and connectivity to other inventoried stands.

Conclusion

The implications of CISC II, CFI, land suitability classification analysis and the old growth mapping project indicate that forest stands with some old growth characteristics do occur over extensive areas of the Ouachita National Forest. Older stands occur on a variety of landscapes on both suitable and unsuitable lands. Many older stands appear to be connected to other old stands.

Opportunities to further identify and manage relatively large areas in an effort to restore old growth characteristics appear good.

Current and future uses of GIS and other remote sensing technologies will provide additional methods of mapping and assessing older stands and may allow vegetation mapping and analysis of both inventoried and non-inventoried privately owned lands adjacent to the Ouachita National Forest. These new opportunities along with current knowledge of the forest conditions will help resource specialists to better identify and classify older stands and analyze their relative extent, location and condition while recognizing landscape-level linkages. These tools along with prudent management hold the key to restoring and managing old growth on the Ouachita National Forest.

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Older Stands of the Ozark-St. Francis National Forests: Type, Extent, Location, and Condition¹

O. D. Smith, Jr.²

The Ozark National Forest has been designating timber stands to be managed for development of old growth conditions for the past 13 years.

The Ozark Timber Management Plan (USDA Forest Service 1978), approved in September, 1978, divided the forest into four working groups. Nomenclature for these types is based on the Region 8 forest typing system which sub-divides Society of American Foresters (SAF) forest cover types into several additional classifications. The indicated forest types most closely resemble SAF type 53, white oak; SAF type 52, white oak-black oak-northern red oak; and SAF type 76, shortleaf pine-oak.

The pine working group, consisting of 347,800 acres of pine and mixed pine/hardwood stands, was scheduled for even-aged management using a rotation length of 80 years. The hardwood working group, consisting of 208,300 acres of hardwood and mixed hardwood/pine stands located on average to better sites, was set up to use even-aged management with a 100 year rotation. The marginal working group consisting of 332,800 acres of mostly hardwood stands on lower quality sites was not considered to be suitable for timber management. Timber cut within these areas would be for wildlife habitat improvement or salvage only.

The unique feature of the Ozark Timber Management Plan was the inclusion of an old growth working group consisting of 150,000 acres of hardwood stands located on both good and average sites. It is believed that this was the first timber management plan on a southern national forest to recognize the need to develop old growth conditions. The unit plan for the St. Francis National Forest, approved a year earlier in August 1977, did not mention establishment of old growth on the 22,000 acre St. Francis National Forest.

Of the stands to be included in the old growth working group on the Ozark, approximately 38,000 acres were to be located on good sites (Site Index 70 or better for red oak) with the remainder on lower quality sites. Included timber stands would be

¹ This paper was presented at the Conference on Restoring Old Growth Forests in the Interior Highlands of Arkansas and Oklahoma, held at Winrock International, Morrilton, Arkansas, September 19-20, 1990.

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identified as a part of the silvicultural prescription process over the ten year life of the plan. The entire forest would be examined during this ten year period.

The timber management plan stated the purpose of old growth was to "provide an ecological niche or habitat for plant and animal species that is not otherwise provided for in the other land classes or working groups". Stands selected for inclusion in the old growth working group would consist mainly of longer-lived species and would include stands classified as white oak, white oak-red oak-hickory, and southern red oak-yellow pine forest types. Selected stands would be widely distributed over the forest and would generally range in size from 25 to 100 acres, but no limits were placed on stand size.

Stand age was not specified as a criterion for selection of old growth candidate stands. Young stands as well as old ones could be designated as part of the old growth component if they met species composition and site quality requirements.

Even-aged management with a 200 year rotation length was specified for the old growth working group. Trees on good sites were expected to attain an average diameter at breast height of 30 inches or more in this time period while those on average sites would reach diameters of 18-20 inches. Under the proposed system of management, stands comprising the old growth working group would be regulated using area control with an annual regeneration objective of 750 acres. Stands would be reproduced by the clearcut or shelterwood method and receive periodic thinnings up to age 60 in order to maintain them in a healthy, vigorous condition. Thinning and salvage operations would be continued on an as-needed basis after age 60.

In other words, old growth would be managed similar to the rest of the forest but with a much longer (200 year) rotation. In the future the old growth component on the Ozark National Forest would consist of 750 acres of 200 year old stands, 750 acres of 199 year old stands, 750 acres of 198 year old stands etc. on down to 750 acres of bare ground which had been harvested the previous year. This model fits the classic even-aged management concept of a regulated forest and would provide for a continuous but constantly shifting mosaic of old stands.

The 1978 Timber Management Plan did not describe an old growth condition or specify any particular scheme of management designed to promote development of old growth conditions beyond lengthened rotations. Old growth was simply visualized as consisting of old timber stands with large trees which had been kept in a vigorous growing condition through good forest management practices and by maintaining a species composition consisting mostly of long lived species. In actual practice, most stands selected for inclusion in the old growth working group during the past 13 years have been older stands and few if any of them have been regenerated.

The 1978 Ozark Timber Management Plan and the St. Francis Unit Plan were superseded in October 1986 by the Ozark-St. Francis Land and Resource Management Plan

(USDA Forest Service 1986), a document which integrates management of all the resources of the two forests into one plan. The plan continued the commitment to develop an old growth component on the Ozark National Forest and extended that commitment to the St. Francis National Forest as well.

The plan also described the desired old growth condition as follows:

Old growth prescriptions create a condition instead of an age or rotation length. Old growth stands are diverse ecosystems exhibiting plant, vertebrate and invertebrate animal and aquatic organism diversity. The old growth prescription should furnish the following characteristics:

- two or more tree species with a wide size and age range, often containing long-lived shade tolerant associates
- a deep multilayered canopy
- more than ten individual live trees per acre that are over 120 years old, or that are over 22 inches diameter at breast height
- significant coarse woody debris including more than ten snags per acre over 20 feet tall
- at least four snags and logs per acre that have a greater than 22 inch diameter and 30 foot length.

Despite this rather detailed description of the old growth condition, the plan is not nearly as specific about how old growth candidate stands are to be managed as was the 1978 Ozark Timber Management Plan. The term "old growth prescriptions" as used in the plan refers to a set of linear programming model prescriptions which were used in FORPLAN analysis. These prescriptions consist of a set of constraints to the model which specify rotation length and thinning interval but provide no detail as to appropriate management practices for development of the desired old growth condition.

The plan does specify that old growth prescriptions will apply to 150,000 acres. Of this total, 65,000 acres will be designated for even-aged management practices. The remaining 85,000 acres will be managed using group selection cutting. These group selection stands will be at least 60 years old before cutting is initiated. Cuttings will be imposed at 20 year intervals thereafter and will consist of removing about 1/6 of the stand volume in small openings at each entry. Thinning will be done as needed between the openings to keep the stands healthy. The oldest trees in the stand will thus be about 180 years old before they are cut during the first sequence of 20 year cutting cycles. In subsequent cycles, assuming this method of management continues unchanged beyond the year 2100, the oldest trees in each stand would be 120 years old. While such stands would not have the same character as will 200 year old even-aged stands, they would contain many older trees and should have at least some of the characteristics associated with old growth.

Thus, the Ozark-St. Francis National Forest has been designating timber stands for inclusion in the old growth component for the past 13 years. How well have we done? There are currently over 900 individual timber stands containing about 57,000 acres designated for old growth management. The 1978 Timber Management Plan indicated that 150,000 acres would be designated within 10 years. The requirements set forth in the Land and Resource Management Plan have, however, largely been achieved. The plan provides for the old growth component to be made up of 65,000 acres of even-aged stands plus 85,000 acres of group selection stands. Most of the currently designated 57,000 acres is in even-aged stands. The 85,000 acres of group selection stands include all hardwood stands within retention visual quality objective areas and were designated by the plan to be managed for old growth conditions.

The kinds of stands designated as old growth candidates are located in all parts of the forest but most occur on the main division districts as shown in table 1. Stands range in age from zero to 150 years.

Table 1. Location of old growth candidate stands on the Ozark-St. Francis National Forest.		
District	Number of stands	Acres
Sylamore	140	4592
Buffalo	221	15669
Bayou	194	14187
Pleasant Hill	112	7355
Boston Mountain	231	13471
Magazine	15	1454
St. Francis	3	84

Table 2 shows a breakdown of old growth candidate stands by 25-year age classes. The old growth candidate stands include a wide range of forest types but the white oak-northern red oak-hickory type predominates.

Table 2. Old growth candidate stands on the Ozark-St. Francis National Forest by 25-year age class.		
Age class	Number of stands	Acres
0-25	29	698
26-50	20	1051
51-75	438	27966
76-100	346	23182
101-125	74	3472
126-150	9	443

Table 3 provides a breakdown of old growth candidate stands by forest type. Average candidate stand size is 62 acres with the largest currently designated stand being almost 700 acres. Thirty seven stands larger than 200 acres are included. Table 4 shows number of stands by size class.

Forest type	Number of stands	Acres
White Oak-Northern Red Oak-Hickory	789	48747
White Oak	61	3471
White Oak-Black Oak-Yellow Pine	15	1184
Sugar Maple-Beech-Yellow Birch	8	710
Beech-Magnolia	9	619
Post Oak-Black Oak	5	567
Shortleaf Pine	7	497
Shortleaf Pine-Oak	8	427
Eastern Red Cedar-Hardwood	3	252
Bottomland Hardwood-Yellow Pine	2	166
Oak-Eastern Red Cedar	2	89
River Birch-Sycamore	2	53
Eastern Red Cedar	1	30

Selection of old growth stands is a continuing process and the data base is subject to change almost daily. Information presented here was current as of April 1990.

Stand size	Number of stands	Acres
<100 acres	765	30869
101-200 acres	112	15014
201-300 acres	26	6324
301-400 acres	6	1966
401-500 acres	3	1309
500+ acres	2	1330

In addition to the designation of old growth candidate stands, the Ozark-St. Francis National Forest is moving toward developing old growth in other ways. Consider the following:

Of the 1,123,400 acres of forested land contained within the forest at the time the plan was developed

- 66,800 acres are in Congressionally designated wilderness areas
- 8,800 acres are in developed recreation sites
- 23,500 acres are in special interest and research natural areas
- 287,700 acres are considered to be unsuitable for timber production due to topographic condition or low productivity.

All of this 386,800 acres is currently withdrawn from timber production and it is not likely that this will change in the future. If Mother Nature can be counted upon to produce old growth conditions in stands which are left undisturbed over long periods of time, almost all of this land should eventually develop into old growth. In fact, in one hundred and fifty years, under the management scheme set up by the plan, almost one half million acres of the Ozark-St. Francis National Forest would be occupied by timber stands that are greater than 200 years old.

Currently there are not very many timber stands on the Ozark-St. Francis which meet the definition of old growth contained in the Forest Land and Resource Management Plan. The forest is, however, committed to development of old growth conditions on significant acreage in the years ahead. We look forward to refining old growth definitions for our physiographic region and would welcome information about treatments which could be prescribed to speed up the process of old growth development.

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USDA Forest Service. 1986. Land and Resources Management Plan. Ozark-St. Francis National Forests, Russellville, AR.

Older Stands Characterized and Estimated From Sample-based Surveys¹

Margaret S. Devall²
Victor A. Rudis³

Abstract

Old growth criteria from the literature are applied to existing data from systematic sample-based surveys to obtain estimates of detailed attributes for private as well as public stands in the Interior Highlands of Arkansas and Oklahoma. Approximately 1/4 of the region's forest is mature. With the most stringent old growth criteria applied, less than 2% of the forested land in the region qualify, and less than 1% is undisturbed by fire, livestock, and/or wood production. In addition, stand histories for selected tracts of older growth outside the National Forest are described, including stands in Hot Springs National Park, around several lakes on U.S. Army Corps of Engineers land, on International Paper Company land, on acreage owned by the heirs of James Garrison Clark, on Cossatot River Natural Area in Arkansas, and on Cucumber Creek watershed in Oklahoma. This report makes clear that there are limited areas of older stands, which suggests the overwhelming importance of efforts to manage and restore old growth on National Forests and elsewhere in the region.

Key words: old growth, Interior Highlands, mature forest

Introduction: Characterizing and Estimating Old-growth Stands

Old-growth forests are increasingly scarce throughout the United States. These forests developed undisturbed over a long period of time and occupied much of the presettlement landscape of the Interior Highlands of Arkansas and Oklahoma. Although native Americans used wood, cleared land for farming, and set fires, European settlers increased the pressure on the forests. Forests provided a valuable source of wood to the European settlers and were an impediment to farming.

¹ This paper was presented at the Conference on Restoring Old Growth Forests in the Interior Highlands of Arkansas and Oklahoma, held at Winrock International, Morrilton, Arkansas, September 19-20, 1990.

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European exploration of the region began with DeSoto in the 16th century, followed by Marquette, Joliet, LaSalle, and others. LaSalle claimed the land from the Mississippi River to the Rockies for France in 1682 and called it Louisiana (USDA, 1986). By the early 19th century, Europeans had pushed the Indians of the Ouachitas farther west; by the second half of the century, Europeans had settled the most fertile lands in the major valleys. Little cultivable land was available at the end of the century (Smith, 1986). The Ozarks had similar settlement patterns.

Before the 1900's, laborers and slaves sawed logs into lumber by hand; one man could produce 100 board feet a day. After the invention and development of water and steam power, circular and band saws, and improved sawmill equipment, the crew of a large sawmill could produce 100,000 board feet a day. The development of powerful steam locomotives and the extension of trunk-line railroads allowed sawmill owners to locate mills near large forests. The sawmillers would exhaust the timber at one location and move on. Around 1908, sawmillers arrived at the Interior Highlands. The forests of the eastern United States had been cut and lumber companies had purchased the forests to the north and south of the Interior Highlands. By 1940, much of the virgin forests of the Ouachitas had been cut (Smith, 1986). Considerable naval stores were produced from the forests of the Interior Highlands; the oak and pine forests were used by the railroad (Martin, 1990). Virtually all the forests in the Interior Highlands have been cut at one time or another.

Recently there has been increased interest in old-growth forests, including those in the Interior Highlands. Scientists, land managers, and the general public are interested in managing and conserving the remaining old-growth forests. This interest arises from concerns that the species, communities, and roles of the older forests are endangered and that the older forests may have functions that are not fully understood, but that may be important to other species.

Methodology

The area of mature forest land by ownership class, disturbance type, forest type, and old-growth criteria was estimated based on the Southern Forest Experiment Station's Forest Inventory and Analysis (FIA) database. The systematic, sample-based surveys in the database provided statistical estimates of forested land for the whole Southern region. Old-growth criteria were drawn from the literature and applied to survey data to obtain estimates of detailed attributes for the region.

The Southern Forest Experiment Station's FIA Unit conducts an inventory of private and public forest resources. The sampling frame comprises permanent 1 acre plots located at the intersections of perpendicular grid lines spaced at 3 mile intervals throughout the south-central states. Detailed field observations are obtained in some 17,000 plots classified as timberland (i.e., at least 0.4 ha in size, 36.6 m in width, and capable of producing crops of industrial wood). Since 1987, additional field

observations have been made for forested areas that have been commercially unproductive (less than 1.4 m³/ha/year) or withdrawn from timber production by statute or regulation (productive-reserved areas).

When combined with ground-truth of photointerpretation for counties, states, and regions, field observations were expanded statistically to estimate all forest resources. Field observations are updated every 8 to 10 years. Periodic analytical assessments and tabular summaries report the current status and trends in tree species, density, basal area, forested area, ownership, forest type, and timber productivity.

Older stands

Stand age is relatively easy to measure in undisturbed, even-aged stands with known stand history, but is difficult to assess in uneven-aged stands and those that have undergone changes, such as succession following the absence of fire, livestock use, or partial cutting. Information on stand history from FIA surveys of the Interior Highlands region is limited to comparing tree records of the 1976 and 1986 Oklahoma surveys and the 1978 and 1988 Arkansas surveys. More than two-thirds of the forests sampled are classed as mixed-aged stands and many stands have undergone varying levels of change in condition.

The data presented in this report represent an *a posteriori* classification of forest stands based on recorded field observations. It was not possible to classify "older" or old-growth stands based on the age of dominant trees, the age of stand, history of stand disturbances, the age of older trees in undisturbed stands, or the presence of a multi-layer forest canopy. Characteristics typical of "mature" stands were used to define older stands.

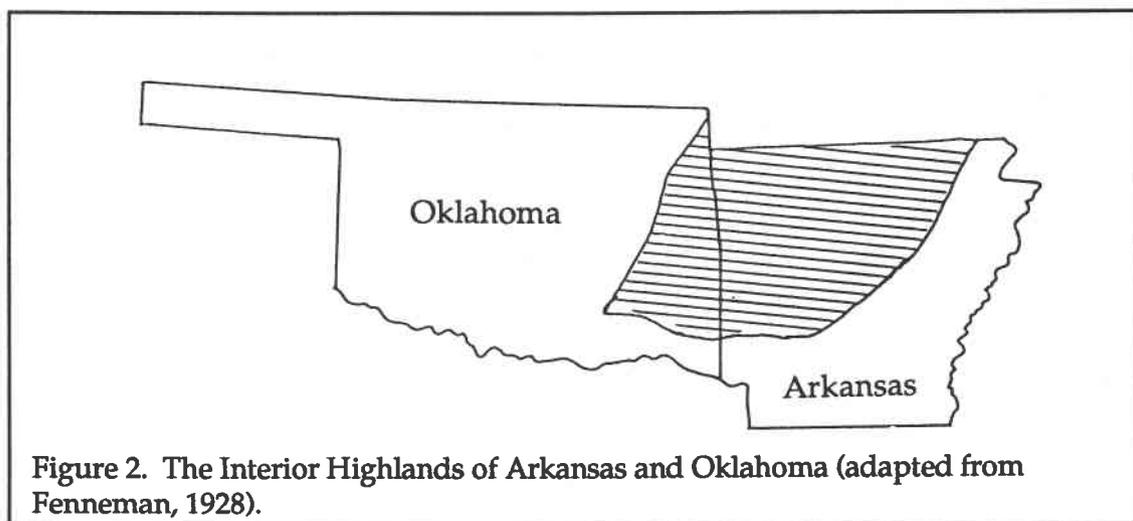
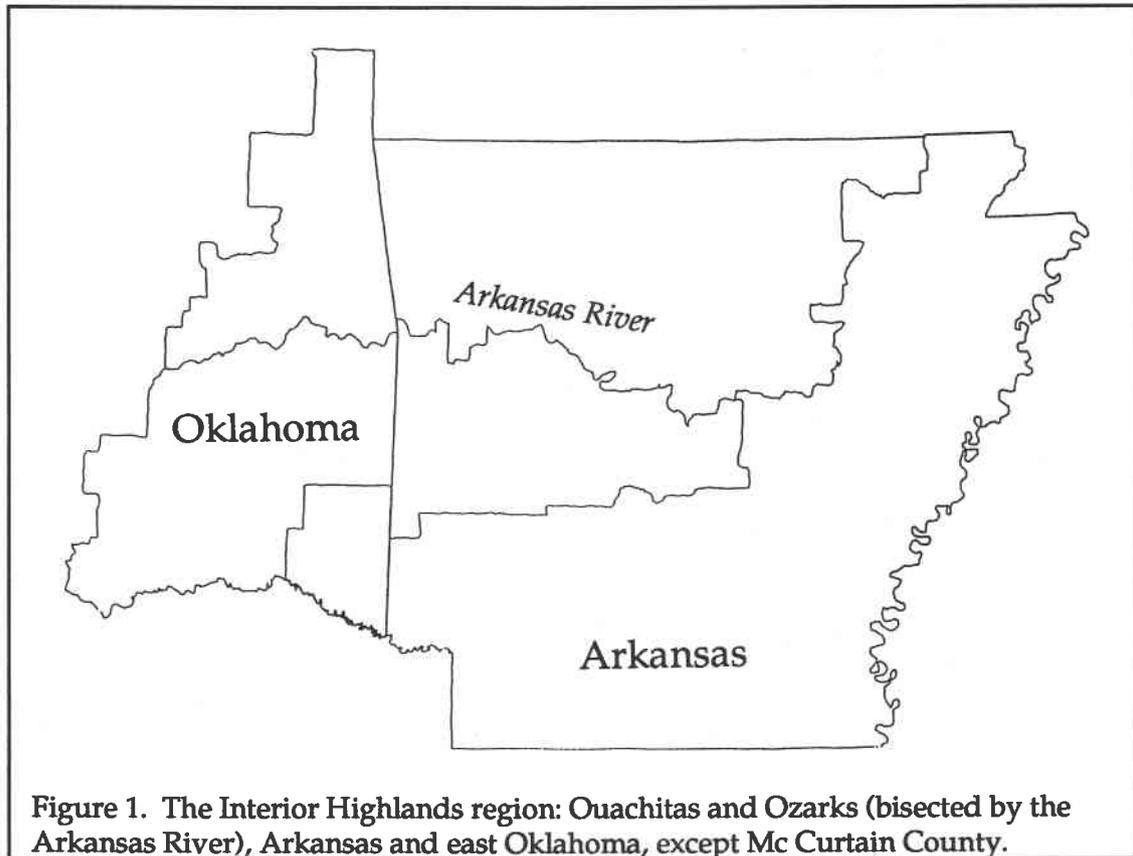
To obtain more detailed information about older stands in the Interior Highlands of Arkansas and Oklahoma (outside of the national forests), landowners, members of conservation organizations, and land managers were interviewed.

The FIA's estimate was based on the total area of counties with the majority of their territory within the highlands (figure 1). The interviews were based on a broader area, and included land extending into counties that were not predominantly in the highlands (figure 2).

Results and Discussion

A mature stand is defined as a stand that has not undergone a forest-type change since the previous survey (approximately 10 years earlier) and that has a basal area of pole timber and larger trees (12.7 cm dbh and larger) generally greater than the site's potential for fully-stocked stands, expressed as mean annual growth, or site class. For example, site class 6 (1.4-3.4 m³/ha/yr) stands must have a basal area of live trees 12.7 cm dbh and larger of 11.5 m²/ha or more. This definition should eliminate all

seedling stands, sapling stands, stands undergoing succession, most poletimber-sized stands, and understocked sawtimber-sized stands where stand size is based on all live trees.



The minimum basal area for mature stands in each site class are given in table 1.

Table 1. The minimum basal area in each site class for mature stands in the Interior Highlands of Arkansas and Oklahoma.		
Site class	Productivity	Minimum basal area
#7	0.0-1.4 m ³ ha/yr	4.6 m ² ha
#6	1.4-3.4	11.5
#5	3.5-5.9	19.5
#4	6.0-8.3	27.6
#3	8.4-11.5	37.9
#2	11.6-15.7	37.9
#1	15.8 or more	37.9

Minimum basal areas for site classes 4, 5, and 6 are derived from observations that undisturbed stands at least 50 years old never fall below this level for even-aged stands in Arkansas, and all stands classed as timberland in eastern Oklahoma (unpublished data, on file with the Forest Inventory and Analysis Unit, Starkville, MS).

At present, there are no stand age data available for site class 7 plots, and few samples of stands for site classes 1, 2, and 3. For this reason, the minimum basal areas for these site classes are drawn from the conceptual model that site conditions and basal area of relatively undisturbed climax stands in mesic forests are directly related (*sensu* Held and Winstead 1975). The minimum basal areas for site classes 1 and 2 are lower than that of the model, because the highest basal area known for climax forests in this part of the United States (a mesic forest in Tennessee: 42.6 m²/ha [Held and Winstead 1975]), suggests a theoretical maximum.

Other characteristics

Old-growth criteria assume that stand conditions are at an equilibrium. Given this assumption, characteristics of old-growth include:

- net growth of live trees approaches zero (Hunter 1989)
- older, standing dead trees are present (Hunter 1989; McComb and Muller; 1983, Smith 1989)
- the proportion of standing dead trees is similar to the proportion of live trees in a stand. (Data from Tritton and Siccama (1990) suggest that the ratio of dead-to-live trees is around 0.5 to 1.5 for selected older stands in the northeast.)

The disturbances most likely to affect the stand regeneration layer of potential old-growth stands are fire and livestock use. Wood-production activities are likely to affect overall stand conditions. These disturbances may be temporary or insignificant for some definitions of old-growth. Once some disturbances are eliminated, opportunities may emerge for old-growth restoration. Some disturbances may be typical of old-growth, such as fire in a fire-dependent climax forest.

Details of criteria for data on livestock, fire, and wood production are available in FIA survey manuals (FIA Unit 1989a, FIA Unit 1989b). Livestock is defined as the presence of livestock-use evidence including observations of livestock, tracks, dung, and trails. Fire is defined as burn evidence including burn scars on trees, reduced litter depth with charred remains, etc. Wood production is defined as evidence of harvesting, timber management, and presence of logging debris, including noncommercial wood harvesting.

Standard error

The sampling scheme was not specifically designed to survey older stands, therefore some such areas may have been omitted. Given the assumptions associated with classification accuracy, the statistical confidence in area estimates is given in table 2.

Table 2. The statistical confidence in area estimates of older stands in the Interior Highlands of Arkansas and Oklahoma.	
Area estimate (1000's ha)	95 percent confidence, +/- (1000's ha)
20.2	4.48
40.1	6.33
202.4	14.16
404.7	20.01
1,214.1	34.70

The total forested acreage in the Interior Highlands is estimated at 5537.6 thousand ha (figure 3). Of this, 190.9 thousand ha of commercially unproductive forest or production-reserved timberland in Oklahoma were excluded because field data were not available, leaving a total of 5346.7 thousand ha.

Past data were unavailable for 244.0 thousand ha of mature forest that are either commercially unproductive (potential productivity less than 1.4 m³/ha/yr), productive-reserved timberland on public land (withdrawn from timber production by statute or administrative regulation), or timberland with large trees that has recently reverted from agricultural land (Hines and Bertelson, 1987; Hines, 1988a,

1988b). Of the remaining 5,102.6 thousand ha of forest, 1,199.4 thousand ha qualify as mature forest (figure 4).

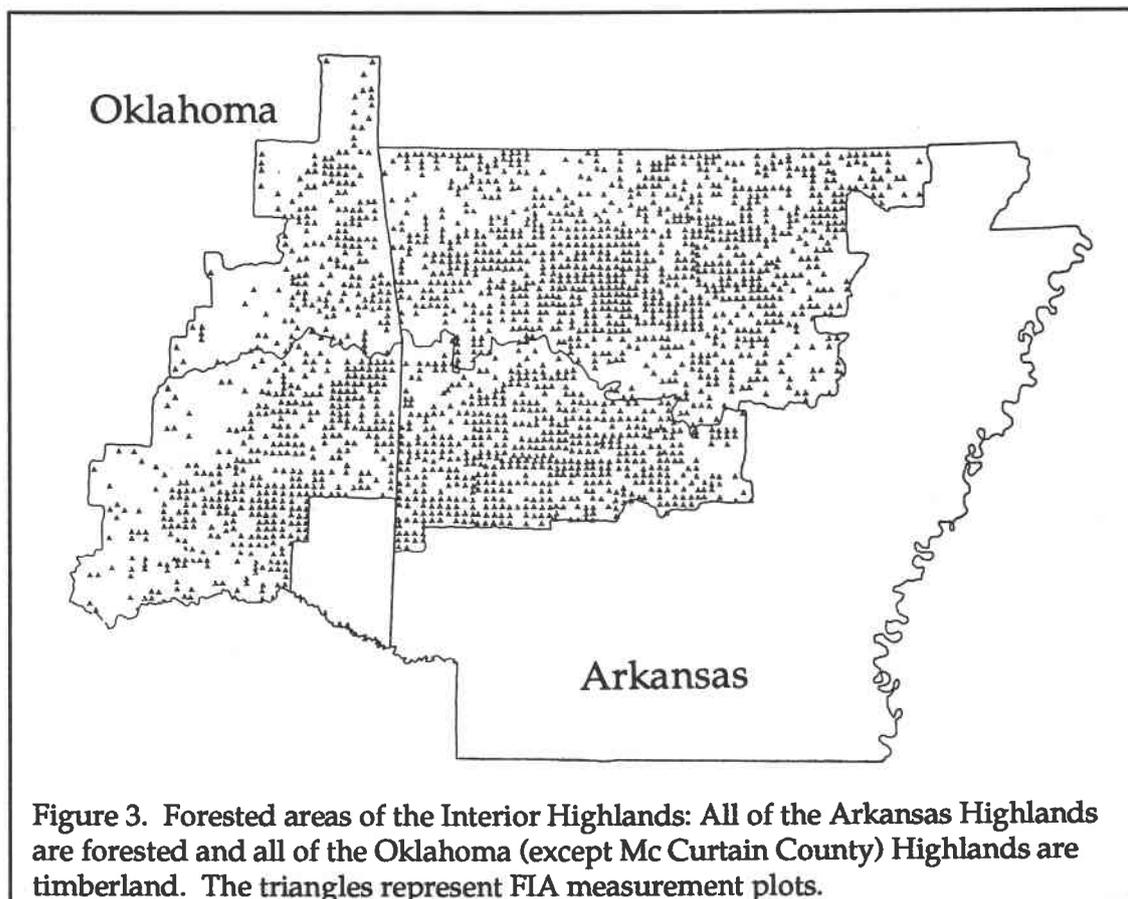


Figure 3. Forested areas of the Interior Highlands: All of the Arkansas Highlands are forested and all of the Oklahoma (except Mc Curtain County) Highlands are timberland. The triangles represent FIA measurement plots.

When the old-growth criteria are applied to the mature-forest data (figure 5), the estimate of older growth in the Interior Highlands without any disturbances from livestock, fire, wood production or any combination of these is 63.2 thousand ha (table 3).

The amount of older growth without any disturbances is estimated to be 18.1 thousand ha of national forests, 2.7 thousand ha of land owned by other public agencies, 2.4 thousand ha of land owned by forest industries, and 40.0 thousand ha of land owned by private individuals (table 4). There is evidence of some disturbance in 21.7 thousand ha.

Estimates of undisturbed older growth can also be subdivided by forest types (table 5). The national forest includes 2.3 thousand ha of oak-pine forest and 15.9 thousand ha of oak-hickory forest; other public land includes 2.7 thousand ha of oak-hickory forest; private land contains 2.4 thousand ha of loblolly (*P. taeda*)-shortleaf, 6.2 thousand ha of oak-pine, 51.0 thousand ha of oak-hickory, and 2.3 thousand ha of bottomland hardwood forest.

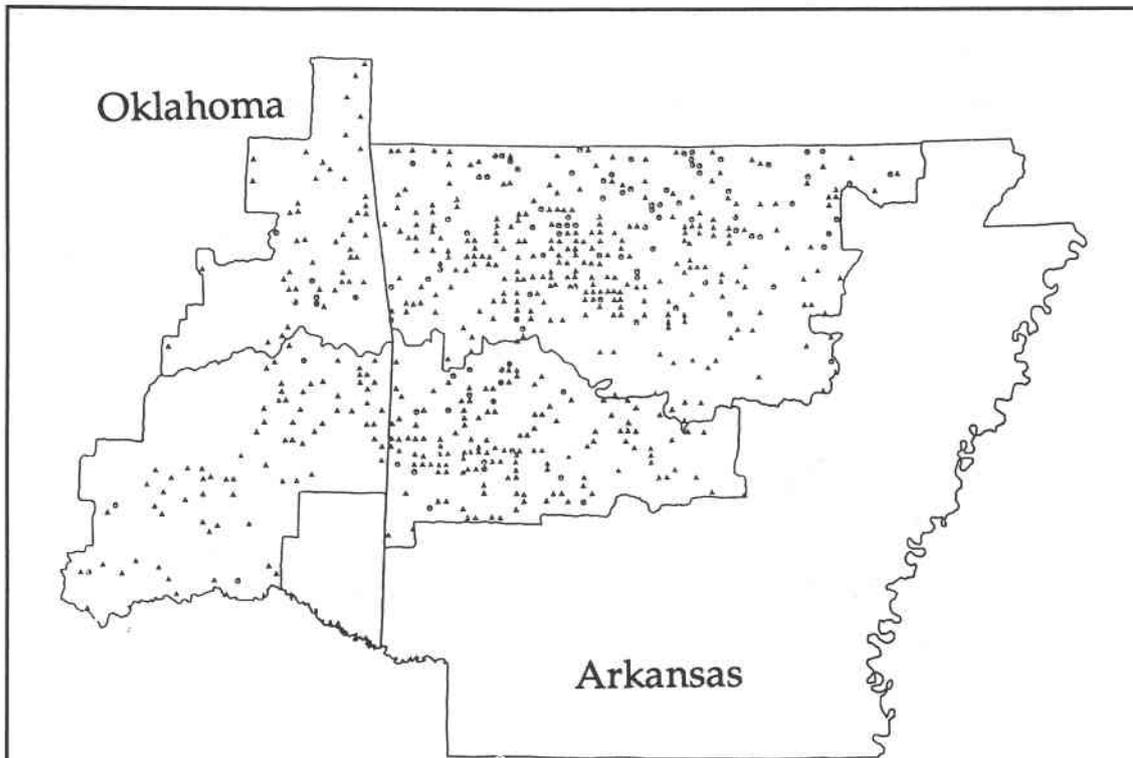


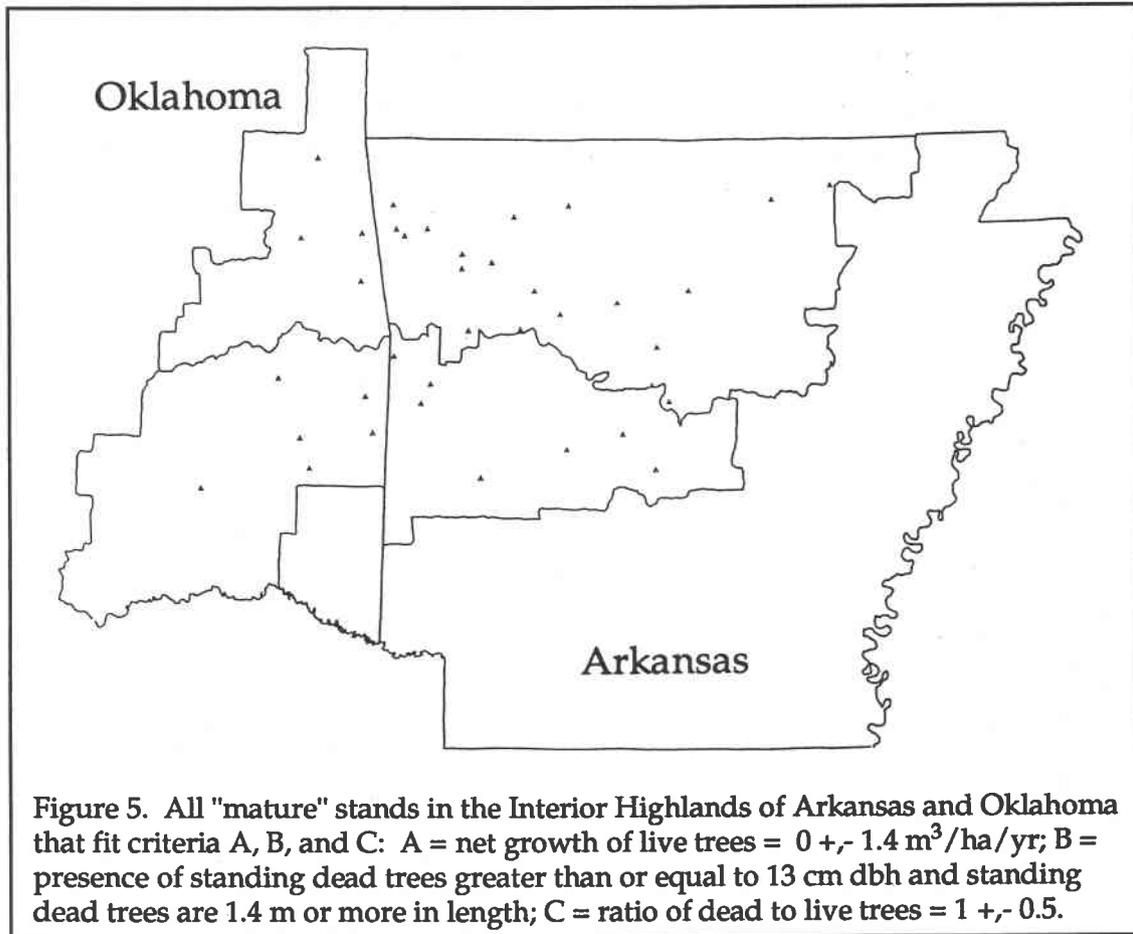
Figure 4. All "mature" stands of the Interior Highlands of Arkansas and Oklahoma. The current basal area fits the requirements: 1) no change in forest type since the last survey, 2) basal area in poletimber and larger-sized live trees generally greater than the site's potential yield of wood for fully stocked stands, expressed as mean annual growth, or site class. The triangles represent remeasurement plots; the circles indicate no prior tally (in Arkansas, most are commercially unproductive).

Selected Tracts of Older Growth

Stand histories for selected tracts of older growth outside the National Forests are described. These summaries provide descriptions of several of the finest older growth forests in the Interior Highlands.

Hot Springs National Park

Hot Springs National Park, in Arkansas, contains some of the finest natural pine communities in the Ouachita Mountains. Forest stands on Sugarloaf Mountain, North Mountain, and Hot Springs mountain, totaling approximately 121 ha have not been disturbed much by people for over 60 years; some areas may have been undisturbed for over 100 years. The south-facing slopes are fairly open, stunted forest, while the north-facing slopes are covered with a luxuriant, closed forest. On both slopes the age of trees often exceeds 130 years. One tree on the south-facing slope of Sugarloaf



Mountain had 191 annual rings; the oldest tree cored so far had 242 rings. Many trees on north- or east-facing slopes are 51-66 cm diameter. In addition to shortleaf pine (*Pinus echinata*), blackjack oak (*Quercus marilandica*) can be found on the drier slopes and white oak (*Q. alba*) on the north-facing slopes. Some patches appear younger than the rest of the forest, apparently due to natural disturbance. There are also some treeless openings, especially on the upper southeast-facing slopes of Hot Springs Mountain. These forests are important natural shortleaf pine communities because of their age and natural condition. Fifty-two hectares of Sugarloaf Mountain are registered as a Society of American Forester's Natural Area (Pell, 1982).

Hot Springs National Park is managed as a natural area of the national park system. Hazard trees near trails are removed and trails and culverts are kept in good repair. Except for the hazard trees, no cutting has been done since the National Park Service took over management in 1921; the areas had been in a federal reservation established in 1832. There is no evidence that extensive cutting has taken place during the last 150 years, although some firewood was cut during the 19th century (Pell, 1982). A study to determine the fire history of the area established that the

overall mean fire-return interval has changed from under 32 years in the period before 1938 to approximately 1,200 years after 1938 (Johnson and Schnell, 1985).

Table 3. Area of "mature" forested land by disturbance type and old-growth criteria, Interior Highlands.

Disturbance type ¹	(Old-growth criteria ²)			
	None	A	A,B	A,B,C
-----thousand hectares-----				
Livestock	108.6	44.2	32.0	10.0
Fire	101.9	27.4	19.7	4.5
Wood production	93.9	8.7	2.2	2.2
Fire and wood production	55.6	9.2	4.9	--
Livestock and wood production	24.8	4.9	2.4	2.4
Fire and livestock	17.8	5.1	2.5	2.5
Fire, livestock, and wood production	5.3	--	--	--
None of the above	791.4	222.9	158.6	63.2
Total³	1,199.4	322.5	222.4	84.9

¹Disturbance. Presence of livestock evidence is noted regardless of age, but is assumed to be less than 10 years old. Presence of fire and wood production evidence is noted if the disturbance occurred since the previous survey (approximately 10 years).

²Criteria:

A: Net growth of live trees = $0 \pm 1.4 \text{ m}^3/\text{ha}/\text{yr}$. Based on a survey of trees on permanent plots between surveys: east Oklahoma 1976, 1986; Arkansas 1978, 1988.

B: Presence of standing dead trees greater than or equal to 13 cm dbh. Standing dead trees are 1.4 m or more in length.

C: Ratio of dead to live trees = 1 ± 0.5 . Calculated as (average dbh of dead trees 13 cm or more)/(average dbh of live trees 13 cm or greater).

³Excluded are 244.0 thousand ha that qualify as mature for which there is no prior tree tally. These stands are either commercially unproductive (i.e., potential productivity less than $0.6 \text{ m}^3/\text{ha}/\text{yr}$, productive-reserved timberland on public land (i.e., withdrawn from timber production by statute or administrative regulation), or timberland with large trees that has recently reverted from agricultural land. Excluded also are forests in east Oklahoma that are commercially unproductive or productive-reserved timberland.

Table 4. Area of "mature" forested land by disturbance type, old-growth criteria, and ownership class, Interior Highlands.

Disturbance type (a)	All owners	National Forest	Other public	Forest industry	Other private
----- thousand hectares -----					
No old-growth criteria					
Livestock	108.6	—	—	—	108.6
Fire	101.9	16.5	4.5	7.0	73.8
Wood production	93.9	56.3	—	2.4	35.2
Fire and wood production	55.6	27.8	2.6	4.2	20.9
Livestock and wood production	24.8	—	—	4.6	20.2
Fire and livestock	17.8	—	—	—	17.8
Fire, livestock, and wood production	5.3	—	—	—	5.3
None of the above	787.1	314.3	37.3	37.0	402.7
Total	1,199.4	414.9	44.5	55.3	684.7
Criteria A, B, and C					
Livestock	10.0	—	—	—	10.0
Fire	4.5	—	—	—	4.5
Wood production	2.2	2.2	—	—	—
Livestock and wood production	2.4	—	—	2.4	—
Fire and livestock	2.5	—	—	—	2.5
None of the above	63.2	18.1	2.7	2.4	40.0
Total	84.9	20.3	2.7	4.9	57.0
(a) Excluded are 39.6 thousand ha on National Forest land, 23.4 thousand ha on other public land, and 181.0 thousand ha on other private land that qualify as mature for which there is no prior tree tally.					

U.S. Army Corps of Engineers land

The U.S. Army Corps of Engineers manages several lakes in the Interior Highlands which are surrounded by older-growth forests. Lake Ouachita is in the east-central part of the Ouachita Mountains, in Montgomery and Garland Counties in Arkansas. The Corps of Engineers has jurisdiction over a band of land around the lake which contains several stands of older growth. The largest stand contains 96 ha (table 6) and is forested predominately with red and white oaks with an average age of 95 years (J. Kiser, personal communication).

Table 5. Area of "mature" forested land by ownership class, disturbance type, forest type, and old-growth criteria, Interior Highlands.

Ownership class and disturbance type	All types	Loblolly-shortleaf pine	Oak-pine	Oak-hickory	Bottomland hardwoods
----- thousand hectares -----					
National Forest					
No prior tree tally	39.6	12.1	4.5	22.9	—
No old-growth criteria					
Fire, livestock, or wood production	100.6	62.6	13.7	24.2	—
None of the above	314.3	98.7	32.5	183.2	—
Total	414.9	161.3	46.3	207.4	—
Criteria A, B, and C					
Fire, livestock, or wood production	2.2	—	—	2.2	—
None of the above	18.1	—	2.3	15.9	—
Total	20.3	—	2.3	18.0	—
Other public					
No prior tree tally	23.4	4.5	16.2	2.7	—
No old-growth criteria					
Fire, livestock, or wood production	7.2	2.5	—	4.7	—
None of the above	37.3	2.6	2.3	19.1	13.3
Total	44.5	5.1	2.3	23.8	13.3
Criteria A, B, and C					
Fire, livestock, or wood production	—	—	—	—	—
None of the above	—	—	—	2.7	—
Total	—	—	—	2.7	—
Private owners					
No prior tree tally	181.0	11.9	28.8	140.2	—
No old-growth criteria					
Fire, livestock, or wood production	300.2	42.5	30.5	212.5	14.7
None of the above	439.7	63.5	53.7	317.6	4.9
Total	740.0	106.0	84.3	530.1	19.5
Criteria A, B, and C					
Fire, livestock, or wood production	19.4	2.4	—	14.8	2.3
None of the above	42.5	—	6.2	36.2	—
Total	61.9	2.4	6.2	51.0	2.3

Table 6. Lake Ouachita old growth stands.					
Compartment	Stand	Ha	Ba (m ² /ha)	Average age	Predominant species
1	1	4	14.9	82	Shortleaf pine
6	17	96	8.4	95	Red and white oaks
13	29	16	8.4	147	Sweetgum and oaks
13	30	14	9.3	122	Sweetgum and oaks

Data provided by J. Kiser, U.S. Army Corps of Engineers

Lake Greeson is on the southern border of the Interior Highlands, in northern Pike County, Arkansas. The Corps of Engineers bought the land around Lake Greeson (3440 ha – not including the lake) a few years before 1950, when the lake was impounded. The ridges and valleys surrounding the lake are forested mostly with shortleaf pine; in most stands the trees are from 40 to 65 years old, but a few stands are a little older. These forests are in the same condition as much of the Ouachita National Forest: The forest was cut around the turn of the century and again in the 1940's. Little timber was then cut until 10 years ago. The Corps is concerned about the visual impact of cutting: The land appears very different from the surrounding timberland. Detailed information on the stand is available (see table 7) (K. Meeks, personal communication).

Gillham Reservoir is also on the southern edge of the Interior Highlands, in Pike County, Arkansas. The Corps of Engineers has 2687 ha of land at this site, including the 550 ha of the reservoir. The forest, which is composed of shortleaf pine and several oak species, has been selectively cut in the past, probably in the 1950's. The older shortleaf pines at the upper end of the reservoir are 50 to 70 years old and the oaks are 70 to 100 years old (M. Price, personal communication).

International Paper Company land

International Paper Company owns land in the Bismarck Mountains around Needle's Eye, a rocky, steep, droughty site with spots of mature growth, located in Hot Springs County, Arkansas. The area comprises around 6070 ha of upland forest; the valleys are managed, but the steep ridges are left alone. The slopes are predominantly forested with shortleaf pine, but scrub oaks, including post oak (*Q. stellata*), southern red oak (*Q. falcata*), blackgum (*Nyssa sylvatica*), and sweetgum (*Liquidambar styraciflua*) also occur. The presence of black gum and sweetgum suggest that the area may have burned in the past. The trees are at most 80 years old, and are not large (Ron Davidson, personal communication).

Table 7. An average tree summary for a stand on compartment 09 of land around Lake Greeson.

Acres	Product	Species	DBH cm	BA m ² /ha	Net Vol. m ³ /ha
740	Reproduction	Shortleaf	9.9	0.02	0.00
		Red oaks	9.7	0.02	0.00
		Other white oaks	9.9	0.02	0.00
		White oak	9.7	0.02	0.00
		Other hardwoods	7.6	0.02	0.00
		Gum	9.1	0.02	0.00
		Hickory	8.9	0.02	0.00
		total	9.4	0.02	0.00
	Pulpwood	total	19.7	0.07	0.00
	Sawtimber	Shortleaf	39.1	0.30	8.14
		Red oaks	39.4	0.30	5.26
		Other white oaks	41.4	0.32	5.17
		White oak	39.6	0.30	4.84
		Gum	39.4	0.30	6.34
Hickory		35.6	0.30	3.43	
total		39.1	0.30	7.52	
Culls	total	20.8	0.09	0.00	
Chip and sa	total	27.7	0.16	3.00	

Data provided by K. Meeks, U.S. Army Corps of Engineers

James Garrison Clark's land

James Garrison Clark bought land near Arkadelphia, Arkansas around 1900, to provide timber for his sawmill. He selectively cut timber until the 1930s, and his heirs have continued his tradition. Bob Rhodes owns some of this land and has developed large stands of old-growth pine. Peggy Clark's holdings include stands scattered in Hot Spring County, Clark County, and surrounding counties, totaling 1214 ha in the Interior Highlands, but not all of this is large timber. A few stands have been selectively cut in recent years. The forests include shortleaf and loblolly pines. Hardwoods, including southern red oak, willow, and water oaks (*Q. phellos* and *Q. nigra*) white oak, post oak, overcup oak (*Q. lyrata*) and Nuttall oak (*Q. nuttallii*), can be found in the creek and river bottoms. There are some five log pines, and some of the trees are 91 to 107 cm in diameter (Peggy Clark, personal communication).

Cossatot River State Park Natural Area

There are small, scattered stands of old growth in the Cossatot River area, which includes the Cossatot River State Park - Natural Area – approximately 19.3 km along the river owned by the Arkansas Natural Heritage Commission, adjacent to and downstream from the Ouachita National Forest. The area includes 329 ha of pine plantations and 600 to 800 ha of forest that has recently been selectively cut. Old-growth forest occurs on the steeper slopes and includes mixed pine - oak forest and woodland and glade communities comprised of eastern red cedar (*Juniperus virginiana*), oaks, and elms (*Ulmus spp*). The glade vegetation appears to be intact; the trees are old but not large (William Pell, personal communication).

Cucumber Creek Watershed

The Cucumber Creek watershed, located in Le Flore County south of the Ouachita National Forest in Oklahoma, includes 7285 ha. The Oklahoma Nature Conservancy owns 607 ha – some of the forest was cut in the last 20 to 30 years, but the forest includes some large shortleaf pine on the steeper slopes that are 51 to 76 cm in diameter and blackgum and hickory (*Carya spp*) may be up to 91 cm in diameter. Large sycamore trees (*Platanus occidentalis*) occur along the stream. The upper part of the watershed has probably not been cut since the turn of the century (Robert Hamilton, personal communication).

Conclusions

Based on FIA data, an estimated 24% of the Interior Highlands is mature. Applying the most stringent old-growth criteria, 7% of the mature stands are older growth. These 84.9 thousand ha represent less than 2% of the total forested land in the region. The 45.1 thousand ha of the relatively-undisturbed older growth outside of the National Forests represent less than 1% of the forested land in the Interior Highlands. Little of this older growth represents true "old growth," because most of the forests have been disturbed in the past.

Knowledge of the structure and composition of the older-growth forests of the region is sparse. Few scientific studies have been carried out in the older stands outside of the National Forests. Some of these stands are among the best examples of older growth in the Interior Highlands. Additional research is needed regarding the function of developing old-growth forests, the plants and animals inhabiting these forests, and the relationship of older forests to younger forests. The older forests differ in composition, density, basal area, and the amount of logs and snags. Old-growth definitions of the different forest communities of the Interior Highlands are needed (Martin, 1990, this volume).

There are limited areas of older stands. This suggests the overwhelming importance of efforts to manage and conserve older forests and to begin restoring old growth in

the Interior Highlands. The managers of the National Forests are in the best position to manage and restore the old-growth resource because little remains on private and other public land. The remaining stands are small and scattered. The older growth within the National Forests can be managed to ensure that use of the surrounding lands does not negatively impact the older stands. Stands that represent a variety of forest types and situations can be chosen for restoration.

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Defining Old-growth Deciduous Forests: Seeing the Forest and the Trees¹

William H. Martin²

Abstract

Characteristics of old-growth mixed mesophytic forests can be applied to old-growth deciduous forests in general: high levels of diversity and a distinct mixture of canopy species; uneven-aged forest structure; old, large, commercially-important trees; a predictable range in density and basal area; standing snags and downed logs at various stages of decay; tree-fall gaps formed by windthrow; plants and animals that prefer old-growth; undisturbed soils; little evidence of human disturbance. Values for these characteristics need to be determined for each forest type. Natural disturbance regimes and specific plants and animals have to be identified by forest type. The disturbance regime for a regional forest should serve as one guide to the size required to maintain adequate forest interior conditions and integrity in old-growth forests. Old-growth characteristics show that management should emphasize protection.

Introduction

What are old-growth forests? Are they undisturbed, virgin forests? Are they the forests existing prior to the presence of the American Indians? Are they the forests of pre-European settlement times? Are they forests that have essentially recovered from human disturbance?

One question can be answered rather quickly: an "undisturbed, virgin forest" does not exist. All forests have some kind of disturbance regime that affects development, survival, and composition. Old-growth forests will reflect that disturbance regime (see below).

Old-growth should reflect the evolutionary history of a forest, but it is difficult for us to understand it. The long-term history of a forest is like a motion picture representing thousands and millions of years. Unfortunately, we will only see one or two frames in our lifetime.

¹ Contribution Number 12, Lilley Cornett Woods, Appalachian Station, Eastern Kentucky University, Richmond, KY. This paper was presented at the Conference on Restoring Old Growth Forests in the Interior Highlands of Arkansas and Oklahoma, held at Winrock International, Morrilton, Arkansas, September 19-20, 1990.

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From these frames we are supposed to interpret the past, predict the future and manage accordingly. The Delcourts (Delcourt and Delcourt this proceedings, and 1987) show how our interpretation of forest history has also changed. In contrast to the perception that the forests of the Ouachita Mountains and on the Ozark Plateaus have been in existence for millions of years, evidence from the current pollen record shows that these forests have been in place for just a few thousand years. At the end of the Pleistocene, the plant populations moved back into the area from their southern refugia. The Ouachita/Ozark forests probably were undergoing compositional and structural changes that were witnessed by generations of native Americans.

For all practical purposes, today's old-growth forests are recovering from repeated burnings and grazing by livestock in the 19th and early 20th centuries, and turn-of-the-century logging. To have a sufficient level of old-growth, a national forest may have to designate some younger forests as future old-growth to insure that all types are represented.

Characteristics of Old-Growth Forests

To see these forests and the trees, we need to identify some attributes of old-growth that enable us to define it. I have identified characteristics of old-growth mixed mesophytic forests (also called cove hardwood) of the southern Appalachians (Martin 1991, in press). These mesic forests of coves, ravines, north, east, and other protected sites on the uplands were best discussed by Braun (1950). They also occupied the well-drained river bottoms and terraces but virtually all of those sites have been converted to nonforest uses. In terms of composition, productivity, and history, they are significantly different from oak-hickory, oak, oak-pine, and pine forests of the Ouachita Mountains and Ozark Plateaus (Braun 1950).

In this paper, characteristics of old-growth mixed mesophytic forests are used to help define old-growth in the drier upland oak and pine forests. These characteristics can also be used to compare and contrast the two regional forests.

1. High richness/diversity of species, dominants and communities

Mixed mesophytic forests are floristically rich and diverse. Several canopy species can be dominants and dominance varies from site to site (Braun 1950; Martin 1975). Major trees are beech (*Fagus grandifolia*), white oak (*Quercus alba*), northern red oak (*Q. rubra*), tulip poplar (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), sugar maple (*Acer saccharum*), yellow buckeye (*Aesculus octandra*), white basswood (*Tilia heterophylla*), and eastern hemlock (*Tsuga canadensis*). An old-growth mixed mesophytic forest should have at least 20 tree species in the canopy and should show high diversity index values. Lower strata will also show high plant species richness and display many fruit and seed types.

Upland Ouachita/Ozark forests may not have as high a level of total diversity but canopy diversity may be as high as the old-growth mixed mesophytic forests (Parker 1989; Martin 1991, in press). Certainly the old-growth forests will be substantially more diverse and floristically richer than the prevailing younger stands (Meyer 1986). In oak and oak-pine forests, white oak should be the common dominant, often sharing dominance with post oak (*Quercus stellata*) and black oak (*Q. velutina*) on drier sites; northern red oak should become more dominant on more mesic sites. Shortleaf pine (*Pinus echinata*) of old-growth oak-pine and pine forests in the Ouachita/Ozarks is not present in mixed mesophytic forests but it is a common dominant or codominant on the driest southern Appalachian sites (Braun 1950).

2. Uneven-aged structure with tree species in several size classes

Most old-growth deciduous forests will be uneven-aged or all-aged. Forests damaged by relatively recent destructive events such as an intense fire, hurricane or tornado, or ice storm may be even-aged. Common examples are the even-aged coniferous forests of the western states and southeastern Coastal Plain. Mixed mesophytic forests have shade-tolerant dominants in the canopy (e.g., sugar maple) that are present in all strata. In Ouachita/Ozark old-growth forests, shade tolerant trees and shrubs that are missing in younger forests will be present in the understory, adding to structural and compositional diversity (Meyer 1986).

3. Several large canopy trees

The presence of large canopy trees is one of the most common and recognizable attributes of old growth forests. In old-growth mixed mesophytic forests, we should expect at least 7 trees/ha \geq 75 cm dbh. In the Ouachitas/Ozarks, trees of this size will be more difficult to attain because of drier sites and recurring fire histories. Meyer (1986) suggests that old-growth forest in Missouri should have at least a 25 percent stocking rate of live trees that are \geq 35 cm dbh.

4. Large, high quality, commercially important trees

Several trees in mixed mesophytic forests are commercially important: black walnut (*Juglas nigra*), black cherry (*Prunus serotina*), white oak, northern red oak, sugar maple and tulip poplar. In old-growth forests, they should be expected particularly if the area has not been burned and the forest has not been logged since the turn of the century. In oak and oak-pine forests, the presence of high quality white oak, post oak, and shortleaf pine should be expected and desirable.

5. Old trees \geq 200 years old

In old-growth mixed mesophytic, most of the dominants have life spans that easily exceed 200 years. Parker (1989) uses 150 years for the entire central hardwood region and Meyer (1986) notes that 100-250 years are required to produce old-growth forest in Missouri. The oldest forests would be dominated by white and post oaks. Current

old-growth in the Ouachita/Ozarks should be at least 100 (preferable 150) years old, while many areas designated to develop as old-growth may have a stand age between 50-100 years.

6. Overstory density ca. 250 trees/ha

This average for old-growth mixed mesophytic is based on a study where densities ranged from 160-478 stems/ha (Martin 1975). In studies cited by Parker (1989) for Interior Highland forests, densities ranging from 161-427 stems/ha were reported. Density values alone are not useful for defining old-growth but they are a commonly used estimate of abundance and stocking that is a more reliable indicator of old-growth conditions than cover class and frequency values.

7. Overstory basal areas $\geq 25 \text{ m}^2/\text{ha}$

Higher values than these are easily attained in old-growth mixed mesophytic forests. Parker (1989) cites values ranging from 25-35 m^2/ha but values of $\leq 25 \text{ m}^2/\text{ha}$ or less should be expected in the drier Ouachita/Ozarks forests. Dry sites dominated by shortleaf pine and black jack (*Quercus marilandica*) and post oak may be excellent old-growth forests, but exhibit basal areas $\leq 20 \text{ m}^2/\text{ha}$

Neither density nor basal area values alone are good indicators of old-growth conditions. Both values should be used for old-growth determination only in conjunction with the other characteristics discussed here.

8. Logs and snags

After large and old trees, downed logs and standing snags are the most obvious characteristics of old-growth forests. These attributes are extremely important in defining old-growth for wildlife (Meyer 1986) and for ecosystem function. In a Kentucky old-growth forest, I estimated that 3 each of logs and snags $\geq 60 \text{ cm dbh}/\text{ha}$ should be present. One should also expect logs and snags to be at all stages of decay. Few data on logs and snags exist for different forest types, but this characteristic is easily measurable and a range of values should be determined for all forest types.

9. Tree fall gaps formed by windthrow

Single and episodic tree falls are the most important disturbance features of mixed mesophytic forests. Fires are local and infrequent. Thunderstorms, widespread natural fires, and frequent droughts are regular disturbance events that cause widespread mortality in Ouachita/Ozark forests. These disturbance phenomena can be expected to occur at least once within the lifetime of a forest in this region. Forest history is discussed elsewhere in this proceedings and it is important to know the fire/thunderstorm/drought disturbance histories for these forests to the extent possible. Old-growth should be designated in tracts that are sufficiently large to survive an extensive, intensive fire, thunderstorm, or drought.

10. Plants and animals that prefer old-growth

In mixed mesophytic forests, lists of species that prefer old-growth are currently being developed. No endangered species are known to be confined to those old-growth forests.

It is well-known that the red-cockaded woodpecker requires old-growth pine. In Missouri, Meyers (1986) notes that 87 terrestrial animals require some features of old-growth as part of their habitat, and he provides a comparison list of these species and the feature of old-growth they use during specific stages in their life history. This publication should be useful for the Ouachita/Ozark region.

11. Undisturbed soils and soil macropores

Undisturbed soils are a critical feature of old-growth. Soils that have not been disturbed by logging operations and trampling by people and livestock will not be compacted and will have well developed organic and surface horizons. Exceptions will be recently burned areas and in recent tree-fall gaps where mineral soil may be exposed by an overturned tree, but old gaps show that these sites recover with little or no compaction. The soil organic layer consists of undisturbed leaf litter, small branches, and rotting herbaceous material (O horizon). Remnants of old logs can be recognized at advanced crumbling stages of decomposition. On dry sites, the O and A layers may be thin but they should be intact; on exposed, steep slopes the layers may be missing. In mixed mesophytic forests, it appears that soil macropores are widespread. They are formed by decayed lateral roots of older trees and/or by burrowing activities of animals. The extent of these macropores among old-growth is not known, but their presence should be evaluated on the more mesic sites in Ouachita/Ozark forests.

12. Little or no evidence of human disturbance

Existing old-growth forests and candidate sites in the Ouachita/Ozark region should not show evidence of recent logging and other activities. Like the mixed mesophytic and other forest types of the southern Appalachians, Interior Highland forests have been heavily exploited. Old skidding roads, wire fences, and piles of rocks are common. However, the forest should show recovery by the presence of the large trees, uneven-aged structure, logs and snags and undisturbed, intact forest soil. Any evaluation of old-growth should include an assessment of human use so that we have a more complete forest history.

Old-Growth Characteristics Applied to Management

Old-growth forests are busy, dynamic viable places. They are not "overmature", "decadent", or "senescent" stands, nor are they "pristine", "virgin", and "climax". They are very much alive and changing.

The 12 characteristics of old-growth forests discussed above should be useful in defining deciduous old-growth forests anywhere in the eastern United States. The level of biodiversity, the number and structure of strata in the uneven-aged condition, and ranges of specific values for each characteristic will vary among forest types. All of these characteristics are measurable in the field, so it is now a matter of defining "forest types", developing the inventory procedure, and training people to conduct the field inventories.

Other papers in these proceedings raise questions about old-growth that will have to be addressed for all national forests. Some of these questions relate to the twelve characteristics discussed above. Characteristics such as expected diversity (number 1) and old-growth plants and animals (number 10) provide some guidance for estimating the minimum patch size required for maintaining adequate biodiversity. Another important guide for size is the nature of the disturbance regime of a forest type (number 9). In mixed mesophytic forests, the major disturbance phenomenon is windthrow and the formation of single and multiple tree fall gaps. Based on an intensive study of tree fall gaps at Lilley Cornett Woods in Kentucky (Romme and Martin 1982), it is suggested that the minimum size for contiguous (or nearly so) old-growth mixed mesophytic forest should be 100 ha. This amount insures that forest interior and integrity will be maintained. Parcels of this size will accommodate a percentage of the forest in gaps as a result of the annual gap formation (usually single trees and scattered gaps) and the periodic episodes when several hectares of the forest can be blown down.

Old-growth forests in the Ouachita/Ozarks must also take into account other disturbances such as natural fire, regular thunderstorms, and drought. These natural disturbances can be extensive and can be expected at least once in the generation of a forest. The designated areas of old-growth should be based on a consideration of the extent and frequency of these disturbances and their effect on forest integrity. Meyer (1986) suggests tracts of 7.5 ha in Missouri, but this size is too small when the regional disturbance factors are taken into account. A single, intense fire or a thunderstorm could completely eliminate an old-growth stand of this size.

In national forests, a larger contiguous area in old-growth forest means that the configuration and location of old-growth should not be as scattered isolated stands in compartments. Determination of the desired size, location, and configuration of old-growth should be made for the entire forest, not by districts and compartments.

Old-growth forests require an entirely different management approach. The emphasis is not on wood production in relatively short rotations, but on protection over a longer interval. Because of the recreational and aesthetics value of old-growth forests, activities of people will have to be managed. Active management for "desired species", removal of dead trees, and other timber production activities are counter to the characteristics of undisturbed soils (number 11) and limited human disturbances (number 12).

Possibly the most important characteristics of old-growth are the variety and age of standing snags and downed logs (number 8), and the accumulation of organic matter and its incorporation into undisturbed soils (number 11). These attributes are extremely important in furnishing wildlife habitat, the retention of nutrients, maintaining the availability of water, and protection against surface runoff of water and erosion. These features must be allowed to develop naturally, which means that protection must be afforded during that time. In short, in old-growth forests we are managing for the dead; the living will take care of themselves.

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Tree and Non-tree Dimensions of an Old-growth Shortleaf Pine Stand: Lake Winona Research Natural Area¹

Michael S. Fountain²

Abstract

Herbaceous, shrub, and overstory woody vegetation on 177 nested quadrats in the Lake Winona Research Natural Area were inventoried to assess the successional status of the area. Shortleaf pine (*Pinus echinata*) was the dominant species in the overstory, comprising over 60% of the total overstory basal area. The shrub component was dominated by various combinations of hardwoods, particularly seedlings/saplings of several oak species. Herbaceous vegetation was sparse throughout most of the area; 40 of the quadrats contained no herbaceous species. Increment cores extracted from pine stems to examine the tree diameter – tree age relationship indicated that many of the dominant pine stems are of advanced age (120+ years). Diameter distributions plotted for shortleaf stems and for total stems reflect the unevenaged condition of the stand.

Key words: old-growth pine, research natural area, stand structure, uneven-aged

Introduction

The Lake Winona Research Natural Area (LWRNA) was established in 1977 to represent a virgin forest vegetation complex in a major physiographic province of Arkansas. The establishment report states that the LWRNA encompasses approximately 113.3 ha of old-growth shortleaf pine-dominated forest. The area is located in the southeastern end of the Fourche Mountain subdivision of the Ouachita Mountain physiographic province (Ferguson 1975). The LWRNA does not possess the east-west orientation of ridges that typifies this province. It lies between two such ridges and is bisected by a north-south ridge that creates predominantly eastern and western exposures. Topography ranges from relatively gentle slopes (< 10%) to areas where the slope exceeds 50% (U.S. Dept. Agric. 1979).

¹ This paper was presented at the Conference on Restoring Old Growth Forests in the Interior Highlands of Arkansas and Oklahoma, held at Winrock International, Morrilton, Arkansas, September 19-20, 1990.

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The objective of this study was to determine the ecological status of the flora of the LWRNA as reflected in the distribution of tree age and size (diameter) classes.

Methods

This paper re-examines data collected in 1979, and reported by Fountain and Sweeney (1987). The original data were collected from 177 systematically located sample units. At each sample location the herbaceous, shrubby, and overstory woody components were inventoried. Herbaceous species were inventoried by estimating the percentage of a 1 m by 2 m plot covered by the crown of each species. Shrubs, woody stems less than 4 cm diameter at 1.37 m above groundline (dbh), were inventoried on a 4 m by 6 m plot. Dbh was measured on each stem that reached breast height (1.37 m); the remaining stems were tallied by number of stems per species and by estimating the crown canopy coverage of each species. Stems greater than or equal to 4 cm at dbh were tallied by species and dbh on an 8 m by 12 m plot. Importance values, based on relative frequency, relative density, and relative basal area, for the dominant species were computed. Data were sorted and tested for significant differences according to several topographic classifications, i.e. aspect, slope, and position on slope.

During the summer of 1990, additional data were collected on the shortleaf pine component of the LWRNA. Increment cores were extracted from 35 shortleaf pine stems, selected to represent the range of tree diameters present, in order to determine age. Cores were stored in drinking straws until ring counts were made with a microscope. Equipment limitations restricted the sample to trees less than 50 cm. Diameters of overstory stems were then assigned to 2 cm diameter classes and the distribution of trees per diameter class was plotted for shortleaf stems and for total stems (pines plus all hardwoods).

Results and Discussion

Detailed results, including the list of species recorded and analyses of the original data, are found in Fountain and Sweeney (1987). Only a summary of those results is given in this paper. A total of 75 herbaceous species was identified within the herbaceous quadrats. However, 48 species occurred on 3 or fewer plots. Only 14 species were found on more than 5% of the plots and only 9 occurred on more than 10% of the plots. Forty plots contained no herbaceous vegetation.

Fifty shrub, woody vine, and tree species (seedling to sapling size; less than 4 cm dbh) were inventoried within the designated sampling quadrats for the shrub component. None of the species had a high mean crown canopy coverage. Lowbush blueberry (*Vaccinium vacillans*) had the highest average (14.6%) and it occurred on 83% of the quadrats. Only 16 species were found on more than 20% of the total plots; 9 of these were actually advance reproduction stems or sapling-size stems of overstory tree

species. Shortleaf pine reproduction was found on 18% of the shrub quadrats. Twenty-two tree species were found within the LWRNA. Shortleaf pine had the highest overall dominance (table 1). The average basal area per hectare for shortleaf pine (23.74 m²) was nearly 5 times greater than the second ranked species (white oak, *Quercus alba*). The average shortleaf pine had a diameter of 25.7 cm (basal area = 0.052 m²) while the principal hardwood associates averaged 11.0 to 12.8 cm. Shortleaf pine was the dominant species in every classification scheme tested, thus verifying the obvious dominance of this species in the overstory canopy of the LWRNA.

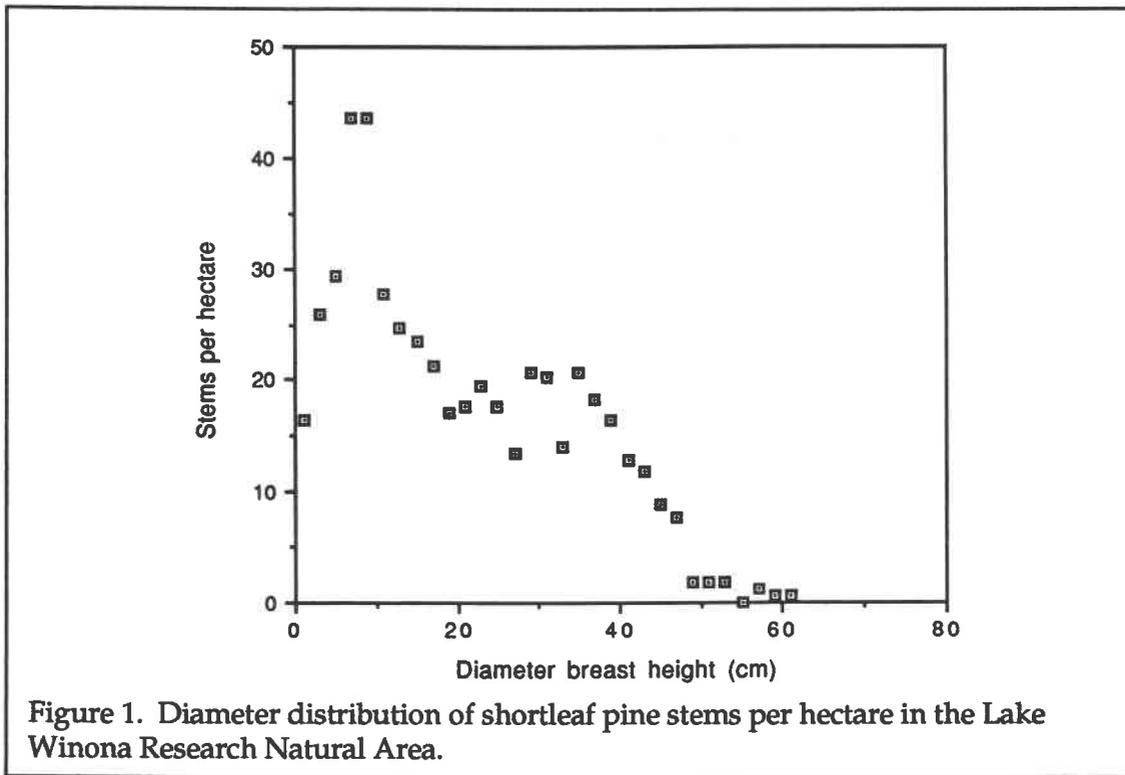
Table 1. Importance values for dominant tree species of the Lake Winona Research Natural Area.

Species*	Frequency	Relative frequency (%)	Trees/ha	Avg. relative density (%)	Avg. basal area/ha (m ²)	Avg. relative basal area (%)	Importance value
Shortleaf pine	95.48	19.36	456.1	32.42	23.74	67.13	118.91
White oak	88.70	17.99	408.4	27.20	5.23	16.63	61.82
Blackgum	51.98	10.54	107.7	7.79	1.07	4.53	22.88
Black oak	40.68	8.25	71.2	5.22	0.55	1.99	15.46
Red maple	30.51	6.19	75.3	5.07	0.53	1.50	12.76
Post oak	33.33	6.76	57.7	4.04	0.42	1.56	12.36
Hickory	28.25	5.73	48.3	3.29	0.59	1.75	10.77
Blackjack oak	26.55	5.38	37.1	2.73	0.27	1.13	9.24
Dogwood	24.29	4.92	40.0	2.61	0.16	0.65	8.24
So. red oak	20.90	4.24	34.1	2.52	0.20	0.81	7.57

* Other species found on the area, listed in order of decreasing importance values, were: northern red oak (4.40), sweetgum (3.75), hawthorn (0.79), ash (0.76), winged elm (0.68), black cherry (0.65), eastern redcedar (0.51), and sparkleberry (0.31).

The distribution of shortleaf pine stems by diameter classes (figure 1) does not follow the typical normal curve that would be representative of an evenaged stand, nor does it illustrate a balanced reverse-J curve that would typify an unevenaged stand. The two evident deviations from the balanced curve could be the result of major perturbations, such as fire or wind damage. The diameter distribution for total stems is typical of a balanced unevenaged stand. It exhibits a reverse-J distribution (figure 2) but the curve is different from what would be expected from a balanced, unevenaged stand that had been managed utilizing the procedures outlined by Farrar and Murphy (1988). The quotient (Q) for the number of total stems in successively smaller diameter classes was estimated to be 1.1. Pines comprised the majority of the larger stems (>20 cm dbh) in the stand and hardwoods comprised the majority in the smaller diameter classes (figure 2).

Analysis of the increment cores indicated that the shortleaf pine component in the LWRNA did contain a wide range of age classes. Tree age was regressed against tree dbh and the resulting equation indicated that tree dbh was a good estimator of tree



age (figure 3). For this stand, these data dispute the commonly held assumption that even though the trees were of different size classes, they would be essentially even-aged.

The LWRNA serves as an excellent example of an old-growth, unevenaged pine dominated stand. The dominant feature of the landscape is the 100+ year old shortleaf pine. Shortleaf pine dominated both in terms of stems and basal area per hectare, regardless of the aspect, slope, or position on slope. The understory and midstory canopy layers are dominated by various associations of hardwood species. The distribution of stems per hectare (figure 2) by diameter classes for the pine component and for total stems reflects the dominance of pines in the overstory and the dominance of hardwoods in the lower crown canopies.

It is evident that the vegetation of the LWRNA is in transition from a seral stage that is pine dominated toward a hardwood dominated seral stage. In the absence of natural or man-caused catastrophic perturbation, the pines will eventually become a minor component of the stand. Small patches of pine will continue to develop in some of the gaps created by death of overmature stems. Most potential gaps, however, are already filled with hardwoods that have invaded over time in the absence of periodic fire.

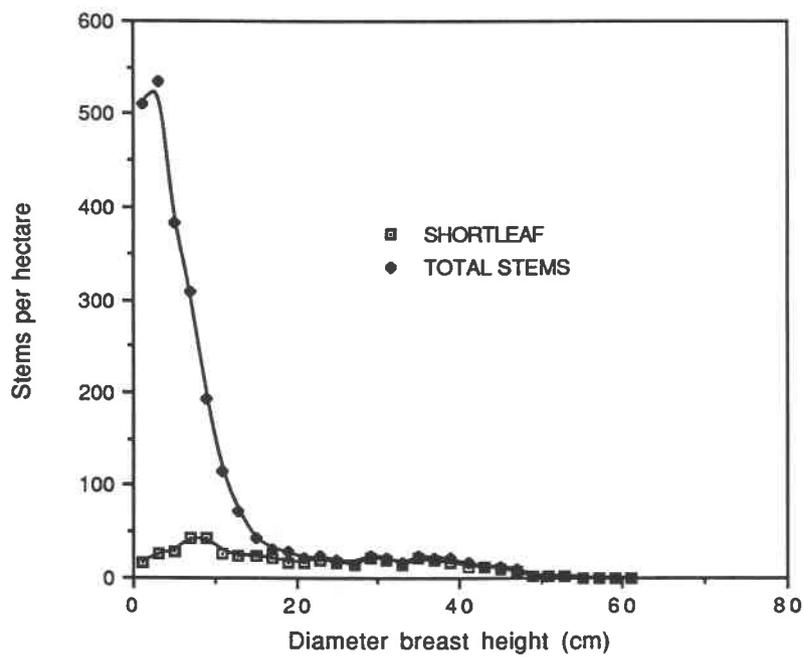


Figure 2. Diameter distributions for shortleaf pine and for total stems in the Lake Winona Research Natural Area.

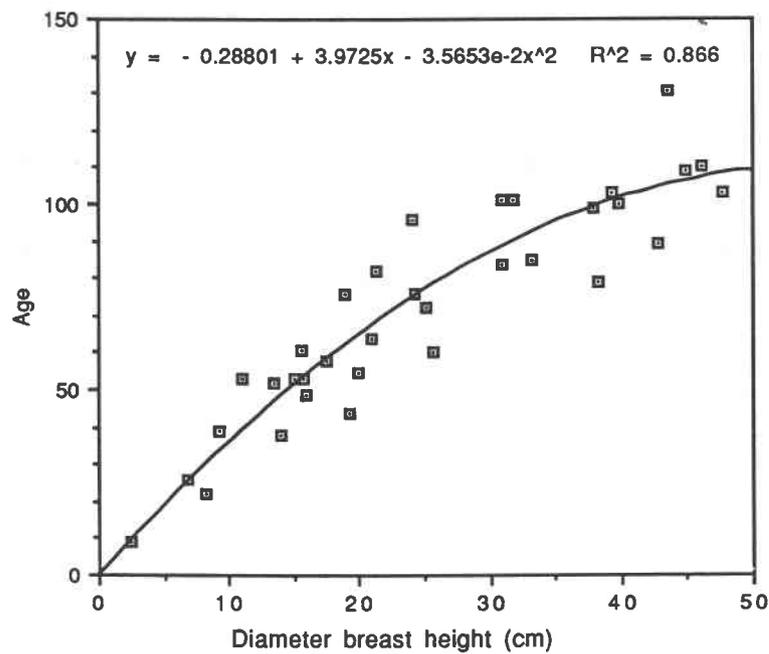


Figure 3. Relationship between tree age and tree diameter for 35 shortleaf pines in the Lake Winona Research Natural Area.

Management Implications

Since the LWRNA is part of the USDA Forest Service research natural area program, the primary recommendation needed is to maintain its protected status and to continue long-term monitoring of the successional pattern. The relative importance of this particular RNA will increase as predicted changes in management strategies occur. The trend toward more acreage in the National Forest system being managed with unevenaged silviculture and more acreage being managed for old-growth qualities dictates that we understand the pattern of succession that is evolving. Fire history in the area needs documentation. If the dominance of shortleaf pine is to continue, then active use of fire must be incorporated into silvicultural/management plans for the LWRNA.

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Old Growth Forests by Design: Applying the Concepts of Landscape Ecology¹

John L. Vankat, Jiango Wu, and Stephanie A. Fore²

Abstract

The field of landscape ecology, covering landscape structure, function, and dynamics, is introduced for the purpose of indicating its significance to land use planning and management. In applying concepts of landscape ecology to the problem of maintaining biodiversity in landscapes, a model is introduced that integrates the life-history characteristics of mobility and habitat selectivity with landscape structure. The model involves classification of species into four basic types, each of which depends primarily on a different set of landscape structural attributes. Type 1 species have low mobility and narrow habitat selectivity. Their success in landscapes is largely determined by patch size, patch content, patch shape, and corridors. Type 2 species have high mobility and narrow habitat selectivity and are most influenced by patch number and distribution. Type 3 species have low mobility and broad habitat selectivity and are most affected by patch boundary characteristics and landscape contrast. Type 4 species have high mobility and broad habitat selectivity and are largely unaffected by landscape structure. The model shows how land managers and landscape designers can focus on particular species when designing specific structural aspects of landscapes to maintain high biodiversity. The use of mathematical modeling in landscape ecology studies is described and System Dynamics is recommended as a useful tool for implementing the model. It is suggested that land managers no longer focus on population size alone but rather include genetic diversity in the criteria for the success of species in landscapes.

Introduction

Interest in landscape ecology has a short history in the United States, having developed in the 1980s. Nevertheless, the field of landscape ecology is already recognized as bringing a needed perspective to land use planning and management.

This paper introduces the field of landscape ecology and then presents a framework for applying concepts of landscape ecology to land use planning. The framework is applicable to the Interior Highlands area of Arkansas and Oklahoma, as well as to

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other areas where such issues as maintenance of biodiversity are important in land use planning.

Introduction to Landscape Ecology

What is a landscape? Forman and Gordon (1986) provide excellent coverage of landscape ecology. They defined a landscape as a heterogeneous area composed of a cluster of interacting ecosystems that is repeated in similar form throughout. The geographic scale of interest is that typically portrayed on aerial photographs.

The purview of landscape ecology is the study of landscape structure, function, and dynamics. As with other ecologists, landscape ecologists borrow methods and insight obtained by researchers working on other ecological units, such as population ecologists, community ecologists, and ecosystem ecologists. So how does landscape ecology differ, for example, from ecosystem ecology? An ecosystem ecologist typically would study an individual ecosystem or type of ecosystem in a landscape, such as a pond, stream, forest woodlot, or agricultural field. A landscape ecologist, in contrast, would treat these individual ecosystems as landscape elements and may examine the arrangement of these ecosystems across the landscape (an aspect of landscape structure), interactions among these ecosystems (an aspect of landscape function), and changes in the arrangement and interactions of these ecosystems (an aspect of landscape dynamics).

Landscape structure deals with the distribution of matter and energy across a landscape. The distribution of plant and animal species plays a key role in defining the structure of most landscapes. For example, most agricultural landscapes in the eastern and midwestern United States have forest woodlots scattered among agricultural fields and obviously these two ecosystem types are characterized by different species.

This example of woodlots in an agricultural landscape also illustrates that a major structural element of landscapes is a patch. Basically, a patch is defined as a non-linear landscape element that differs from its surroundings. A landscape may have many different kinds of patches. In addition to the woodlot patches, the agricultural landscape may also have ponds, and farm houses with lawns. This illustrates that patches may differ in content, origin, and boundary characteristics. Patches also may differ in size, shape, number, distribution, etc.

A second major structural element of landscapes is the matrix. This element is defined variously as the landscape element surrounding a patch; the landscape element that is most extensive and connected; or the landscape element that plays the dominant role in landscape functioning (Forman and Gordon 1986). In our example of an agricultural landscape, the agricultural fields could be considered to be the matrix. Historically, however, the forest had been the matrix. Matrixes of different landscapes may differ in content, origin, boundary characteristics, size, shape, etc.

The third major structural element is a corridor, a linear landscape element that differs from its surroundings. Examples of corridors in a typical agricultural landscape include fence rows, streams, roads, and right-of-ways for power lines. As with the other structural elements of landscapes, corridors may vary in shape, size, number, distribution, content, origin, boundary characteristics, etc. Corridor width is an especially critical characteristic because of its influence on the dispersal of species. In regard to this, corridors may tie together landscape elements by providing for the movement of species, but they also may divide landscapes by inhibiting the movement of species from one landscape element across the corridor to another element.

Two concepts that relate to landscape structure and are important to this paper are connectivity and contrast. Connectivity refers to the degree of spatial continuity of sets of structural elements of landscapes. Some landscapes or landscape elements are highly connected and others are not. For example, fencerow corridors can result in forest woodlots being highly connected while separating agricultural fields. Landscape contrast refers to the degree of difference between adjacent landscape elements. Landscapes of high contrast have differences that are great, as opposed to the similarities that characterize low contrast landscapes. Agricultural landscapes with interspersed forest woodlots typically are high contrast landscapes.

Landscape function deals with the movement of matter and energy among the structural elements of a landscape. The flows of mineral nutrients, water, and species are frequently of primary concern to landscape ecologists and to other scientists and resource managers employing a landscape perspective. Examples of the functional aspect of a typical agricultural landscape include the flow of water and nutrients from forests and agricultural fields into and along streams, transport of farm commodities along roads, movement of deer from woodlots into fields and back, and nutrient flux as deer browse in fields and defecate in forests.

Landscape dynamics, the third aspect of landscape ecology, deals with changes in landscape structure and function. Two or more aerial photographs taken at different times may reveal changes in landscape structure if not also landscape function. Examples of changes likely in an agricultural landscape include the development of more forest patches where agricultural fields were abandoned and old-field succession followed, shrinkage or loss of other forest patches where logging and conversion to agriculture occurred, and decreases in runoff and erosion where soil conservation measures were enacted.

The Interior Highlands Landscape

The restoration of old growth forest in the Interior Highlands of Arkansas and Oklahoma will produce a landscape with a relatively simple, low contrast structure. This is illustrated diagrammatically in figure 1. At a low level of resolution, it will consist primarily of scattered patches of old growth forest interspersed in a matrix of stands of short-leaf pine, pine-hardwood, and hardwood-pine managed primarily for timber production. Although this publication focuses on the old growth patches, a landscape ecology perspective requires that these old growth patches be considered in association with the management-dominated matrix.

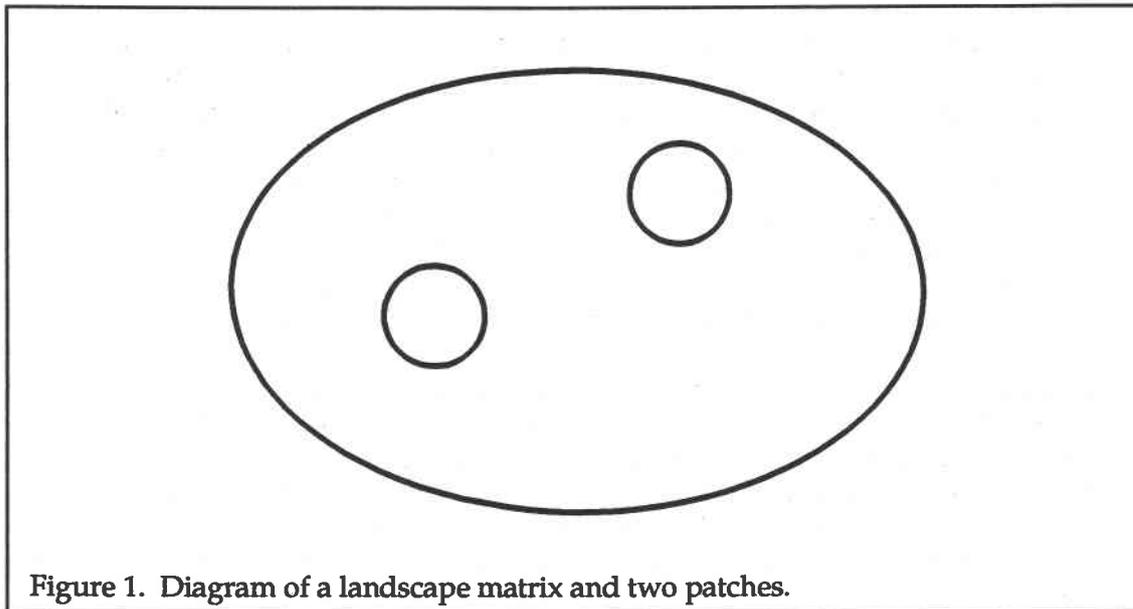


Figure 1. Diagram of a landscape matrix and two patches.

Among the primary objectives for this landscape is the protection of resources, including air and water quality as well as biological resources. The protection of biological resources includes the maintenance of viable populations of native species, including threatened and endangered species. The remainder of this paper focuses on these biological resources and illustrates the application of the landscape ecology perspective.

The proper management of the Interior Highlands landscape requires information on the species in and near the region. Most useful would be a complete life-history study of every species, and much of this information may be necessary for ecological restoration. However, the task of understanding all life-history characteristics of every species in relation to all aspects of landscapes (size, shape, number, distribution, content, origin, boundary characteristics, etc. of patches, corridors, and the matrix) is seemingly impossible.

We suggest an alternative that greatly simplifies this task by focusing on those life-history characteristics that are most critical to the success of species relative to landscape design.

Introduction to the Model

This section introduces a model developed by the senior author that integrates species' life-history characteristics with landscape structure. Landscape function is also considered, at least in terms of species movement. Landscape dynamics are involved in that the model can be used as a guide for designing changes in landscapes to maintain biodiversity.

The model involves classification of species into four basic types, each of which depends primarily on a different set of landscape structural attributes. The model shows how land managers and landscape designers can focus on particular species when designing specific structural aspects of landscapes to maintain high biodiversity. This paper presents only the foundation of the model; a detailed elaboration of it is being developed.

In terms of landscapes, there are two critical aspects of species: mobility and habitat selectivity. Mobility is a species' ability to move across a landscape. It depends on two factors. One is dispersal distance, i.e., the capacity of a species to move genetic material (whole organisms or pollen) through the landscape element in which it occurs. The dispersal distance depends on features of the landscape element and therefore may be different in different elements. The second aspect of mobility is the species' penetrative ability, i.e., its capacity to move into other landscape elements. This ability may be different for different boundaries. Given these two aspects, a species' mobility across a landscape may be limited by either short dispersal distance or by the inability to cross landscape boundaries. High mobility in landscapes necessitates both long dispersal distance and the ability to penetrate the landscape elements present.

The second critical aspect of species in relation to landscapes is habitat selectivity. This refers to the percentage of habitat types within a landscape where the species has the potential to reproduce. Species whose reproduction is limited to a small fraction of habitats in the landscape are narrowly selective, while those capable of reproducing in many or most habitats are broadly selective.

If the two factors of mobility and habitat selectivity are considered qualitatively, with mobility categorized as low and high and habitat selectivity as narrow and broad, the resultant 2 X 2 table produces four species types:

	low mobility	high mobility
narrow habitat selectivity	Type 1	Type 2
broad habitat selectivity	Type 3	Type 4

Type 1 species have low mobility and narrow habitat selectivity. Examples of Type 1 species from the Interior Highlands of Arkansas and Oklahoma are thought to include the Caddo mountain salamander (*Plethodon caddoensis*) and the southern yellow lady's slipper (*Cypripedium kentuckiense*). Type 2 species have high mobility and narrow habitat selectivity. Local examples may include the red-cockaded woodpecker (*Picoides borealis*) and American pokeberry (*Phytolacca americana*). Type 3 species have low mobility and broad habitat selectivity. Local examples are thought to include horse-mint (*Monarda fistula*). Type 4 species have high mobility and broad habitat selectivity. Examples from the Interior Highlands of Arkansas and Oklahoma may include white-tailed deer (*Odocoileus virginianus*).

Type 1 species, because of their low mobility and narrow habitat selectivity, may be characterized as species that must make do mostly with what they already have. They lack the mobility to get to other suitable patches and their narrow habitat selectivity means that adjacent landscape elements are likely unsuitable habitat. Therefore, the key aspects of landscapes for Type 1 species are patch size, patch content, patch shape, and corridors.

Patch size may be important in several ways. For example, where disturbance makes a habitat unsuitable for a species, patches must be planned for a size such that disturbance does not affect the entire patch (figure 2; cf. the "minimum dynamic area" concept of Pickett and Thompson 1978). This example also illustrates patch content, a factor important to all species but especially to Type 1 species because of their inability to move to other patches or to reproduce in adjacent landscape elements. The significance of patch shape may be illustrated by narrow patches that cannot be inhabited by species that require territories of isodiametric dimensions (figure 3). Corridors are also important to Type 1 species, especially those whose mobility is restricted by their inability to penetrate other landscape elements (figure 4). Obviously, the characteristics of corridors are important. For example, Type 1 species must be able to reproduce within corridors whose lengths exceed the dispersal distances of the species.

Type 2 species, i.e., those with high mobility but narrow habitat selectivity, can get to other habitats relatively easily but are limited in what habitats are suitable for their reproduction. Therefore, their success in landscapes depends less on characteristics of

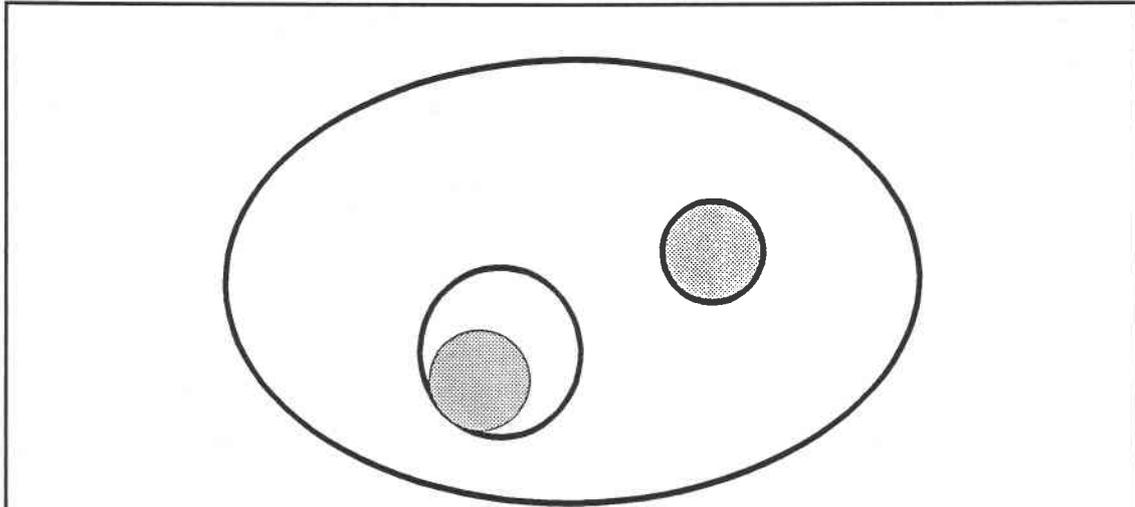


Figure 2. Hypothetical example of the importance of patch size and patch content to Type 1 species. The same size of disturbance (shaded areas) makes the entire small patch uninhabitable, but leaves much of the area of a large patch habitable.

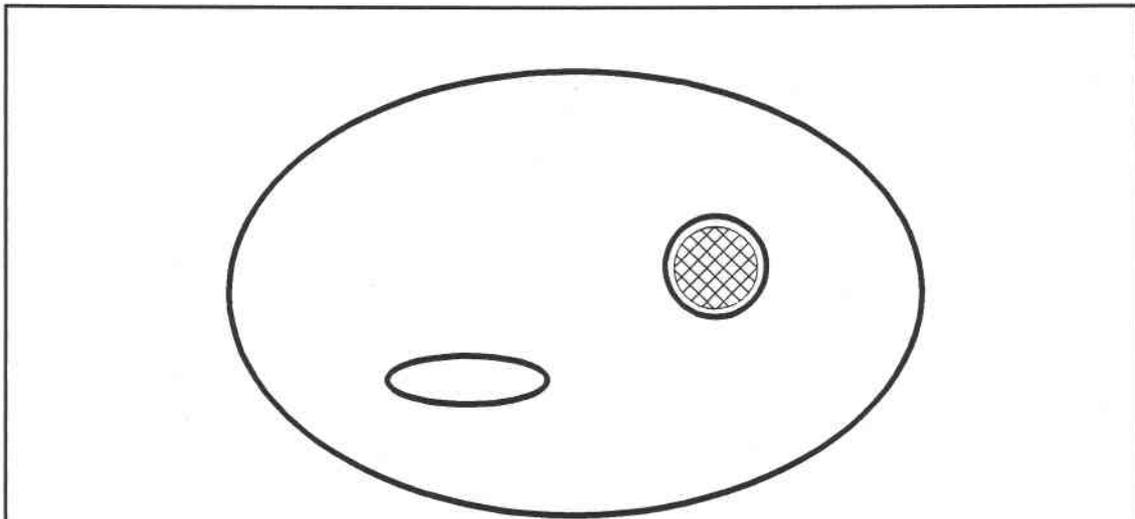


Figure 3. Hypothetical example of the importance of patch shape to Type 1 species. Species whose territory is isodiametric (cross-hatched area) successfully inhabits the circular patch but not the elongated patch.

individual patches and connections by corridors than on patch number and distribution. Patch number is important in that the greater the abundance of patches of a particular habitat type, the more likely the species will reach another suitable patch

(figure 5). Patch distribution is important in that interpatch distances must be within the range of mobility of the species (figure 6).

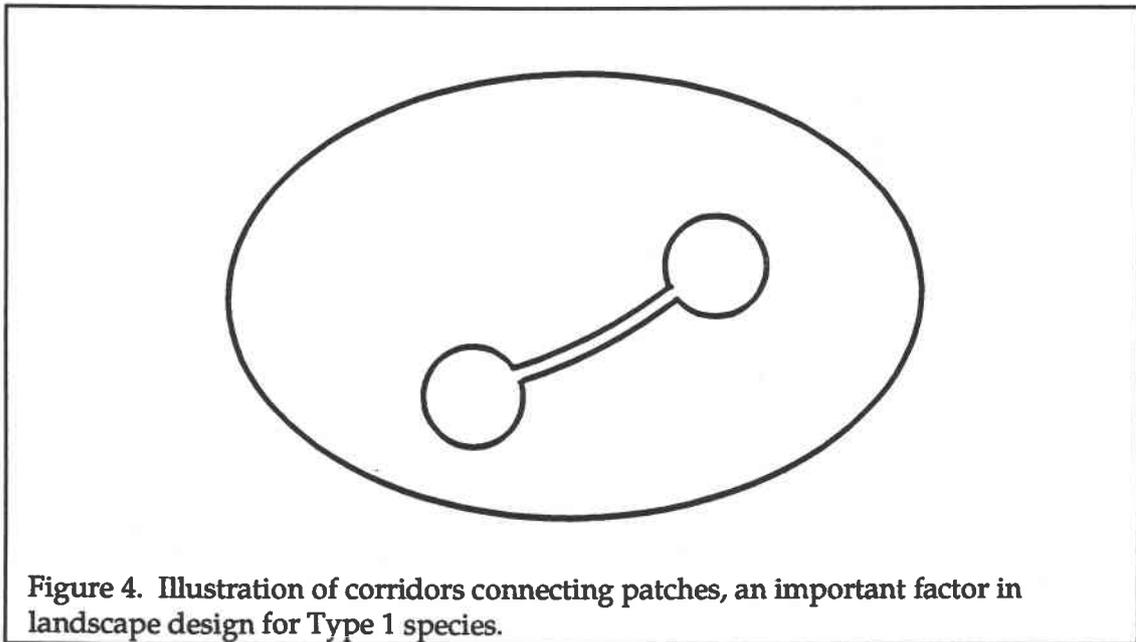


Figure 4. Illustration of corridors connecting patches, an important factor in landscape design for Type 1 species.

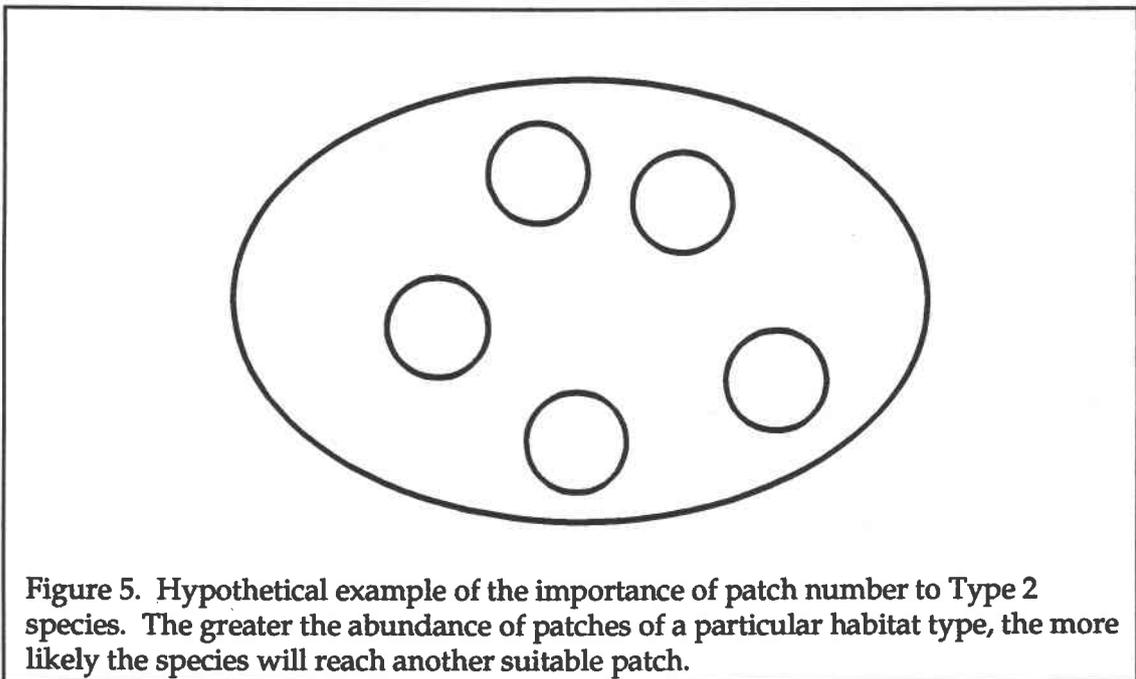


Figure 5. Hypothetical example of the importance of patch number to Type 2 species. The greater the abundance of patches of a particular habitat type, the more likely the species will reach another suitable patch.

Type 3 species, with low mobility and broad habitat selectivity, are species that are likely to reproduce in many landscape elements adjacent to their original area of

distribution but may have difficulty getting to the adjacent element. The aspects of landscapes most critical to Type 3 species are patch boundary characteristics and landscape contrast.

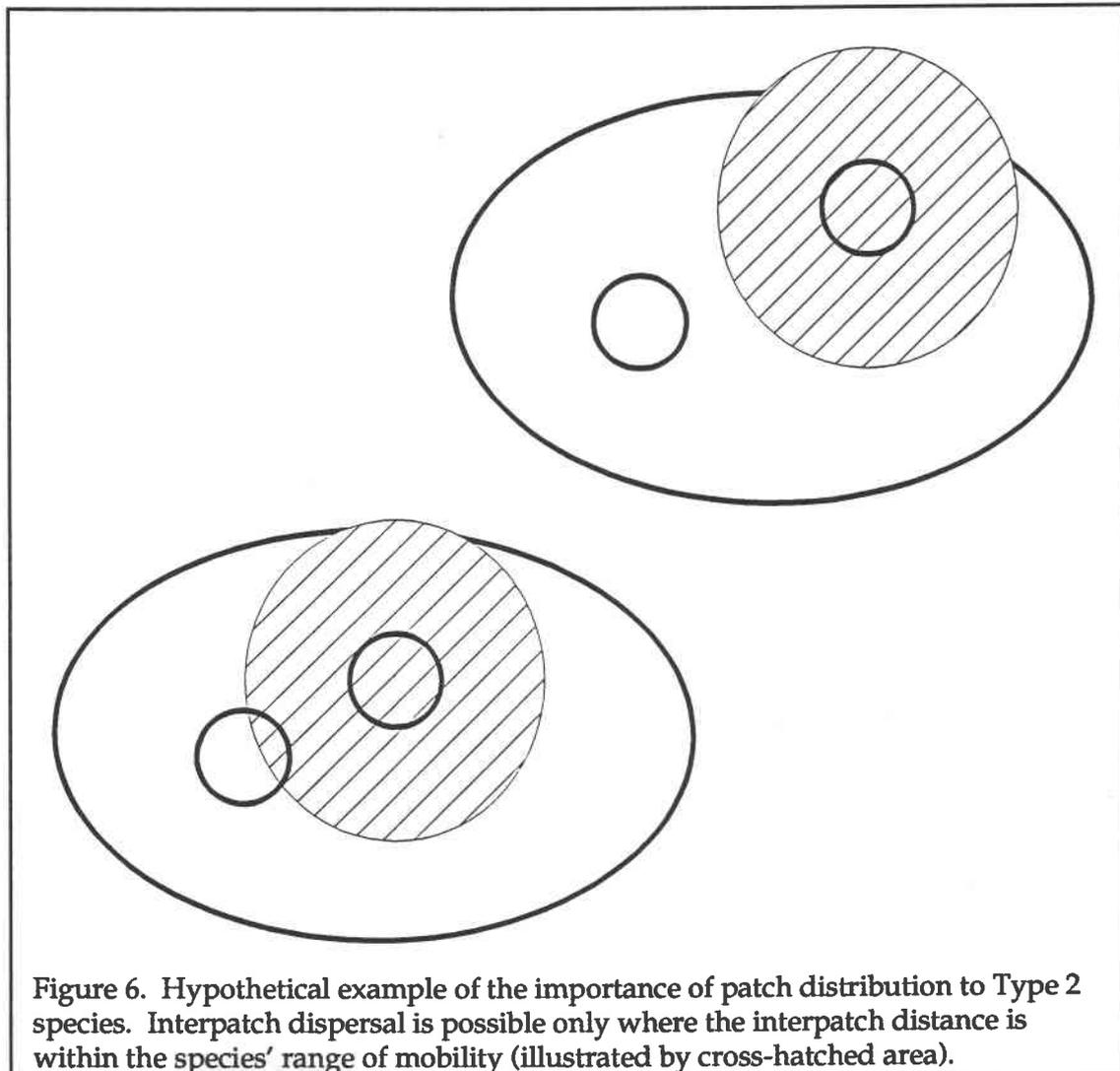


Figure 6. Hypothetical example of the importance of patch distribution to Type 2 species. Interpatch dispersal is possible only where the interpatch distance is within the species' range of mobility (illustrated by cross-hatched area).

Patch boundary characteristics are important to Type 3 species whose mobility is limited by poor penetrative capability. Patch boundaries may differ in form, such as the curved form shown in figure 1 vs. the angular form shown in figure 7. The angular boundary may affect the immigration of organisms across the patch boundary by providing focal points where organisms may concentrate. Also, elongated boundary projections may encourage immigration by providing accessible habitat protection for species immigrating into an area where exposure (such as to predators) puts them at risk. Patch boundaries may also differ in whether they are abrupt or gradually transitional with surrounding landscape elements (figure 7). A gradual transition may help alleviate species' poor penetrative capability.

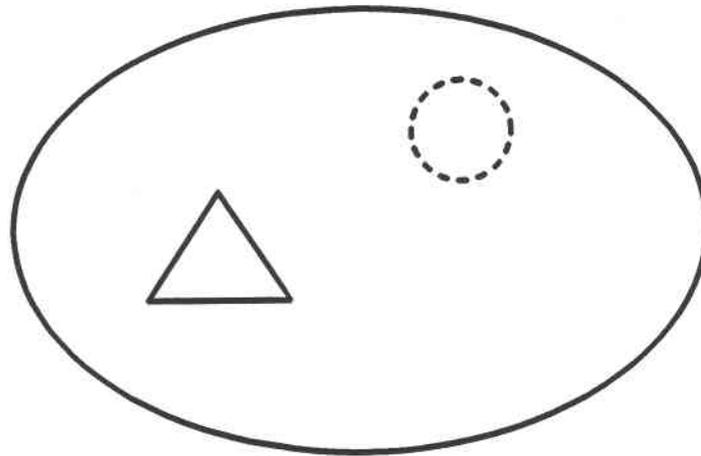


Figure 7. Hypothetical examples of the importance of patch boundary characteristics to Type 3 species whose mobility is limited by poor penetrative capability. Angular or gradual boundaries may alleviate mobility limitations (see text).

Landscape contrast is also important to Type 3 species whose mobility is limited by poor penetrative capability. Such species are more likely to be successful in landscapes of low contrast (figure 1) rather than high contrast (figure 8). While the plans for the Interior Highlands landscape would appear to result in a low contrast landscape of old growth forest patches surrounded by other forest, land managers in this region may find it critical to effectively limit the disturbance regime (i.e., logging) in the surrounding matrix so that it affects only one part of the boundary region of old growth patches in any time interval.

Some Type 3 species may have high penetrative capability but low dispersal distance. It may appear that patch content should be critical to these species, because content may affect dispersal. However, it is unlikely that organisms in a homogenous patch would be restricted to areas so far from patch boundaries that dispersal to the boundaries would be a limiting factor. Therefore, because Type 3 species with poor dispersal but high penetrative capability may be expected to readily cross boundaries and to reproduce in many habitats, they are similar to Type 4 species.

The success of Type 4 species, i.e., species with high mobility and broad habitat selectivity, may be largely unaffected by aspects of landscape design other than content of landscape elements. These are species that not only readily move to suitable habitats but also find most habitats suitable. Such species may be expected to be successful in landscapes that meet the requirements of Type 1, 2, and 3 species.

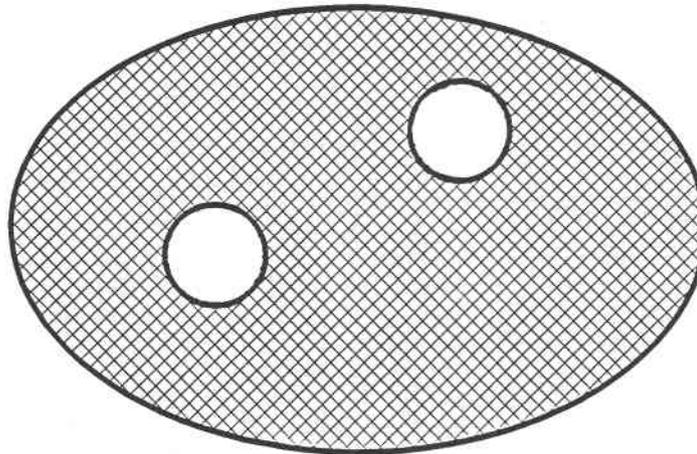


Figure 8. Hypothetical example of the importance of landscape contrast to Type 3 species whose mobility is limited by poor penetrative capability. This landscape has higher contrast than the landscape diagrammed in Figure 1 and may reduce species' mobility.

Application of the Model

Land management agencies such as the U.S. Forest Service should find the perspectives provided by landscape ecology to be important in planning. In addition to insuring that patch content somewhere in the landscape provides suitable habitat for all species, such agencies, when considering what range of patch sizes to include in the landscapes for which they are responsible, should focus on Type 1 species. Additional considerations of patch content, as well as patch shape and corridors, should also focus on the requirements of Type 1 species. In contrast, resolution of concerns over patch number and distribution should focus on Type 2 species. Lastly, questions about patch boundaries and landscape contrast can be addressed effectively by focusing on Type 3 species whose mobility is limited by poor penetrative capability.

The model presented above provides a guide to the application of principles of landscape ecology to the maintenance of biodiversity. One of the more useful aspects of this model is its simplicity, in that it focuses on only two life-history characteristics. Moreover, these characteristics of mobility and habitat selectivity are reasonably well known for many species (although common knowledge may need verification through research). However, given the large number of species found in National Forests and other landscapes, application of the model will require extensive landscape planning. One tool that should prove useful in developing plans for the simultaneous success of many species in a single landscape is mathematical modeling.

Mathematical Modeling and Landscape Design

Models in general are indispensable to understanding ecological systems. In fact, any conceptualization of nature is a model in that it is a simplification or abstraction of reality. Models can be qualitative, i.e., expressed in words or diagrams, such as the model presented in this paper. Or they may be quantitative, i.e., expressed in mathematical equations or computer languages. Quantitative models are usually referred to as formal models.

Models in landscape ecology may be categorized into three groups on the basis of decreasing level of aggregation or combination of variables (i.e., increasing ability to treat specific, individual factors): whole landscape models, distributional models, and spatial landscape models (*sensu* Baker 1989). Whole landscape models use highly aggregated variables to model landscape phenomena as a whole. They concentrate on the value of each variable, e.g., the total species richness of a particular landscape. Distributional landscape models, in contrast, focus on the distribution of values of each variable among different categories of landscape components. For example, a distributional model may focus on the apportionment of species richness among landscape elements. Spatial landscape models, as the least aggregated, are the most detailed. They explicitly incorporate information on location and configuration of landscape elements and, therefore, are able in principle to answer specific questions for particular landscapes.

Whole landscape models have not been widely used because of their inability to provide specific information. Spatial landscape models have been developed only recently and their advancement has been restricted by lack of data, insufficient understanding of landscape processes, and computational limitations (Baker 1989). Distributional models are the most widely used in landscape studies, and many variations in modeling philosophies, mathematical approaches, and degree of detail have evolved.

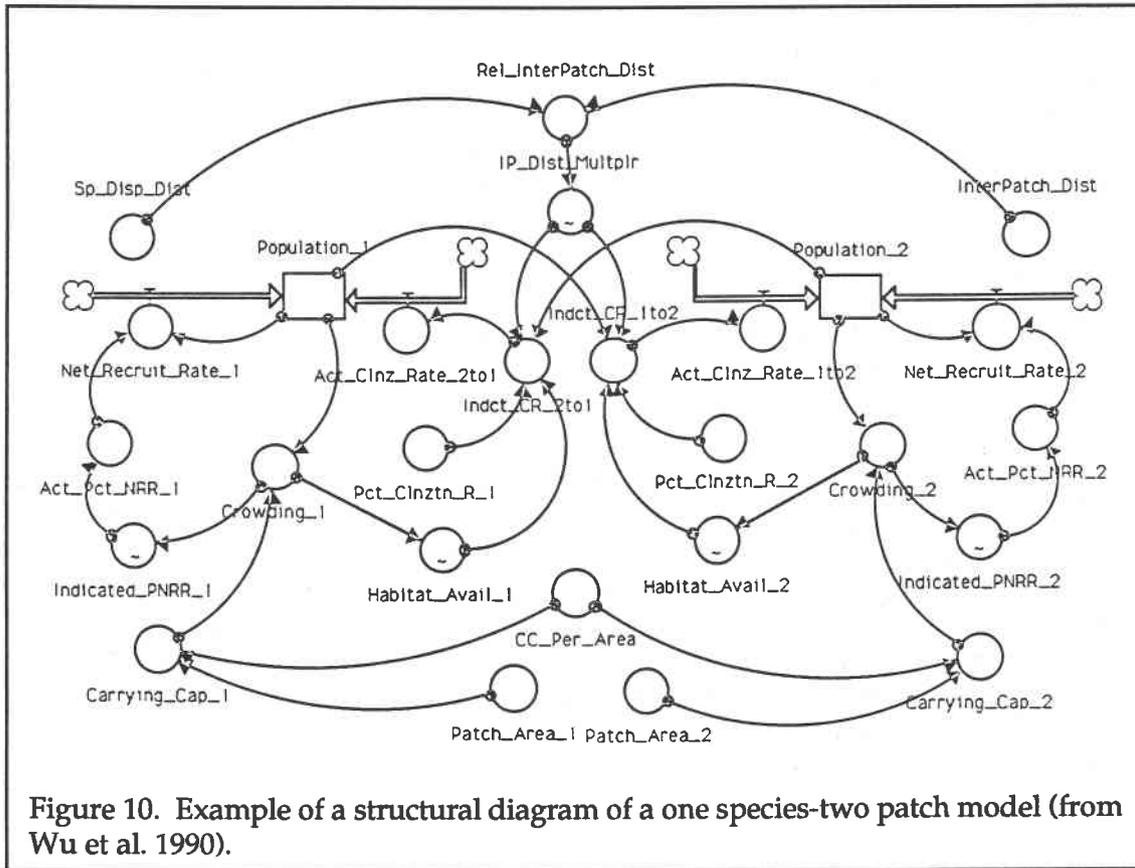
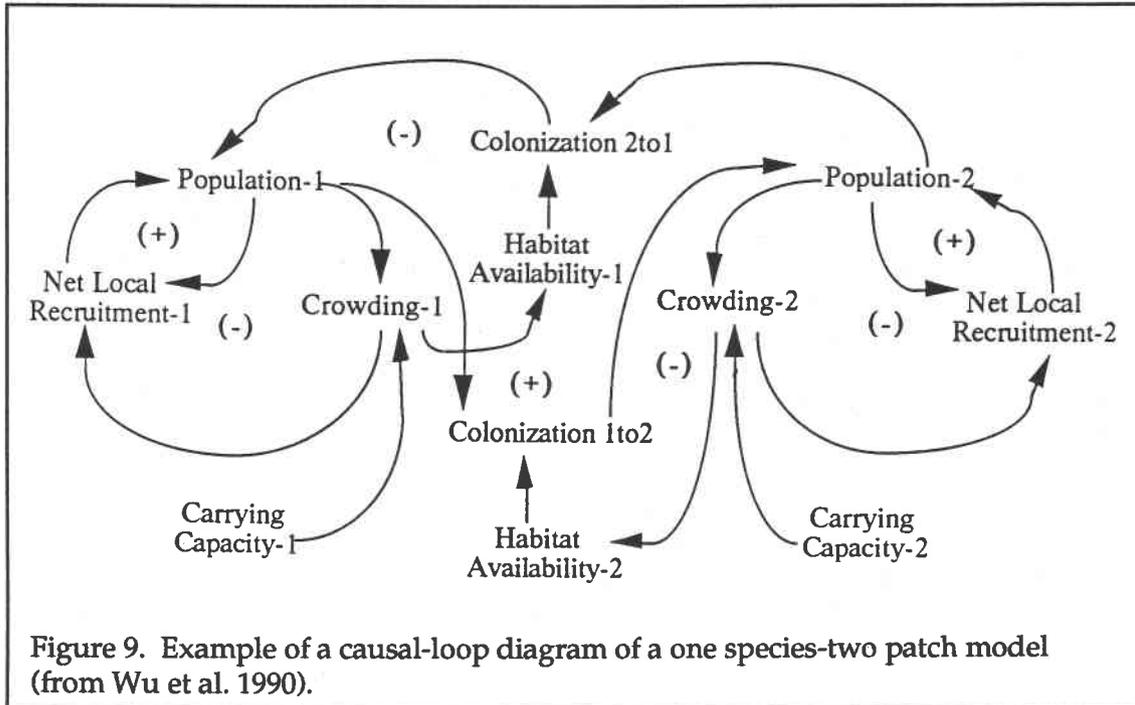
One conceptual basis for distributional landscape models has been the dynamic equilibrium theory of island biogeography (Munroe 1953, MacArthur and Wilson 1967). This theory has been the conceptual basis for some general rules used in designing nature reserves, which in most cases are patches in a landscape. These rules include having reserves (patches) large in size, close in distance, and isodiametric in shape. Although the theory has been useful in generating important ecological questions (Haila and Jarvinen 1982), its validity and hence its applications have been challenged (Gilbert 1980, Burgman et al. 1988). Its application is limited, for example, because it overaggregates many factors affecting species richness and therefore can provide limited insight into the mechanisms of population dynamics over a landscape.

Population models, which utilize species-specific information, can be more valuable. Such models when applied to landscapes necessarily must deal with heterogeneity; however, modeling patchy systems presents a great challenge. There have been two basic approaches for such models. "Patch-occupancy" models (*sensu* DeAngelis et al. 1986) use percentages of habitat patches occupied by populations as major variables, without considering such parameters as patch size and inter-patch distance. "Diffusion-reaction" models (named for their usage of diffusion-reaction equations) deal with the dynamics of species populations in spatially-structured ecological systems such as landscapes. For example, DeAngelis et al. (1979) developed a series of models on the persistence of tree species which incorporated population size, growth rate, carrying capacity, immigration, and emigration, as well as inter-patch distance.

In developing another population-based model, Wu and Vankat (1989) proposed a framework to study population dynamics over a patchy landscape. Wu et al. (1990) extended their work by developing a System Dynamics model of a population divided into two patches and investigating effects of inter-patch colonization on the persistence of the species. The model included factors believed to be important in regulating a population within patches, as well as regional (landscape) factors thought to be involved in inter-patch species colonization (figures 9 and 10). Systems Dynamics proved to be an especially fruitful approach to modeling species in landscapes. System Dynamics modeling maximizes the utilization of data by incorporating qualitative information. This permits complex, imprecisely-defined ecological systems to be studied quantitatively, effectively, and comprehensively. Three features of System Dynamics, i.e., causality, realism, and simulation, make it an attractive and powerful modeling approach for this task. The newly-developed simulation software STELLA greatly facilitates modeling procedures (Costanza 1987).

The "Success" of Species in Landscapes: Addressing the Question of Population Genetics

When defining what is a "successful species," conservation biologists and land managers often have focused on the number of individuals in a population. Recently, however, conservation biologists have recognized that the long-term viability of a species depends not only on its population size, but also on its genetic diversity. Just as ecological systems such as landscapes are dynamic rather than static, so are species. Indeed, a species may be defined as an evolving unit comprised of groups of populations sharing similar co-adapted gene complexes (Woodruff 1989). To assure long-term viability of species, it is essential that continued evolution be a focus of conservation. This requires the preservation of genetic diversity (for a comprehensive review of conservation genetics, see Schonewald-Cox et al. 1983).



Genetic diversity can be defined in several ways. We treat it as gene diversity, which is determined by two components, richness and evenness. Richness is determined by the number of alleles (variant forms of a gene), and evenness by the frequency distribution of those alleles. Genetic diversity is commonly studied by electrophoresis of enzymes, a method which allows the rapid and inexpensive analysis of genetic variation within and among populations. The importance of genetic diversity is clear for many species. Species in which it has been reduced are likely to be more vulnerable to changes in environment, such as new pathogens, climate change, etc., because of their more limited evolutionary potential.

A serious problem in conservation biology is the lack of information on the genetic diversity of species, including the distribution of that diversity. Genetic differences in a species exist at two basic levels: among individuals in a single population and among individuals of different populations (Allendorf 1983). The spatial (or temporal) differences in the distribution of alleles or genotypes is referred to as genetic structure. It results from the joint action of many factors, including mutation, migration, and selection. For example, different environmental conditions in different parts of the geographic range of a species result in selection for genotypes adapted to the local environments. This increases genetic differentiation among populations (migration or other forms of gene flow between populations can modify this effect, decreasing genetic differentiation among populations). Unfortunately, little is known about the genetic structure of most species.

This lack of knowledge is a serious problem in designing landscapes that protect biological diversity. For some species, a landscape design involving multiple patches of suitable habitat (and hence multiple populations) may be required to maintain genetic diversity of the species if the variability within a single population is insufficient for adaptation to the environmental diversity that a species may experience (Namkoong 1983). However, a landscape of multiple patches may adversely affect other species. For example, depending on the specific landscape design, the gene flow patterns among populations of some species may be restricted. This in turn may change the genetic structure of populations by increasing genetic differentiation among populations. Restricted gene flow among small populations can decrease the diversity of genotypes within local populations by increasing the frequency of homozygous individuals. For species that ordinarily outcross, the loss of heterozygosity due to inbreeding is generally associated with inbreeding depression, i.e., a decline in viability, growth, and fertility.

In contrast, a landscape design that clusters patches or connects them by corridors may seem to be advantageous (and may be for many species). Clustering and increasing connectivity can enhance gene flow; however, this may prove deleterious for some species, depending on their genetic structure. If genetic differences among populations occur because of differential selection producing locally adapted genotypes, linking these genetically distinct populations may lead to outbreeding depression (Vrijenhoek 1989), a decrease in fitness occurring when locally adapted

genotypes hybridize and produce offspring with genotypes that are not adapted to either environment.

With the possibilities of inbreeding and outbreeding depression closely related to landscape structure and function, it is essential that landscape design incorporate findings of population genetics and not focus solely on population size. Unfortunately, until the genetic structure of native species is more widely understood, this critical factor is likely to be underappreciated by landscape designers and land managers.

Conclusion

We have introduced concepts of landscape ecology with the hope that their application to the question of restoring old growth forests to the Interior Highlands would be apparent. Moreover, we have tried to make a new and unique contribution to the application of landscape ecology concepts by land managers. Critical and constructive comments on the model proposed will be useful in developing it further.

Lastly, although the objectives of landscape management should be based on species specific information, any management plan must recognize that the species pool of a landscape is not static but dynamic. This has been clearly documented for the past, as paleoecologists have shown long-distance migration of species altering floras and faunas over North America. Future global climate changes may dramatically demonstrate the instability of local floras and faunas again, and land managers must plan for this.

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Silvicultural Practices Applied to Old-growth Stand Management¹

James M. Guldin²

Abstract

A theoretical paradigm is presented to reconcile the seemingly incongruous application of silviculture to old-growth stands. In existing old-growth stands, timber extractions of all kinds should be prohibited; management should reintroduce excluded natural disturbances such as fire, and should control exotic flora and fauna. In stands that border old-growth core stands, uneven-aged systems that approximate the stand structure of the old-growth core should be applied; the goal is to protect the core stand from adverse off-site ecological effects, and to minimize ecological contrast between stands. Potential replacement old-growth stands can be managed in two ways. In one, the same standards are applied as in existing old-growth core stands -- no extractions, natural dynamics imposed. If this was done in Arkansas wilderness areas, a major addition to the sustained yield of functional, dynamic old-growth stands in the Interior Highlands would be achieved. Alternatively, the proposed replacement old-growth stand can be treated as an uneven-aged buffer stand, until the stand is allowed to revert to old-growth condition. In either alternative, stands adjacent to the candidate old-growth stand should be managed as uneven-aged stands, to minimize exogenous disturbance and off-site degradation.

Silviculture and Old Growth -- The Quintessential Oxymoron?

To the zealous advocates that either singlemindedly support intensive timber management or singlemindedly oppose it, the notion of silvicultural practices for old-growth stands is no doubt oxymoronic. The use of silviculture -- the time-honored or -dishonored tool of timber management -- for so noble or ignoble a purpose as management of old-growth stands is seen by one group as a poor excuse for silviculture and by the other as a corrupt venality of ancient forests. But under a less dogmatic interpretation, the ecological attributes and character of old-growth stands

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may respond positively to the benevolent manipulations of a silviculturist who plies the craft with an ecologically sensitive and technically dexterous hand.

In theory, silviculture is an applied ecological science (Smith 1986), in which the biotic influences of the component species are configured so that the goals of the landowner can be satisfied. When the landowner emphasizes timber production, silviculture encompasses the establishment, tending, and harvest of a stand of trees that have valuable wood properties. But a landowner may seek forest resource values such as wildlife habitat, protection of endangered species, or aesthetically pleasing forest stands, either in conjunction with or independent of timber production. The manipulations required to achieve those values are still wholly in the realm of silviculture. The same silvicultural theories that in one pattern of implementation give rise to an even-aged single-species plantation can, in a second pattern of implementation, maintain multi-aged mixed-species natural stands that are very old and full of large trees.

The primary ecological decision a silviculturist makes is whether to retain the biotic influence of a given individual tree, shrub, herb, or forb in the stand. In timber management, the term "crop tree" describes a desirable tree whose biotic influence is to be optimized (Smith 1986). However, the "crop tree" concept also applies to non-timber resources. Under a silvicultural system for red-cockaded woodpecker (*Picoides borealis*) habitat, a large loblolly pine (*Pinus taeda* L.) with decayed heartwood classically defines a "crop tree", if so utilitarian a term can be used for so noble an example. That same tree is a less-than-ideal product under timber management, because sawmill owners think that decayed wood makes lousy lumber. This illustrates the breadth of vision that contemporary and future silviculturists must increasingly acquire and easily espouse.

The silvicultural decision to eliminate the biotic influence of a given individual tree, shrub, herb, or forb -- that is, to cut it down, burn it up, kill it with herbicides, trample it, or browse it to death -- is thus of secondary importance (Smith 1986). Ideally, a silviculturist will prescribe the removal of only those plants that show immediate or incipient adverse effects on the survival, growth, and/or reproductive ability of the desired individuals. This occurs through silvicultural judgments about relative competitive ability (either interspecific or intraspecific, within the main canopy or between canopy and understory), the threat or reality of infection by disease agents, infestation by insects, or actions of abiotic stresses.

It is strictly a tertiary theoretical factor, albeit one with significant monetary implications, that the "removed" trees can be hauled from the stand for economic gain. The noble concept of resource renewability emanates from this concept. So does the current lack of old-growth stands. There have been all too many instances where lumbering, greedily wrought within a stand, makes absolutely no provision for regeneration or reestablishment of a productive forest community. There are, sadly, a few foresters who are more concerned about what is being removed from the stand than what is being retained. Such attitudes are based in the economic constraints

under which foresters perceive themselves, sometimes mistakenly, to labor. Silviculture ends by imposing ecologically-based treatments that remove unwanted biotic influences; timber management begins by arranging for the commercial extraction of the residue of those treatments.

As modern silviculture embraces wildlife, recreation, watershed, and other non-timber resource values, it becomes increasingly important, and increasingly difficult, to define the often nebulous goals of the landowner. For example, the first objective in management for the red-cockaded woodpecker is to quantitatively define the preferred habitat for the bird; the second objective is then to devise silvicultural systems that recreate that habitat. As recent court activity in the issue will attest, this is not an easy task. Devising silvicultural systems to emulate intricate ecological conditions will be most limited by the lack of quantification, and perhaps even the lack of qualitative descriptions, of the target stand condition toward which the silviculturist should aim.

This is exemplified in the management of old-growth forests. As we have seen during the course of this symposium, old-growth stand characteristics are often difficult to quantify, and occasionally even to qualitatively define. However, since a broad ecological definition of old-growth stands is generally accepted, it is within my purview to undertake some discussion as to how a silviculturist can achieve these broad characteristics. Accordingly, my comments will address the manner in which silviculture can be applied to further the development of existing and potential old-growth stands; I will use a few examples from Arkansas in the process.

The Old-growth Stand and its Silvicultural Emulation

A simple definition of old-growth forest is neither universally agreed upon, nor generally applicable to all forest types (Franklin and Spies 1984, Hunter 1990). Common denominators in the definition are that stands are dominated by old trees, though the age may vary among forest types (Parker 1989, Barnes 1989, Alaback and Juday 1989, Achuff 1989), that the ecosystem is more or less undisturbed by human activity for an extended period, again the details of which vary among forest types (Franklin et al. 1981, Barnes 1989, Achuff 1989, Hunter 1990, Whitney 1987), and that the structure of the stands is multi-aged, multi-diametered, multi-layered, and with large woody biomass on the ground within the stand (Parker 1989, Barnes 1989, Juday 1988). Conceptual models of forest succession place old-growth stands in the final developmental stages, called the old-growth stage (Oliver 1981) or steady-state phase (Bormann and Likens 1979). Beyond this conceptual framework, definitions of old growth are admirably imprecise, allowing for adjustments specific to given regions and forest types.

An obvious feature in the character of old-growth forests is that the dominant trees are impressively large, with common reports of trees exceeding 100 cm (Parker 1989, Guldin et al. 1989, Alaback and Juday 1989, Lorimer 1980). Large tree size is an awe-inspiring attribute in the eyes of most people (Juday 1988). It also strikes at the very heart of why there is so little old-growth forest remaining, in that large trees have (or had) an extremely high conversion value when manufactured for lumber (Kirkland and Brandstrom 1936). From this combination of attributes, I draw the conclusion that large tree size is a highly desirable attribute of old-growth stands.

A second feature of old-growth is the prevalence of large woody biomass on the ground. Current knowledge about old-growth forests is too limited at this time to firmly establish the ecological importance of fallen or downed woody biomass (Hunter 1989). It is firmly established that timber extractions through the harvest of standing or fallen trees would alter the decomposition dynamics of this large woody biomass component. The ecological footprint of equipment designed to extract large boles from the woods can be made to be light, but, in felling and skidding, even the most benevolent timber extraction will, if not by definition then certainly in spirit, disrupt old-growth character. Even selective cutting under the best intentions has been shown to devastate old-growth forest stands (Isaac 1956). Timber extractions of any sort would thus appear to be inconsistent with old-growth stand dynamics.

With respect to other ecological characteristics, old-growth reserves should be functionally dynamic ecosystems rather than static botanical exhibits. Old-growth stands should be subject to as natural a disturbance regime as can be ecologically imposed (Noss 1985). This has a dual implication; disturbances that have been excluded by humans should be imposed, and disturbances made more significant through human activity should be constrained.

Some disturbances are quickly suppressed whenever they occur, because they can be potentially devastating. For example, fire, insect outbreaks, and disease epidemics were at one time common disturbance agents in the forest; suppression of these natural forces may increase their catastrophic potential (Moir and Dieterich 1988, Barnes 1989, Achuff 1989). Other disturbances may be more prominent as a result of forest management. For example, white-tailed deer are more common in managed forests than in presettlement forests (Tilghman 1987), because of the prevalence of seral stands, the elimination of predators, and political pressure from hunters to maintain high populations; the increased foraging activity of deer clearly affect understory vegetation dynamics in natural stands. Finally, forest fragmentation may place old-growth relict stands at greater risk of disturbance, such as by windthrow, simply because they are surrounded by managed stands of vastly different structure (Noss 1987). To determine whether disturbances are over- or under-represented in existing old-growth stands, significant progress must be made in quantifying the role of biotic and abiotic influences in old-growth ecosystems.

The physical boundaries of most existing old-growth stands are not based on ecology, but rather on historical accidents of land ownership that prevented the stand from, in

the words of Chekhov, "groaning under the axe" (Fen 1959). It is the rare land line that corresponds with ecologically significant physiographic, edaphic, or ecological factors (Noss 1987). However, the disturbances that occur in a stand often depend greatly on the ecological characteristics of adjacent stands (Forman 1987). The absence of a mature stand adjacent to an old-growth stand creates an ecological discontinuity that may promote an unnatural disturbance regime in the old-growth stand.

Stand demarcation is a major silvicultural task. Boundaries should ideally conform to natural landscape features such as ridges, streams, soil types, or physiographic patterns. Stands should be sufficiently large to account for prevailing natural dynamics in the community (Pickett and Thompson 1978). It would be especially logical to delineate old-growth stands according to preserve design criteria (White et al. 1983) and landscape features, such that stand identity could occur at the primary, secondary, or tertiary watershed level in a dendritic pattern (Harris 1984).

Given the fragmentation and altered disturbance regime of old-growth stands, questions arise regarding the ultimate species composition in these stands. One facet of this is the question of exotic species (Harty 1987, Parker 1989) such as honeysuckle (Evans 1984). Exotics might be viewed as evolutionary factors to which forest communities must adapt, or as a perniciously degrading human influence to be removed from old-growth stands. A key silvicultural question is whether the influence of exotics in an old-growth system is ecologically significant. If a decision is made to conduct a botanical holy war against exotics in natural areas, questions of degree, economic feasibility, and appropriate tactics will become prominent.

The more intriguing facet of old-growth species composition is the relative importance of native species in a given old-growth stand in a given location – for example, pines versus hardwoods. Selective lumbering, intensive management in adjacent stands, exclusion or alteration of disturbance agents and patterns, and the influence of exotic species all affect species composition. If the existing vegetation in an old-growth stand is inappropriate, the landowner might consider either selective removal or selective introductions to better reflect the natural species composition. Such interventions are quite within the abilities of the typical silviculturist, in that they resemble treatments conducted when timber goals are important in a stand. Yet, because such treatments will resemble treatments imposed for timber management, old-growth proponents may view them as ecologically mercenary. Because of this, discussions of old-growth stands should also occur within the field of restoration ecology and its silvicultural tactics.

Silvicultural Objectives in Mature Old-growth Forest Stands

Silvicultural treatments within old-growth core stands

The forestry community, represented through as professionally mainstream an organization as the Society of American Foresters (S.A.F. 1984), is unequivocally clear with respect to old-growth stand management:

With present knowledge, it is not possible to create old-growth stands or markedly hasten the process by which nature creates them. Certain attributes, such as species composition and structured elements, could perhaps be developed or enhanced through silviculture, but we are not aware of any successful attempts. Old growth is a complex ecosystem, and lack of information makes the risk of failure high. In view of the time required, errors could be very costly. At least until substantial research can be completed, the best way to manage for old growth is to conserve an adequate supply of present stands and leave them alone.

In my interpretation, to "leave them alone" means that harvest of the old growth should be prohibited. Salvage of fallen old-growth material should be administratively prohibited as well, given the increasingly recognized importance of downed biomass in defining old-growth character.

For example, in the past decade in Arkansas, two old-growth stands have had significant numbers of large trees blow down during windstorms. In the early 1980s, the boundary of an existing research natural area containing old-growth shortleaf pine was altered to permit salvage logging of windthrown timber (Grimmett, personal communication). In the second case, requests to log windthrown material in a bottomland hardwood tract under administration of the Arkansas Natural Heritage Commission were rejected (Pell, personal communication). These changing outcomes reflect a heightened political and ecological awareness of old-growth dynamics in the natural resources community in the past decade. To the scientist, the processes by which old-growth forests respond to major disturbance are of equal interest to those processes that occur in small gaps. An important goal of management at this stage should be to ensure that neither instance be subverted through human activity such as salvage logging.

There are, however, two legitimate reasons to consider silvicultural intervention in an old-growth core stand. The first relates to pre-settlement disturbance dynamics in old-growth forests (White 1987, Whitney 1987). For example, many stands in the Interior Highlands have developed in intimate association with fire. But since the 1930s, fire suppression activities by forest management agencies have removed this critical natural influence on forest ecosystem development. An initial administrative effort to reintroduce fire in old-growth systems should be made by land managers in consultation with the landowner, or more appropriately with an interdisciplinary team of resource professionals who can provide input or formulate policy for the

landowner. A logical extrapolation of this reasoning would be to study equally natural and potentially devastating biotic disturbances such as the southern pine bark beetle in an old-growth stand (White 1979) – though I suspect that ecologists and silviculturists are a long way, both by scientific support and professional inclination, from reintroducing anything except fire.

The second decision concerns control of exotic species that currently exist in old-growth stands. Several standards, corresponding to traditional silvicultural decision-making about such matters, might be considered – such as whether the exotics are ecologically significant and, if so, how to control them. Tactics might include mechanical, chemical, or ecological control, or perhaps some combination of the three. However, employing CCC-like squads of "honeysuckle pullers" in every research natural area in Arkansas would probably ensure the devastation of the very plants for which protection is sought. On the other hand, if kudzu has impeded gap-phase regeneration dynamics in every natural gap created in the past 20 years in an old-growth bottomland hardwood stand, one might build a case for imposing a control effort. In making a decision to control an exotic species, the problem must be defined and quantified, tactics for conducting the control effort must be designed, and criteria for judging success must then be formulated.

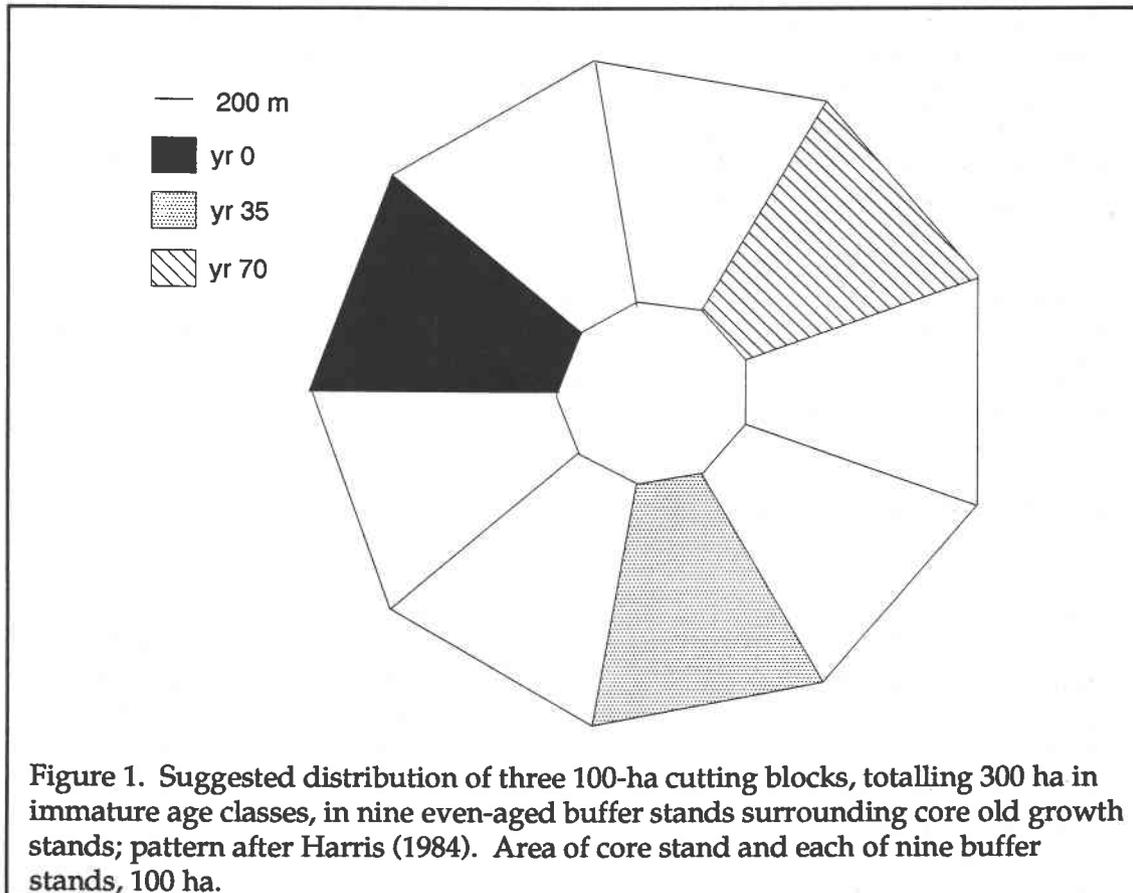
Silvicultural treatments in stands adjacent to old-growth core stands

The most direct use of silviculture in old-growth stand management is in the configuration of the old-growth stand boundaries and management of adjacent stands. A simple silvicultural goal could be stated as reserving an old-growth stand at a watershed level, and managing adjacent watersheds so as to maximize their value as an ecosystem buffer for the old-growth stand. Configuration of the buffer stand should ensure that the probability of exogenous disturbance affecting the old-growth core stand is within acceptable ecological norms.

For example, in his innovative book, *The Fragmented Forest*, Harris (1984) espouses the concept of a system of long-rotation islands that surround each stand currently established as old-growth. He develops a rather detailed example in which an old-growth stand is surrounded by nine even-aged stands managed with a 320-year rotation, and with a 35-year age difference among each stand, such that 66% of the managed buffer stands are over 100 years old, and 33% are less than 100 years old (figure 1). Unfortunately, the proposed area regulation approach, resulting in even-aged stands, will less effectively resemble the gap-phase dynamics of old-growth stands than would a big-tree uneven-aged system.

Use of the even-aged buffer model, imposed according to Harris' recommendation as a circular sequence of even-aged cuttings around the core old-growth stand, contains a rather prominent flaw in areas subject to heavy winds, as are common in Arkansas. Most prevailing storm winds in Arkansas come from a single consistent westerly

direction. At some point in the proposed sequence of cutting, a wedge-shaped section of forest will be cut whose widest point faces the direction of these prevailing winds, and the narrowest section of which is immediately adjacent to the old-growth stand, as illustrated by the year 0 age class in figure 1. This silviculturally-created wind tunnel will accelerate the speed of the prevailing winds, and will direct those accelerated winds directly toward the old-growth stand.



This untenable situation contravenes the intention that buffer stands should promote the resistance of the old-growth core stand to unnatural levels of exogenous disturbance.

For well over a century, silviculturists throughout the world have devised regeneration methods whose fundamental goal was to never expose a wall of mature timber to the force of prevailing westerly winds (Troup 1928). For example, the shelterwood wedge system *Keilschirmschlag*, developed by Eifert (1903) in the Black Forest of Germany, consists of making cuttings in the shape of wedges whose narrow end was pointed toward the direction of prevailing winds, the explicit purpose for which was to diminish the risk of damage by wind. Logic suggests that a

reproduction harvest implemented in the converse manner, with the the broad base of the wedge oriented toward the wind, correspondingly increases the risk.

A suggested modification of Harris' even-aged long-rotation islands would be to establish the adjacent stands as an equivalent area of uneven-aged mixed-species stands managed to rather large (100+ cm) maximum diameters. Uneven-aged stands are thought to be much more resistant to wind damage than even-aged stands (Troup 1928, Knuchel 1946). The processes of gap-phase regeneration by which old-growth forests regenerate themselves serve as the basis for regenerating uneven-aged stands at the hand of the silviculturist. Harris (1984) advocates thinning in the managed buffer stands, presumably throughout all age classes, and further suggests that the exclusion of thinning in any single age class for an extended duration of time might confer old-growth attributes to the border stands. The same argument can be applied to the uneven-aged buffer stands, perhaps with stronger emphasis in that stands managed under the uneven-aged condition for an extended period, and subsequently left to its own developmental devices, will sooner and more closely resemble the structure of the uneven-aged core stand than would an even-aged stand similarly managed and abandoned.

The uneven-aged scenario provides another advantage when considering edge effects. Harris (1984) observed that his even-aged long-rotation scheme contains 33% of the area in young habitat and 66% of the area in stands over 100 years old, and retains connectivity through the old-growth core. An uneven-aged long-rotation scheme can be similarly configured and organized and has an added advantage in that the entire 1000-acre block is heterogeneously interconnected. For example, assume a 1000-ha section subdivided into a 100-ha central "core" old-growth nonagon-shaped stand and nine 100-ha stands, of isosceles trapezoidal configuration, harvested in conformance with Harris' theory such that three 100-ha blocks (33%) of the managed stand are in younger age classes whose perimeter provides significant edge effect adjacent to older managed age classes (figure 1). Calculating the perimeter area of the isosceles trapezoids, and expressing that perimeter in units of m of edge/ha, the linear edge ratio is 12.7 m/ha through the entire 1000-ha managed block (table 1).

If, however, one creates group selection openings consisting of 3-ha nonagons covering 300 ha (33%) of the managed block (figure 2), the linear edge ratio is roughly 5 times the length of edge under the even-aged alternative (table 1).

Similarly, creating 300 1-ha nonagonal group openings (figure 3) produces nearly 9 times the edge of the three 100-ha blocks (table 1). At the extreme, creating 3000 0.1-ha nonagonal "single-tree" selection openings produces 27 times the edge of the three 100-ha blocks; creating 12000 gaps of 0.025 ha or 250 m², a size previously reported as common in old-growth woods (Runkle 1984), produces over 50 times the edge of the 100-ha blocks (table 1).

Thus, I propose a modification of the long-rotation island scheme proposed by Harris (1984), in which the old-growth core area would be surrounded by a continuous block

Table 1. Number of openings, area of openings, and resulting summed perimeter of openings as an index of edge effect, under different cutting patterns in buffer stands surrounding old-growth core stand.

Pattern of reproduction	Number of openings	Size per opening, ha	Cumulative opening perimeter, m/ha
Even-aged	3	100	12.7
Uneven-aged, large groups	100	3	62.7
Uneven-aged, small groups	300	1	108.6
Uneven-aged, large single tree	3000	0.1	343.4
Uneven-aged, small single tree	12000	0.025	686.8

Total area in regeneration, 33% of buffer stands, or 300 ha in this example. Even-aged pattern as proposed by Harris (1984).

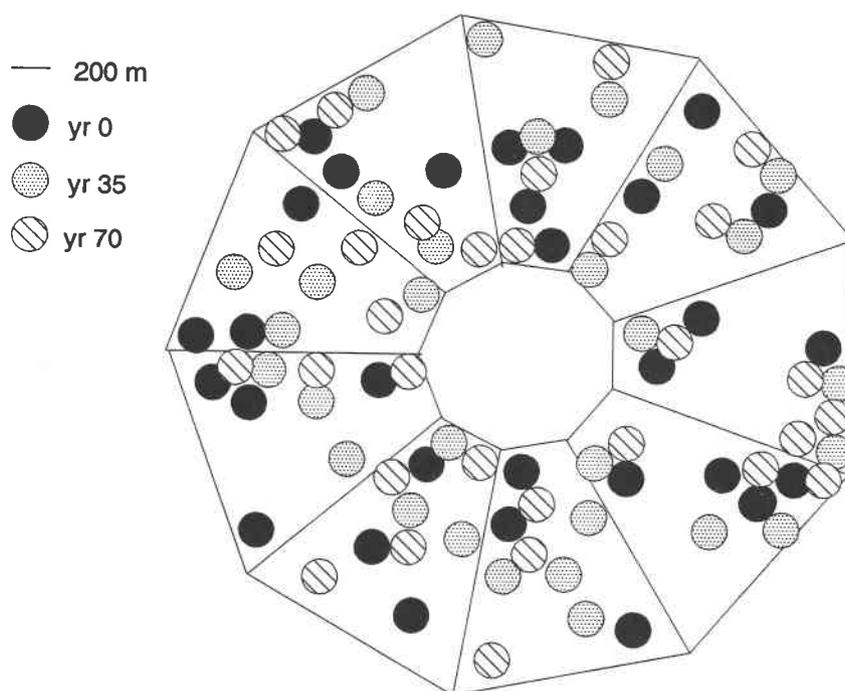
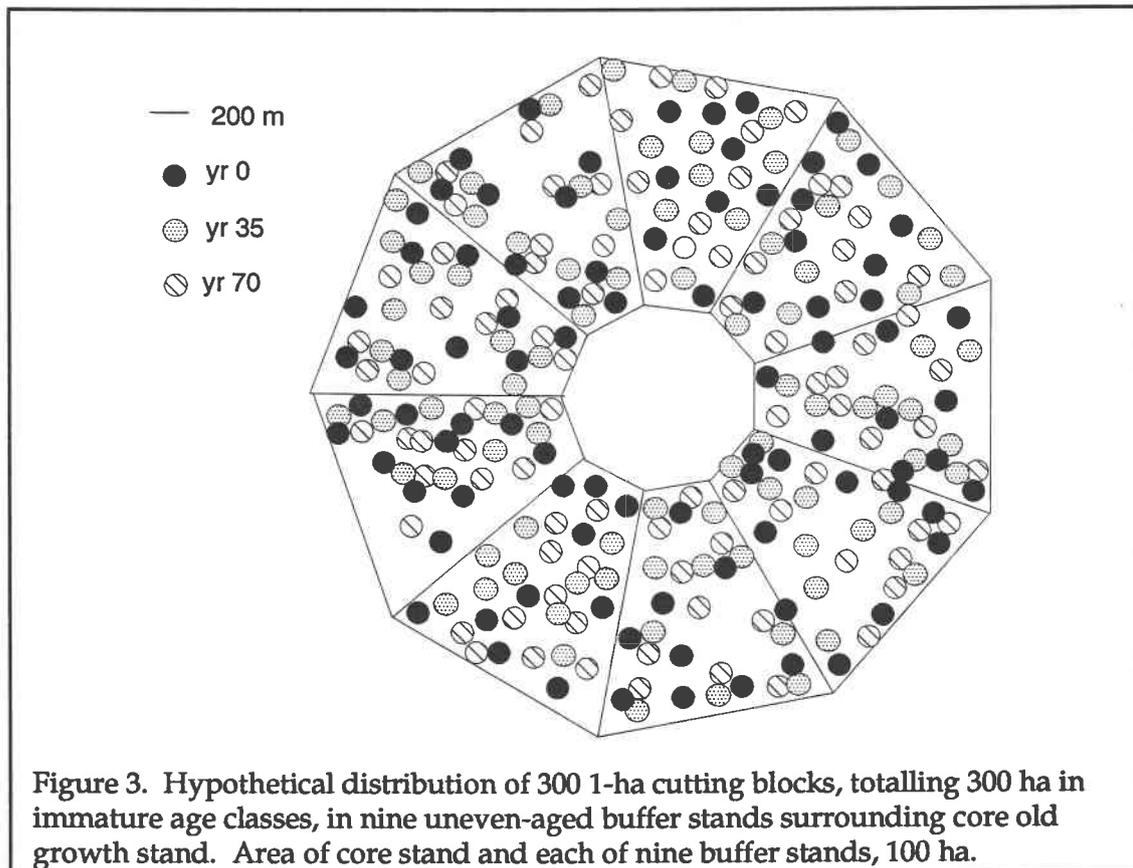


Figure 2. Hypothetical distribution of 100 3-ha cutting blocks, totalling 300 ha in immature age classes, in nine uneven-aged buffer stands surrounding core old-growth. Area of core stand and each of nine buffer stands, 100 ha.

of uneven-aged stands. Silviculture within the uneven-aged stand would promote the species composition and stand structure, in both diameter class distribution and canopy profile, as found in the old-growth core stand. Sizes of openings would be

consistent with recommendations from forest ecologists and wildlife biologists. Some openings might be quite large, but others would be quite small, and the goal would be to reduce the incidence of allogenic disturbance on the core stand.



The proposed uneven-aged stands should be managed under the selection system using structural control-BDq methodology. Under this regulation method, the target species composition and distribution of species by diameter classes in the managed stands can be configured to resemble that expected in the old-growth core stand. The basal area of the managed stands should be proportional to that of the old-growth core stand, with adjustments made to provide levels favorable for regeneration development. The maximum retained diameter should be set to approximate the big tree size in the old-growth core, with from 60 to 100 cm appropriate for forest types in the Arkansas interior highlands. The pattern of implementation of the BDq target stand, specifically the size of gaps within which regeneration is to become established and develop, should also parallel the gap size either existing or expected in the old-growth stand. Data from the Lake Winona Research Natural Area on the Ouachita National Forest (Fountain 1991) give an initial target structure for the pine component of an old-growth stand. In the pine component of such a stand, the target after-cut basal area B is $20 \text{ m}^2/\text{ha}$, the maximum retained diameter D is 75 cm, and the negative-exponential ratio q is at approximately 1.1275 for 2-cm dbh classes (figure 4).

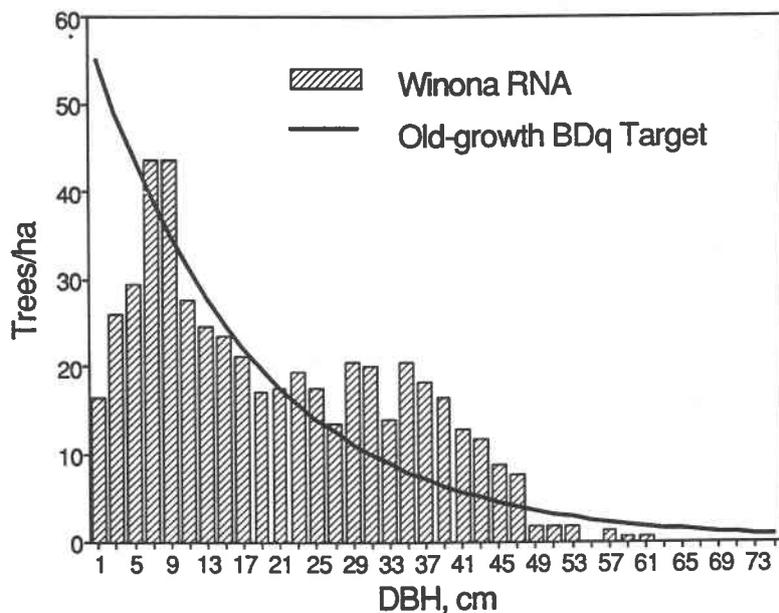


Figure 4. BDq target structure proposed for old-growth shortleaf pine component in buffer stands in the shortleaf pine forest type of the Ouachita Mountains. Winona RNA stand structure data from Fountain (1991). BDq structural parameters: residual basal area B , $20 \text{ m}^2/\text{ha}$; maximum retained diameter class D , 75 cm ; negative exponential ratio q (2-cm diameter classes), 1.120715 .

Unfortunately, the acquisition of a ring of buffer stands around each old-growth stand in Arkansas, each equal to nine times the area of the core stand, is unrealistic given the time, human resources, and organizational budgets.

An alternative is the use of conservation easements, in which the buffer-strip landowner agrees, for a fee, to constrain his or her use of the buffer strip to the terms outlined in the easement. A buffer strip 200 m wide (in English units, about the width of a forty-acre block) might confer an acceptable degree of site protection, if managed under the uneven-aged scenario described above.

For example, under application to the Lake Winona RNA of the Ouachita NF, the forest service would enter into a conservation easement with the forest industry that owns the surrounding plantations, whereby those plantations are taken under transition to uneven-aged stand structure, imposed in a manner similar to that of the buffer stands.

Within adjacent stands, silvicultural treatments must be conducted to minimize adverse effects on the old-growth stand. For example, poor logging technique or improper road construction up-watershed from the old-growth stand should be controlled at the source. Use of herbicides directly adjacent to old-growth stands should be carefully constrained, if not prohibited; nonselective application methods

such as aerial sprays or broadcast application of soil-active herbicides upstream of the old-growth stand should be eliminated in favor of selective application of soil-inactive herbicides to individual trees, or other application procedures and chemicals that result in low mobility and in situ decomposition of the herbicide.

Any silvicultural treatments imposed in the old-growth stand should also be imposed in the adjacent stands. For example, the reintroduction of fire should be undertaken concurrently in both the old-growth core stand and adjacent stands; this would minimize the ecological discontinuities in the area. Fire is certainly not a tool amenable to uneven-aged silviculture practiced on short cutting cycles, but it is probably feasible to use fire under the irregular structure imposed in buffer stands that feature long cutting cycles, large openings created for regeneration that are skirted by surface fires for lack of fuel, and development of a poorly-balanced stand structure that is less than perfect in its conformation to the target stand structure. Similarly, any decisions made to control exotic species in the old-growth core stand should also be imposed in the buffer stands.

Nearly all of the old-growth stands in Arkansas would benefit from designation of adjacent stands as uneven-aged buffer stands, perhaps under long rotations or uneven-aged structure. This activity should be given high priority, especially where the same landowner manages the adjacent stands, such as those on government ownership. High priority should also be given to consolidation of ownership around existing old-growth stands. A classic example is the group of industry-owned, even-aged plantations that surround the Lake Winona RNA of the Ouachita NF; priority should be given to trading for or purchasing these plantations, removing the exotic pine planted adjacent to the old-growth stand, and managing for a natural pine-hardwood stand. A similar high priority should be given to convening a statewide professional advisory group to recommend reintroduction of excluded disturbances or control of exotics in existing and proposed old-growth core and buffer stands.

Silvicultural Objectives in Stands Under Transition to Old-growth

Many researchers in old-growth stand dynamics have commented on the temporal fragility of reserving small tracts of old growth. The small size of many existing tracts of old growth makes them susceptible to devastation by catastrophic ecological event, or reduction in the core size of the area through disturbance either at the stand border or in the core area. As a result, many existing old-growth sites may not retain in perpetuity the kind of community for which the area was dedicated if the border areas are not carefully managed. To ensure that which in management parlance could be termed a sustained yield of old-growth stands, replacement potential old-growth stands such as imagined by Harris (1984) can fill a key role.

Unmanaged replacement old-growth stands

The first alternative in the creation of replacement old-growth stands is to follow the same procedures as are established for the reservation of existing old-growth, namely to identify the boundary of a potential old-growth stand and cease operations within the stand. Under this scenario, many of the similar concerns discussed in the preceding section apply, with the exception that the potential old-growth stand, undisturbed by human intervention and silvicultural operation, have the characteristics of the existing old-growth stand. The same decisions with respect to identification and management of buffer stands, conduct of prescribed fire or other excluded ecological influences, elimination of adverse exogenous influences from adjacent stands, and control of exotics must be made in a potential old-growth stand as in an old-growth stand.

A major land base that might play an extremely prominent role in the old-growth forest resource in the next century is wilderness (Juday 1988). Wilderness areas in Arkansas are large tracts, occurring disproportionately in the Interior Highlands of the state, and include both shortleaf pine and upland hardwoods forest types. However, these wilderness areas are not typically managed as old-growth stands. For example, management provisions do allow wildfires to burn until they threaten adjacent areas. However, there are no explicit provisions to ignite controlled fires that might recreate an old-growth fire regime. Some insect and disease outbreaks within wilderness areas are suppressed. However, no efforts are currently made to prevent the establishment or control the development of exotic species. If wilderness areas are to contribute to the old-growth resource, and it is logical to presume that they can, it will be necessary to resolve some of these issues so that the prevailing ecological dynamics within the wilderness areas approximate old-growth conditions.

Managed replacement Stands

A second alternative, of lesser theoretical desirability but perhaps of more practical value in the political reality of contemporary resource management, is to allow some timber extractions in areas selected as old-growth replacement stands. A similar uneven-aged silvicultural system previously discussed for old-growth buffer stands would apply, if modified to meet several interim objectives. First, at some point, timber extractions would cease, and a lengthy unmanaged period would follow prior to an area being labelled as "old-growth". The goal of this silvicultural system would be to develop the stand structure, species composition, and prevailing disturbance regime characteristic of existing old-growth stands, or reasonable ecological approximations of them.

For example, consider imposing an uneven-aged system based on the parameters presented previously. The goal of this silvicultural system would be to develop a stand structure that resembles that of an old-growth stand, emphasizing the development of accurate species composition either through removal of species that are overrepresented in the stand or through artificial establishment of species that are

underrepresented. A highlight of the system would be the fostering of a big-tree component; as trees exceed 75 cm, they would no longer be candidates for harvest. When, within any subunit of the stand, a certain minimum number of trees (e.g., 5) per ha exceed 100 cm, that subunit would be withdrawn from harvest. We know from existing uneven-aged stand dynamics that this is likely to occur more rapidly in the coves, benches, and near streams than in the upper-elevation subunits of the stand. If land ownership patterns allow, a final specification might assert that timber harvest ceases within the entire stand when one-third of the stand, by area, is no longer open for harvest. The stand that results would have big-tree character, some regeneration openings of various sizes, and a heterogeneous distribution of diameters and crown canopy.

However, it should be clearly understood that these stands are silviculturally, not naturally, created. Timber extractions can promote openings in the canopy that resemble natural exogenous disturbances, but they do not reproduce the micro-climatic environment that occurs under natural disturbances. For example, when a large tree in an old-growth stand is blown over by heavy winds, the uprooted roots and the soil pit from whence the roots came form the characteristic pit-and-mound microtopography that is simply not emulated by a stump. Of course, the stump could be dislodged from the soil using a bulldozer and laid on its side, but not without other ecological impacts. In addition, the bole of the windthrown tree remains on the site, and its decay contributes an important ecological component of large woody biomass; this is clearly absent if the log is hauled off.

Accordingly, such stands should not be called "old-growth" stands. "Old-growth" should only refer to existing or future stands not subject to human influence. Big-tree stands created silviculturally should be given a different name, such as "reserve stands" or "forest reserves". Upon cessation of harvest operations in a replacement core area, timber extractions will continue to be excluded, even in the event of catastrophic disturbance. It would only be through catastrophic disturbance that the managed past of the tract could be purged, and the stand that arises in the absence of management and under natural influences would immediately be established as a "research natural area", eventually over the centuries to qualify as "natural old-growth". This has the added advantage of, ultimately, allowing additional old-growth stands to come into existence.

Of these two alternatives, the greatest potential for significant expansion of old-growth forests in Arkansas is through existing wilderness areas, where management adjustments focus on reestablishment of an ecologically-based natural disturbance regime. Using managed stands as a source of replacement old-growth stands is less theoretically wholesome, though may have an advantage of political expediency by remaining open for some timber extractions. However, the area available through a broadened definition of wilderness is so much greater than that which might occur through managed replacement that prominent effort should be made in that direction. In areas where old-growth is lacking or in forest types where wilderness areas do not currently exist, managed replacement stands may be the major alternative. Other

areas, especially buffer zones around old-growth or potential old-growth core stands, might be managed according to the uneven-aged systems described, with the ultimate goal being the withdrawal of timber extractions when stands reach minimum standards of tree size, community composition, or stand structure.

Summary

When considering silvicultural practices in old-growth stands, several lines of thought emerge. The first relates directly to protected old-growth stands; the second applies to those stands considered as candidates for eventual classification as old-growth.

In areas currently identified as old-growth stands, there should be no timber extractions of either living or dead trees. This unequivocal prohibition would encompass not only minor gap-creating disturbance events but also the ultimate eventuality of catastrophic disturbance. For example, should the old-growth shortleaf pine stand of the Winona RNA entirely blow down tomorrow, salvage logging should be absolutely excluded, and the area should retain its RNA status.

However, in existing old-growth stands, decisions must be made regarding the imposition of excluded ecological treatments and control efforts for exotic species. Ideally, on national forest lands, the advice of an ad hoc committee drawn from outside the forest service and including plant ecologists, wildlife biologists, botanists, and silviculturists, would be solicited and incorporated into the land management planning process. Discussion should, at this time, center primarily on the use of fire, and the control of honeysuckle and kudzu.

Serious and immediate consideration should also be given to the establishment of buffer stands around every core old-growth stand in the state. The purpose of this buffer would be to protect the core area from adverse ecological effects that might occur in the old-growth stand due to its fragmented character, to adverse effects from the intensive or adversely extensive management of adjacent forest stands, and/or to non-forest development of adjacent lands. Ideally, the buffer would be under management control of the landowner that owns the old-growth stand, and would be on the order of 9 times as large as the area itself (*sensu* Harris, 1984). However, a small buffer is better than none, and an attainable target might extend at least 200 m from the boundary of the tract. On tracts that border other landowners, outright acquisition may be impossible; in that event, conservation easements might be negotiated.

Management of all lands adjacent to old-growth core stands should be under big-tree uneven-aged silvicultural systems, applied through structural control methodology to targets derived from existing old-growth stands in the same forest type. The target species composition and distribution of species by diameter classes in the managed stands should resemble that expected in the old-growth core stand. Excluded

disturbances and control of exotics should be implemented as in the old-growth core stand.

Replacement old-growth stands could originate from two sources. The first is through a slight reorientation of management of existing wilderness areas on federal lands. In a century, most of these areas will begin to approach the structure of old-growth. Re-introduction of excluded ecological treatments such as fire may, in fact, render wilderness areas more nearly like primeval old-growth than current older stands whose past six decades of development have occurred largely in the absence of fire. Alternatively, replacement old-growth stands can be established by preventing timber extractions and other high impact uses, by re-introducing excluded ecological factors, and by establishing buffer strips.

The second source is through managed replacement stands. Under this alternative, stands of desirable even-aged or uneven-aged character would be configured to resemble old-growth stand structure through application of innovative silvicultural tactics that recreate species composition, stand structure, and natural disturbance regime. Timber extraction would continue in these areas until the attainment of a given target old-growth structure, at which time harvests would cease. Such areas, more appropriately termed "forest reserves" rather than old-growth, might help augment the current supply of potential and existing old-growth. This approach may be most feasible in the buffer stands such that, over time, buffers might serve to enlarge an old-growth core area.

The ultimate goal of old-growth management should be to produce a sustained yield of functionally dynamic old-growth ecosystems. At its simplest, a nondeclining even flow of old-growth would be achieved by a long-term approximation of area regulation: by determining the natural disturbance interval and the duration of existence of an old-growth stand from the time it is identified as old-growth until it is subject to major disturbance. If the disturbance interval is 200 years, and the average old-growth stand is catastrophically disturbed within 50 years of being identified as "old-growth," at an absolute minimum there should be one stand in existence and three stands in the old-growth developmental pipeline, all under an exclusion of harvest and all with suitable buffer stands surrounding them. The adaptation of wilderness areas to old-growth character represents the most direct single step whereby this sustained yield of old-growth can be assured into the next century.

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