PIONEER FOREST

A Half Century of Sustainable Uneven-Aged Forest Management in the Missouri Ozarks

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Cover Photo:

Ed Woods observing old growth white oak at Pioneer's Randolph Tract along the Current River. *(Courtesy of Pioneer Forest)*

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PREFACE

This collection of papers analyzes the Pioneer Forest, a privately owned 150,000-acre working forest in the Missouri Ozarks on which the science and art of forest management has been practiced for more than 50 years. The papers discuss how this half century of management has contributed to forest restoration and sustainability on the forest itself and, through its example undergirded by a remarkable body of research, throughout the Ozark region and beyond.

Pioneer Forest embodies the stewardship ethic of its founder and long-time owner, Leo Drey. Much more than a working forest producing timber and jobs on a sustained basis, Pioneer Forest has contributed to the local economy, served as a working demonstration for other private forest landowners, cooperated imaginatively with an array of public agencies, conducted its own research and been widely available to outside researchers, and been open for hunting, fishing, and a wide variety of primitive recreational pursuits. Through his leadership and commitment, Leo Drey has influenced many developments in conservation by pioneering in landscape restoration, natural areas preservation, forest recreation, and sustainable ecosystem management. In his daily activities and in his remarkably consistent, public-spirited vision over the half century of his ownership, Leo Drey has set a new standard for what it means to be a private forest landowner, not only in the Ozark Mountains but also in the Nation.

In July 2004, Leo Drey and his wife Kay donated the lands of Pioneer Forest L.L.C., along with its offices, staff, and long-standing management and research experience, to the L-A-D Foundation. With this magnificent gift—valued at $180 million, one of the top philanthropic gifts in the Nation that year—the work of Leo Drey's lifetime will continue to be available as a living embodiment of his stewardship ethic and as a working model for all who are interested in innovative approaches to sustainable management of private forest lands throughout the Nation.

Most of the research and discussion papers in this volume grew out of a symposium held in October 2001 in St. Louis, MO, on the occasion of the 50th anniversary of the founding of Pioneer Forest. The Missouri Botanical Garden and Tower Grove Park hosted the event. The symposium was an opportunity for nearly 200 individuals to gather and reflect on this forest's long history of accomplishment.

Following the symposium, the authors of several of the principal papers substantially rewrote and augmented their analyses, and the editors commissioned a number of additional papers to round out a volume that highlights the wide reach of the forest and its most important influences. As a result, there is a spectrum of academic rigor and scope in these papers. A few have been developed into much more ambitious treatments than the original presentations. Despite the mixed character of the final product, we feel that it is worthwhile for the sake of the overall record to include all of the presentations.

The volume opens with two papers offering historical perspective. Forest ecologist James Guldin traces 500 years of change in the forests of the Ozark Mountains and in people's attitudes toward and management of them from pre-European conditions through exploitation and recovery to the era of modern forestry. Environmental historian Susan Flader follows with an extensive analysis, grounded in original archival records, of the establishment and management of Pioneer Forest over the past half century and its influence on regional development in the Ozarks, including both private and public land management.

The next four papers analyze the uneven-aged silviculture by single-tree selection that has been practiced consistently on Pioneer Forest over the years and some of its ecological context and implications. Silviculturist Edward Loewenstein, who has studied the science and art of forest management on Pioneer for more than a decade, discusses the evidence from quantitative analysis and practical observation that suggests the methods being applied on Pioneer are both sustainable and productive over time. Greg Iffrig, Clinton Trammel, and Terry Cunningham, the senior management staff of Pioneer, present a detailed description of the implementation of single-tree selection on the ground, in the context of the development of the technique and the scholarly debate about its efficacy. Dendrochronologist Richard Guyette and research specialist Michael Stambaugh analyze the degree of topographic roughness of Pioneer Forest lands and discuss the effect of that roughness on the long-term history of local disturbance factors and the implications this has for the efficacy of silvicultural practices on the forest in mimicking historical vegetation regimes. Biologists Gerardo Camilo and Nick San Diego report that the single-tree selection method practiced by Pioneer Forest has benefits to forest and leaf litter arthropod communities by creating conditions that maximize diversity.

The final group of papers explores the economic and social values fostered by Pioneer Forest. Forest economist Makoto Hamatani and Katherine Goslee of Appalachian Voices analyze the profitability of the single-tree selection management practiced on Pioneer over the past half century and consider its implications for smaller landholdings. John Karel, president of the L-A-D Foundation, surveys the roles of Leo Drey, Pioneer Forest and the L-A-D Foundation in the protection of natural areas and the provision of public recreational opportunities, not only on Pioneer but also on several thousand acres of other L-A-D properties. The third paper is a compilation of personal reflections from the 50th anniversary symposium that evokes a wide range of values fostered by the forest. They represent the perspectives of many who have studied, worked on, thought about, enjoyed, or lived near the lands of Pioneer Forest.

An appendix presents an annotated bibliography of scholarly research publications and nontechnical information on Pioneer Forest and other properties of the L-A-D Foundation. The bibliography contains more than 150 entries that further substantiate the breadth and depth of research and the range of values fostered by the forest.

The scientific process would be incomplete without peer review of papers. We are grateful to the following scientists and professionals for providing reviews of the manuscripts contained in this volume: Don Bragg, Leon Cambre, John Dwyer, Tom Foti, John Groninger, John Kabrick, Bill Kurtz, Earnest Lovett, Ross Melick, Rose-Marie Muzika, Paul Nelson, Tim Nigh, Walter Schroeder, Steve Shifley, Martin Spetich, Rick Thom, James Trager, and Don Voth. We are especially grateful for the collaboration of the Southern Research Station of the Forest Service, U.S. Department of Agriculture, that enabled the publication of this volume.

In addition to the Missouri Botanical Garden and Tower Grove Park, the following organizations contributed significantly to the success of the 50th anniversary symposium and represent a fair sampling of the range of organizations with which Pioneer Forest and the L-A-D Foundation have cooperated over the years, and we would like to thank them here: Akers Ferry Canoe Rental, Antioch College, Appalachian Voices, Auburn University, Forest Stewards Guild, John Burroughs School, Mark Twain Forest Watchers, Mark Twain National Forest, Missouri Chapter–Society of American Foresters, Missouri Coalition for the Environment, Missouri Consulting Foresters' Association, Missouri Department of Conservation, Missouri Department of Natural Resources, Missouri Forest Heritage Center, National Park Service–Ozark National Scenic Riverways, Ozark Regional Land Trust, Saint Louis University, Sierra Club–Ozark Chapter, Southern Illinois University–Edwardsville, Trees L.C., U.S. Forest Service–North Central Research Station, U.S. Forest Service–Southern Research Station, and University of Missouri–Columbia.

We also wish to acknowledge and thank the following individuals for their efforts in making the symposium a success and for their cooperation with Pioneer Forest over the years: Mike Adams, Paul Brunkow, Leon Cambre, Robert Devine, Eleanor Drey, Laura Drey, Leo and Kay Drey, Louis Drey, Tim Dyer, Dorothy Ellis, Robert Fishbone, Gregg Galbraith, Bob Gestel, Wayne Goode, David Hamilton, Eric Hanson, Mike Hoffman, Jim Jackson, Elena LaVigne, D.B. Mabry, Sheri Pena, Alex Primm, Nick San Diego, Randy Sarver, Jo Schaper, Debbie Schnack, Dan Skaggs, Aaron Smith, Jon Smith, Richard Smith, Claudia Spener, Bob Todd, Clint Trammel, George Yatskievych, Jim Vandyke, Jerry Vineyard, Pat Waterston, and, of course, all the authors of papers or reflections in this volume.

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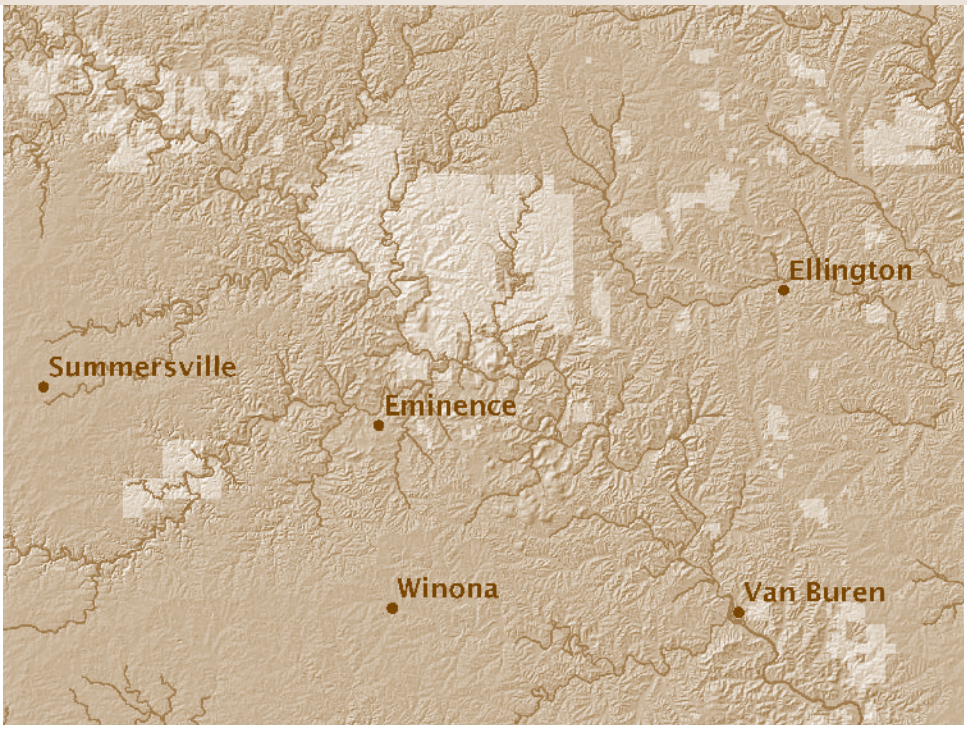
Leo A. Drey with an ancient white oak, ca. 1950s. *(Courtesy of Leo Drey)*

HISTORY



Distribution of Pioneer Forest lands. *(Source: R. Guyette and M. Stambaugh, Missouri Tree Ring Laboratory, University of Missouri)*

A HISTORY OF FOREST MANAGEMENT IN THE OZARK MOUNTAINS

James M. Guldin[1]

Abstract—The origins of modern forest management in the Ozark Mountains go back roughly 500 years. This history has five stages: pre-European conditions (prior to 1750), European settlement (1750–1880), the era of exploitation (1880–1920), forest recovery (1920–1950), and the era of modern forestry (1950–present). The greatest adverse influence on Missouri forests was the era of exploitation, during which virtually all of the presettlement forest of the Ozarks was commercially liquidated. Fire control and the creation of large forest reserves triggered the period of recovery, which includes the establishment of Pioneer Forest in 1951. Highlights of the era of modern forestry include management of forests for productive value and aesthetic appeal, use of voluntary best management practices, and a commitment to forest stewardship. The private owner and professional staff of Missouri's Pioneer Forest have long embraced and applied these progressive attitudes and practices.

INTRODUCTION

To fully appreciate the past 50 years of management on the Pioneer Forest, one must consider the past 500 years of Missouri history. Throughout that 500–year period, Missouri's human inhabitants have looked at forests from a series of different perspectives. Five stages of Missouri forest history can be recognized, and each has vastly different implications for its own and subsequent generations.

The accomplishments for which we honor Pioneer Forest in this volume are even more meaningful when one considers the disruptive influences to which Missouri Ozark forests were subjected in the past. The goal of this paper is to briefly recount the history of the Missouri Ozark forests, describing earlier eras of forest disruption as a background for the progressive forest stewardship practiced at Pioneer Forest.

PRE-EUROPEAN CONDITIONS PRIOR TO 1750

As recently as 20,000 years ago, the Ozarks were under the influence of glaciers from the Wisconsinan period, and supported boreal flora. Oaks became established in the region about 14,000 years ago. During the past several thousand years, climatic trends have given rise to a forest-dominated landscape with prairie inclusions (Foti and others 1999).

It is estimated that in 1500 forests covered 70 percent of the State of Missouri; that oak savannas covered an estimated 13 million acres, or one-third, of Missouri; and that vast herds of elk and buffalo were common (Palmer 1991). According to early descriptions, forests were previously much more open, ranging from open woodlands to closed forests. These open woodlands and closed forests had grasses and forbs in the understory, and little midstory.

However, forests were under human influence—that of the native American inhabitants in the region. Historical documents note the widespread occurrence of fire, and summary accounts generally conclude that presettlement conditions were much influenced by fire (Nigh 1992). Other evidence supports the notion that native populations set fire to the woodlands, possibly for territorial defense or hunting purposes, and cleared small areas for subsistence agriculture (Spetich and others 1999). The open understory that would result from this activity can still be seen in photographs from the turn of the century (fig. 1).

Exposure to European explorers was the beginning of the end of these native civilizations, and the decline probably began between 1500 and 1600. DeSoto is known to have explored the Arkansas and Ouachita Rivers, reaching Hot Springs in 1542; French traders came into the region from the north during the 1600s. Native populations are believed to have declined as a result of these and other contacts with Europeans, through exposure to diseases for which the indigenous peoples had little or no immunity (Strausberg and Hough 1997).

Figure 1—Native shortleaf pine stand, Missouri Ozarks. *(Courtesy of American Lumberman)*

[1] James M. Guldin, Supervisory Ecologist and Project Leader, U.S. Forest Service, Southern Research Station, Hot Springs, AR 71902.

The early recorded descriptions of forest vegetation reflect the waning influence of the native American cultures as well as the early influence of European settlement. Schoolcraft (1821) published the best and most accessible of these, based on a journal kept during his journey through the Missouri and Arkansas Ozarks in 1818–1819. His description of the vegetation in the vicinity of the White River in the northern Arkansas Ozarks conveys the general presettlement forest condition:

> ". . . One of the most conspicuous objects among the trees and vegetables which skirt the banks of the river, is the sycamore, (*Platanus occidentalis*) rearing its lofty branches into the air, and distinguished from other forest-trees by its white bark and enormous size . . . Another vegetable, scarcely less conspicuous, and occupying a similar soil and situation, in the latitude in which it grows, is the reed, called cane in this region, and which I take to be the *Cinna arundinacea* of botanists. This plant is common to all the streams of the valley of the Mississippi below the 38 deg. of north latitude . . . The other forest-trees and plants noticed at this place, and which may be set down as composing, the forests of White River generally, are the following: Cotton-wood (*Populus angulata*); white elm (*Ulmus Americana*); red elm (*Ulmus fulva*); buckeye (*Aesculus hippocastanum*); black walnut (*Juglans nigra*); white walnut (*Juglans tomentosa*); white ash (*Fraxinus acuminata*); swamp-ash (*Fraxinus juglandifolia*); white oak (*Quercus alba*); red oak (*Quercus rubra*); sugar maple (*Acer saccharinum*); mulberry (*Callicarpa Americana*); dogwood (*Cornus florida*); sassafras (*Taurus sassafras*); persimmon (*Diospyros virginiana*).
>
> To these the valleys will add spice-wood, papaw, wild cherry, hemlock, several species of grapes, the wild pea, etc.; and the bluffs and high-lands, white and yellow pine, mountain-ash, post-oak, and cedar. The wild hop is also indigenous to the river alluvion, and the crab-apple, red plumb, and black haw, upon the plains. Many others might be added, but these are the most conspicuous on passing through a White River forest, and such as would readily attract the eye."[2]

EUROPEAN SETTLEMENT, 1750–1880

The first Europeans to tour the territory that would become Missouri found a rich land with few human inhabitants. Settlers arrived by the rivers and cut wood for houses, for fuel, and to sell. Timber was cut and floated downstream to mills in larger settlements, where it might be used for lumber or as cordwood to fuel the boilers of steam-powered riverboats.

About the time that Missouri became a State (1821), settlers began trickling in from the South. Subsistence farms were established in the river valleys and larger hollows. Timber cutting was largely limited to forest stands that were readily accessible to homesteads, farms, and towns; and domestic livestock was allowed to roam the forest freely. Tree cutting and stump removal created agricultural fields and improved pasture; selective cutting of selected tree species in the woods met local needs for lumber, for related wood products (such as oak baskets), and for fuel. The aboriginal use of fire was continued by early Missouri settlers, probably both to promote grasses and to control ticks and chiggers.

Regarding the abundance of pestiferous insect fauna, the best record comes from Thomas Nuttall (Lottinville 1999), the botanist, who explored the southern Ozarks during a journey up the Arkansas River during 1819:

> ". . . Returning from my rambles today. . . . I picked off my skin and clothes more than 50 ticks, which are here more abundant and troublesome than any part of America in which I have yet been . . ."

The seeds of the demise of buffalo and elk populations were no doubt sown in the early 1800s, as European settlement slowly expanded. Schoolcraft noted that:

> "The Indian considers the forest his own, and is careful in using and preserving every thing which it affords. He never kills more meat than he has occasion for. The white hunter destroys all before him, and cannot resist the opportunity of killing game, although he neither wants the meat, nor can carry the skins . . . this is one of the causes of the enmity existing between the white and the red hunters of Missouri."[3]

As early as 1816, sawmills were established along the Big Piney River in Texas County to manufacture lumber from shortleaf pine (*Pinus echinata*). By 1860 logging was one of the dominant industries of the region. With the coming of the railroad, the making and shipment of railroad ties became an important industry.

In 1860 the population of Missouri was about 1.2 million people (U.S. Census Office 1864), about 21 percent of the 5.595 million people tallied in the State's 2000 census. Estimates of forested area in Missouri in 1860 are difficult to obtain, but the available data suggest that < 20 percent of the arable land in Missouri's forested counties was farmed at that time (Maizel and others 1998). Conversion of forests to pastures and harvest of trees used to meet specific needs were no doubt locally important, but the impact of subsistence farming and the beginnings of industrial activity was probably not widespread. The activities of early settlers probably had a greater immediate impact on the State's fauna, and especially on game species. Nevertheless, it probably did not take long for some settlers to realize that a rich timber resource covered the region and awaited exploitation.

ERA OF EXPLOITATION, 1880–1920

The Ozark lumber industry boomed from 1880 to 1920 (Cunningham and Hauser 1992). Lumbermen bought vast acreages of forest land, sometimes for a few cents an acre, and

[2] Henry R. Schoolcraft, 15 January 1819.
[3] Henry R. Schoolcraft, 30 December 1818.

cut, graded, and trestled hundreds of miles of narrow-gauge railroad track into the steep hills and hollows (fig. 2). Logs were carried to mills by train and by rivers and streams. Any tree that had value was cut (Palmer 1991).

At its peak in 1899, production from Missouri sawmills exceeded 724 million board feet of lumber annually (Cunningham and Hauser 1992), a level of production not seen since that time.

Figure 2—Log train. *(Courtesy of American Lumberman)*

The sawmill at Grandin, east of the Current River (fig. 3), consumed 70 acres of woodland a day, and produced in excess of 250,000 board feet of dimension lumber (fig. 4) and related products (mostly lath and shingles) daily (Cunningham and Hauser 1992).

Although these mills consumed enormous quantities of timber, they supported the industrialization of Missouri at the turn of the century. Comparable figures for Missouri are not available, but the lumber industry employed 73 percent of all factory wage earners in Arkansas in 1909.[4] Many small towns came into existence in rural Missouri during that time. While some disappeared with the mills, others remain to this day. But without question, industrialization came at a cost—the loss of all but a few acres of Missouri's virgin forests.

FOREST RECOVERY, 1920–1950

By 1920, the pine forests, and the mills, and the jobs were gone. Those who had come to work the woods tried to stay and eke out a living from the thin soils of the deforested hills. Their efforts only produced meager crops and more erosion (fig. 5). Forest recovery was further inhibited by the common practice of allowing domestic livestock to wander over the countryside, foraging for any available vegetation. By 1928, large areas of the once rich timberland had become wasteland.

In 1929, the Missouri National Forest Association successfully lobbied the Legislature to permit the Federal government to purchase land in Missouri for a national forest. Eight purchase units were set up in 1934–35, and the Mark Twain and Clark National Forests became a reality. Eventually, 1.5 million acres of cut-over forest land was acquired in these two national forests—the land that nobody else wanted.

Figure 3—Grandin mill. *(Courtesy of American Lumberman)*

[4] Gray, John. Cited on http://arkforests.org/favorite-history.html.

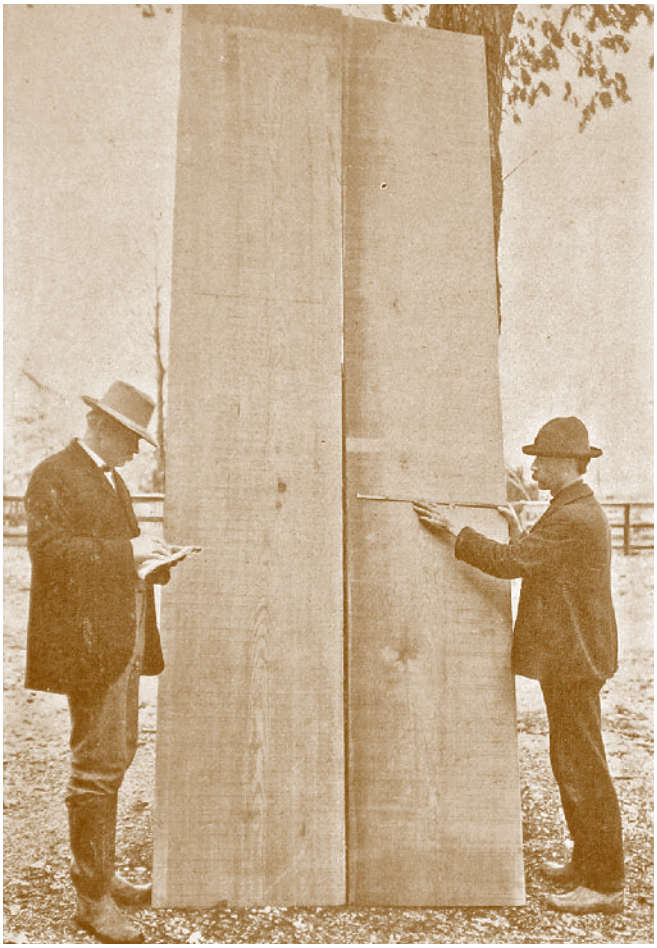


Figure 4—Shortleaf boards, from the Grandin Mill. *(Courtesy of American Lumberman)*

By the mid–1930s, Missouri forest and wildlife resources were at an all-time low. The forests were burned and abused. Gravel, eroded from the hillsides, choked the once-clear streams. An estimated 2,000 deer remained in the entire State, and turkeys declined to a few thousand birds in scattered flocks. An additional factor that reduced harvesting pressure on the recovering forest in the 1930s was a sharp drop in building and corresponding lumber demand. And over the 1930s and 1940s, there was a shift away from the use of wood as a home heating and cooking fuel.

Forests benefited greatly from services provided by the Depression era Civilian Conservation Corps (CCC) Program. Enrollees in the CCC helped fight forest fires, built fire lookout towers, and, on the national forests, constructed roads, campgrounds, picnic areas, and swimming lakes. Enrollees also planted trees on thousands of acres of worn out and eroded highland farmland in national forests in the 1930s.

Fire control was the first step in restoring forest cover. Voters approved the Missouri constitutional amendment creating the Conservation Commission in 1936. This new Agency included a forestry division—an innovative idea at a time when most other fish and wildlife agencies were separate from forestry departments. Missouri's early conservationists recognized that a healthy forest resource was essential to healthy fish and wildlife populations.

By World War II, fire prevention programs began to pay off. Once fires were reduced, efforts could be turned to managing the forest. Foresters planted thousands of seedlings, harvested trees damaged by fire, and removed undesirable trees. Private landowners were taught how to improve their forests and

Figure 5—Missouri hillbilly farm, U.S. Forest Service photo 380537. *(Photo by Leland J. Prater, April 1939)*

wildlife habitat. Among the more interesting social events in small towns during that time was the arrival of a State or Federal forester in a truck equipped to show movies about fire control and forest management.

ERA OF MODERN FORESTRY, 1950–PRESENT

Tremendous progress in forest management has been made in Missouri since the late 1940s (Law 1992). The once impossible task of fire control in the Ozarks has been accomplished. Today less than one-tenth of 1 percent of Missouri burns each year. Deer and turkey are found in record numbers. Restoration programs have reintroduced ruffed grouse and river otters (Palmer 1991).

Since the 1940s, Missouri Ozarks forests have had to meet major increases in demand for all forest values. There has been a strong increase in demand for lumber and other wood products. In response to the increasing worth of Missouri forest products and values, public and private forest landowners have made capital and resource investments to improve timber productivity, grow wildlife populations and expand wildlife habitat, protect watersheds, and promote forest vigor and health.

Among the most important products of Missouri forests is high-quality water. Water use in Arkansas increased by 200 percent over the past 20 years and is expected to increase by another 140 percent by the year 2035; trends in water use in Missouri are likely to be similar. This has focused attention on effective protection of forested watersheds and on the adequacy and application of voluntary best management practice standards as a tool for minimizing nonpoint source water pollution caused by logging and other forest operations (Missouri Department of Conservation 1997).

Finally, forest management includes a large measure of government and private support for the practice of forestry, especially on private lands. Since 1950, there has been extensive public and private investment in forestry. This has included investments not only in the forests themselves, but also in the intellectual capital of forestry—forestry education, research in forestry and natural resources, and improvements in the manufacture of forest products and the efficiency with which they are produced. These advances have been applied on public lands and forest industry lands, where professional foresters and biologists translate research into practice.

For nonindustrial private forest (NIPF) landowners, who in 1989 owned 83 percent of Missouri's timberland area, technical assistance and public cost sharing have been important incentives to participate in forest management. But perhaps the most important determinant of NIPF landowner activity in forest management has been, simply, the landowner's knowledge of forest management and his or her desire to apply that knowledge.

THE PIONEER FOREST, 1951–2001

This is where Pioneer Forest merits special attention. Not only is it the largest NIPF ownership in Missouri, it is also second to none in the dedication of the owner and professional staff to the art and science of forestry. It stands as a testament to the recovery of Missouri Ozark forests under a program of modern forestry that embraces wood products, wildlife, recreation, aesthetics, and water resources. Three elements of modern forestry receive special emphasis at the Pioneer Forest.

First, the Pioneer forest staff and owners are committed to productive forest management. They employ an uncommon form of forestry—uneven-aged silviculture and the single-tree selection method, whose goal is the production of large, high-quality logs of desired species (fig. 6). Competition least as concerned about what remains after the cut as they are about what is removed. Finally, Pioneer Forest maintains long-term inventory plots to ensure that the management program in fact meets the goal of maintaining and improving species composition, stand volume growth, and successful regeneration over time.

Figure 6—Three age classes of oak on Pioneer Forest property. *(Photo by J.M. Guldin)*

Second, the forest management practiced on Pioneer Forest maintains the forest canopy on every acre throughout the forest. Such practices provide continuous protection of water quality and go beyond the traditional best management practices referenced earlier. Examples of the practices employed include keeping all logging equipment out of stream bottoms, leaving a forested stream buffer in which only high-value trees are considered for removal, and removing less than one-half of the volume on any given acre to be harvested. Further protections are used where significant areas of the forest are adjacent to the Current and Jacks Fork Rivers and the Ozark Scenic Riverways National Park. Here, a no harvest zone extends a minimum of 300 feet from the river center.

Finally, these activities speak to a larger element of the success of Pioneer Forest over the past 50 years—a stewardship ethic. Both the forest owner and the professionals who manage the forest are personally and professionally committed to the highest standards of land stewardship. The financial stakes that drove the period of exploitation are still in play; NIPF landowners can get more quick cash by liquidating their forests than they can get by managing them.

Resisting the impulse to liquidate forests for this short-term cash potential is perhaps the most difficult test that NIPF landowners face—and they face that test daily. The founder of Pioneer Forest, Leo Drey, and his committed staff of professional resource managers have met that test daily for 50 years. There is no better example of enlightened and abiding stewardship of NIPF land, or any timberland, than the stewardship practiced at the Pioneer Forest.

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MISSOURI'S PIONEER: A HALF CENTURY OF SUSTAINABLE FORESTRY

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Abstract—Pioneer Forest, at some 150,000 acres Missouri's largest private landholding, has been a lodestar of sustainability during more than half a century of dramatic oscillation in the goals and techniques of forest management nationwide. Initially intended by its owner, Leo Drey, to demonstrate the potential for developing a viable natural resource-based economy in the Missouri Ozarks, the forest, through Drey's remarkably consistent vision and well-documented management by single-tree selection came, over time, to represent a workable alternative to even-aged management regimes being promulgated on federal and state forests as well as a model of sustainability for other private forest holdings.

This historical analysis, based largely on original unpublished archival records, explores the history of the forest from its acquisition by Leo Drey beginning in 1951 to its donation to the L-A-D Foundation in 2004; it considers not only the development and management of the forest over more than a half-century of Leo Drey's ownership but also its relationship to other public and private lands in Missouri and to related conservation efforts of Leo Drey, such as the preservation of natural streams and natural areas, in the context of the history of conservation in Missouri and the nation.

ASSEMBLING A FOREST

Leo Drey purchased his first tract of Ozark timberland in eastern Shannon County near the Reynolds County line on March 8, 1951, from Doc Jim Buford of Ellington. It was 1,407 acres of oak, much of it butt rotten, but it had some pine reproduction plus some larger pines, and there was not much grazing. There were no squatters or tenants, and theft was not bad. Buford wanted about $4 an acre. So said Drey's notes, scratched in pencil on an envelope along with a sketch map of 80's that were included or not. He had been impressed by the pines when he walked the tract with Buford on January 17, but, in retrospect, he decided he must have seen the same pines more than once that day.[2]

Drey was 34 years old, a 1939 graduate of Antioch College whose founder, Horace Mann, had entreated students, "Be ashamed to die until you have won some victory for humanity." The son of a St. Louis manufacturer of plate glass and canning jars—Drey Perfect Mason—he served 5 years in World War II and then as assistant to the treasurer of the Wohl Shoe Company before deciding to follow his calling to forest conservation. His father had died when Leo was a child, and the glass company was sold, so he had an inheritance with which to work (fig. 1).

The postwar years witnessed a turn to emphasis on private forest management after nearly half a century of preoccupation with the role of government in forest conservation. The U.S. Forest Service had been established in 1905, joining forestry programs previously established in a number of states, but Missouri was still in the throes of its greatest era of exploitative logging and would not see establishment of public forests until the depression years of the 1930s. The general assembly authorized acquisition of national forests in the early 1930s, and Missouri citizens, in 1936, approved a constitutional amendment for a new conservation commission with responsibility for forests as well as for fish and wildlife, which had previously been overseen by a politically appointed game and fish commissioner. By then, most public officials nationwide had

Figure 1—Leo A. Drey with an ancient white oak. *(Courtesy of Leo Drey)*

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[2] This history is based largely on original unpublished correspondence, reports, and other records from the files of Leo Drey, Pioneer Forest, the L-A-D Foundation, other repositories, and on author interviews with various participants, as indicated at the beginning of the Literature Cited section. Only a few of the thousands of unpublished sources are separately listed in General References.

given up on private land management, and a succession of New Deal reports and plans called for half the timberland in the country to enter public ownership; in Missouri, 8 million acres of public forests were proposed—7 million federal and 1 million in state forests—out of about 15 million acres of forest land (Flader 2004). About 1.25 million acres of national forest and 125,000 acres of state forest had been acquired when the pressure for public purchase abated, and acquisition funds dried up during and after World War II. In 1946, the legislature adopted a forward-looking State Forestry Act, which was intended to encourage the practice of forestry on private lands.

Leo Drey invested in Missouri timberland with his eyes open but also with a large measure of faith. Most Ozark timberland was badly cut over and had been further degraded by timber trespass and by frequent fires set by locals to encourage forage for their cattle and hogs still roaming wild under the longstanding tradition of open range. He had considered buying land in Florida or Tennessee but decided against it because land titles ran back to old Spanish grants that could be devilishly troublesome, whereas in the parts of Missouri in which he was interested the titles were tied to the original federal rectangular survey. Professional foresters and industry leaders with whom he had consulted—among them state foresters George White and Bill Towell, University of Missouri professor R.H. Westveld, forest manager Ed Woods of National Distillers Products Corporation, and John Mabry of the T.J. Moss Tie Company—told him he would need about 25,000 acres profitably to employ one forester. With a liberal arts and business background, he was determined to rely on professional advice, so he sought assistance in land locating and management from Lee Paulsell, who resigned from his position as forestry instructor at the university to work for him (fig. 2). With Paulsell's help, Drey bought about 10,000 additional acres in 1951 and 7,000 in 1952, mostly in Carter and Reynolds counties. Then, in 1953, he bought nearly 14,000 acres, including large purchases of 9,099 and 2,812 acres from the Moss Tie Co. in Carter and Ripley counties. The Moss acquisitions would be warm-ups for the big opportunity to come.

Figure 2—Lee Paulsell, Leo Drey's first forester. *(Courtesy of Pioneer Forest)*

Drey was taking a break from fighting fire on state land at Peck Ranch at about 3 a.m. one morning in the fall of 1953 when Charlie Kirk, a forester for National Distillers, flopped in the weeds beside him to say that the company was liquidating its Missouri timber—nearly 90,000 acres, much of it in a nearly contiguous block in northeastern Shannon County that was considered the largest tract of old-growth white oak in the United States—and then would sell its land. Knowing that Drey had been buying up timberland, Kirk undoubtedly hoped that he would come to the rescue of the Distillers' tract. And Drey did not disappoint. He began an intense negotiation at corporate headquarters in New York City, in his own "hole-in-the-wall office" in St. Louis, and out on the land that ended on June 1, 1954, after more than 6 months of hard bargaining, with the purchase of 89,906 acres.

Much of the new acreage had been assembled over the course of 40 years by the Pioneer Cooperage Company of St. Louis, which was interested in oak for barrel staves. Pioneer had in turn sold to the Millman Lumber Company in 1937 the right to cut its yellow pine timber totaling about 60 million board feet, an operation that required some 11 years (Millman c. 1981). In 1940, Pioneer sold a 400-foot-wide strip of old growth pine along Highway 19 south of Round Spring to the state highway department for motorists to enjoy (warranty deed, PF). At about the same time, the firm asked the U.S. Forest Service to study the potential for operating its acreage as a business venture with good forestry practice (Anon. c. 1940). The findings were not encouraging; nearly two-thirds of the land was completely cut over and half of the remainder partly cut over, with the trees below average in thrift and a large quantity overmature. The forest was "decidedly understocked" with a shortage of "wood-making machines," said the report, the result of repeated fires having destroyed the young material and a small though exasperating amount of timber theft. "As a result, production suffers, and the factory may operate in the red." Nevertheless, much of the white oak in the old growth or partly cut stands was of medium or higher quality and vigor, and the climate and soils were relatively good. Instead of the current clearcutting, the report recommended hiring an experienced professional forester and staff to inventory, classify, and post the lands, develop management policy, and mark timber for "the business man's cut," or selection cutting of about 30 percent of the lowest quality and at-risk trees in order to allow better growth in the residual stand.

In 1945, Pioneer Cooperage decided to hire a professional forester, securing the services of Ed Woods, a forestry graduate of Washington State University who had come to Missouri with the U.S. Forest Service in 1933, and then local surveyor Paul Faulkenberry and M.G. "Gus" Hoyer from the Iowa Forest School. Woods advocated better forest management practices, and he was soon put in charge of production. On his recommendation the firm contracted with Millman to allow Pioneer to mark and reserve up to 200,000 board feet of mature yellow pine seed trees on the yet uncut pine acreage—eventually amounting to 1,076 trees on 3,200 acres—to provide for natural reproduction (PF corres. 1955, tract notes). The pathbreaking reservation of

seed trees in what was regarded as the only substantial tract of virgin pine left in the state created widespread interest, resulting in a request from Charles Callison of the *Missouri Conservationist* to publicize the effort—a cause of consternation to company officials who regarded their long-range management policies as still unsettled. To Woods's dismay, company officials caved in to Millman's complaints about under-scaling by letting Millman cut the 65 largest pines from the list of those reserved (PF corres. 1946).

In July 1946, control of Pioneer Cooperage was sold to the National Distillers Products Corporation of New York, and its business reorganized as the Pioneer Cooperage Division, with most of its staff intact. The focus of cutting thereupon shifted from red oak to white oak cooperage for whiskey barrels. In the next 2 years, the firm cut some 6 million board feet of white oak, a rate far in excess of growth; but Ed Woods and his staff persuaded cooperage department head Leonard Steidel of the wisdom of selective cutting, taking the timber that was overmature or at risk with a goal of improving the stand (NDPC 1948, Woods 1965). During the same period, the firm abandoned plans for four of six intended stave mills, and, in 1948, added another professional forester, Charles Kirk, formerly with the U.S. Forest Service in Minnesota and then one of the original foresters for the Missouri Conservation Commission, now called the Missouri Department of Conservation (MDC), to complete an inventory of the forest. Woods also won approval from Steidel and other corporate officials for designation of the Pioneer tract as Missouri's first official tree farm under a national program sponsored by American Forest Products Industries, and Arthur Meyer, chairman of the Missouri committee overseeing the program, wrote a laudatory history of Pioneer as a model of forest management (Meyer 1949). Missouri Tree Farm Number One was dedicated in September 1949 before close to 100 people, including some 70 professional foresters from Missouri and other states (PF).

As Ed Woods and his staff continued their cutting and began an ambitious program of tree planting for regeneration of pine and hardwoods on old fields and other vacant acreage, Woods also continued to work with Steidel to make the case to corporate officials for continued conservative management of the forest (fig. 3). In spring 1951, the firm renamed the Pioneer tract the Seton Porter Forest, after a former conservation-minded chairman of the board. In July, H.H. Chapman, Yale professor emeritus and one of the most influential foresters in America, accepted an invitation to examine the practicability of managing the forest for a continuous yield of white oak and other products (fig. 4). After traveling 1,500 miles by jeep and on foot through the forest, he pronounced the white oak reproduction "nothing short of spectacular," though fire control remained the most urgent problem; he recommended guidelines for selective harvest, silvicultural improvement, and establishment of permanent sample plots to track future growth (Chapman 1951). The firm began a continuous forest inventory in 1952, and it advertised its conservation consciousness and the white-oak-enhanced quality of its whiskies in the *Wall Street Journal* and other national publications: "90,000 Acres of Natural Beauty . . . and Barrel Staves, Too!" (fig. 5).

Figure 3—Ed Woods and radio operator with a map of Seton Porter Forest. *(Courtesy of Pioneer Forest)*

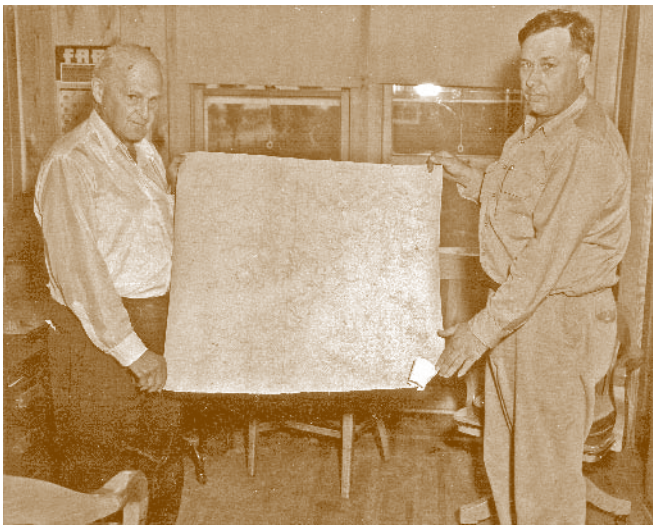

Figure 4—H.H. Chapman and Ed Woods in Salem headquarters, July 1951. *(Courtesy of Pioneer Forest)*

In March 1953, the chairman of the Society of American Foresters Committee on Natural Areas, John Shanklin, asked the firm to consider setting aside a tract of old growth white oak in the Current River Hills as a virgin-type association for white oak under a natural areas program SAF had established in 1947 (Shanklin 1953). In November, the forestry staff and five SAF members from Missouri selected a 10-acre plot in an area previously identified by Dr. Julian Steyermark of the Missouri Botanical Garden and began negotiations for the release of cutting rights (LD). In his enthusiasm for more conservative management of the forest, Woods even asked the Missouri Conservation Department to reintroduce beavers into the wild backcountry block in Shannon County (PF).

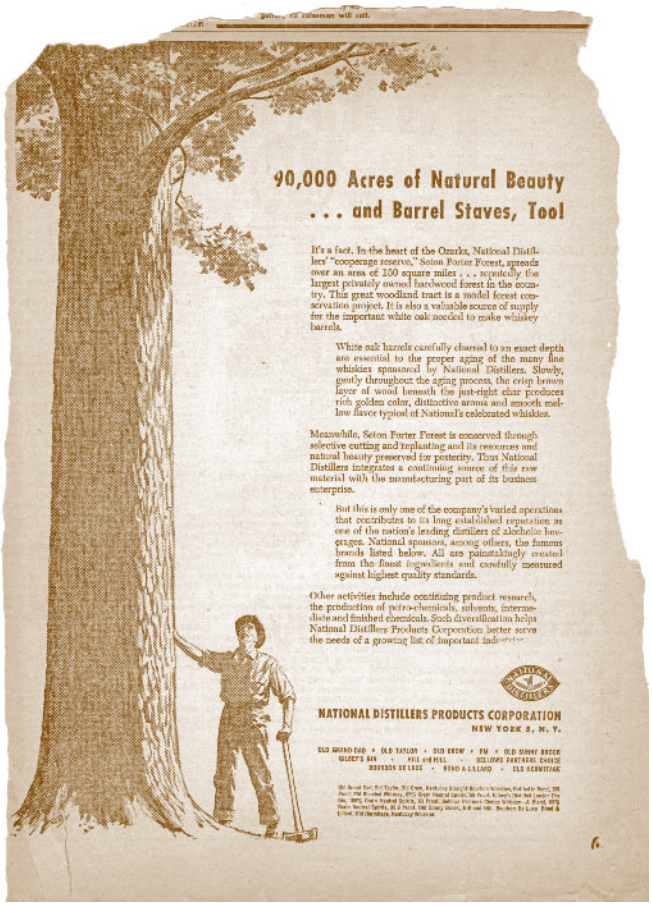

Figure 5—National Distillers advertisement in the *Wall Street Journal*, 1953. *(Courtesy of Leo Drey)*

But Steidel died unexpectedly and was replaced by an accountant, after which Distillers decided to liquidate the book value of its white oak, apparently for tax reasons; officials told Woods to cut 19 million board feet, including all trees over 12 to 14 inches in diameter at breast height (d.b.h.), within 3 years (LD, Woods 1965). Woods challenged the plan as "a cutting program not a forestry program" (Woods 1953) and alerted H.H. Chapman, who replied, "Damn all accountants!" (Chapman 1953). Probably because of the ongoing natural area negotiations and Distillers' advertising campaign touting its model forest, the destructive cutting resulted in considerable furor in professional circles in Missouri and beyond, including letters to corporate headquarters and a sharply critical editorial, "Not as Claimed," in *Nature Magazine* (1955). After castigating the "butchering" of the virgin white oak, the editorial noted that Distillers had sold off the forest, apparently to distance itself from the furor. The editorial did not say to whom the forest had been sold, implying that it was a lost cause in any case.

The buyer, of course, was Leo Drey. In his negotiations with Distillers, Drey was determined to salvage as much as possible of the integrity of the forest despite the ongoing liquidation. He sought at first to purchase the entire forest intact, with an agreement to supply Distillers with 18 million feet of cooperage stock over a period of 9 years, but the firm insisted on retaining the right to cut all remaining white oak (LD). The best he could do was to limit the cutting to trees over 15 inches in d.b.h. and to reserve 300,000 board feet in large trees of his own choosing (fig. 6). He selected several stands of white oak, including some in the vicinity of the 300-year-old trees already under discussion with SAF, and within a year, following conveyances by both Drey and Distillers, the 10-acre Current River Natural Area would be dedicated as the first official natural area in Missouri (Shanklin 1955).[3] Drey also bargained for the equipment and the headquarters building in Salem and retained five of the forestry staff—Ed Woods, Charlie Kirk, Russel Noah, Rayborn Skaggs, and Paul Corder. Just as the negotiations were concluding, Drey would later recall, Distillers added another request—to reserve a one-half interest in any minerals that might be found. After checking with a geologist and hearing no intimation of any minerals of value, he agreed to the provision.

Figure 6—Large white oaks on Pioneer Forest, early 1950s. *(Courtesy of Pioneer Forest)*

[3] In May 2005, the L-A-D Foundation, Pioneer Forest and representatives of the Missouri Natural Areas Committee and the Society of American Foresters would celebrate the 50th anniversary of the first natural area in Missouri by dedicating an additional 255 acres for an expanded Current River Natural Area equal in quality to the original 10-acre tract (Drees and others 2005).

As of June 1, 1954, Drey had nearly 123,000 acres that he renamed Pioneer Forest out of respect for its history and in anticipation of his intent to pioneer in private land management in the Ozarks (Drey 1963). The land had cost him an average of $4.12 an acre, he calculated; the cost was a measure of the limited economic potential for forest land in the Ozarks at the time. To manage the operation he had a team of five headed by Woods as general manager and Kirk as forester, Lee Paulsell having left to take over the University Forest near Poplar Bluff shortly before Drey had begun negotiating for the Distillers' tract.

In an article some years later, Ed Woods (1965) would be able to cite a long list of pioneering "firsts" for the forest—"the first private forest to undertake the job of maintaining itself solely by the sale of stumpage [standing timber] from its lands," the first to adopt the International Log Rule in its sales and also in the cruising of its own timber, the first in Missouri with its own radio frequency, the first to adopt the mechanical tree planter, chain saws, four-wheel drive vehicles, crawler tractors, and 6 by 6 army trucks in the rugged terrain of the Ozarks. Most important, it pioneered in what Woods called "the unceasing job of timber stand improvement," tracked and documented by a system of sample plots covering its entire acreage. And it pioneered in maintaining about 20 active timber sales per year, which in turn maintained about 100 families and their communities. It also opened its lands to public recreation and designated some tracts as samples of uncut old growth. "I could cut out and get back the purchase price of the land," Drey told a reporter for the *St. Louis Post-Dispatch* (Leeman 1956). "The challenge is whether I can spend money on it at the present rate and come out successfully."

The early years of the new Pioneer Forest were a struggle. It could not have been easy for Drey or his foresters to witness the cutting of nearly 12 million board feet of white oak worth an estimated $1 million by National Distillers in 1954 alone, and the heavy cutting would continue. Hints of Ed Woods's angst may be found here and there in notes on his tract records: "butchered for bolts by NDPC contractors," or "National Distillers crew slobbered around over the section trying to cut the bolts but only got the easy ones" (PF). Early in 1955, H.H. Chapman wrote to Richard H. Pough of the American Museum of Natural History that his recommendations for the management of the forest had been "totally ignored and violated." He went on to charge, "The practices now pursued in this supposed 'Tree Farm' are . . . grossly and criminally wasteful of the material in the trees cut, in every possible respect, so that it can be truthfully stated that nowhere even in the heyday of destructive logging practices was there a worse example of wood butchery than is now taking place in the Seton Porter Forest" (Chapman 1955, LD). It was no longer National Distillers' Seton Porter Forest, however, but Leo Drey's Pioneer Forest, and Drey had a more durable set of values.

PIONEER IN REGIONAL DEVELOPMENT, 1955–1976

Ever the idealist, Leo Drey was probably more dedicated to pioneering a course of regional development for the benighted Ozarks than he was in turning a personal profit. His vision for the future of the region was not essentially different than that of many Ozarkers in that it built on the woods, waters, and wildlife that had always sustained the area. But, at a time of postwar change nationwide and in Missouri, the means Drey would favor to secure that future would sometimes risk conflict with his new neighbors.

The heavy-handed harvesting by contractors for National Distillers coincided with a period of major drought and fires that resulted in the loss of yet another 12 million board feet of timber to natural causes. To make matters worse, the Shannon County tax assessor greatly overvalued the land, in Drey's view, leading Drey to enter a protracted and widely reported legal dispute with the county. Drey had entered some of his holdings under the state's Forest Crop Program, by which landowners were allowed to defer part of their annual taxes while timber was regenerating in exchange for following management guidelines and paying a yield tax when the timber was harvested; but, he had not done so in Shannon County, where his holdings amounted to nearly 20 percent of the county's taxable land. He believed in supporting the local economy, but he was willing to fight for the principle of fair and equal taxation.

When the assessor in 1955 valued Drey's 87,414 acres in Shannon County at $376,655—more than the $360,692 he had paid for it—Drey succeeded in winning an order from a circuit judge in Clayton, in St. Louis County, reducing the assessment to $108,207, based on the usual assessment at 30 percent of fair market value (SLPD 1956). But Shannon County continued to assess the land at nearly $5 an acre, arguing that it was worth $15-20, and the State Tax Commission of Missouri and another circuit judge supported the county (Leeman 1960). When a case involving taxes due for 1957-1959 was heard by the Missouri Supreme Court in 1961, the court sent it back to the tax commission, asking it to investigate whether there was an intent to discriminate against Drey since it was obvious that property in the county was not being assessed uniformly (SLPD 1961). Drey and the county agreed in July 1962 to a compromise worked out by the tax commission whereby Drey paid about $52,000 plus penalties and interest for 5 years of back taxes, down from about $78,000, and the land would be assessed at an average of $4.50 an acre. Both sides expressed satisfaction, with Drey explaining that the long litigation had "established the important principle that timberland should be treated the same as any other property in assessments" (CW 1962). The reality, of course, is that Drey drove a hard bargain in his purchase of timberlands and his sound management constantly increased their value.

The protracted and highly public dispute with Shannon County was an irritant in Drey's effort to establish Pioneer Forest as a good corporate citizen of the Ozarks, but it did not prevent him from undertaking other initiatives during those years to advance his vision of sound private forest management. In addition to fighting for the principle of equitable taxation, he decided to extend the inventory system established by National Distillers to his entire holdings in order to track improvements in timber stands. He also led an effort through a new Missouri

Forest Industries Committee to increase public awareness of the problems of fire and open-range grazing and the promise of forest conservation, chairing a major conference on Missouri forest resources in 1958. He cooperated with The Nature Conservancy and other groups to promote the concept of wild, free-flowing rivers protected by national legislation, beginning with the Current River that flowed through some 35 miles of his holdings. In each effort, his stance was that of a private landowner advancing programs and policies favorable to sound private forest management and regional development.

From the start, Drey was determined to measure and demonstrate the effectiveness of his management through a continuous forest inventory (CFI). The U.S. Forest Service, under authorization from the McSweeney-McNary Act of 1928, had completed its first intensive survey of Missouri forest resources in the late 1940s (King and others 1949). Following H.H. Chapman's recommendation, Woods and Kirk, in 1952, had sought assistance from Calvin B. Stott, who had begun developing CFI methodology for the U.S. Forest Service in the 1930s (Stott 1968), to mark out a system of 1/5-acre circular survey plots in order to maintain an inventory of volume, growth, harvest, and mortality on National Distillers' holdings. In 1957, Drey and his managers resolved to repeat the inventory every 5 years on the entire holdings of Pioneer Forest, with sample plots to represent each 320 acres. Stott helped them set up a complex, 152-step system to track some 12,000 individual trees, using IBM punch cards that could be processed in a new "mechanical brain" (SLPD 1957) at the Ford Forestry Center in L'Anse, MI (fig. 7). The Pioneer inventory was a more comprehensive and intensive system than that of the U.S. Forest Service in that it would track each individual tree over 5 inches in d.b.h. on the same plots every 5 years, whereas the service inventories would be more sporadic (1947, 1959, 1972, 1989) and more schematic, utilizing a much less dense system of ground plots that varied from survey to survey. The Pioneer Forest inventory, conducted religiously every 5 years at considerable expense, would become the longest continuous forest inventory in the central hardwood region, and it would gain increased credibility and value with the years (fig. 8).

Drey began working with other private timberland owners and wood-processing industries in 1955 to form a Missouri Forest Industries Committee affiliated with American Forest Products Industries, Inc. (AFPI), an educational and public relations organization spun off from the National Lumber Manufacturers Association that coordinated the American Tree Farm System and sought to increase public awareness of the need for forest fire prevention. As the owner of the first officially designated tree farm in Missouri, constituting the bulk of the 141,000 acres in the state system at the time, Drey was the natural choice for chairman. He hosted the committee at his headquarters in Salem and at a barbecue at Randolph Hole on the bank of the Current River chronicled by *St. Louis Post-Dispatch* columnist Leonard Hall (1956). The new committee ran a "Keep Missouri Green" campaign and worked through schools to "preach the gospel of forest conservation" (DP 10-12-55). AFPI claimed credit nationally in the 1950s for a 90-percent reduction in the

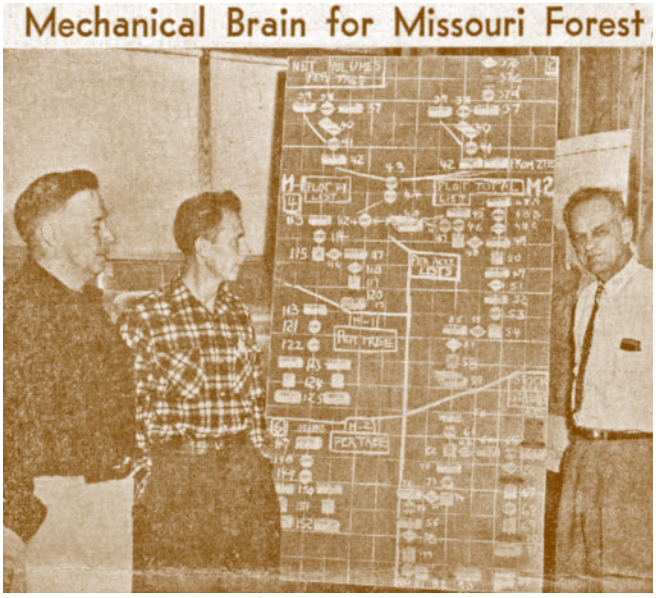

Figure 7—Ed Woods and Charlie Kirk (left) view a blackboard schematic of the continuous forest inventory system for Pioneer Forest developed by Cal Stott (right) in April 1957. *(Courtesy of Pioneer Forest)*

Figure 8—The 1957 inventory following National Distillers' heavy harvest indicated there were fewer than 1200 board feet per acre on Pioneer Forest. *(Courtesy of Pioneer Forest)*

incidence of forest fire, though in Missouri the credit for an even more dramatic reduction by that time was attributable largely to the efforts of the forestry division of the new Missouri Conservation Commission.

Under Drey's energetic leadership, the Missouri Forest Industries Committee in 1957 began planning for a statewide fire conference, its focus later broadened to forest resources more generally, including wildlife, water, and recreational as well as industrial potential (DP f8-37). They cast a wide net in their organizing, endeavoring to engage not only landowners, businesses, and forestry groups but youth groups (scouts, 4-H, Future Farmers of America), conservation organizations (Audubon, Conservation Federation, Izaak Walton League, Nature Conservancy), recreational interests, women's and men's clubs, social and educational organizations, federal and state agencies, and the media. It was the first major forestry conference in Missouri. Held October 18, 1958, in Jesse Hall Auditorium on the University of Missouri Campus, it featured a headline array of speakers, including the governor and attorney general, a U.S. senator, and federal and state forestry officials. A business leader from Chicago talked about the outlook for an Ozark pulp and paper industry; the outlook was good, he said, but dependent on an adequate supply of wood from small private owners. Leonard Hall addressed the scourge of open range grazing, which would not finally be terminated statewide by law until 1967, despite years of dogged campaigning by Spencer Jones, Drey, Hall and other conservationists. In his own speech, Leo Drey encouraged landowners and policymakers to "convert lazy acres into busy acres" through sound forest management (Drey 1958).

If there was a subtext for the conference beyond raising public support for forest conservation, it was to build political support for protection of the Current and Eleven Point rivers as national rivers in order to defeat proposed dams and reservoirs. Senator Stuart Symington, undoubtedly with prior encouragement, called for "thoughtful attention" to the proposal; other speakers commented favorably, and it was reportedly a topic of discussion during breaks (DP f11, Drey to Idol f28, f36, f231). Leonard Hall's book about the Current River, *Stars Upstream*, had just appeared with its argument for a free-flowing stream. Within a few years, Drey and Hall would be pitted against each other with competing proposals for how to protect the rivers, but, in 1958, they and most others at the conference were united in their desire to protect the streams from dams by some sort of national designation.

Dams on the Current and Eleven Point had been among dozens authorized in Missouri in the 1930s. Two dams at Blair Creek and Doniphan on the Current, proposed by the U.S. Army Corps of Engineers in the 1940s, had been beaten back by an unusually strong coalition of local and statewide interests, both public and private, but, in the early 1950s, the dam proposals resurfaced in the course of further flood-control studies. Blair Creek was the major drainage of the National Distillers' holdings purchased by Leo Drey, who now owned nearly 35 miles of frontage along the Current River in the vicinity of the proposed dam. Drey had been an avid floater of Ozark streams even before he owned land there, so he was supportive of efforts to forestall the dams and preserve the rivers by developing the recreational resources of the region, as proposed in a National Park Service led, federal-state cooperative plan issued in 1956 (MDRD 1956), but he had some misgivings about the extent of public ownership and the scope of mass recreation development focused on the narrow river corridor in subsequent National Park Service proposals (fig. 9).

As a bandwagon for National Park Service development of the rivers gained steam, Drey began meeting with the Ozark Committee of the Nature Conservancy and other Ozarkers to shape an alternative proposal more sensitive to the concerns of local residents who wanted more sustained economic development and less interference with their way of life. They formed a Current-Eleven Point Rivers Association that sought to forge a consensus among a wide array of local groups around a multiple-use program that would emphasize forestry and wood-using industries, locally controlled watershed conservancies, and small impoundment recreational areas (f 1, 231). In a lengthy 1959 letter to Governor James T. Blair, Jr., (f 172), Drey made the case for comprehensive planning for "the wise, harmonious development of the two great natural assets of the Ozarks—the region's forested watersheds and their running rivers," with full local participation. He advised only limited additional public land acquisition—without resort to eminent domain—and more creative use of individually negotiated scenic easements tailored to the natural values, land uses, and appropriate recreation patterns along particular stretches of rivers or highways and near springs, caves, and other natural features. He also advocated safeguarding the unique wild values of the rivers by dispersing recreation to the extensive woodlands of the region; this could be accomplished by developing hiking, riding, and jeep trails, small impoundments and scenic overlooks—not only on public lands "but on private as well if the owners are agreeable." Surely the owner of Pioneer Forest was agreeable, so long as his forestry operations could continue (fig. 10).

Figure 9—Leo Drey owned 35 miles of frontage along the Current and Jack's Fork Rivers. Left to right: Leo Drey, Ed Woods, and Charlie Kirk. *(Courtesy of Pioneer Forest)*

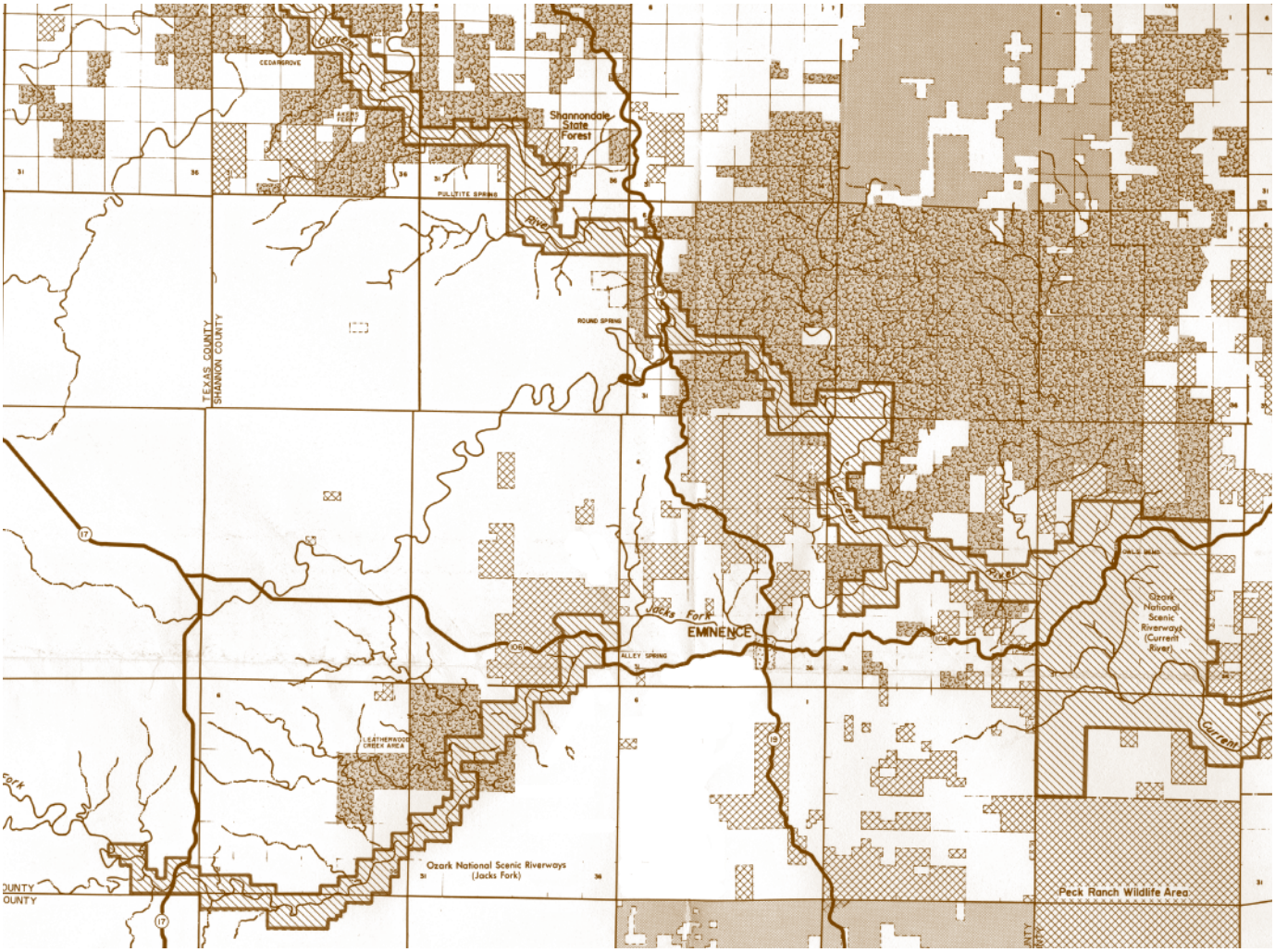

Figure 10—Pioneer Forest (tree crowns) in relationship to Ozark National Scenic Riverways (diagonals within corridors), Missouri Conservation Department land (cross-hatch), and national forests (shaded). Source: Bureau of Outdoor Recreation (Stokes 1976).

In his effort to find an alternative to the National Park Service and encourage more extensive planning for economic development in the region, Drey engaged in intense correspondence with Sigurd Olson of Ely, Minnesota, ecologist Robert McDermott of Pennsylvania State University, economist Mason Gaffney of the University of Missouri, forest consultant August Beilmann, and many others, most of whom sought gently to temper Drey's optimism about the willingness of Ozarkers to accept the sort of comprehensive planning he envisioned (DP f 199, 204, 226, 232). With little support for regional planning, Drey and his colleagues developed a proposal for management of the rivers by the U.S. Forest Service that incorporated their notion of scenic easements, dispersed recreation and other aspects of multiple use management, including continued timber production and mining (Drey 1960). By 1961, there were two contending bills in Congress, a measure providing for a National Park Service-managed Ozark Rivers National Monument introduced by Congressman Richard Ichord in the House and Senators Stuart Symington and Edward Long in the Senate, all Democrats, and a bill drafted by Drey and St. Louis attorney Davis Biggs to establish a U.S. Forest Service-managed Ozark Scenic Riverways, introduced by St. Louis Congressman Thomas Curtis, a Republican (Stevens 1997; see also Senate 1961, 58-80). Though neither bill made it out of committee, the contest opened a rift between Leo Drey and his friend Leonard Hall, who supported the National Park Service bill.

The election of 1960, which brought the Kennedy Administration to office, had made a victory for Drey's alternative considerably less likely, introduced as it was by a Republican. Secretary of the Interior Stewart Udall, who floated the Current with Ichord, Hall, and National Park Service officials in September 1961, became an advocate for National Park Service management and won President Kennedy's endorsement, effectively defusing the objections of the U.S. Forest Service, the major landholder

in the region (Sarvis 2002, 47). Even the Missouri Conservation Commission agreed to endorse the National Park Service bill after negotiating assurances that their land would not be taken without their consent and that hunting would be allowed along the rivers, prompting charges from Drey that they were thereby undermining the future of forestry and markets for forest products in the region (DP f 227).

By 1962, it was clear that Missouri would be a proving ground for a new concept of national rivers advocated in the report of the Outdoor Recreation Resources Review Commission (1962). At Senate field hearings in June 1962 at Big Spring State Park, Drey forcefully argued for preservation of the quality rather than quantity of the recreational experience along the riverways by developing economic incentives for management of their forested watersheds along conservation lines. Using diagrams drawn by his sister-in-law (fig.11), he charged that the National Park Service proposal, though seemingly—when viewed from "celestial heights"—aimed at regional development through preservation of the rivers, would actually—when viewed from a proper perspective with one's feet on the ground—overshoot preservation and fall short of development by its emphasis on mass recreation (DP f 177). Several months later, Drey circulated his own proposal for a system of national riverways, explaining that many more rivers could remain wild and natural if they were secured through conservation easements to restrict development in riparian corridors, rather than through government ownership; the easements could be held by whatever agency—federal, state, or private—was most appropriate for the particular river, whatever agency was best able to encourage and demonstrate proper management and productive use of timbered watersheds by private owners (House 1963, 65-67; DP f 232). Along the Current and Eleven Point, that would be the U.S. Forest Service.

Though Ozark voters in the November 1962 elections favored local candidates opposed to the National Park Service approach, most of the significant political players at the national level supported a considerably revised National Park Service measure in the 1963 Congress. The new bill removed the entire Eleven Point River and the Ripley County portion of the lower Current, a region of significant national forest ownership, good farm land, and strong local opposition to the National Park Service; on the remaining land it provided for easements as well as outright acquisition, the easements intended, perhaps, as a sop to Drey, and it contained language satisfactory to the MDC providing for hunting, fishing, and retention of their lands.

In a last ditch effort to forestall passage, Drey and 41 other riverway landowners signed "letters of intent" by which they would offer voluntary scenic easements to the state, not to the federal government, and Drey himself toyed with the idea of donating a recreation easement of some 50,000 acres to the state as a Current River Remote Area (Senate 1963, 74, 84-85; DP f 232). Knowing that National Park Service officials were

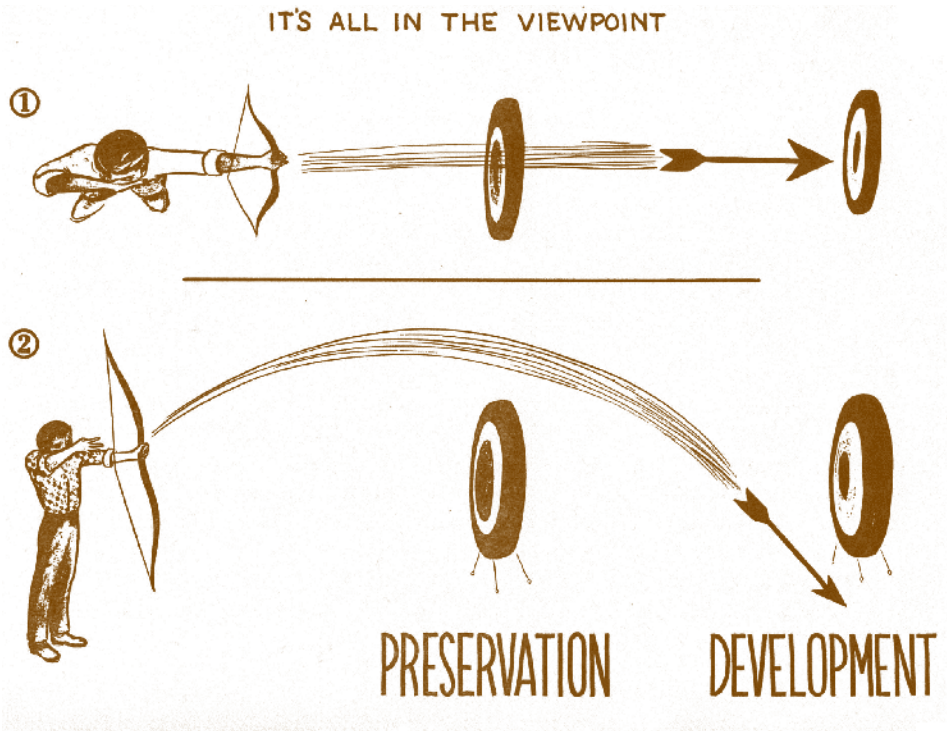

Figure 11—Park Service proposal overshooting preservation and falling short of development, as sketched by Leo Drey's sister-in-law. *(Courtesy of Leo Drey)*

distrustful of easements, he also worked with his foresters, Ed Woods and Charlie Kirk, on a statement on the "possible effects on Pioneer Forest of the loss of approximately 10 percent of its present area" (DP f 177). The 13,000 acres of Pioneer lands within the proposed boundaries held some of the finest standing timber on the richest, deepest soil, according to the statement. Moreover, some 30 of the 400 permanent sample plots in Pioneer's continuous forest inventory would be lost, including nearly all of the fast-growing bottomland hardwoods type, potentially invalidating the comparative value of the inventory. And Pioneer's heavy investment in timber stand improvement would be interrupted before its benefits could be realized either by the firm or by the local economy. But there is no evidence Drey ever circulated the statement or spoke in public hearings about his own potential personal losses.

The bill for National Park Service administration of the Ozark National Scenic Riverways passed Congress in August 1964 and was signed into law by President Lyndon Johnson on August 27, thereby establishing the country's first national river. By that time, the secretaries of Interior and Agriculture had already appointed a study team to establish criteria and suggest rivers for a national system of wild rivers. Four years later, Congress followed through with the Wild and Scenic Rivers Act which, much as Leo Drey had suggested, provided for administration by whichever federal agency was most appropriate in the region. Missouri's Eleven Point was included among the first nine rivers designated, and it was placed under the jurisdiction of the U.S. Forest Service.

In the immediate aftermath of enactment of the National Park Service bill, Drey was understandably upset, even shell-shocked, about the divisiveness within the conservation community and the beating he himself had taken. In a letter to MDC Director William Towell intended to mend badly frayed personal relations, he even suggested, "I'm no longer sure that I know what conservation means, or that there is any longer a place for me in the pic[t]ure. . . . If the emphasis is to be on recreation throughout the region, there is no point in pouring money into the sort of intensive forestry we've been practising[sic] because it won't pay off. Mind you, I'm not saying I won't make money out of our land, because I will, one way or another. I'm only saying it can no longer be taken for granted that forestry should be, can be, or will be practiced by private landowners in the Ozarks." After adding that he was even thinking of devoting his efforts to other interests such as education and health rather than conservation, he pulled back a bit: "I haven't quite decided to pick up my marbles and quit, but I'm giving it serious consideration because it seems that the basic premise on which I've been operating in the Ozarks—that the timber should be developed and the rivers preserved—is about to be reversed" (DP f 227).

But even as he expressed his dismay and seeming uncertainty about his own future in conservation, Drey, with his characteristic idealism, had been engaged in educating gubernatorial candidates about Missouri's conservation needs—especially a statewide system of scenic rivers (DP f227). The winner of the 1964 contest, Warren Hearnes, appointed a Governor's Wild Rivers Advisory Committee that included Drey and other members he had suggested. Drey immediately offered a list of 19 rivers for the committee to study and, months later, suggested draft language for a state wild rivers bill that emphasized protection of streams by scenic easements (DP f 152, 167, 170, 164).

After 4 years of meetings and failed legislative efforts, a coalition of urban environmentalists in 1970 launched an initiative petition campaign aimed at voter enactment of a state system of scenic rivers by simple zoning of some 850 miles along 20 Ozark streams against further development (Adams 1970). The initiative campaign put Drey on the spot, as he was then president of the Coalition for the Environment, a St. Louis umbrella organization he had helped found in 1969 whose board agreed to endorse the initiative, whereas Drey himself had long been committed to working with local landowners in the Ozarks and protecting their rights. Now urban environmentalists were urging him to jump into the campaign to put it over, on the grounds that no bill could satisfy the more recalcitrant Ozarkers (DP f 155). But sober second thoughts following the bombing of a campaign leader's car led finally to abandonment of the initiative; and, after a thousand angry landowners packed a hearing on yet another attempt at a legislative bill, the scenic rivers measure was dead (Wolf 1971).

In retrospect, it is likely that condemnation of lands and other management problems of the National Park Service along the Ozark National Scenic Riverways in its early years helped to fuel landowner opposition to the state scenic rivers bill (Sarvis 2000). Drey himself was disturbed that the National Park Service was using easements opposite the way he thought appropriate, offering perpetual easements for lands with cabins and other nonconforming developments that should have been condemned, or, at most, granted life tenure, but buying out farmers by insisting on public right of access to easements, which in practice forced most farmers to sell or be condemned. On his own Pioneer Forest, while Drey preferred to offer easements, the National Park Service insisted on condemning his most valuable land near Round Spring State Park, for which he received $100 an acre, and trading interior lands formerly owned by other condemned landowners to him for some of his other riverine lands. He was able to retain only 961 acres along the river under easement (DP f 149, 157). Meanwhile, public use of the rivers, including motorized equipment, burgeoned out of control, so much so that by 1973 even Leonard Hall, glossing over his own role in the conflict, bemoaned the overemphasis on recreation: "Thus the Riverways, except as an area for mass boating, is failing its purpose to preserve the stream, its fauna and flora, and its scenery in their natural condition."

In spite of his misgivings about the National Park Service, Drey began discussions as early as 1965 with the regional director of the Bureau of Outdoor Recreation, a sister agency established in 1962, regarding ways in which the recreational opportunities on Pioneer Forest might be coordinated with those of the riverways, the national forests, and state agencies to better serve the public (DP f 523). Drey had not given up his dream of more dispersed recreation in the region—focused on trails,

primitive camping, and related activities back from the rivers—and he was willing to cooperate by making his land available, especially on the big block east of Current River near Round Spring. Perhaps owing to bureaucratic rivalries and the desire of the National Park Service to get its feet on the ground in the riverways before branching out, a BOR study was put off until 1974, when recreation planner Gerald Stokes prepared a broad—some thought even grandiose—range of proposals for development of recreation on Pioneer Forest (DP f 512).

When Stokes subsequently reported that National Park Service officials were not interested in participating in recreation management on Pioneer Forest, viewing their responsibility as confined solely to the river corridor, Drey contracted with the Coalition for the Environment in St. Louis, MO for yet another study that would help in assessing priorities for recreational development in light of federal and state agency attitudes (DP f 513). From the two recreation studies (Stokes 1976, Bedan and Goetz 1976), and especially from the mapping of Pioneer lands in juxtaposition with public lands, grew plans for an Ozark Trail extending from St. Louis, MO to Arkansas, a proposal enthusiastically supported by staff in Missouri's newly established Department of Natural Resources (DP f 523-25). The first segment of this trail to be completed, with help from Sierra Club volunteers, traversed Pioneer Forest for nearly 13 miles along Blair Creek (fig. 12), providing a critical link between the Mark Twain National Forest to the north and the Ozark National Scenic Riverways to the south (Creighton 1979).

THE PIONEER SYSTEM OF FOREST MANAGEMENT, ca. 1970

During all the turmoil over the Ozark National Scenic Riverways, the proposed state scenic rivers bill, and the Pioneer Forest recreational studies, forest management activities continued on Pioneer very much as they had from the start (fig. 13). At nearly 150,000 acres by 1970, the forest was still operated by five foresters and technicians—the same five who had transferred to Drey from National Distillers—though a sixth would soon be added in anticipation of the retirement of Ed Woods, who had suffered a series of strokes. Three of the staff were assigned to supervise districts at some distance from the Salem headquarters—Russ Noah at Eminence in Shannon County, Rayborn Skaggs at Bunker on the Reynolds-Dent county line, and Paul Corder at Ellington in Reynolds County—while Woods and Kirk handled the Salem district and other administrative and supervisory matters (SLPD 1962, Merritt 1962).

In each district, foresters monitored the forest, marked boundaries, marked and scaled trees for timber sales, and supervised sales, visiting each active sale at least once a week to ensure that the harvest, skidding, and transport of trees were not causing unnecessary damage. Sales were put out on bid to local sawmills or loggers, and staff made an effort to schedule sales fairly evenly in the areas worked by certain loggers and mills so as to help keep them in business. They generally marked trees only about a week in advance of harvest, placing

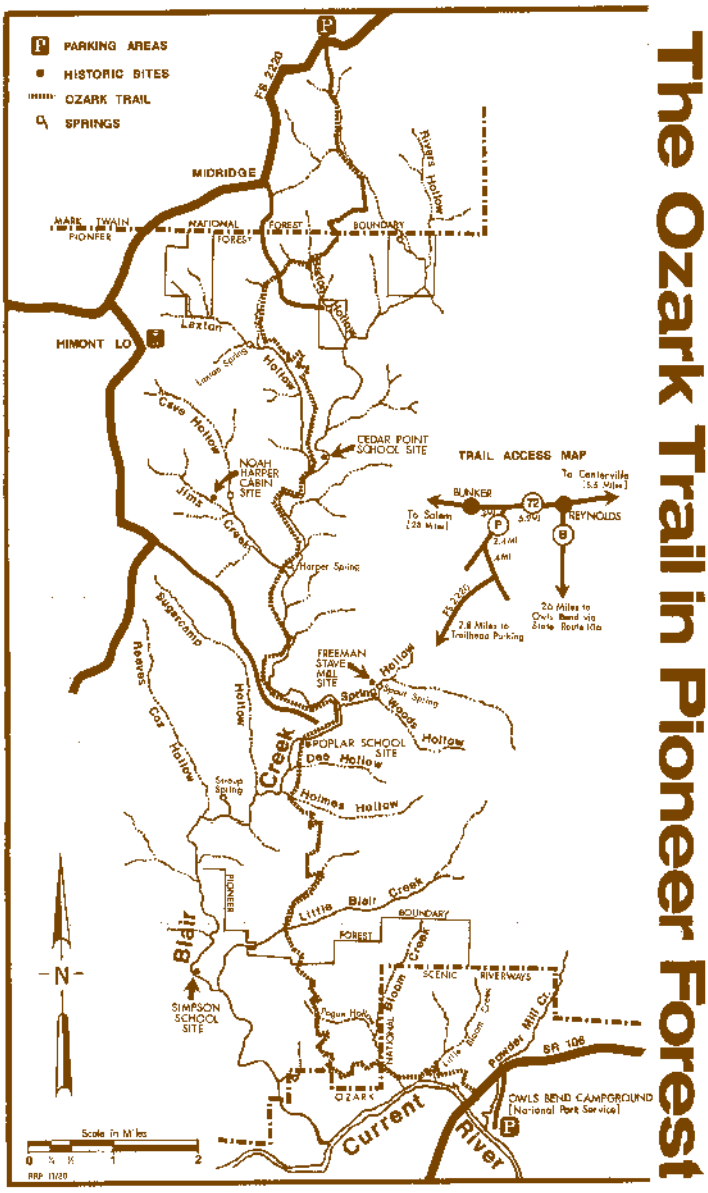

Figure 12—The route of the Ozark Trail through Pioneer Forest, connecting the Mark Twain National Forest with the Ozark National Scenic Riverways, from a 1980 Pioneer Forest brochure. *(Courtesy of Pioneer Forest)*

paint both at breast height and at the base of the stump, so they could check regularly to make sure the proper trees were being cut. And they asked loggers to harvest from the bottom of the slope toward the top, using marked trees as fulcrums for the skidding cables, so as not to damage trees intended to remain. In those years there were 10 to 15 active timber sales on the forest, each harvesting about 40 percent of the standing volume for a total harvest of about 1 to 3 percent of standing volume on the forest as a whole (Iffrig and others 2004).

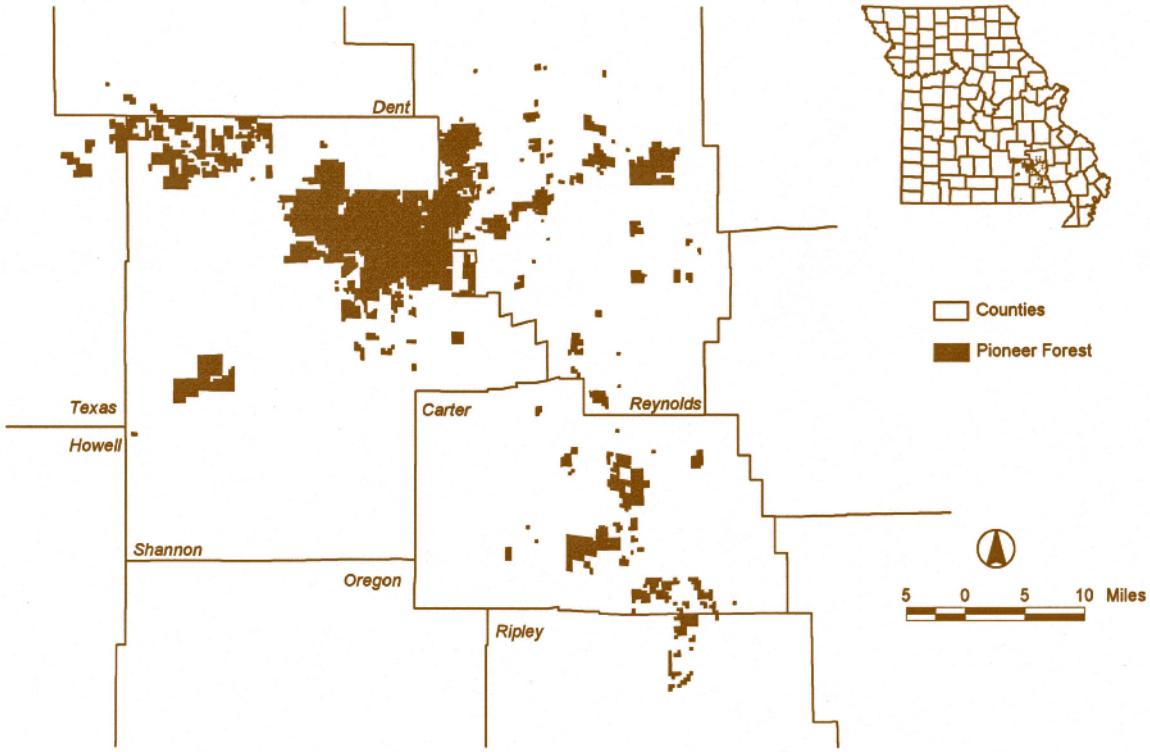

Figure 13 (right)—Pioneer Forest. By 1970 the forest had reached nearly its extent as of 2000, when this map was made. *(MoRAP)*

In the early years of their single-tree selection system, there was a good deal of trial and error experimentation in the marking of timber and scheduling of sales. Woods and Kirk apparently intended to return to each unit approximately every 12 years, but, by 1970, they were beginning to realize that once every 20 years was more realistic. In the beginning, they removed a large amount of rotten or deformed material, as relatively few trees were fully mature and ready for harvest. In marking trees for removal, they had to be cognizant of slope and soil conditions and the desirability of creating sufficient space and light to favor young reproduction of desired species as well as continued growth of the best specimens in a range of species and size classes. But, in truth, there was little to go on except observation and instinct. Despite the fact that selection cutting had been standard procedure in the U.S. Forest Service for decades, and both Woods and Kirk, as well as Noah, had experience with it elsewhere in the country, there had been little work on the rotation for oak-hickory in Missouri and virtually no long-term research.

The paucity of long-term data made the Pioneer staff more committed than ever to keep up their continuous forest inventory, even though it required a great deal of effort every 5 years for their small field staff to painstakingly locate, measure, and record individual trees on each of the more than 450 1/5-acre sample plots (fig. 14). By the 1972 inventory, the average board-foot volume per acre had increased from about 1,200 in 1952 to more than 1,750 (Trammel 1998), in spite of all the white oak harvested by National Distillers as well as Pioneer's improvement cuttings and losses from drought, fire, ice, and windthrow. If Pioneer was not yet fully paying its way, at least the quantity of standing timber was increasing.

As owner of the forest, Leo Drey operated out of an unpretentious room in the Syndicate Trust Building in downtown St. Louis, MO handling all financial transactions and keeping records, which he stored in an office safe. Though he had spent weeks on end in the Ozarks in the early 1950s when he was getting started, his marriage to Kay Kranzberg of St. Louis in 1955, followed within 7 years by the arrival of three children (Laura, Leonard, and Eleanor), led him to cut back on his time away from home. In any case, his involvement in conservation issues and his myriad land transactions and forestry activities required massive paperwork—Drey never employed a secretary—as well as countless meetings with fellow activists and lawyers in the city. But, he loved spending days afield with his foresters, and he rarely missed monthly meetings and field trips of the Karkhagne Club, an association of foresters and other Ozarkers founded by Ed Woods to discuss land management issues. The Karkhagne, a figment of Woods's imagination, was a mythical beast with a habit of eating section corners (Woods 1964); it was reputed to make its home in the wilder reaches of Pioneer Forest (fig. 15).

In addition to his efforts on the Ozark Riverways and the scenic rivers bill, Drey was also deeply involved in conservation campaigns nearer home. He was a founder and first president of

Figure 14—Russ Noah and Paul Corder measuring a tree during the Pioneer Forest inventory. *(Courtesy of Pioneer Forest)*

the St. Louis Open Space Council in 1964 and worked tirelessly for passage of a proposed $25 million bond issue to acquire 5,000 acres of land for 24 major parks in St. Louis County that fell a heartbreaking 376 votes short of a required two-thirds majority in 1966. He was also a founder and president of the Missouri Coalition for the Environment, which fought against encroachment of development on flood plains, against pollution and sprawl, and for environmental quality and parks, joining the Open Space Council in a successful effort in 1969 to secure a smaller bond issue to enable purchase of 2,800 acres. Through both organizations he also promoted a national recreation area along the lower Meramec River, in part to forestall proposed dams (Sanford 1970, Drey c.1984).

On his own, Drey established the L-A-D Foundation in 1962 to acquire, protect, and promote forests and natural areas. Some of his own forest contained significant sites, and he was also a soft touch for conservationists seeking a savior for other threatened areas. In December 1970, concurrent with adoption by the Missouri Conservation Commission of a new policy providing for establishment of a state system of natural areas, Drey announced the availability of four sites—Cave Spring in Shannon County, Clifty Creek Natural Arch in Maries County, Balancing Rock Narrows on the Piney River in Texas County, and Grand Gulf in Oregon County—for lease to any public agency that could protect them while allowing public access (Adams 1970). The following year the foundation contributed funds to a survey of natural areas being coordinated by Professor William H. Elder of

Figure 15—A drawing of the Karkhagne by Ward Degler from Ed Woods' description. Source: Woods, *Missouri Log*, 1964.

the University of Missouri. Two L-A-D sites, Clifty Creek and Piney River Narrows, were included in the first set of natural areas designated by the state in 1971, a number that would grow to eight by the end of the decade (Kramer and others 1996). In 1974, Drey transferred to the L-A-D Foundation the ownership of the 961 acres along the Current and Jacks Fork rivers under scenic easement to the National Park Service. And, in 1975, the foundation began funding a county-by-county survey of natural areas headed by R. Roger Pryor (1980).

As owner of Pioneer Forest, hoping to demonstrate that he could make a profit through conservative land management, Drey must have been somewhat disheartened by his prospects after 20 years of operating experience. During the entire period from the mid-1950s to the early 1970s, stumpage prices for timber remained stagnant, not even keeping pace with inflation, so that in real terms, they declined (Hamatani and Goslee 2008: fig. 7). In 1970 and for several years thereafter, prices were

lower than at any time since 1954-55, when severe drought had thrown a glut of salvaged timber on the market. The stagnant prices in the 1960s and early 1970s probably resulted from weak economic conditions during the Vietnam War, exacerbated by massive clearing of forest land for pasture in the Ozarks that further glutted the market for sawlogs; the U.S. Forest Service reported that more than 1.7 million acres of commercial forest land had been converted to other uses between its 1959 and 1972 surveys in Missouri.

By an ironic twist of fate, the Pioneer enterprise during these years was buoyed by substantial revenue from an unexpected source—royalties from the mining of newly discovered veins in the rich new lead belt known as the Viburnum trend, which became the leading lead-producing area in the world. When Drey was first asked by an exploration firm to allow wildcatting on his land, he said no. But he was soon informed by William Blunt of National Distillers, with whom he had originally negotiated for the land, that he was not being fair; under terms of his contract to purchase the Distillers' land, the firm had reserved a one-half interest in any minerals found on the property and now wished to profit from it. So, Drey reluctantly signed an option agreement with Bear Creek Mining Co., the exploration subsidiary of Kennecott Copper Co. He eventually bought out National Distillers' half interest in order to forestall mining on any additional land, but mining continued under a 50-year lease he had signed in 1969 with Ozark Lead Company, another subsidiary of Kennecott (later Doe Run), in return for which he would receive substantial mineral royalties (LD).

THE CHALLENGE OF SILVICULTURAL REVOLUTION, 1965–1985

The early 1970s were a time of transition in the Ozarks to a more intensive form of forestry characterized by even-aged management, or clearcutting, rather than uneven-aged management of the sort long practiced on Pioneer and on federal and state lands up to that time. The shift came later to the Ozarks than to other forests in the West, South, and East. It began on private industrial lands during World War II when firms such as Weyerhaeuser in the Pacific Northwest began practicing tree farming, using clearcutting to prepare land for new high-yield stock that would grow quickly to maturity. During the dramatic housing boom after the war, private operators sought permission to harvest timber by clearcutting on national forests, but the U.S. Forest Service adamantly insisted on the time-honored practice of single-tree selection and, in fact, advocated public regulation to forestall destructive clearcutting on private lands. As political pressures to increase the cut from public forests mounted, the U.S. Forest Service finally in 1955 authorized clearcutting on the Boise National Forest in Idaho. Clearcutting was soon being practiced on national forests throughout the West, where it was said by its proponents to be necessary for regeneration of Douglas-fir, lodgepole pine, and other species that are intolerant of shade (Hirt 1994: 137).

In the East, U.S. Forest Service officials initiated the new practice of even-aged management in 1964; one of the earliest national forests to see extensive clearcutting was the Monongahela National Forest in West Virginia. An early intimation of the applicability of the new technique to the oak-hickory forests of the Ozarks came in a 1962 article by U.S. Forest Service research forester Benjamin Roach on "Practical Silviculture for Central Hardwood Stands," published in the *Southern Lumberman*. "With the silviculturist obligated primarily to growing products for industry," Roach wrote, "it follows that he should do so as efficiently as possible. . . . And to keep silvicultural costs low, he must be satisfied with doing only what is necessary to produce the required products, not what might be desirable to produce the ideal forest." Researchers in Missouri conducted a 40-acre clearcut on the Sinkin Experimental Forest near Bunker in the mid-60s, but the first commercial clearcut on a public forest in Missouri did not occur until 1969, in a sale near Eminence overseen by District Forester Charles Santhuff on MDC land (Trammel 6-24-02).

As public outrage erupted nationwide over clearcutting on national forests as far flung as Montana, West Virginia, and Alaska, and as millions of acres of hardwoods on public and private lands in Missouri were being converted to pine or to pasture by aerial spraying and planting, wildlife biologists in the MDC, concerned about adverse impacts on wildlife, began working with foresters in MDC and on the Mark Twain to develop a cooperative program to assure a variety of wildlife habitat in each management unit (Evans 1974). Specially funded by Congress in 1974, it was called the Missouri Plan owing to its pace-setting cooperative elements. Along with the later onset of clearcutting in Missouri, the Missouri Plan may have had the effect of forestalling controversy of the sort witnessed elsewhere, even though the plan was fundamentally grounded in even-aged management.

Most of the silvicultural research that was being done in the 1960s and 1970s, almost all of it funded by the U.S. Forest Service or by private industry, focused on highly specialized studies of the most efficient way to grow timber volume and enhance present net worth through even-aged management, with little emphasis on tree size and quality (Boyce and Oliver 1999: 430). That was also what was being taught in forestry schools. Clint Trammel visited Pioneer Forest on a forestry field trip during his junior year at the University of Missouri in 1967 and was so impressed by Ed Woods and his uneven-aged management system that he came back on his own two weeks later, pitched his tent on Big Creek, and spent the weekend exploring the forest. But when he raved about it to a professor he was told, "Don't worry about it. It's just an experiment. It won't work." This was the attitude that pervaded the ranks of professional foresters at the university, in the conservation department, and on the Mark Twain all during the 1970s and into the 1980s, Trammel recalled (interview). To them, Leo Drey was just cutting timber, not managing the forest; he would find out in time that he wasn't getting reproduction of oak and that his forest would become increasingly dominated by less valuable, shade-tolerant maple (fig. 16).

Figure 16—Pioneer Forest Manager Ed Woods, Owner Leo Drey, and Chief Forester Charlie Kirk. *(Courtesy of Pioneer Forest)*

But, regardless of prevailing attitudes, Trammel jumped at the chance to apply for a rare opening on the Pioneer Forest staff in 1970 and was hired. In 1972, when Ed Woods retired and Charlie Kirk took over as forest manager, Trammel was promoted to chief forester. That fall, Terry Cunningham, who had experienced similar attitudes at MU during his quest for a degree, was hired as a temporary to help with the 1972 forest inventory and then was kept on to handle operations near Van Buren. Rayborn Skaggs retired in 1975 and was succeeded by his son Danny, who had learned the trade and the forest by accompanying his father. Trammel became forest manager in 1979 when Charlie Kirk retired, and Cunningham took over as chief forester. Another veteran, Paul Corder, became ill and died in 1980. So, except for Russ Noah at Eminence, who would continue until 1985, the forest, by 1980, witnessed a turnover of the original staff that had come from Distillers—and from Pioneer Cooperage before that—and a new generation was in charge on Pioneer, none of them yet out of their 30s.

The 1970s and early 1980s must have been lonely years for the staff on Pioneer, especially for the younger recruits whose entire education had emphasized the virtues of even-aged management and detailed the myriad problems of older uneven-aged approaches. They kept doing what they had been doing—what they learned from the seasoned staff and what their boss, Leo Drey, wanted them to do: continue to individually mark trees by single-tree selection. But, Drey was dubbed "conservation's Don Quixote" in the popular media (Stevens 1971) because of his leadership in environmental causes as well as his dreams for Pioneer, and professional foresters, most of whom were circling the wagons to ward off attacks by environmentalists, began to look askance at the management of Pioneer as well. Trammel and Cunningham in particular, after they were left in charge by the retirements of Woods, Kirk, and the other veterans, admitted they felt quite isolated from the professional forestry fraternity, wondering whether, in fact, their system would work in the long run. Virtually all the silvicultural studies published in those years, and there were hundreds of them, were saying one couldn't expect to get oak reproduction without clearcutting. There was virtually no research on uneven-aged management in the central hardwoods region.

Charlie Kirk, who had begun his career in the 1930s and had come to Missouri in 1938, the first year of the new state forestry division, had been socialized into the profession in a different era when single-tree selection was the norm. It was not until the last decade of his career that he witnessed the wholesale revolution in silvicultural orthodoxy. Shortly before he retired, he wrote a moving rumination on his own management philosophy born of 40 years of experience in the Ozark woods: "I Think on It Often" (Kirk 1979). There was a spot high under his right shoulder blade that itched off and on for years. It finally occurred to him, he said, "that this itch occurs only when the mind is wrestling with questions that have, at least to me, no immediate, concrete answer. I have learned the hard way that whenever this shoulder itches, I should rethink my answers."

For 30 years, he admitted, he had been haunted by something Cal Stott said: "There is little doubt that man has the authority to say what will happen to a wild woods. The question is, does he have the wisdom?" Kirk compared rings in cross-sections of two 16-inch black oaks recently cut on Pioneer, one of which was 14 inches in diameter at age 22 but grew only 2 inches in its final 12 years, whereas the other was only 11 inches at age 68 but had grown a full 5 inches in the next 7 years. His shoulder itched as he pondered the imperfect art of marking timber. He ended with a litany of altered ideas in a "strange half-century of forestry," from condemnation to acceptance of fire and clearcutting, to the shift from multiple to single use, to the glib notion of preservation, and the "silvicultural suicide" of diameter-limit cutting. "I am older now—I have come to know that things are not always as they seem," he concluded; "I am older now—my shoulder continues to itch."

The new young crew on Pioneer soldiered on into the 1980s, conducting the seventh forest inventory in 1982. Trammel decided to save money by doing his own computer work rather than sending the raw data to Michigan, so he bought a Radio Shack Model 3, taught himself programming, and then waited anxiously for 2 full days while the machine crunched the data. Volume was up to more than 2,000 board feet per acre from only about 1,200 in 1952. Even more heartening, growth per acre per year had again started to rise after stagnating and then falling during the late 1970s, a time of rather significant losses from oak decline (Trammel and others 1998: 4). Prices for timber also began to rise in the late 1970s after decades of stagnation, leading to a more profitable enterprise. The inventory seemed to suggest that the various commercial tree species were maintaining their relative proportion of the forest mix and that the various diameter classes were also maintaining themselves or increasing (Iffrig and others 2004). But 30 years of data were hardly enough to answer long-range questions of oak reproduction, especially in view of the deluge of skepticism about uneven-aged management in the silvicultural literature.

There had been an independent study of the Pioneer data by David Larsen for a 1980 masters thesis in forestry at the University of Missouri, but it did not directly assess the management system on Pioneer. Larsen, who had grown up in Salem near the Pioneer headquarters and participated in the 1977 inventory, utilized CFI data and experimental plots on Pioneer to test the applicability of a growth and yield model developed for loblolly pine to upland oak-shortleaf pine stands in Missouri. But, aside from anecdotally noting the inability of pine to compete well with oak, the study did not address the issue of even versus uneven-aged management. Another MU master's thesis in forest ecology by Tim Nigh and others (1984, 1985), which sampled sites on Pioneer as well as other forests in the Ozarks and along the Missouri River, found widespread invasion of sugar maple, especially in the loess hills along the Missouri River but also in scattered areas across the Ozarks, and a striking paucity of oak regeneration, a pattern largely attributable to a reduction in site disturbance through fire, grazing, and heavy logging. Surely such findings must have been unsettling to the Pioneer staff.

PIONEER'S ROLE IN CONTROVERSIES OVER PUBLIC LAND MANAGEMENT, 1985–1995

The prospects for uneven-aged management in the Ozarks were addressed in a limited way during a planning process for the Mark Twain National Forest under the leadership of Forest Supervisor Leon Cambre, which began in 1980 and led to an approved Land and Resource Management Plan in 1986. The process had been mandated by the National Forest Management Act of 1976, which in turn had been precipitated by a 1975 federal appeals court decision that clearcutting on the Monongahela National Forest violated a requirement in the 1897 Organic Act to harvest only "dead, matured, or large growth" trees that had been individually marked, a practice the U.S. Forest Service had religiously followed for more than half a century before switching to clearcutting. The 1976 act repealed the 1897 act and legalized clearcutting, but it also expanded requirements for protection of environmental quality and for broad public involvement in the planning process. Every forest in the nation engaged in NFMA planning during the 1980s, and in virtually all there was a contest of interests. Before coming to the Mark Twain, Cambre had been in Washington, DC helping to shape the 1976 act, so he was committed to making a success of the planning process in Missouri.

In the 1970s and early 80s, Missouri had an unusually effective coalition of environmental groups and individuals—the Missouri Wilderness Coalition—that established a good working relationship with Cambre and the staff of the Mark Twain during its successful effort to secure congressional approval of seven wilderness areas on the forest totaling more than 63,000 acres between 1976 and 1984 (Karel 1978, Farmer 1999). During the forest planning process, the coalition was especially intent on securing more protective management for seven additional areas totaling 39,000 acres that could also qualify as wilderness. When the U.S. Forest Service issued its draft plan in 1985, environmentalists were generally pleased with recognition of the seven de facto wilderness areas as "sensitive" and with efforts to protect other special areas and scenic rivers, though they favored suspension of timber harvest in all such areas. They also appreciated the plan's emphasis on management for wildlife values, but they challenged the emphasis on deer, rabbits, and turkeys—all ubiquitous species that thrive under clearcutting—rather than interior forest species such as bears, mountain lions, certain hawks, and red-cockaded woodpeckers. And, they indicated a general preference for uneven rather than even-aged management (Sierra Club 1985).

If environmentalists were generally supportive of the proposed plan, the forest industry and local Ozarkers were outraged, believing that the plan would unduly restrict future timber harvests and access roads. In one newspaper account (Auchly 1985), the reporter even managed to cast Pioneer Forest Manager Clint Trammel with the industry opposition when Trammel rated the plan at best a C- and questioned the closing of some access roads. In fact, Trammel, unlike the industry, was also opposed to the plan's increased goals for timber harvest—up to an average 105 million board feet per year, from 78 million in 1984—fearing that smaller diameter trees would be taken before they were mature. And he must also have been dismayed by the emphasis on even-aged management, though he apparently did not publicly question it.

The final plan for the Mark Twain issued in 1986 increased the acreage on which uneven-aged management would be applied to 166,000 acres, or about 11 percent of the forest, even though it argued that "research does not support the wide-spread use of the uneven-aged system in the Ozark area when perpetuation of the oak forest is the objective." The U.S. Forest Service pledged, however, to evaluate the effectiveness of the uneven-aged system during the next 10 to 15 years and, if results were positive, to analyze its potential for greater application (USDA-FS 1986).[4]

It was the first chink in the armor of the clearcutting juggernaut, and it came in the only possible place on public lands in Missouri, as the MDC at the same time was taking a turn toward even more adamant insistence on even-aged management. Relations between Leo Drey and his foresters, on the one hand, and the forestry leadership of MDC, on the other, had grown increasingly testy during the 1970s and early 1980s, in part over differences in management philosophy exacerbated by a decade-long, unsuccessful effort to effect a mutually beneficial land exchange (PF). Then in 1985, a new governor, John Ashcroft, appointed his campaign manager, Rolla lumberman John Powell, to the conservation commission. Powell, whose

[4] In 2005 the USDA Forest Service would issue a revised forest plan and accompanying environmental impact statement for the Mark Twain grounded in principles of ecosystem management (USDA–FS 2005). About 29 percent of the forest would be managed with an emphasis on restoration of natural communities by prescribed fire and other techniques; about 67 percent would be identified as suitable for timber management. But with an emphasis on adaptive management and flexibility of techniques, the balance of even- and uneven-aged management under the new plan would be somewhat unclear and hence a matter of concern to the staff of Pioneer Forest and others (Trammel and others. 2005).

own 18,000-acre tree farm was a model of conservative, even-aged management, had long been a fierce opponent of wilderness and an unabashed advocate of clearcutting, and he would become the dominant force on the commission for the next 12 years. The commission in turn promoted state forester Jerry Presley to department director and Presley appointed the longtime head of the Missouri Forest Products Association, Gerald Ross, as state forester; both remained strongly committed to even-aged management of state forests.

Following through on the Mark Twain's commitment to move forward with uneven-aged management, U.S. Forest Service officials arranged for 39 employees including foresters, rangers, wildlife biologists, and technicians to visit Pioneer Forest in June 1987 to view and discuss its management system with Trammel, Cunningham, and Leo Drey (fig.17). The group toured eight sites on the forest, discussing everything from Pioneer's objectives and history to its strategies for marking, the history of cutting in the various stands, methods for working with loggers, the CFI system, and the prospects for reproduction of various species (Melick 1987).

Figure 17—Forest Manager Clint Trammel leading a tour on Pioneer Forest. *(Photo by Susan Flader)*

In addition, two silviculturists on the Mark Twain, Jay Law and Ross Melick, worked more closely with Pioneer staff in the course of special studies of how they might implement the new approach. Pioneer was the only forest in Missouri with substantial experience in uneven-aged management and, as Law and Melick now increasingly appreciated, there was precious little other research or experience to use as a guide. What published research there was dealt almost entirely with failures of the method elsewhere in the country, so they would of necessity have to start with an examination of the Pioneer system. The two had somewhat different assignments. Law, who had experience with single-tree selection early in his career in the Lake States and drafted the sections of the revised forest plan dealing with uneven-aged management, put in some measured plots on the Salem district and worked with Craig Lorimer at the University of Wisconsin to develop brief "how-to" guidelines for applying the method (Law and Lorimer 1989). Though the guidelines drew on the Pioneer methodology, they recommended group selection to create openings of up to .35 acre if oak regeneration was desired. Melick, as part of his quest for advanced silvicultural certification, was preparing to recommend silvicultural prescriptions for the first 68 acres selected for uneven-aged management on the Mark Twain, three stands near the Mill Creek Recreation Area in the Rolla District (interviews, Law and Melick).

Melick's more discursive unpublished report (1989) began with an unusual "apologia" in which he acknowledged that his project design had been influenced by "political realities"—the need to move expeditiously toward initiating and evaluating uneven-aged management "as directed in the Forest Plan"—and hence his report included more detail than usual about various questions related to fire, insects and disease, regeneration, herbicides, genetics, logging damage, and economics under uneven-aged management, and it omitted formal evaluation of a complete range of silvicultural alternatives. Melick recommended "selection with groups" as the harvest method for all three stands, evidently drawing on Law's guidelines and seeking a compromise between shelterwood, which was already being utilized as an even-aged technique on the Mark Twain, and single-tree selection as practiced on Pioneer.

Melick's report acknowledged the greater difficulties of applying uneven-aged management on a public forest with lack of prior experience in the techniques, frequent staff turnover, and more restrictive contracting requirements. Pioneer foresters, by contrast, were able to work closely with loggers to prevent damage to unmarked trees, and they could terminate contracts immediately if excessive damage occurred. Nevertheless, Melick concluded that uneven-aged management had substantial applicability not only in visually sensitive areas or in riparian or other fragile environments but also on upland sites with some of the best potential for high-value timber products such as white oak, which was often cut prematurely in even-aged rotations. Although there were as yet no detailed economic comparisons of the two regimes in management of central hardwoods, and the staff on Pioneer was unable to provide a

benefit/cost analysis, there were some data emerging from southern pines (Guldin and Baker 1988) that suggested an advantage for uneven-aged management in producing and sustaining large good-quality sawtimber yields, especially from cutover stands; and virtually all the oak-hickory forests in the Missouri Ozarks had been cut over. The prospects for uneven-aged management obviously did not appear as bleak to Melick as they did to most other professional foresters in Missouri.

While Mark Twain foresters—now under a new supervisor, B. Eric Morse—were taking initial steps toward implementation of uneven-aged management in limited areas, they continued with clearcuts on the bulk of their acreage. In early 1988, 1,100 people in southern Missouri signed a petition of protest against the clearcuts, winning considerable media coverage. Several of them formed a group called Mark Twain Forest Watchers, which began studying federal law and the 1986 forest plan to find leverage points for citizen action (Dorst 1988). They also visited Pioneer Forest to study and photograph uneven-aged management, after which they filed an official appeal with the U.S. Forest Service contending that environmental assessments for proposed timber sales had to be site specific and assess the effects of uneven-aged as well as even-aged management. To their amazement, not only did they win on the Mark Twain, but Forest Service Chief F. Dale Robertson on February 6, 1989, issued a directive to all regional foresters nationwide to undertake site-specific analysis for all timber sales in implementing forest plans (Dorst 1989). By 1991, the Mark Twain reported a shift from 70 percent even-aged and less than 1 percent uneven-aged sale acres in 1988 to 29 percent even-aged and 32 percent uneven-aged sales (USDA-FS 1991).

The larger context of the Missouri struggle and the relatively rapid shift toward uneven-aged management on the Mark Twain included renewed public uproar over clearcutting on national forests nationwide combined with the ready example of successful single-tree selection technique on the neighboring lands of Pioneer Forest. Missouri foresters including Clint Trammel and environmentalists, including Hank Dorst of Forest Watchers, traveled to a number of conferences in Arkansas, where foresters and environmentalists had been debating clearcutting for years. Trammel found himself so disgusted by the attitude of Arkansas foresters at one meeting that he walked out (interview).

In 1990, beleaguered U.S. Forest Service Chief Robertson announced a shift nationwide to a new ecosystem-based management approach called "New Perspectives." When Arkansas's Ouachita was designated a "new perspective" forest with a moratorium imposed on the use of clearcutting, MDC Director Presley (1990) roiled the waters in Missouri with a widely circulated letter of protest to Robertson, suggesting the decision was largely based on "the emotionalism of ill-informed preservationists" and asking that MDC be notified in ample time to provide input if anything similar were contemplated for the Mark Twain. Commission Chair John Powell (1990) backed him up, railing against environmental fanatics who dared to challenge "good sound professional resource management expertise."

In numerous meetings and debates in Missouri around that time, Trammel was invited to present the prospects for single-tree selection, leading to much greater visibility for Pioneer Forest with environmentalists, in the media, and even among professional foresters. But there is some evidence that even Trammel, who was working on a master's degree in forestry at the University of Missouri at the time, was not entirely convinced of the greater benefits of uneven-aged management. In private correspondence with Drey (LD 9-18-90), he acknowledged his "very real concern" about "the increasing effort to eliminate even-aged management as an option because of emotional rather than biological reasons." "Leo," he explained, "even-aged management is the 'best' way to manage oak-hickory forest. The silvics of the species call for open sunny areas for best growth of regeneration. . . . Your decision to use uneven-aged management means you have decided to accept the trade-offs necessary to make the system work. Both Ed and Charlie must have discussed this with you in the past. We get less regeneration. We get a slower rate of growth. We get a reduced volume per acre. . . . I can easily show on Pioneer that uneven-aged management works. It would be far more difficult to show that it works 'best.'"

Drey, however, was not dissuaded: "Nothing we do will ever eliminate the use of even-aged management by the government. No fear of that, and that's not our purpose, which I'd say is rather to demonstrate that individual tree selection is a viable option, so land managers can then make informed decisions in accordance with their priorities." Ed and Charlie had already established the parameters of the operation before he bought out National Distillers, Drey explained (LD 9-21-90). "Realizing that they were operating in a complicated field with many unknown interrelationships, I believe both felt that they didn't want to be as manipulative as the government is, with their installation of food plots, their construction of watering holes, and their clear-cutting. In fact, if I understood them, they thought it best to go light on the land and to try to follow nature's lead rather than to clear cut and then regenerate after such heavy manipulation." And then the kicker: "I'm not sure about Charlie, but I know Ed was fully convinced that his method was not uneconomic, and he had it as one of his basic goals to show that such was indeed the case."

Leo Drey himself was frequently in the spotlight during the late 1980s and early 1990s, owing to his involvement in two other hotly contested issues, the disposition of the most pristine of Missouri's big springs and a second major effort to secure an act to protect the state's remaining natural streams. A media frenzy erupted over Greer Spring (fig. 18) and its surrounding 7,000-acre tract when Anheuser-Busch negotiated to purchase it in 1987 with assistance from The Nature Conservancy, intending to extract more than 2 million gallons of water a day to bottle and sell. Drey, a longtime member of TNC's Missouri board, was so incensed by this threatened "commercial exploitation and degradation" that he eventually stepped forward with an offer of $4.5 million to buy and hold the Greer Spring tract himself, arranging a creative deal with Busch for each of them to donate $500,000 through the Trust for Public Lands to reduce the price for eventual U.S. Forest Service acquisition of the land as an

Figure 18—Leo Drey at Greer Spring. *(Courtesy of Leo Drey)*

addition to the Eleven Point National Wild River (Bertelson 1988). Congress finally appropriated funds, and the tract was conveyed to the Mark Twain in 1992, after an intense political effort to prevent leaving a large part of it open to clearcutting.

There were numerous articles on Drey in state media at the height of the Greer issue, including one that reached back to the Shannon County tax battle of the 1950s to suggest that Drey was still regarded as "public enemy number one" in Shannon County for fighting against economic development. Drey responded that he felt he was helping the economy through all his local contracting for Pioneer, then admitted feeling a bit hurt by the negative attitudes of some Ozarkers, saying quietly to the reporter, "I respect them and admire them. . . . They value their independence and their freedom. You have to respect that" (Lemons 1988). The most appreciative account of Drey's management of Pioneer and his efforts for Greer and other causes appeared in the magazine of the National Audubon Society under the title, "Every State Should Have a Leo Drey" (Jackson 1988).

When the Greer Spring issue heated up, Drey was already involved—quietly behind the scenes—in strategizing and financing an effort to win support in Missouri through yet another initiative petition campaign for a system to protect the state's remaining natural streams: "The greatest unfinished piece of conservation business in Missouri," supporters called it (Bradley 1996). The measure would have designated stretches of 52 streams on which dams, bankside clearcutting, all-terrain vehicles, and loud motors would be prohibited. At Drey's insistence, owing to his respect for Ozarkers' desire to control their own destiny, it also offered local governments and citizens the opportunity to prepare management plans enforceable by a review commission within the Department of Natural Resources.

But the MDC, having several times promised Drey to remain neutral on the issue, came out publicly in strong opposition to the initiative, citing potential interference with its own management prerogatives; and, after a raucous campaign with charges and countercharges from angry partisans on both sides, the Natural Streams Act went down to resounding defeat in November 1990, an election in which environmental initiatives nationwide were turned down by voters. So upset was Drey with the ethics of the foresters running MDC that he refused to participate in several forestry conferences, allowed his membership in the Society of American Foresters to lapse, and removed Pioneer Forest from the Tree Farm Program. He had joined at a time when the Ozarks were ravaged by fire, open-range grazing, grandmawing, and overcutting, he explained, but he had always been managing for biodiversity and ecosystem sustainability and was "no longer comfortable" with the program's heavy emphasis on timber production (LD).

Yet another environmental initiative in which Leo Drey and Pioneer Forest became deeply involved also eventually blew up. As scientists worldwide began developing an international system of Man and the Biosphere reserves under the auspices of UNESCO in the 1980s, scientists in the Midwest became more aware of the globally significant biodiversity of the Ozarks. A National Park Service biologist at the Ozark National Scenic Riverways, David Foster, took the lead in developing a proposed Ozark Highlands Man and the Biosphere (MAB) Reserve in Missouri and Arkansas, centered in the Current and Jack's Fork River region in which Pioneer Forest was located and along the Buffalo River in Arkansas. He enlisted various entities in the two states including state and federal natural resource agencies, the Nature Conservancy, and Pioneer Forest in a cooperative planning effort to prepare a nomination. Drey and his staff, including Greg Iffrig—a naturalist hired in January 1992 as a sixth employee to handle recreation, natural areas, and various research and writing projects for Pioneer—were keen to partner in the biosphere effort, as their lands would be the only substantial privately managed forest included in an otherwise largely public effort, and they would be able to demonstrate the feasibility of protecting biodiversity while engaging in profitable forestry on private land.

In January 1993, they submitted nomination papers (Iffrig 1993) for the entire acreage of Pioneer Forest and, in addition, for eight properties owned by the L-A-D Foundation in the biosphere area. Seven of the L-A-D properties totaling 910.5 acres, most of them already officially designated as Missouri Natural Areas, and six additional reserves on Pioneer Forest totaling 1,963 acres were proposed for management as strict nature reserves. Another L-A-D property, Grand Gulf, was already a registered National Natural Landmark; the 159-acre tract in Oregon County near the Arkansas line, known as "Missouri's Little Grand Canyon" and promoted as a park since 1939, had been acquired by Drey in 1970 for preservation and leased to the state for one dollar a year for inclusion in the state park system in 1984. The 350-acre Laxton Hollow Reserve, an old growth remnant that Pioneer was protecting for research and comparison with the surrounding second-growth forest, was proposed in the resource reserve category. And the remaining 154,279.5 acres of Pioneer were proposed as a multiple-use management area that could help promote local participation, regional planning, and integrated rural development—efforts in which Leo Drey had been interested ever since his earliest days as a forest owner.

Unfortunately, by the time the complex interagency nomination was completed and nearing approval, a backlash began in the Ozarks among property rights activists who charged that the biosphere project was a United Nations conspiracy to confiscate Ozark land and herd Ozarkers into concentration camps in an effort to implement an environmental world government. The leadership of the opposition was well organized and linked to similar "wise use" and property rights movements elsewhere in the nation. It may have been emboldened by the stunning election victory in November 1994 of the Republican 'Contract for America,' and it successfully appealed to Ozarkers' traditional distrust of government in mass meetings throughout the region (Rikoon and Goedeke 2000). The result was that not only the biosphere nomination but also other promising cooperative planning, resource management, and ecosystem restoration efforts among federal and state agencies and private groups in Missouri were quietly killed by the agencies responsible for them.

VINDICATION, 1990–2000

In spite of all the turmoil in the Ozarks, for Pioneer Forest the decade of the 1990s was a period not only of increasing profitability of forest operations but also of more widespread professional recognition of the viability of its management system. Prices for oak stumpage had begun to increase substantially in the late 1970s. With an increasing export market for oak, a strong domestic economy spurring demand for lumber (Hoover 1985), and continuing investment in management to enhance the quality of standing timber especially in larger dimensions, Pioneer Forest was beginning to repay its owner's faith and commitment.

As the last decade of the century began, the jury was still out on the viability of Pioneer's system of uneven-aged management for securing oak reproduction for the long term, as opposed to the even-aged system practiced by most public and industrial forests. But, enough student and professional interest had been piqued by the clearcutting issue of the late 1980s to result finally in some research. Owing in part to the need of the Mark Twain for a more solid basis on which to apply the uneven-aged approach being demanded by citizens and mandated by U.S. Forest Service officials, the North Central Research Station and the forestry program at the University of Missouri initiated a project in the early 1990s to describe the methods used on Pioneer Forest, analyze its continuous forest inventory data, and assess the results on the ground. Three graduate students would focus on different aspects of the study: Edward Loewenstein came first (fig. 19), and began working immediately on age and size structure; Zhiming Wang investigated predictability of diameter distributions; and Monty Metzger focused on oak regeneration.

Clint Trammel recalled a visit to Pioneer, probably in the fall of 1991, by Loewenstein and several professors in which he asked Loewenstein what he would write if he found evidence that the Pioneer system worked and whether he expected his professors to sign the dissertation. Such was the level of trust at the time (though Trammel might have worn a grin, as he was himself finishing up a master's thesis with one of the same

Figure 19—Edward Loewenstein at work on Pioneer Forest. *(Courtesy of Edward Loewenstein)*

professors). As Loewenstein recalled, Trammel was looking for an advocate, whereas he and the other researchers were committed to scientific inquiry and would report the results just as they found them. Loewenstein has also admitted, however, that he originally thought he would work 6 months, prove the system did not work, and then move on to something more interesting. Instead, he would devote more than a decade to studies of Pioneer.

In 1993, when the research had scarcely begun, silviculturist Paul Johnson, who was coordinating the study for the research station in Columbia, published an assessment of oak ecology and silviculture as a contribution to resolving the conflict over management of oak forests (Johnson 1993). In it he acknowledged, for perhaps the first time in a U.S. Forest Service research publication, that single-tree selection, though generally "considered inappropriate for managing oak forests," has "nonetheless been used successfully for 50 years on a large industrial forest in the Missouri Ozarks." Though he did not name

the forest, he cited personal communication with Clint Trammel; and he went on to describe the method, to suggest there was evidence it could be sustainable, and to call for further study.

As the three students began their fieldwork on Pioneer, yet another graduate student, Michael Jenkins, completed a master's thesis in 1992 that utilized sites on Pioneer as well as on the University Forest and the Mark Twain to study the vexing problem of widespread oak decline. Oak decline was a consequence of the rapid exploitation of the pine and pine-oak forests of the Ozarks around the turn of the century, which had been followed by the establishment of fairly homogeneous even-aged stands of scarlet and black oak on sites formerly dominated by pine. These aging and dense, unthinned stands, stressed by drought, were now dying synchronously over large areas; more than 35 million board feet of dead or dying timber had been harvested in salvage sales on the Mark Twain alone between 1980 and 1986. Although Pioneer, too, had suffered some losses, its losses were not as severe or continuing as on the Mark Twain and the University Forest, and its regeneration was more favorable. At the Central Hardwood Conference in 1993, Jenkins and his professor, Stephen Pallardy, suggested that the uneven-aged management practiced on Pioneer not only harvested substantial numbers of oaks before they died but also reduced stress on the remaining trees and opened the canopy to allow regeneration (Jenkins and Pallardy 1993).

While the Missouri graduate students were engaged in their research, U.S. Forest Service Chief F. Dale Robertson in June 1992 officially announced a new policy direction, ecosystem management, to guide the national forest system in its second century. Appropriately ambiguous and crafted to address political exigencies in the continuing controversy over clearcutting (Freeman 2002), the new policy emphasized an ecological approach and a broader range of values than the older policy of sustained yield management with its emphasis on timber.

Whether to explore the implications of ecosystem management or in continuation of its effort to develop a viable approach to uneven-aged management as mandated by the 1985 forest plan, the Mark Twain in summer 1994 asked a team of silviculturists, wildlife biologists, and an ecologist, among them Paul Johnson and David Larsen, to spend a week visiting various sites where Mark Twain staff had initiated uneven-aged and other types of vegetation management and comment on their practices. One of the scheduled stops was at Pioneer, but a thunderstorm intervened, and the team left after only a few minutes. Although their report (Johnson and others 1994) recommended a full spectrum of silvicultural systems including uneven-aged, it questioned the applicability of the Pioneer system of single-tree selection, noting there was "no written prescription or procedure for this method" and it was "scientifically unproven and entails risks that may be unacceptable"—a finding that produced substantial tension between Trammel and team members. In his comments on the report, Trammel (1994) asked rhetorically, "How can a group of such influential people in research and academia, fields of supposedly open-mindedness, make favorable comments about uneven-aged management and, in the same breath, discredit the longest applied study in Missouri and probably in the eastern United States." Instead of single-tree selection, the review team recommended "group selection with thinning between groups," a method they said could draw on "guidelines based on years of research on regenerating oak in clearcuts."

The review team, which included ecologist Douglas Ladd of the Missouri Nature Conservancy, also endorsed and encouraged the use of fire on the Mark Twain to control competing vegetation, prepare sites, and restore natural processes to the landscape. Most scientists and land managers had come relatively late to an appreciation of the role of fire in Missouri ecosystems, probably because of the long and intense effort to stamp out woodsburning by Ozarkers, but, by the 1990s, the use of prescribed burning was accepted practice in the Nature Conservancy, in Missouri state parks, and in the natural history and wildlife divisions of the conservation department to restore prairies, glades, savannas, and other ecosystems. Most forest managers, however, whether on the Mark Twain, in the conservation department, or on the staff of Pioneer Forest, still resisted the use of fire in working forests, believing they could accomplish the same results more efficiently through timber harvest. When Pioneer's Greg Iffrig asked Ladd to comment on the silvicultural issues regarding uneven-aged management and single-tree selection, Ladd (1994) said he was unqualified, but he volunteered the observation that the woodlands on Pioneer "appeared relatively low in vegetational diversity per unit area," saying: "I think it will be difficult for Pioneer to exemplify a high quality, upland timbered landscape without including fire as an ecological tool." The skepticism that summer was coming from both ends of the professional conservation spectrum. It was a low point for the Pioneer staff.

The sole support for the Pioneer model that summer came from Carolyn Pufalt of the Sierra Club, who expressed her disappointment in the review team's dismissal of the Pioneer system to Mark Twain supervisor Randy Moore, adding: "It is somewhat ironic that the research team judges consideration of single- tree selection to entail unacceptable 'risks.' Oh that such voices of caution could have been raised within the agency years ago against clearcutting" (PF).

The first substantial scientific analysis of the Pioneer system was completed by Ed Loewenstein in May 1996 when his dissertation, with its analysis of Pioneer's CFI data and measurements from a random field sample of 600 oaks, was officially accepted. Testing CFI plots aggregated in three groups by time since harvest to determine the minimum spatial scale at which the forest could be said to exhibit a balanced uneven-aged distribution, he found the minimum to be a remarkably small 0.6 acres; that is, any randomly selected 0.6-acre plot would likely exhibit the distribution of the forest as a whole. A year earlier, he and three of his advisors had presented preliminary results of his study at the Central Hardwood Conference (Loewenstein and others 1995). It was the first report of an extensive examination of single-tree selection in an oak-hickory forest west of the Mississippi River and the most sophisticated independent analysis of Pioneer Forest data up to that time, and it demonstrated that the forest was not shifting toward shade-tolerant species, that the density of the most valuable species, white oak, had increased three-fold since 1954

while basal area more than doubled, and that the other species held their relative proportions (fig. 20). Hence the conclusion: "The single-tree selection system can be used to sustain an uneven-aged oak forest."

When Ross Melick of the Mark Twain invited Loewenstein and Johnson on another tour of management sites in June 1996, the three collectively found themselves backing away from the earlier emphasis on group selection under the formally structured approach developed by Law and Lorimer in 1989 and edging toward the more flexible single-tree selection system applied on Pioneer, recognizing, as Melick (1996) put it, that uneven-aged management "requires a different mindset than even-aged." But they also recognized that Pioneer and the Mark Twain had very different forest conditions when they began uneven-aged management. Mark Twain lands had in general been cut over somewhat earlier than Pioneer, which was in more remote and rougher terrain, and the oak that sprouted on former pine lands in the Mark Twain had been protected from cutting and fire since the early 1930s. By the 1990s, many of the stands were mature with tightly closed canopies, many were suffering from oak decline, and there was relatively little oak reproduction in the understory. It would not be easy to convert such fully stocked stands to uneven-aged management.

Much of Pioneer Forest, by contrast, had been quite heavily harvested in the 1940s and 1950s by Pioneer Cooperage and National Distillers so that Drey's management system began with a relatively open, understocked forest. Moreover, Pioneer foresters had religiously been doing improvement cuttings during which they consciously removed a higher proportion of scarlet, black and other red oak species—especially weak or deformed trees—in order to favor reproduction of the more valuable white oak. They were thus using regular cutting to mimic the function of natural fire and had maintained the forest in diverse, uneven-aged stands at the lower end of the stocking range.[5] Hence, the hesitance of some professional foresters to recommend direct application of Pioneer's methods to the Mark Twain. Nevertheless, Melick accepted with gratitude 15 bound copies of Loewenstein's dissertation for distribution to Mark Twain staff.

In April 1997, at Melick's invitation, Loewenstein organized an uneven-aged management training session for some 20 U.S. Forest Service staff and a few MDC foresters at which discussion again turned to the applicability of the Pioneer system to the Mark Twain. MDC was initiating uneven-aged management with a group-selection system on three of nine 1000-acre study sites devoted to a cooperative Missouri Ozark Forest Ecosystem Project; the other sites would be managed by even-aged and no-harvest treatments. With the applicability of single-tree selection to similar relatively dry ecosystems of the Ozarks now less in doubt, discussion at the training session turned to more managerial and functional questions of how to take a system developed on private land and apply it to public land. When Johnson, Larsen and other instructors, for example, said

Figure 20—Pioneer Forest, 1996. *(Photo by Susan Flader)*

the place to start was an inventory of stands to be managed, national forest trainees said they didn't have the staff or budget to do it (interviews: Johnson, Larsen, Loewenstein, Melick).

This led the group to compare staffing levels on Pioneer and the Mark Twain. Pioneer had long operated with five foresters and technicians plus ecologist Iffrig to manage 154,000 acres, while the Mark Twain in the mid-90s had a staff of some 280 on 1.5 million acres. The Mark Twain thus had four to five times as many staff hours per acre as Pioneer, though, to be sure, many were wildlife, fisheries, recreation, or planning specialists rather than foresters, and a good many were clerical or maintenance personnel; the Mark Twain also had far more physical infrastructure and a much higher level of public use. The disparity in staffing led in turn to top-of-the-head calculations of how much time people with forestry training actually spent in the field per acre of forest on the Mark Twain as compared with Pioneer; here virtually everyone was astounded to realize that Pioneer staff likely spent as much as four times more time per acre on the ground as Mark Twain foresters, who were often chained to their desks doing environmental assessments and legal compliance. It was a graphic illustration of the costs of public service, accountability, and bureaucracy on national forests as compared with private land (interviews).

There were other consequences of U.S. Forest Service bureaucracy, especially in the new era of ecosystem management. On Pioneer, unlike the Mark Twain, there was very little staff turnover, and all its people spent years of apprenticeship; they were intimately familiar with the forest and the marking system and spent at least a day per month in the field together to cross-check their judgments and calibrate their work, advantages that could hardly be expected on a national forest. When the instructors suggested that perhaps uneven-aged management could be implemented by a single silvicultural team that would handle marking and supervision

[5] These practices closely parallel management of uneven-aged stands elsewhere in the Nation, such as the well-documented research in southern pines at Crossett (Baker et al. 1996).

of timber sales for the entire Mark Twain, trainees pointed out that no district ranger would let someone from outside the district come in to do the management. And besides, money was allocated in separate pots by Congress for inventory, marking, timber stand improvement, sale administration and regeneration as well as other functions such as wildlife and fish, soil and water, recreation, roads, and fire protection, and the funds were not interchangeable, making integrated management such as that practiced on Pioneer virtually impossible. It was a bureaucratic system inherited from the postwar era when the emphasis shifted to maximum timber production by the most efficient possible means—even-aged management—and all could agree it was poorly suited to the new emphasis on ecosystem values (interviews). The U.S. Forest Service, and, even in time, the MDC, would develop their own more standardized versions of uneven-aged management, but many observers—especially environmentalists—would argue that they were not the same as on Pioneer.

In the second half of the 1990s, several additional publications based on the Pioneer research appeared, each confirming and supplementing the others (Wang 1997, Larsen and others 1997, Larsen and others 1999, Lootens and others 1999, Loewenstein and others 2000). These studies, several published in the *Canadian Journal of Forest Research*, were a major confirmation through the methods and language of science of the management approach being applied on Pioneer. Perhaps most significant was the 1999 U.S. Forest Service report by Larsen, Loewenstein, and Johnson that summarized the findings and made silvicultural recommendations for others wishing to pursue uneven-aged management in the Ozarks, based almost entirely on what was learned on Pioneer.

Meanwhile, in an effort to learn more about other components of the ecosystem, perhaps in part to get at the concerns raised by TNC forest conservationist Doug Ladd and others about the difficulty of enhancing ecosystem quality and biodiversity without the use of fire, Pioneer's Greg Iffrig made deliberate efforts to recruit other nonforestry research projects from colleges and universities in the region and beyond. The first was a 1995 M.S. thesis in biology by E.M. Annand at the University of Missouri-Columbia measuring the relative abundance of migrant songbirds in response to different managed forest treatments (Annand and Thompson 1997). L.A. Herbeck (Herbeck and Larsen 1998, 1999), also at the university in Columbia, found that plethodontid salamanders maintained relatively higher densities on Pioneer than in forests elsewhere under even-aged management. Several years later, N.M. San Diego of St. Louis University completed an M.S. thesis (2001) on the diversity of leaf-litter arthropod communities under different management treatments that demonstrated the benefits of Pioneer's uneven-aged management in generating a spatial gradient throughout the landscape that maximized diversity. Several other St. Louis University students began related studies conceived as part of a long-term ecological research project, one of which (LaVigne 2002) calculated the average turnover rate for Pioneer's canopy to range from 189 to 228 years. Pioneer Forest developed a long-term relationship with the Cave Research Foundation concerning critical habitat for endangered species. And other studies of black bears and the potential for red-cockaded woodpeckers were also in the works.

Perhaps most significant was new research about the historical role of fire in the Current River watershed where the bulk of Pioneer Forest lands are located. University of Missouri geography graduate student Michael Batek completed a thesis on presettlement vegetation of the watershed in 1994, grounded in detailed analysis of Public Land Survey notes from the early 19th century. Batek and others (1999) then extended the analysis by combining with dendrochronology-based fire histories to reconstruct disturbance regimes and utilizing GIS to relate to geological parent material, topography, and mean fire intervals. The results revealed a distinct fire 'shadow' northeast of the Current River above its junction with the Jack's Fork, where Pioneer's big block is located. Dendrochronologist Richard Guyette, who had participated in the Batek study, then extended the analysis in a series of papers (2000, 2002, 2003) that developed implications of the concept of topographic roughness. As he writes (this volume), "Here lies Pioneer Forest 'in the heart of roughness,' a landscape that has resisted the pressures of human population and disturbance for millennia." He goes on to suggest that Pioneer's management system effectively mimics historic disturbance regimes, as supported by studies of forest interior wildlife species, especially those sensitive to disturbance.

At a symposium to commemorate the 50th anniversary of Pioneer Forest in 2001, Loewenstein observed (SF notes) that he had spent the last decade trying to figure out just what it is that the foresters on Pioneer do, but they themselves are not able to tell you; they can only show you on the ground. The book has not yet been written, he said—though a book on *The Ecology and Silviculture of Oaks* that drew in part on the Pioneer data was even then nearing publication (Johnson and others 2002). The system works on Pioneer, Loewenstein explained, because of its dedicated staff and its extremely low turnover. So instead of trying to describe what the Pioneer foresters were doing, he had designed his research to see if they were accomplishing what they said they were trying to accomplish. And they are, he concluded: "Every argument that has been leveled against Pioneer Forest seems to be invalid from the data we have collected." As he put it, the Pioneer foresters were practicing as much art as science. "They are magicians," he said, but there was no gainsaying their success.

PIONEER AND THE MANAGEMENT OF PRIVATE FOREST LANDS, 1997–2004

Just as the uneven-aged management practiced on Pioneer began to gain professional credibility and even to be applied, to some extent, on public forests in Missouri, a new threat to private forests of grave concern to Leo Drey and his staff appeared on the horizon: the entry of two high-capacity chip mills to the Missouri Ozarks with the likelihood of more to come. There were already 140 such mills operating elsewhere in the southeastern states, each capable of gobbling 10 times as much wood as an ordinary sawmill. Though the MDC and many professional foresters tended to view chip mills as opening a

significant new market opportunity, especially for low-grade or 'cull' material that needed to be cleared out in order to establish a vigorous new forest, Drey and his foresters were concerned that the very scale of demand could result in a wave of destructive clearcutting, watershed erosion, and land conversion not seen in Missouri since the logging era a century earlier. In Drey's view, the market problem was no longer as severe as in years past, and the voracious new chip mills might 'steal' the timber that smaller local mills needed to operate. With the new industrial-style logging equipment used to supply chip mills, there would be increased pressure on individual landowners and speculators to allow complete clearing of their land (Vaughn 1997, Drey 1997, Gray and Guldin 2001).

The threat loomed especially large to Clint Trammel, who had begun cooperating with the Dogwood Alliance, a coalition of 60 grassroots organizations across the South that was working to document the problems caused by chip mills and to protect forests from the devastation of clearcutting. He wrote a number of articles for the organization's newsletter on his experiences with Pioneer, most of which were subsequently incorporated in a report, *Forest Management for the 21st Century* (Smith 1999), fully a quarter of which was devoted to the alternative represented by Pioneer Forest.

As they began seeing large-scale clearcuts of material apparently headed for the new mills, Drey and his staff invited property owners, foresters, loggers, politicians and environmentalists on a field trip in May 1998 to view the devastation, compare with management on Pioneer, and debate the issue on the ground (Uhlenbrock 1998). A fact sheet the Pioneer staff produced for the tour contrasted the low value, low employment (10 mill workers) and devastated land resulting from a year's operation of one of the chip mills with the higher value product, higher employment (35-40 sawmill workers) and healthy forest on an equal number of acres in a year of Pioneer's operations. A few days later, the *St. Louis Post-Dispatch* (1998) editorialized on Missouri's need for sustainable forestry on private lands, spotlighting the Spencer family of loggers, three generations of whom had cut timber on Pioneer Forest—responsibly—since the 1950s.

Though many professional foresters, especially in the conservation department, continued to support the chip mills for their market potential, Drey joined other concerned landowners, higher value producers, and environmentalists in appealing to Governor Mel Carnahan for a moratorium on new chip mills until the state had a proper program in place to lessen their impact. The governor responded in September with an executive order establishing an Advisory Committee on Chip Mills, ordering state agencies to refrain from providing any further incentives to mills until the committee reported, and directing a more restrictive permitting process.

Deliberating for nearly 2 years in a remarkably open process with public participation, the governor's committee began by considering chip mills but moved inevitably to the problem of forest management—or rather, the lack of it—on private lands, which constituted 85 percent of Missouri's 14 million acres of forest land. The committee heard presentations and received statements from a spectrum of individuals, many of whom had previously prepared materials for a conference on sustainability of the state's private forests convened at the University of Missouri-Columbia by the Environmental Studies Program and various co-sponsors in March 1999 (Flader 2004). Included was a paper by the Pioneer Forest staff (Iffrig and others 2004) explaining their approach and methods and, for the first time, making a case for the economic advantages of uneven-aged management over even-aged.

Unlike the debate over the Mark Twain Forest Plan in the mid-1980s, when Pioneer may have been in certain people's minds but was not discussed publicly as an example, during the deliberations of the governor's committee there was scarcely a session when the Pioneer experience was not invoked by someone. In June, the advisory committee and its entourage traversed the southeastern Ozarks, visiting a chip mill, lands clearcut for the mill, and other harvest sites, and ending at Pioneer, which a reporter described as looking "more like a state park" (Leonard 1999). The Pioneer staff submitted a six-page letter of commentary on the committee's draft report, making the case yet again for more attention to single-tree selection in Missouri and arguing that even-aged management carried more uncertainties than uneven-aged for the long-range future of Ozark forests, especially in view of the frequent turnover of ownership on most private lands and the chip mill-induced spur to clearcutting and land conversion (Trammel and others 1999). But, though all members of the governor's committee agreed about the evident need for better management of private lands and though Missouri was one of the few states without any forest practices regulatory programs whatever, when it came down to voting, a majority was unwilling to approve any recommendations that encroached in the least on private property rights (Lewis 2004).

As it became obvious that little of substance would come from the governor's committee—and as independent research on Pioneer vindicated the viability of uneven-aged management—the Pioneer staff, with the full encouragement and support of Leo Drey, formed a new entity, Pioneer Consulting Group, to promote the benefits of their system of single-tree selection and help other private landowners with management planning, timber marking, and sale services. Some 97 percent of the timber sold from private land in Missouri was harvested without a forest management plan or advice from a forester, making it vulnerable to exploitative logging. Trammel and Cunningham had offered their services as consulting foresters on their own time for years, but the new consulting group had an important educational mission and promoted the staff's services as a viable economic alternative to clearcutting for the chip market. In December 1999, they began test mailings to all private landowners in Reynolds County with 400 acres or more, then expanded to include owners with more than 200 acres in the procurement area of the currently operating chip mills. They produced a flier and a primer on uneven-aged management, offered landowners an initial visit and consultation at no cost or obligation, and invited them to field days on Pioneer Forest, the first of which was at Ellington in June 2000 (PF, PCG 2000). In an effort to keep in touch with landowners who expressed

interest in management assistance, they also developed a Pioneer website and began issuing a periodic newsletter, *The Acorn*, with news from the consulting group and the forest. By early 2001, a Google search for "single-tree selection forest management" on the worldwide web brought up the Pioneer Forest site first.

In summer 2000, in the wake of the disappointing results of the governor's advisory committee and a lack of legislative enthusiasm for any action on forest practices, Clint Trammel, Terry Cunningham, and several landowners, forest products manufacturers, and environmentalists in the Ozarks met to lay the groundwork for a new organization, Value Missouri, that would work to improve forest management on private lands and develop new markets for higher quality timber and value-added manufacturing. The idea was to develop public support and an infrastructure in Missouri for ecologically responsible forest management and certification of timber products along the lines of an international movement that had been developing since 1993 under the leadership of the Forest Stewardship Council (FSC). Clint Trammel had already been deeply involved in establishing a parallel effort for responsible forestry, the Forest Stewards Guild, founded in 1997 by forest managers across the nation who were dedicated to an approach similar to that on Pioneer; and he participated on a committee that refined FSC certification standards for forests in the United States. These and related efforts had already resulted in independent third-party certification of some 6 million acres of public and private forest in the United States and some 38 million acres worldwide (Kerasote 2001). The idea was not only to maintain the ecological integrity of the forest environment but also to assure responsible handling throughout the entire chain of custody from harvest through production to the point of retail sale, in the hope of commanding a better price at market from consumers willing to pay. Supporters saw Value Missouri as a way both to encourage environmental stewardship and to improve markets for higher value-added forest products in Missouri.

As they geared up to promote more responsible management of private forest lands in the Ozarks in the late 1990s, Leo Drey and the Pioneer staff also redoubled their efforts to provide education and recreation for the general public on Pioneer Forest itself. Shortly after Greg Iffrig was hired as staff naturalist in 1992, he had begun efforts to develop a self-guiding interpretive drive in the forest off heavily traveled Highway 19 south of Round Spring. The Missouri Department of Transportation offered to sell Drey the bulk of the adjoining strip of virgin pine that had been sold to them unharvested by Pioneer Cooperage in the 1940s as a sample of Ozark pinelands before the great cutover. It was reportedly (Eddleman and Clawson 1987) in these remnant virgin pines that the last red-cockaded woodpeckers in Missouri were sighted back in 1946. The way was cleared for purchase of the excess right-of-way from the state by the L-A-D Foundation in 1996, and by 1998 Iffrig had developed a marked walk through the pines and a drive through several miles of managed forest, complete with marker posts and an interpretive leaflet (fig. 21).

Figure 21—Interpretive drive on Pioneer Forest near highway 19 south of Round Spring, 1998. *(Photo by Susan Flader)*

Another effort in which Drey had been interested for more than three decades also came to fruition around the turn of the century—the establishment of a 60,000-acre backcountry recreational area on managed forest in the huge, nearly roadless block of Shannon County land he had acquired from National Distillers in 1954. After the Ozark National Scenic Riverways declined to accept responsibility for provision of public recreation on the tract in the 1970s, Drey and the Pioneer staff had gone ahead with plans for the Ozark Trail, which had been built and maintained across 13 miles of the forest largely with volunteer labor from the Sierra Club and other organizations. Drey had always allowed public access for hunting, fishing, picnicking and hiking, and he had leased a small tract within the area to his alma mater, the John Burroughs School in St. Louis, for construction of bunkhouses and a lodge at which they could conduct an environmental camp for their students and, he hoped, for the use of local school groups and others. But he was also willing to provide for somewhat greater recreational utilization of the area, if only he could gain cooperative assistance from some public agency without relinquishing ultimate authority. State park director Fred Lafser back in 1978 had proposed a recreational easement and a visitor center, perhaps with an interpretive museum and outdoor education programming, but Drey had concerns about overuse, regimentation, and "who will be in charge."

In 1990, Drey had broached the matter again with the director of the Missouri DNR, in view of the positive relationship he had developed with the agency for management of Grand Gulf and Dillard Mill as state parks. The agency responded with a proposal to restore "an original Ozark wilderness ecosystem" similar to what Henry Schoolcraft would have seen when traversing the Ozarks nearly two centuries earlier. They would restore the landscape to pre-settlement conditions through prescribed burning to create savanna and woodland meadows, and reintroduce elk, bear, and mountain lions, an effort that

would probably require fee title to all or a substantial part of the restoration area approximating 50,000 acres (DNR 1990). Drey and his advisors regarded the plan as grandiose and out of keeping with Pioneer's objectives as a working forest, and discussion again stopped.

When Drey's protégé and environmentalist alter ego Roger Pryor suddenly passed away in spring 1998, Drey and his staff resolved to move ahead with designation of 61,000 acres in the Shannon County block as a backcountry recreational area in honor of Pryor, whether or not a cooperative management arrangement could be struck with a public agency. Drey announced the Roger Pryor Pioneer Backcountry at a Missouri Coalition for the Environment dinner in Pryor's memory in fall 1999. Two areas within the backcountry would also honor Pioneer foresters Ed Woods and Charlie Kirk for their dedication to and vision for the forest. Two years later, in conjunction with the forest's 50th anniversary, Drey and the Pioneer staff dedicated the backcountry in honor of Pryor, Woods, and Kirk, and DNR Director Stephen Mahfood announced his agency's intention to conclude a cooperative recreation agreement between the forest and the Division of State Parks (fig. 22).

The agreement, which took the form of a lease of trails and by-ways for hiking and overnight primitive camping with maintenance and enforcement by DNR, would be signed in March 2002, and by 2004 the park division would have staff on the ground in the backcountry.

A few days after the Pryor Pioneer Backcountry dedication, the Pioneer staff hosted a symposium at the Missouri Botanical Garden in St. Louis to commemorate the 50th anniversary of Drey's management of the forest (fig. 23). The *St.Louis Post-Dispatch* ran a touching editorial cartoon of an oak with a limb embracing Drey, and many papers ran special accounts of the occasion and of Drey's contributions over the years (Sherffius 2001, Allen 2001, Todd 2001).

Figure 22—Dedication of the Roger Pryor Pioneer Backcountry, October 14, 2001. Left to right: Forest Manager Clint Trammel, Randy Skeeter (grandson of Ed Woods), Linda Pryor (widow of Roger), Leo Drey, L-A-D Foundation President John Karel, DNR Director Stephen Mahfood. *(Photo by Susan Flader)*

Figure 23—Sherffius cartoon from *St. Louis Post-Dispatch*, October 19, 2001. *(Courtesy of Leo Drey)*

Not content to rest on laurels, Leo Drey decided in spring 2002 to fund the certification of forestry operations on the entire acreage of Pioneer Forest through the SmartWood Program of the Rainforest Alliance, according to procedures and criteria for ecological and social sustainability approved by the Forest Stewardship Council (Brown and others 2001). An independent team of four specialists in forestry, ecology, and sociology from Arkansas, Tennessee, and Mississippi spent a week visiting field sites on Pioneer in June 2002, conducting public meetings and interviewing Pioneer staff, loggers, millers, and neighbors about the environmental, silvicultural and socioeconomic aspects of Pioneer's operations. Obviously impressed by the quality of forest management on Pioneer and the compelling historical record of its success, the team focused on helping Pioneer staff put in place a more detailed system of documentation to assure that knowledge of the system could be passed successfully to new staff who would one day take over on Pioneer (Trammel and others 2003).

SmartWood announced Pioneer as the first forest in Missouri to be granted FSC certification in February 2003, and a documented chain of custody through certified loggers and sawmills to Smith Flooring in Mountain View would soon be in place to make wood from Pioneer available to consumers as the first Missouri-produced and certified forest products (*Acorn*, 2003). With Pioneer's large volume undergirding the economic viability of the process, the way was now paved for Pioneer Consulting and Value Missouri to encourage other landowners, foresters, loggers, sawmills, and producers to join the system (fig. 24).

Even as the certification was underway, a graduate student in forest economics at Duke University, Makoto Hamatani, spent several weeks at Pioneer's Salem headquarters analyzing inventory and sale records to assess the profitability of the operation over the years. Though the stagnant or decreasing prices for Ozark timber for the first two decades of Drey's ownership had been masked by increases in standing volume

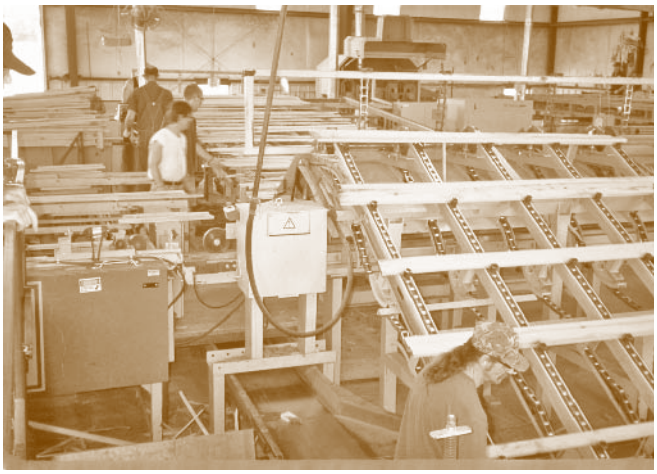

Figure 24—Certified oak flooring, harvested from Pioneer Forest, coming off the line at Smith Flooring in Mountain View, Missouri, bound for the new LEED-certified headquarters of the Missouri Department of Natural Resources in Jefferson City, 2004. *(Photo by Susan Flader)*

per acre and the continuing purchase of land, beginning with the 1972 inventory the acreage of Pioneer Forest was roughly constant and the price of timber began to rise, increasing substantially in the 1990s. Hamatani found that the standing volume in the three decades since 1972 had increased about 2.5 times whereas the sale price of timber had risen more than four-fold, especially in the 1990s, for an asset value approximately 9 times as high in 2001 as it had been in 1972. In the last 6 years, moreover, income had been exceeding expenses by an average of more than 50 percent (Hamatani and Goslee 2008). Clearly the single-tree selection method was profitable for Leo Drey and presumably could be also for other Ozark landowners who had sufficient acreage or joined cooperatives of the sort encouraged by Pioneer Consulting and Value Missouri.

In Fall 2002, the Pioneer staff began field work for their 11th forest inventory, which would give them a 50-year record of growth and change on Pioneer's permanent 1/5-acre plots, now numbering 486. For the first time, they entered data directly into laptop computers in the field, saving substantial time, and their PC now crunched the data in 7 seconds rather than 2 days. Some of the more than 15,000 trees in the inventory plots had been individually measured every 5 years since the first inventory in 1952, whereas others had been cut, and new trees had grown into the 5-inch diameter sample range. Beginning with the 1997 inventory, however, at the suggestion of Ed Loewenstein and other researchers on Pioneer, the inventory now included all other trees and shrubs between 1.6 and 5 inches in diameter (an additional 20 to 25,000 trees), in order to better track reproduction success (*Acorn* 2003). Standing volume had nearly tripled in the half century of Drey's stewardship whereas species composition had remained relatively stable, except for an increase in the more valuable white oak and pine (fig. 25).

The 50-year record of continuous inventory on Pioneer coupled with the financial results of forest operations and the university studies of forest structure and reproduction success amply confirmed Leo Drey's vision when he began acquiring land in the Ozarks a half century earlier. It *was* possible to manage Ozark timberlands in a conservative, sustainable fashion for a full array of ecological, social, and cultural values and make a profit besides. Drey and his staff had persevered in a remarkably consistent system of management and documentation for over half a century, during which the standard practices taught in forest schools, applied on public lands, and documented in thousands of research papers had turned 180 degrees from uneven to even-aged management. Through their openness to independent research and their willingness to share their experience and results—even with those who openly doubted their methods and, on occasion, even their professional competence—Drey and his staff had demonstrated the viability of a management system that could yield an array of ecological, social, and esthetic values increasingly appreciated by many. Pioneer Forest had played a significant role in the adoption of new management approaches on national and even, to some extent, state forests in the region. The greatest challenge for the future would continue to be that on which Leo Drey had embarked a half century earlier, to encourage other owners of private lands in the Ozarks to follow Pioneer's lead (fig. 26).

It was time to look to the future. On July 6, 2004, after nearly a year of legal effort to sort out land titles, descriptions, and myriad other details, Leo Drey and his wife Kay signed over nearly the entire forest, valued at some $180 million, to the L-A-D Foundation (L-A-D 2004, Lewis 2005). Their intent was that the not-for-profit foundation would ensure the management of the working forest as well as the natural areas through environmentally sound and sustainable practices, much as Leo Drey himself had done, for long-term public benefit. Not only would the forest continue to serve as a demonstration of ecologically and socially sustainable management, but the income stream from its operations would be available to mount a more substantial educational and public outreach effort. It was the most spectacular gift of real estate in Missouri and perhaps ever in the annals of American forestry, and it was Leo and Kay Drey's way of perpetuating the Pioneer tradition.

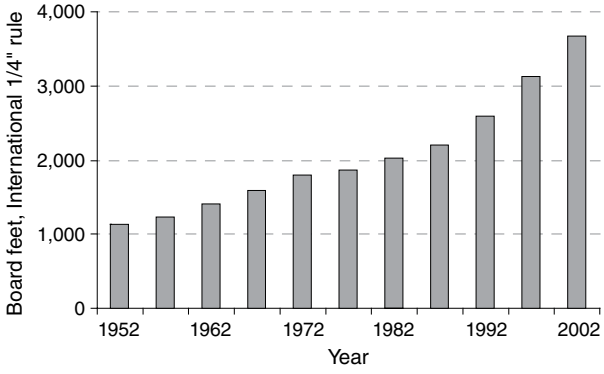

Figure 25—Board feet per acre on Pioneer Forest, 1952-2002, from continuous forest inventory data. *(Pioneer Forest)*

Figure 26—Pioneer Forest staff (left to right): Dan Skaggs, Tim Dyer, Terry Cunningham, Mike Adams, Clint Trammel, L-A-D Foundation President John Karel, Leo Drey, Greg Iffrig. *(Courtesy of Pioneer Forest)*

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SILVICULTURE & ECOLOGY

Forest Manager Terry Cunningham collecting regeneration data on one of Pioneer's Comprehensive Forest Inventory (CFI) plots. *(Photo by G. F. Iffrig, courtesy of Pioneer Forest).*

SILVICULTURE AND THE LONG-TERM DYNAMICS OF SINGLE-TREE SELECTION ON PIONEER FOREST

Edward F. Loewenstein[1]

Abstract—The uneven-aged silvicultural prescriptions being applied to oak-hickory stands on the Pioneer Forest contain elements of both art and science. The scientific element is found in the quantitative analysis of long-term inventory information to guide marking decisions, as stands currently receive their third and, in some cases, fourth cutting cycle harvest. The artistic element is borne of experience, as newly hired foresters and technicians serve the equivalent of an apprenticeship under the watchful guidance of the senior forest management staff. Contrary to popular belief, quantitative evidence and practical observation suggest that the uneven-aged methods being applied in Pioneer Forest are both sustainable and productive over time.

INTRODUCTION

What silvicultural approach do Pioneer Forest managers use (is it classical single-tree selection), and how has this approach affected the forest structure over the last 50 years on this 154,000+ acre, privately owned, oak-dominated forest? Answering these two simple questions might seem straightforward. However, I have been wrestling with the answer to these questions for over a decade. This has been a good exercise because it finally dawned on me why it is so hard to describe what they do on the Pioneer Forest. It all goes back to the basics of silviculture.

Silviculture has been defined as the art and science of producing and tending a forest stand to meet a landowner's objectives on a sustainable basis (Smith 1986). It seems that foresters on the Pioneer tend toward the artistic side of silviculture. Newly hired foresters at the Pioneer Forest essentially serve an apprenticeship; the new forester follows an experienced one around the woods observing and asking questions for about 6 months before they're allowed to mark their first stand for harvest. Even then, they work only under the watchful eye of their mentor until they have shown they understand and can properly apply the system. All the Pioneer foresters are educated professionals with a good background in the science of forestry. The trouble is that a textbook on scientific application of selection silviculture in oak-dominated ecosystems has not yet been written, so the only way to learn the system is from someone who already knows how to apply it. In other words, their practice is quintessentially an art and a science, passed down from master to apprentice.

Several years ago, when asked about their approach to marking stands, Pioneer Forest Manager Clint Trammel stated that their goal upon entry into a stand is to create or maintain a three-tiered canopy composed of an overstory, a midstory, and a sapling/reproduction layer. Assuming that the three canopy tiers represent three broad age classes, the textbook definition of an uneven-aged stand is attained. However, that still says little about how individual trees are selected for harvest. What are the marking rules? Are trees marked from across the entire range of diameter classes with each entry? Is the stand marked to a target diameter distribution? The answers to these questions would help to determine whether the Pioneer Forest managers were practicing classical selection silviculture. Over time, through a series of discussions, the answers provided by the Pioneer Forest staff indicate an empirical rather than an academic approach. Four general rules are followed on the Pioneer Forest:

1. Cut on a 20-year cycle by section (1 square mile; this is the operational unit on the forest). The harvest is scheduled when basal area reaches 95 to 100 square feet per acre rather than by strict adherence to the cutting cycle.

2. Only merchantable trees are harvested.

3. Culls are felled if suppressing crop trees. Snags are left.

4. Removal is based on vigor, canopy position, site/species relationships, and potential for increase in value.

Typically, there are four issues raised that suggest single-tree selection is an inappropriate silvicultural system for regenerating shade-intolerant tree species, in general, or oaks, in particular. First is the concern that oaks will not develop under the shade of a continuous canopy (Sander 1980). Therefore, with single-tree selection it is not possible to develop the age structure necessary for an uneven-aged stand (e.g., three separate age classes). Second, it is thought that an oak-dominated stand cannot develop or maintain the reverse J-shaped diameter structure indicative of a balanced uneven-aged stand (Sander 1980). Third, when single-tree selection is applied in an oak-dominated stand, the result in other situations has been a shift in species composition toward more shade-tolerant tree species (Trimble 1970, Della-Bianca and Beck 1985, Schlesinger 1976). This is related to the first argument. Oak cannot become established beneath the shade of a continuous canopy and so will be replaced by more tolerant species such as red maple (*Acer rubrum* L.) or hickory (*Carya* sp.) that can tolerate these conditions. Fourth, if the data show an age structure, diameter structure, or species composition indicative of a sustainable silvicultural system, then there must be an alternative explanation. Either the long-term results of the current management practices are not yet apparent or the data were collected over too large an area. The response to these concerns by the staff of the Pioneer Forest has always been to invite skeptics out to the forest to see what they are doing, and to witness the results of their management.

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Unfortunately, not everyone is able to make the trip to south central Missouri, nor is seeing necessarily believing. Objective scientific data were required. The purpose of this paper is to quantitatively explore four questions relative to silviculture on the Pioneer Forest. Has the Pioneer Forest staff been able to create uneven-aged stands in an oak-dominated system? Has the species composition of the stands continued to be oak-dominated? Finally, were Pioneer foresters able to create the stand diameter structure necessary to sustain an uneven-aged stand? Only if the answers to these three questions were yes would it make sense to address the final issue. Is the silvicultural system in practice on the Pioneer Forest single-tree selection or is regeneration occurring in distinct even-aged groups better described as group-selection or patch clearcutting? Answering each of these questions required a definition of the uneven-aged state that was much more rigorous than that which is currently in use by the forestry profession. However, it also required an evaluation of the Pioneer system in a manner to which accepted successful applications of a single-tree system had never been subjected.

The Pioneer Forest offers a unique opportunity to see the long-term results of a silvicultural system rarely attempted in an oak-dominated ecosystem. This is possible because a continuous forest inventory (CFI) has been maintained on the forest since the 1950's. The CFI plot network consists of two, 1/5-acre fixed-radius plots per square mile on the forest. These are permanent plots, and all trees larger than 5 inches in d.b.h. are uniquely identified and remeasured at 5-year intervals. This dataset makes it possible to track change through time so that the effect of the Pioneer system on stand diameter structure and species composition can be examined relative to a known starting point. The examination of spatial scale was made with only the most recent inventory (1992), and the dataset used to examine forest age structure was collected apart from the CFI plot network (Loewenstein 1996, Loewenstein and others 2000).

AGE STRUCTURE

In order to determine whether the Pioneer management system created an uneven-aged stand structure, a statistically testable definition of age structure had to be developed. By definition, an uneven-aged stand is one that contains at least three age classes either intimately intermixed or occurring in small groups (Helms 1998). To conduct a statistical test, age class was defined within the context of an even-aged stand where the range of ages is expected to be within 20 percent of the rotation length. One assumption had to be made because the concept of rotation does not apply to uneven-aged silviculture (Meyer 1943); an uneven-aged stand is managed by diameter structure, and tree age is of little or no importance. For purposes of the test, however, a rotation length of 90 years was assumed. This gave an age-class range of 18 years. Based on these assumptions, the test of a binomial proportion was then used to categorize sampled stands as either even-aged, two-aged, or uneven-aged.

Ten 1-acre plots were sampled across one section (1 square mile) on the Pioneer Forest. The section was chosen at random from all Pioneer holdings that had been entered for treatment at least three times since the property was acquired by the forest in the 1950's. This restriction ensured that the observed age structure was influenced as little as possible by management practices applied prior to acquisition by Pioneer Forest. Sample plots were limited to an acre in size to ensure, to the extent possible, that silvicultural treatments were applied in a fairly uniform manner across each plot. Age was determined for 60 oaks on each plot. Our interest was in determining whether the Pioneer system can sustain an uneven-aged oak-dominated forest with oaks maintained in all age classes. If the oak component is unable to establish and periodically recruit additional age-classes into the stand, it is not sustainable in the long-term.

Seven of ten 1-acre plots were classified as uneven-aged, two as two-aged, and a single plot was determined to be even-aged. However, in order to adequately interpret these data, some additional information is required. First, the test used was very conservative. Had an alternative definition of an age class been used (e.g., Schnur (1937) defined an age class as spanning not more than 8 years) or a less conservative statistical test, at least 9 of the 10 samples would have been classified as uneven-aged. It must also be noted that although the Pioneer Forest has been under the current management strategy since the 1950s, trees are very long lived and many of the trees currently standing in the forest were established prior to commencement of the current silvicultural system. The total range in age of the trees sampled was from 12 years to 233 years; but, 87 percent of the sampled trees germinated prior to the creation of Pioneer Forest. Even so, on eight of the ten 1-acre plots, a new age class has been recruited under the current management regime. Given that the Pioneer silvicultural system is recruiting oak into the stand and that on at least 70 percent of the forest sampled the age structure was found to be uneven-aged, it appears that the three age classes required for the uneven-aged state can be developed in this oak-dominated system and that the Pioneer Forest silvicultural system is able to create/maintain this age structure.

DIAMETER STRUCTURE

A reverse J-shaped diameter distribution is considered indicative of an uneven-aged stand because it allows for ingrowth, natural mortality, crop tree selection, and harvest while maintaining a stable diameter structure (Schlesinger 1976). However, it has been suggested that oaks and other shade intolerant species are unable to maintain this reverse J-shaped distribution because they are unable to successfully reproduce or recruit into successively larger size classes under the shade of a continuous canopy (Sander 1980). From the time active management started on the Pioneer Forest in the early 1950s, the composite diameter structure on the forest has maintained a reverse-J shape (fig. 1). However, the forest has been steadily changing. With each succeeding CFI inventory, the stocking percent increased markedly, and the number of stems in each diameter

class increased as evidenced by the increased height of each subsequent distribution (fig. 1). On average, the forest has changed from an open woodland structure (32 percent stocking) to a closed canopy forest.

A sustainable forest structure is expected to be stable over an extended period of time. Forest stocking levels have steadily increased on the Pioneer Forest, so, in a strict sense, forest structure has changed. However, examining the Pioneer Forest diameter distributions on a relative scale rather than an absolute scale produces a somewhat different picture (fig. 2). Even with a marked increase in stocking levels, the relative diameter structure on the Pioneer Forest has remained remarkably stable over time. The forestwide q-value, defined as the proportion of trees in one diameter class relative to the number of trees in the next smaller diameter class, has not varied by more than 0.02 over the 40-year period illustrated. Whether this diameter structure will remain constant as stocking levels on the forest continue to rise is subject to ongoing discussion. However, its stability across the first 40 years of management under the Pioneer system is a matter of record.

SPECIES COMPOSITION

The single-tree selection method has been successfully used to manage shade-tolerant species, which are able to establish and develop in the shade cast by a continuous cover of overstory trees. However, oaks tend to be intolerant to moderately tolerant of shade, and it has been suggested that they cannot be regenerated using the single-tree selection system (Sander and Clark 1971, Sander and Graney 1993). The common perception among foresters is that when selection silviculture is practiced in an oak-dominated ecosystem, a shift in species composition occurs toward more shade-tolerant species that are often of lesser commercial value (Johnson 1977, Niese and Strong 1992). Further, such shifts in composition have been shown in numerous studies (e.g., Trimble 1970, Della-Bianca and Beck 1985, Schlesinger 1976). It should be noted, however, that these studies were conducted in highly productive forests that tend to receive adequate rainfall during the growing season. In those mesic forests, regeneration of oak species can be difficult. Shade-tolerant competitors often overwhelm and out-compete oak reproduction regardless of the silvicultural method employed. However, the Pioneer Forest is located in the Ozark Highlands of Missouri where moisture is limited, and the drought-tolerant oaks are easily regenerated.

In the early 1950s when selection silviculture was first applied on the Pioneer Forest, seven principal species (or species groups) comprised over 90 percent of both the standing basal area and tree density (number of trees per acre). These species were white oak (*Quercus alba* L.), black oak (*Q. velutina* Lam.), scarlet oak (*Q. coccinea* Muenchh.), northern red oak (*Q. rubra* L.), post oak (*Q. stellata* Wangenh.), the hickories (*Carya* sp.), and shortleaf pine (*Pinus echinata* Mill.). By the early 1990s, the average basal area on the Pioneer Forest had increased by approximately 50 percent, and the number of trees per acre (all stems > 5 inches in d.b.h.) had increased by over 70 percent.

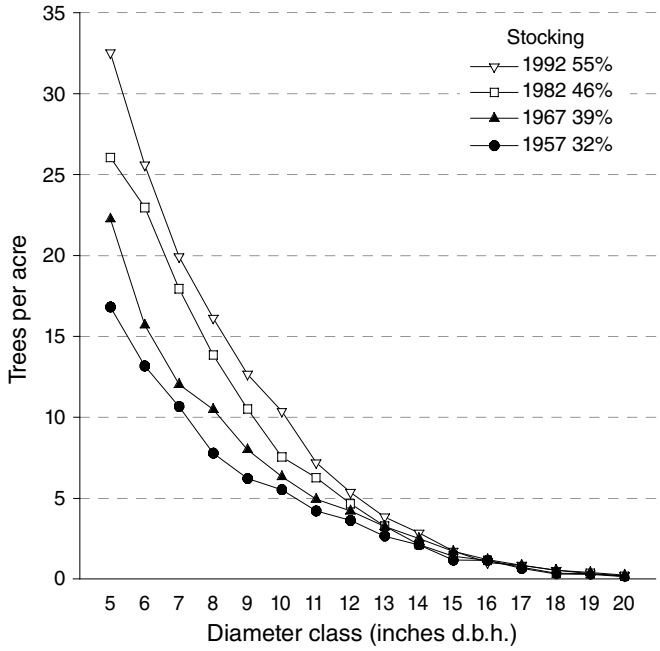

Figure 1—Diameter distributions of all trees inventoried on the Pioneer Forest in 1957, 1967, 1982, and 1992.

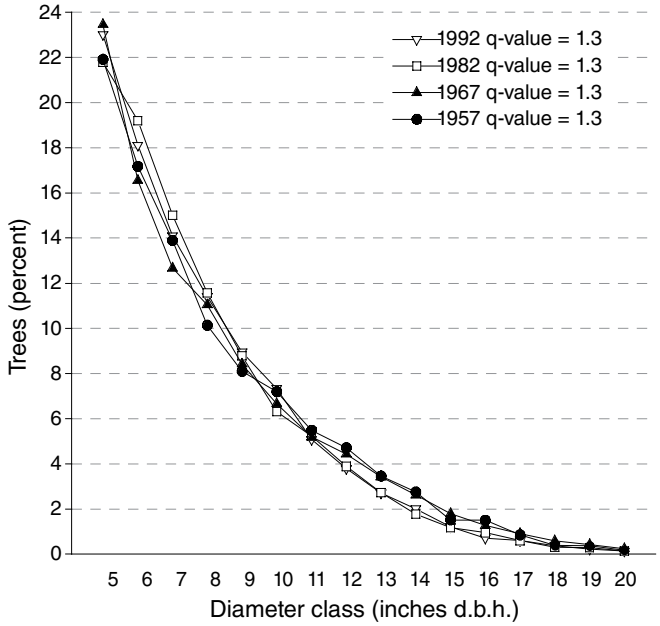

Figure 2—Relative diameter frequency distributions of all trees inventoried on the Pioneer Forest in years 1957, 1967, 1982, and 1992.

Even with this marked increase in both volume and density, the seven species that dominated the forest in the 1950s still accounted for over 90 percent of both basal area and trees per acre (Loewenstein and others 1995). It is true that the proportion of trees among these species has shifted somewhat with white oak increasing in prominence at the expense of the others. However, even this small change in the relative proportions of the oak species only serves to bring the current species mix closer in line with that which is thought to have occurred historically across the region.

Although there were no large shifts in the overstory species composition (trees > 5 inches in d.b.h.), demonstrating that the species composition is sustainable also requires an examination of trees in the understory. Based on a 1992 inventory of subcanopy trees (1.6 to 4.9 inches in d.b.h.), six of the seven principal overstory species were among the 10 most abundant subcanopy species. Only northern red oak was not; it ranked 16th in understory tree abundance (Loewenstein 1996). White oak was the most abundant subcanopy tree, accounting for over 75 stems per acre. Flowering dogwood (*Cornus florida* L.), a shade tolerant, was the second most abundant subcanopy tree. Flowering dogwood, however, rarely reaches the overstory; stems greater than 4.6 inches in d.b.h. were found on less than 7 percent of all CFI plots. The only other subcanopy shade tolerant species of significance were black gum (*Nyssa sylvatica* Marsh.) and maples (*Acer* sp.). Combined with dogwood, these three species groups comprised 98 percent of the subcanopy shade-tolerant species and accounted for 87 percent of the total density of overstory shade-tolerant species. Approximately two-thirds of all shade-tolerant species inventoried in 1992 were in the 2-inch d.b.h. class, and more than 90 percent were less than 4.6 inches in d.b.h. (fig. 3). In general, there is little or no evidence that shade-tolerant species have increased in importance in the overstory. Moreover, and more importantly, the accumulation of shade-tolerant trees in the smallest diameter classes does not appear to have suppressed the establishment and growth of intolerant species including the oaks. In the 2-inch diameter class, which included the greatest proportion of shade-tolerant species, the combined oaks and other intolerants outnumbered the shade-tolerant species nearly two to one.

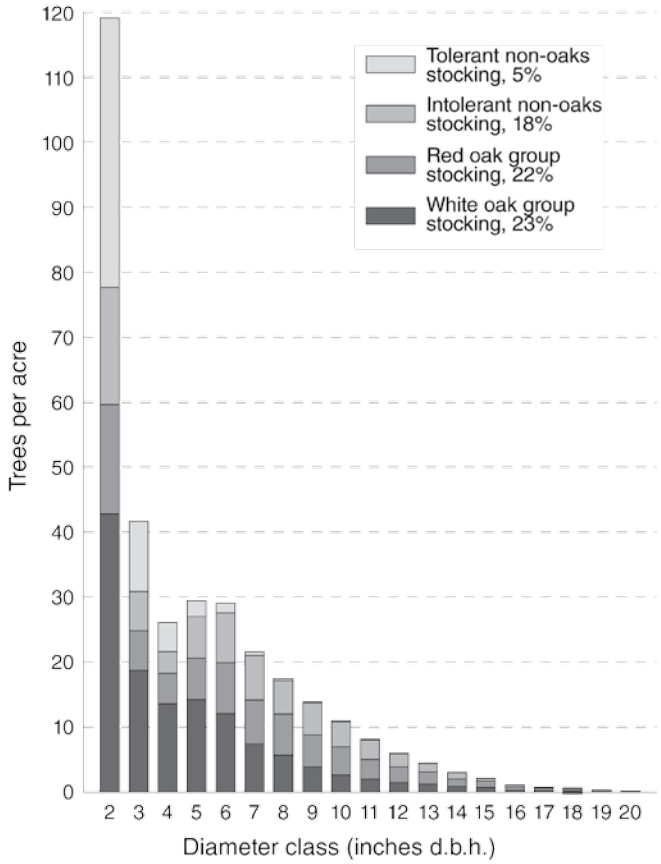

Figure 3—Diameter distributions by species group of all trees in 1992 (stocking, 67 percent).

SPATIAL SCALE

Finally, the issue of spatial scale must be addressed to determine whether or not single-tree selection, as opposed to group selection, can sustain oak recruitment on the Pioneer Forest. Oaks are intolerant to moderately tolerant of shade. Therefore, successful oak reproduction may require small even-aged groups or patches that are larger than those provided by the single-tree selection system.

Beginning with the accepted definition of an uneven-aged stand as one with at least three age classes either intimately intermixed or occurring in small groups (Helms 1998), an attempt was made to develop a test of spatial scale for uneven-agedness. Unfortunately, this definition is unsatisfactory from both a scientific and a statistical perspective. It is too ambiguous to be tested directly for two reasons: first, the maximum size of a single stand is undefined, and, second, the size at which a group opening becomes large enough to be considered a small clearcut (and by definition, a separate stand), is debatable as well. These two issues become problematic only because without spatial limits, it is possible to define group and stand in such a way that three age classes are always included within an arbitrary boundary, thus meeting a 'minimal' definition of an uneven-aged stand.

With any of the even-aged silvicultural reproduction methods (i.e., clearcutting, seed-tree, or shelterwood), regeneration occurs across the entire stand at the start of the rotation. Thus, age and size structure are consistent across the entire area. In group selection, regeneration occurs in small even-aged patches that are periodically created at each cutting cycle. The age structure and diameter structure of a group-selection stand combine measurements from each group into a single distribution. Individually, trees in each group are fairly uniform in both age and diameter. Only when combined across the stand does a recognizable uneven-aged structure appear (a reverse J-shaped distribution is typical). In single-tree

selection, however, regeneration is distributed much more uniformly across the stand. The age (size) classes are intimately intermixed. For this reason, under single-tree selection the diameter structure of the stand should be more uniform and occur at a smaller spatial scale than might be expected with either group selection or by combining separate even-aged stands.

By examining the spatial scale at which a stable reverse J-shaped diameter distribution occurs, it should be possible to place the silvicultural method employed by Pioneer Forest managers along the continuum from single-tree selection, through group selection or into any of the even-aged systems. If this spatial scale is relatively small (1 acre or less, for instance) there could be little question that the diameter structure was stable, sustainable, and occurring in a pattern suggestive of the single-tree selection system. If, however, the spatial scale at which the forest wide diameter distribution reoccurs were fairly large (several acres or more), then the likelihood that this distribution consists of accumulated even-aged groups of trees increases dramatically. On the Pioneer Forest, it was found that the forestwide, reverse J-shaped diameter distribution reoccurred on average at a spatial scale of only 0.6 acres (Loewenstein 1996). Given that the most intensively managed even-aged plantations cover at least 1 acre (Smith 1986) and extensively managed forest stands may be several hundred acres in size (the operational unit or stand size on the Pioneer Forest is one section, 640 acres), this is strong evidence that single-tree selection is indeed the silvicultural system employed on the Pioneer Forest, and it is maintaining a stable diameter structure at a very small spatial scale.

SUMMARY

Despite a widely held belief that oaks regenerate most easily using clearcutting or shelterwood methods, this knowledge leads many to discount the use of uneven-aged methods to manage oaks. However, the data in this paper show that the staff of the Pioneer Forest has successfully used single-tree selection over the past 50 years. The efficacy of the Pioneer system was evaluated in four ways:

1. The age structure of the oak component was found to be uneven-aged across 70 percent of the area sampled.

2. The diameter structure was found to exhibit a stable, reverse J-shaped distribution that has not changed over time. Such a distribution is considered indicative of a balanced, uneven-aged stand.

3. The species composition on the forest has changed little over the past 50 years and shows no evidence of a compositional shift toward shade-tolerant species. The oak component has been maintained in the overstory and understory, and the white oaks are increasing in prominence.

4. Finally, the forestwide diameter structure appears stable at a spatial scale of 0.6 acres. This scale strongly suggests that the entire range of size/age classes is well distributed across the landscape and not occurring in distinct even-aged groups.

The evidence from these studies collectively indicates that the single-tree selection system can be used to sustain an uneven-aged oak-dominated forest in this Ozark ecosystem, and that single-tree selection is indeed the system applied on the Pioneer Forest.

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DESCRIBING SINGLE-TREE SELECTION HARVESTS IN MISSOURI OZARK FORESTS

Greg F. Iffrig, Clinton E. Trammel, and Terry Cunningham[1]

Abstract—The European debate about uneven-aged forest management has been described as comparable to the religious wars of the Middle Ages. Likewise, here in the American Midwest, the forestry community has been largely unreceptive to the uneven-aged system of management, particularly the single-tree selection technique. Whereas a religious war may be more descriptive than accurate, disagreement is almost certain to continue in the literature as well as on the front lines within the forests. Despite that, we present evidence that use of the single-tree selection cutting technique for forests of the Lower Ozarks Region is an appropriate and successful management and restoration application. Drawing on more than a half-century of management experience and continuous forest inventory information, we trace the early development of single-tree selection harvesting, review its use as the harvesting technique on Pioneer Forest, and describe its implementation in detail.

EUROPEAN ORIGINS OF UNEVEN-AGED FOREST MANAGEMENT

The system of forest management, used on Pioneer Forest since the early 1950s, is a very old one, originating in the mountainous regions of Europe in the 1700s (Schutz 1997) in mixed beech-fir forests. As practiced at that time, the system represented an accumulation of knowledge among generations of private forest owners. Europeans viewed forests as an important economic asset that, through careful management, could yield income to be used for important and periodic family needs. Harvest revenues could be used for building construction or repairs, education, weddings, or emergency revenue. Through this experience, beginning nearly 300 years ago, European families passed along what developed into a recognized practice of periodically selecting trees from the forest for harvest.

In the late 1800s, a harvest technique known as single-tree selection was developed as a part of the more formal description of uneven-aged forest management by Henri Biolley (1901) in Switzerland and Adolph Gurnaud (1882, 1884) in France. From Gernaud came the idea of the sustainability of forests through the application of single-tree selection harvests whereas Biolley developed the technical rules for its use as a formal management tool.

Despite these advances, there has been a great deal of debate in European circles about the use of uneven-aged management. Schutz (1997) likened that debate as "comparable to the religious wars of the Middle Ages", with deeply held beliefs about even-aged forestry versus uneven-aged forestry, often to the point where dispassionate assessment of the respective methods on their own merits is difficult to find. But, the European experience is clear in one respect—that in certain forest types, when applied with a combination of scientific analysis and practical experience, uneven-aged management can be successfully implemented in the long term.

UNEVEN-AGED MANAGEMENT IN MISSOURI

In the central United States, the earliest literature describing either uneven-aged management or the practice of single-tree selection first appeared in the 1980s. Larsen (1980) developed a growth and yield model for mixed oak-pine forests using the Continuous Forest Inventory (CFI) information from Pioneer Forest as a database. Melick (1989) presented some of the earliest silvicultural prescriptions for the uneven-aged management of three specific forest stands on the Mark Twain National Forest. At this same time, Law and Lorimer (1989) prepared their own analysis for managing stands to achieve an uneven-aged character across the landscape.

In a series of research projects spanning the 1990s, a more specific analysis of uneven-aged forest management in oak-hickory forests was conducted on Pioneer Forest. Such a thorough analysis was possible primarily because of the long-term database from the CFI established on Pioneer Forest in 1952. Jenkins (1992) and Jenkins and Pallardy (1993) studied oak-hickory stands and suggested that the red oak group in uneven-aged stands on Pioneer Forest were less susceptible to mortality than similar stands under other management systems elsewhere. While not exclusive to Pioneer Forest, Johnson (1992) mentions the use of single-tree selection harvesting in his review of alternatives to clearcutting, although, at the time, only reluctantly recommending it as a prescription. Shortly after Johnson's review was completed, he and other researchers at the University of Missouri-Columbia continued to analyze the single-tree selection method and reported positive results. Loewenstein (1996) and Loewenstein and others (1995, 2000) investigated age/diameter relationships, as well as long-term changes in species composition and basal area (summary of the number and size of trees per acre). Results from this series of papers clearly demonstrated the success of the method over a 50-year period. Wang (1997) and Wang and others (1996) reported on the stability of diameter distributions, confirming that the diameter distributions for scarlet oak (*Quercus coccinea* Muenchh.), northern red oak (*Q. rubra* L.), and white oak (*Q. alba* L.) conformed to the expected negative exponential diameter distribution (described by Johnson and others 2002);

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namely, with more trees in the small size, young age classes and fewer trees in the larger size, older age classes.

Two attempts in the recent past describe how the method applied on the ground. One was an initial work by Larsen and others (1997) where the authors, using regression models, projected height and density classes for regeneration based upon given residual basal area of the overstory. Then Larsen and others (1999) presented criteria for selecting the residual stand structure and density necessary to sustain a forest dominated by oaks. The basis for both of these treatments was a 40-year portion of the data-set from Pioneer Forest. More recently, Johnson and others (2002) thoroughly reviewed uneven-aged silvicultural methods, including an extensive discussion of the principles and some of the theory of the single-tree selection cutting technique. In this paper, we present in more detail the successful practice of marking and decision-making, which has been developed by a group of foresters who have applied the single-tree selection technique of uneven-aged management in Ozark forests since the 1950s.

BACKGROUND AND HISTORY OF THE LANDS OF PIONEER FOREST

Leo Drey began acquisition of the lands that are now Pioneer Forest in March 1951. Today these forests extend over 154,000 acres. He recognized that these forested landscapes could be productive while they were managed using a more conservative harvesting technique. Prior human-induced disturbance on much of these lands included fire, cutting, and grazing. Drey's goal was to establish a demonstration method of harvesting trees while retaining the structure and character of the forest across the landscape. The long-range objective for Pioneer Forest is to develop and manage native tree species of large diameter and high quality for wood products while also providing a host of recreational and ecosystem benefits.

There is significant information on the history of these forests prior to Drey's earliest acquisition. This history is not only interesting, but is also instructive in developing and then validating a successful prescription for single-tree selection harvesting.

Pioneer Forest is located in the oak, hickory, and pine region of the Ozark Highlands. Aside from scenic beauty, these forests provide recreation, water and soil conservation, watershed protection, timber products, fuel, and essential habitat for characteristic wildlife species. The topography was formed largely through a process of erosion with areas of greatest relief reaching a difference in elevation of 700 feet. This area of the Ozarks, and the lands of Pioneer Forest specifically, have many classic features of karst-influenced landscapes, including large springs, sinkholes, losing streams and numerous caves, plus bluffs, glades, fens, and clear streams.

We can only speculate as to the condition of these old and mature forests just prior to their first cutting, but we can learn a great deal from those who have examined, studied, and written about the condition of the Ozarks landscape at that time. Their observations, as well as what we know about the cutting during this early period are particularly helpful in understanding the subsequent results of the harvest method that has been researched and practiced on Pioneer Forest.

The earliest information we have comes from the study of tree ring chronologies. Guyette and others (2002) developed a method for constructing fire and disturbance models extending hundreds of years back in time through pre-European settlement. Study of disturbance regimes resulting from the long-term interactions between humans and their environment can provide specific information on forest succession and species abundances.

In the region of Pioneer Forest, evidence suggests that the highly dissected and heavily forested topography reduces the frequency of fire-related disturbance. Guyette and others (2002) noted that the interval between surface fires ranged from 9.8 to 17 years within the forested uplands immediately north of the Current River, compared to 16 to 29 years for the more mesic mixed-oak forests along the river during the period 1700 to 1850. Thus, the 15- to 30-year entry period that has evolved operationally for single-tree selection harvest parallels the earlier frequency of disturbance from fire in the region.

There also appear to be differences in the scale of disturbance locally versus regionally. Guyette and others (2002) noted that the Ozark Region is more than 80 percent forested, defined as having a percent canopy closure of more than 75 percent. However, they also noted that the locality of Pioneer Forest with its steep ridges and numerous streams and slopes that average 18 degrees, supported a pattern of small-scale rather than large-scale disturbance. The practice of removing individual trees that is typical of management on Pioneer Forest thus approximates the historic scale of smaller disturbances that were common in this vicinity.

Pine and deciduous forests made up most of the pre-settlement vegetation of the Ozarks, especially in areas of greatest topographic relief (Thom and Wilson 1980). From our own long-term work, as well as publications describing this particular area of the Ozarks, the majority of Pioneer Forest is located in what was and still is the most heavily forested region of Missouri. These landscapes are and have always been forests in the truest sense.

More information comes during the mid-20th century from an article about "Pioneer Forest," published by the Missouri Department of Conservation. Meyer (1949) describes these lands during the period from about 1920 to 1945. The following are a few of his observations:

> "The name Pioneer Forest is an ideal one, tying its past history to the cooperage company whose conservative use of the land made it possible for the forest now to be a going concern without a long period of building up the timber volume on the land.
>
> "The history of the forest begins about a quarter of a century ago [ed. note: about 1920] when 50,000 acres of virgin timberland was purchased by the cooperage

company from the old Current River Lumber Company. A lot of this land then supported ancient stands of shortleaf pine and of white oak..."

"And so the company had some land which had not been cut enough to even harvest the growth..."

These writings are clear in their description of forest, timber volume, and the dominant native species found in this region.

Around 1945, National Distillers purchased all of the lands owned by Pioneer Cooperage. By 1954, National Distillers had changed its forest management practices and began cutting all merchantable trees rather than using the more careful and selective approach initiated by Pioneer Cooperage. Cutting during this time removed many of the larger shortleaf pine (*Pinus echinata* Mill.) and white oak, as well as some black and red oaks. Farther away from the sawmills, larger trees were often left. Also, left within these forests were the pine and white oak trees generally smaller than 14 inches in diameter (Martin and Presley 1958). Misshapen or poorly formed trees were not cut. Also left were other abundant species of all sizes, including blackgum (*Nyssa sylvatica* Marsh. var. sylvatica), ash (*Fraxinus* spp.), hickory (*Carya* spp.), other oaks, walnut (*Juglans nigra* L.), basswood (*Tilia americana* L.), mulberry (*Morus rubra* L.), black cherry (*Prunus serotina* Ehrh.), elm (*Ulmus* spp.), and sycamore (*Platanus occidentalis* L.)—trees that we know are characteristic of the Ozark forests, but for which, at the time, there was no market.

Another source of information from the period immediately prior to Leo Drey's purchase of the forest provides a more detailed look at forest composition. H.H. Chapman, a well-known forestry professor from the Yale University School of Forestry, visited the National Distillers holdings in July 1951. The purpose of Chapman's visit was to produce a fairly detailed report (Chapman 1951) of the forest condition. During the period of July 5 to 15, Chapman traveled 1,500 miles, inspected 66,000 acres of land, and completed measurements from 106 of the 179 surveyed sections in which National Distillers owned land. This was during a time when many writers describe these Ozark forests as having been completely cutover. Included in Chapman's report was a 1949 calculation of the number of trees per acre from three diameter classes (4 to 10 inches, 12 to 14 inches, and trees greater than 16 inches in diameter). From his data, we know that there was an average of 38.4 trees per acre, including nearly eight saw log trees (individual trees greater than 12 inches in diameter) (table 1).

Whereas this average represents a relatively low stocking, it should be noted that at the time of his inventory in 1949, the only merchantable species were white oak, red oak, black oak, and shortleaf pine. We speculate that these data may have represented only the species that were merchantable at that time because only one species-specific class (the report lists white oak, the species of primary importance to the distillery company, as one class and then other species as another class) is mentioned in Chapman's report. If all species present had been measured, whether merchantable or not, then the forestwide number of trees per acre would have been higher. Our own data, compiled only 8 years later (table 1, 1957), show nearly double the total number of trees and nearly double the saw log trees when accounting for all species.

There is no question that early cutting (the peak period of which occurred between 1880 and the 1940s) substantially changed certain Ozark forests. Furthermore, there also is considerable evidence that while forests of the Ozarks were indeed cut, it is unlikely that the entire Ozark region would have been left barren.

In 1954, Drey concluded his purchase of all of the land holdings of National Distillers and, adding that to the forest acreage he had already purchased, he then renamed his long-range forest management effort Pioneer Forest. From its beginning, Pioneer Forest has used uneven-aged management, applying the single-tree selection harvest method on a truly landscape scale as an Ozark forest management project.

Table 1—Trees per acre by diameter at breast height (d.b.h.) and year of inventory from Pioneer Forest, Missouri [a]

D.b.h.	Chapman 1951	1957	1962	1967	1972	1977	1982	1987	1992	1997	2002
6		29.0	34.0	38.2	44.4	47.9	47.8	46.6	54.2	66.4	64.73
8	30.5 [b]	18.0	19.0	22.8	24.2	27.3	30.7	32.5	34.2	36.2	33.09
10		11.2	12.5	14.6	16.4	17.0	18.1	20.0	21.8	24.3	22.9
12	5.8 [c]	6.9	7.0	9.0	9.2	10.2	11.0	11.6	12.5	15.1	13.0
14		4.1	4.5	5.4	4.7	5.0	5.4	5.8	6.7	8.0	6.4
16	2.1 [d]	1.6	2.0	2.7	2.3	2.3	2.5	2.3	2.8	3.6	3.0
18		0.6	0.8	1.0	1.0	0.7	0.8	1.0	1.2	1.7	1.2
20		0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.5	0.6	0.7
22		0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.2	0.2	0.1
24		0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total	38.4	71.9	80.3	94.3	102.8	111.0	116.7	120.1	134.2	156.2	145.2

[a] Data for 1951 from Chapman (1951), and for remaining years from the continuous forest inventory.
[b] Accumulated diameter class of all trees measured from 4 to 10 inches d.b.h.
[c] Accumulated diameter class of all trees measured from 12 to 14 inches d.b.h.
[d] Accumulated diameter class of all trees measured ≥16 inches d.b.h.

SINGLE-TREE SELECTION AS APPLIED IN PIONEER FOREST

The application of the single-tree selection harvest method lends itself more to a qualitative description, and somewhat less to being quantified. In many ways, this technique is at least as much art as it is science. From the very earliest days of Drey's ownership, the forest management philosophy was epitomized by the words of Russ Noah, former forester with Pioneer Forest: "if a tree would last for another 10 years (or until the next scheduled harvest), don't cut it." This philosophy is also expressed in a more recent and equally concise description of uneven-aged management by Guldin and Baker (1998), where markers are instructed to "cut the worst trees and leave the best within each diameter or product class." Although simple, both descriptions go a long way toward demystifying what many have been called impossible to describe.

First applied by foresters Ed Woods and Charlie Kirk on the properties of Pioneer Cooperage, the concept was to remove trees from the forest that might be lost before the next harvest. Infestations by insects, disease, or storm damage were all reasons to harvest a tree. Rather than removing all or a large portion of the trees from any given acre, only those trees that might be lost or were expected to significantly decline (in value or health or both) before the next harvest were considered for removal. The principal idea was to devise a harvesting technique that would allow selected trees to be removed periodically from the forest.

This removal was initially suggested to be every 10 years. Neither the expected period for this re-entry, nor the carrying capacity for these Ozark forests, were precisely known when foresters of the present-day Pioneer Forest began. Through practical experience and experimentation, the details of this technique have developed.

In many ways, the nature of the single-tree selection harvest technique is an accelerated version of the natural changes that might occur within the forest over much longer periods of time. Time, combined with risk factors such as mortality, make all the difference in understanding how this method of forest management works (fig. 1).

Overview

The prescription for field-marking, which we describe below does not attempt to quantify the many variables that are at play within the forest. Uneven-aged management, and especially the single-tree selection technique, is, by nature, a highly flexible forest management tool. Single-tree selection harvesting is more consistent with the dynamic conditions within the forest, combining the biological realities with various social objectives (Becker and Corse 1997), including income, recreation, and aesthetics. The biological realities such as drought, fire, ice, and wind, as well as the many human-inspired or human-inflicted changes that have affected these forests over long periods of time, are all constant and highly variable factors. Management and experience with an ecosystem at least several hundred

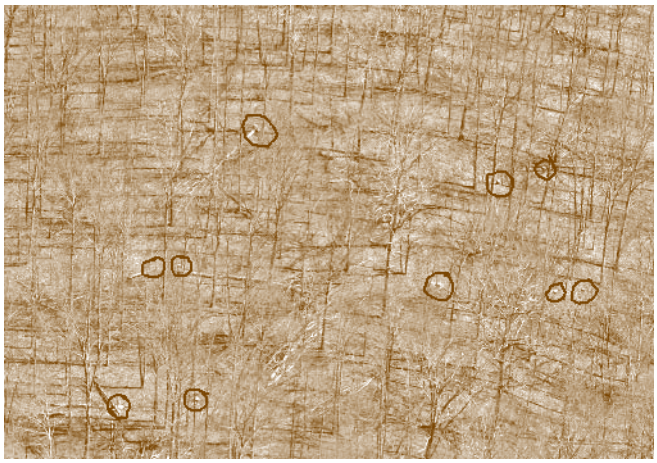

Figure 1—Aerial view of an oak-hickory stand on Pioneer Forest harvested using the single-tree selection method. Stumps of trees harvested during the harvest are circled. *(Pioneer Forest)*

years old continue to leave many details of their effects still unknown. These include the carrying capacity or standing volume, maximum diameter, and a strict Q-ratio—the factor used to calculate the number of trees within individual age/diameter classes (Johnson and others 2002). Therefore, as a purposeful precaution, our marking prescription aims for more broadly defined age and diameter classes within the forest and much less for the academic rendering of a numerical formula. This flexibility allows for specific targeted adjustments to be determined on-site, during each harvest, accounting for both natural and catastrophic change that may occur.

The most basic requirement of uneven-aged management is that the resulting forest shall possess at least three distinct age classes. The age class or diameter distribution of the forest then follows what has become a classic reverse J-shaped curve (Johnson and others 2002). This curve portrays the forestwide array of diameter classes beginning with a greater number of younger aged, smaller diameter trees, and then progressively reducing the numbers of trees within each diameter class to reach fewer older aged, larger diameter trees. The difference between the real curve from actual forest data and the theoretical guiding curve provides the management target. Figure 2 portrays the results of our day-to-day interpretation of the qualitative prescription we describe here. The quantitative analysis of these results and the periodic fine-tuning over long periods of time determine successful management and demonstrate how well the technique works when applied across a large forested landscape.

Merchantability Standards

The merchantability of a given species depends on market conditions within a particular region. In the Pioneer Forest area, minimum merchantable hardwood saw log trees are 11 inches in diameter at breast height, with at least an 8-foot saw log containing a 10-inch diameter at the small end. Pine saw log trees must be at least 9 inches in diameter at breast height

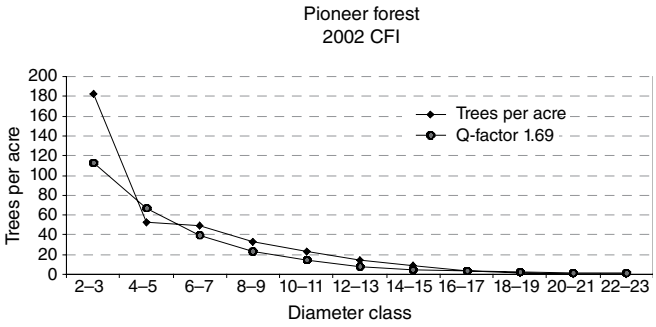

Figure 2—Distribution of stems >2 inches in d.b.h. per acre from the 2002 Continuous Forest Inventory (CFI)—compared with a theoretical 1.69 Q-factor curve using an upper diameter of 23+ inches.

and have at least an 8-foot log length, with a minimum of 6 inches in diameter on the small end. Cordwood trees are those trees large enough to be a saw log but contain defects that will not allow merchantability as a saw log; or are less than the minimum saw log diameter at breast height, contain at least one stick of wood 4 feet in length, and are not less than 4 inches in diameter on the small end.

Harvest Cycle

Rotation describes the length of time between harvests or the maximum age a stand will be allowed to grow under an even-aged management system. The length of a rotation is the time between harvests. Using an uneven-aged management system, however, there is always a forest cover on the land and thus no recognizable beginning or end to the structure of the forest. Forest management through the application of single-tree selection becomes a series of separate entries, called cutting-cycle harvests, where each time a partial harvest occurs. These harvests can be thought to be analogous to the thinnings used in well-managed, even-aged stands, but unlike even-aged thinnings, mature, high-value trees are harvested during every uneven-aged cutting-cycle harvest. Success with single-tree selection management depends on the monitoring of canopy closure as well as a forest's structural characteristics. The ability to continually measure forest structure through time facilitates success and also quantifies and characterizes forest quality.

The timing between each entry has evolved from that used beginning in the early 1950s, of about every 10 years, to a slightly longer period used today of 15 to 30 years for individual stands. Past cutting history and the current condition of the stand are used to determine the timing of each harvest entry. Exact timing depends on the condition of any given area, primarily canopy closure for the forested area under consideration. The canopy cannot be allowed to fully close for any length of time without causing a loss of desirable seedlings, saplings, and poles, and significant components of stand structure. Other factors include physical condition of the trees, growth rate, and signs of mortality.

Marking Method

Marking for a single-tree selection harvest focuses on the condition and health of individual trees. When marking an area for harvest, every tree is examined and an assessment made as to the risk of that tree surviving through the next harvest cycle. Trees not marked are considered to be likely to survive, and, thus, are left to grow and gain in volume and value. The number and quality of retained, or "leave", trees found on every acre of the forested area are a distinguishing measure of single-tree selection harvesting. Leave trees are the dominant and most productive trees in each age and diameter class. As stand marking proceeds across the slope, the focus on any given area is to first determine which trees are to be left and only then to begin marking those trees that are to be cut. The best trees on each site are almost always left to be re-assessed during the next harvest. Specific considerations are age and species, physical condition, vigor, site quality, stand position and density, and cull or snag trees. A decision-tree was developed for marking a stand of timber to aid foresters in the conceptual understanding of the process (fig. 3).

The following marking guidelines have been developed to assist in the evaluation of trees during a particular harvest when using single-tree selection management. It should be remembered that when using this method, foresters mark and leave trees for the present harvest but also look ahead to one or more future harvests when assessing each tree's status.

Age (Size) and Species—The forester must observe characteristics of each tree to estimate its age and determine whether it is approaching biological maturity. For any given tree this requires a general understanding of the capability of any given species within this region. For example, a scarlet oak currently estimated to be 80 years old would be around 100 years of age at the next harvest entry used on Pioneer Forest. An age of 100 years would place a scarlet oak beyond the age considered to be its normal biological maturity, and, thus, would be at high risk of mortality. Such a tree would be marked for harvest. On the other hand, a white oak tree 150 years of age is well within the most productive growth period during its life cycle and could be retained for at least several more harvest entries.

Physical Condition—Each tree is examined for factors such as an unusual number of dead limbs, decay holes, percent crown spread, percent live crown, insects, and disease. For example, trees in poor physical condition or those infested with insects or diseases are considered at high risk of significant volume loss or of dying before the next entry and, thus, become candidates to be marked for removal during harvest. In addition, those trees infested with insects or disease will potentially become an infection site for the surrounding stand and should be removed. As marking moves across the slope or up the hill, each tree is observed from all sides. It is often the case that a tree observed from several sides, and initially thought to be a leave tree, will be reconsidered when a serious defect is observed from a side of the tree not yet seen. Oaks in otherwise good physical

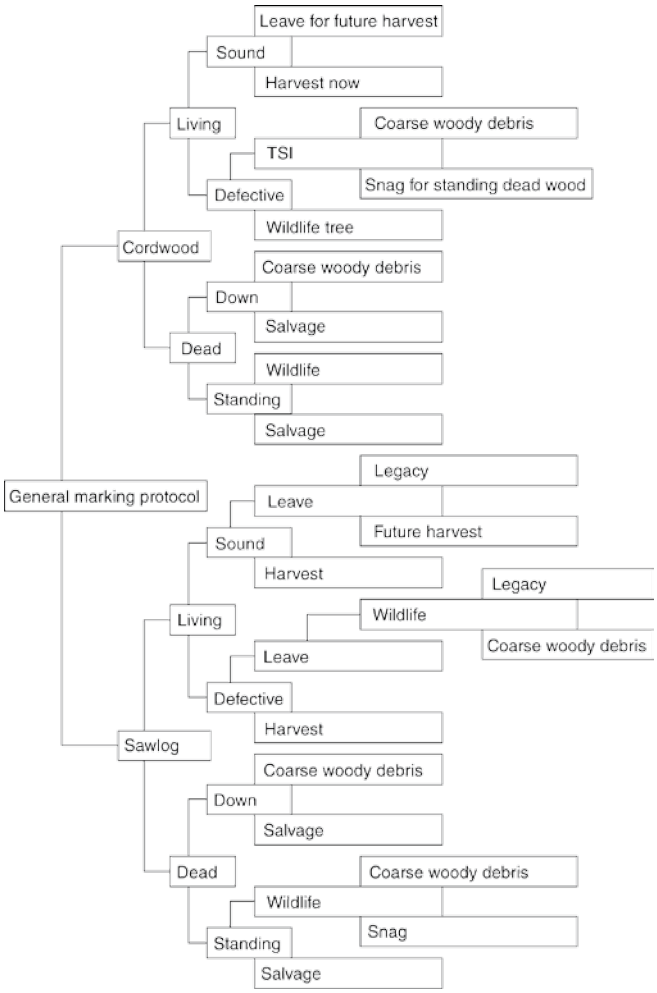

Figure 3—Key for determining cut or leave trees during a single-tree selection harvest. Definitions for terms used here are: cordwood—see definition earlier in this paper under merchantability standards; TSI—abbreviation for timber stand improvement, meaning the tree cut for TSI has no commercial value other than the value of removing it as a benefit to all of the surrounding trees; course woody debris—a cut tree left on the forest floor; wildlife tree—any tree presently or potentially used by any of a variety of wildlife species; legacy tree—any commercial tree left standing for various non-commercial reasons including its size, species, or form.

condition, but with a basal hole as opposed to a hole somewhere up on the trunk or bole, may be candidates for leave trees. The reason for this is that damage to the wood from this source always moves down in a tree, and, if the decay moves up, it does so very slowly. Such a tree could easily grow through another harvest cycle with considerable additional increase in volume but with much less increase in the measured defect.

Vigor—The overall health of each tree is considered. To be retained, a tree must be growing well. For example, red oaks must have a tight, relatively smooth bark with little difference between the bark ridges and valleys. This indicates a strong, healthy tree that is putting on good diameter growth. In this example, the bark indicates that the tree is healthy and growing rapidly. The tree should have a good, relatively thick, healthy-looking crown in relation to its size and position in the stand. A positive assessment indicates an ideal leave tree.

Site—The forester considers the conditions of the site on which the tree is growing, including slope position, aspect, soil type, and soil depth. During a day of marking, site conditions will change several times along and across a given hillside. These changes may be from a dry ridge top to a moist north cove to a warm west hillside. Marking is designed to encourage and leave those species best suited to each particular site condition. Therefore, marking for a single-tree selection harvest requires the continual assessment of site quality and species composition, with the goal of favoring those species that will survive adverse conditions between now and the next harvest cycle. Each harvest is directly related to growth rate as well as the standing volume. For example, a higher volume could be cut from the faster growing cove site than from the drier ridge top. Making these adjustments during marking compensates for varying growth rates and is consistent with the naturally higher stocking possible on better sites.

Stand Position and Density—Consider an individual tree's position in the stand when determining which trees to cut. Legitimate reasons exist to cut both poor and good trees, depending on localized stand conditions. There are two primary reasons why trees otherwise considered to be leave trees might be cut. Trees that have become suppressed for prolonged periods of time are often of poor quality, and do not respond well to release; as such, they are poor candidates to leave until the next harvest entry. On the other hand, a desirable tree may also be a candidate for removal via thinning in order to give other more desirable trees in close proximity room to grow.

Cull and Snag Trees—Cull trees are defined as living trees where more than 50 percent of the total volume is defective from a merchantability perspective. Snag trees are standing dead trees and have no commercial value. However, maintaining a component of defective, dying, and dead trees within the forest is considered a very important measurable benefit for wildlife. Thus, no attempt is made to remove all dead and dying trees from the forest. Individual merchantable trees showing signs of use for dens or nests by forest-dwelling mammals, birds, and reptiles are almost always left. Merchantable trees with no apparent wildlife use may be salvaged or left, depending on the density and distribution of culls and snags within the area. Trees of no merchantable value and no value for wildlife may be felled where they interfere with the growth of a desirable leave tree.

When Several Adjacent Trees Are Candidates for Removal or Leaving—When a small group of trees is under consideration for marking, and the criteria above do not make the choice clear, then choosing which trees to mark and which to leave becomes a matter of thinning. With all other factors appearing equal,

this decision would prioritize the observed spacing within the group and, by removing one or more trees, would provide more opportunity for the leave trees.

Succession

From reviewing the literature on uneven-aged management at sites other than Pioneer Forest within the Central Hardwoods Region and elsewhere, the greatest error in application of single-tree selection seems to occur from overcompensating for succession. This happens when more attention is placed on managing for recruitment of seedlings on the forest floor than in managing the forest at hand. This perception has led others to favor group selection (Law and Lorimer 1989, Johnson 1992, Johnson and others 2002). Yet other researchers (e.g., Becker and Corse 1997) warn that using single-tree selection and group selection together could allocate more growing space than necessary for new regeneration in ponderosa pine forests.

Foresters have, for many years, assumed that oak forests here in the Missouri Ozarks would trend toward some combination of sugar and red maple (*Acer saccharum* Marsh. and *A. rubrum* L., respectively), along with other species such as basswood, blackgum, and dogwood (*Cornus florida* L.) (Law and Lorimer 1989) where these forests either were not managed or where management did not create large enough openings for sufficient light to provide for regeneration. Outside the Ozarks, where soils are deeper such as in the River Hills region of Missouri, there are forested canopies composed of a significant percentage of sugar maple. Shifley and others (1997) report three examples from north Missouri, two of which have sugar maple along with oak species as dominant and one with oak and other species dominant in the overstory. In one instance, one of the present authors measured an unmanaged forest canopy from north Missouri where sugar maple dominated. This was from a transect where sugar maple comprised 70 percent canopy coverage (Iffrig and Elder 1978). Data from another source indicated the canopy from this same north Missouri forest was 90 percent sugar maple (Weaver 1977).

Such evidence indicates that oak-hickory forests on higher quality sites, and perhaps on unmanaged forests, may show succession tendencies toward shade-tolerant nonoak canopies. However, if this were true for the Ozarks, then one would expect to see examples of nonoak canopies, particularly for the oldest aged canopies on the highest quality sites within the region. But this is not apparent on Pioneer Forest. For example, the canopy trees on the Current River Natural Area, located on Pioneer Forest, are oaks that range in age from 250 to 400 years, with the earliest ring width indicating they had regenerated under a full canopy, that is, in shade (Personal Communication. Richard P. Guyette, Associate Professor, University of Missouri, Columbia, MO 65211). This particular site is situated at the lower end of a north slope, and evidence indicates it has never been harvested.

Several anecdotal examples are instructive in further understanding the replacement dynamics within these oak-hickory-pine forests. Dogwood flourishes on the forest floor and frequently forms thick shrub canopies within the forest through which oak saplings grow to replace other oak as canopy dominants. Counts of seedlings on the forest floor have shown particularly high numbers of blackgum, elm, maple, sassafras (*Sassafras albidum* (Nutt.) Nees), and dogwood competing along with equally high numbers of canopy replacement species of black oak, white oak, and hickory (table 2). The data from table 2 suggest that oak, hickory, and even pine are highly competitive on these sites. Scarlet oak, even from relatively small stem counts, maintains its presence while growing into the larger diameter classes. Perhaps most interesting is that shortleaf pine seems to be able to compete into larger diameter classes under single-tree selection management. A particular species representation on the forest floor does not seem to be an accurate indicator of its future presence in the forest canopy. Following 50 years of data collection across thousands of acres of forest, we know of no evidence from the Missouri Ozarks where canopies, which have been dominated by oak, hickory, and pine for centuries, show measurable and significant change away from this historic composition.

Light

One requirement for successful regeneration is the presence of both direct and diffuse light. Harvest activities allow direct light to penetrate the forest canopy where a tree has been removed. Harvesting one or a few trees creates canopy gaps that vary in size but occur in an irregular pattern across the landscape. Light penetration continues for some time into the future until each canopy gap is eventually filled in. Diffuse light is also continuously present within the forest by being transmitted through smaller gaps in the canopy (such as dead limbs or spaces between adjacent trees), as well as by being reflected off of the leaves, trunks, and limbs of the trees within the forest.

Our experience with successful uneven-aged management at Pioneer Forest has shown that removing groups of trees from any given area is not necessary to promote the penetration of sunlight to the forest floor. Replacement of the canopy, primarily by oak and pine, has always been a result of the canopy gap dynamics occurring as a result of periodic harvest of one or more trees. Thus, the light environment promoted by removing individual trees appears to be sufficient to sustain regeneration in these forests.

Forests under single-tree selection cutting benefit from a continual provision of light as a built-in component of this method of forest management. Both direct and diffuse light reach the forest floor as trees are removed during each harvest entry. These sources of light continually shift in space and time. Whereas the actual source for light within the forest may vary (because of the heterogeneous nature of providing light energy through single-tree selection management), the provision of light is automatic. In this manner, light continuously influences the development and maintenance of the forest structure under this method of management.

Table 2—Stems/trees per acre for all species measured from the 2002 continuous forest inventory [a]

	Diameter class [b]														
Species	0	2	4	6	8	10	12	14	16	18	20	22	24	26+	Total
Black oak	224.4	3.9	1.8	4.0	4.7	3.7	2.7	1.5	0.7	0.3	0.1	0.0	0.0	0.0	247.9
Red oak	20.1	0.4	0.2	0.6	1.3	1.1	0.6	0.7	0.3	0.2	0.1	0.1	0.0	0.0	25.8
Scarlet oak	79.2	4.4	2.5	4.4	3.7	3.4	2.4	1.4	0.7	0.3	0.1	0.0	0.0	0.0	102.8
Blackjack oak	3.2	0.9	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	5.2
White oak	423.8	36.5	17.7	20.0	11.1	6.2	2.9	1.9	1.1	0.0	0.1	0.1	0.0	0.0	521.4
Chinquapin oak	15.3	4.4	1.7	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.6
Bur oak	0.0	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Post oak	14.9	4.1	1.4	2.0	1.2	1.0	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	25.6
Shortleaf pine	16.1	1.5	1.2	3.2	3.6	4.0	3.0	1.7	0.7	0.2	0.0	0.0	0.0	0.0	35.2
Cedar	20.1	3.3	1.6	1.7	0.8	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.0
Hickory	296.3	12.5	2.3	6.2	3.7	2.3	0.9	0.5	0.1	0.0	0.0	0.0	0.0	0.0	324.8
Blackgum	239.8	24.7	4.3	1.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	270.3
Sycamore	4.0	8.4	1.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8
Hackberry	0.7	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Elm	351.8	2.4	0.8	1.0	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	356.6
Ash	19.2	3.9	0.6	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4
Birch	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Cottonwood	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Boxelder	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
Basswood	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Locust	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Maple	634.8	4.7	1.6	1.8	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	643.7
Black walnut	3.1	8.3	1.4	0.4	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	13.8
Butternut	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Sassafras	517.9	1.8	0.4	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	520.4
Dogwood	430.0	12.7	1.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	444.4
Redbud	44.9	6.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.8
Ironwood	56.3	15.2	1.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.7
Persimmon	0.9	1.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
Willow	0.8	1.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4
Mulberry	0.7	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
Buckeye	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Blackhaw	19.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.3
Serviceberry	33.7	1.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0
Black cherry	18.3	1.3	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.4
Sweetgum	1.0	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
KY Coffeetree	0.1	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Plum	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Hawthorn	2.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4
Mimosa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Buckthorn	2.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8
Farkleberry	1.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
Hornbeam	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Pawpaw	86.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.6
Totals	3,587.1	171.7	45.5	48.8	32.8	23.4	13.8	8.2	3.7	1.6	0.4	0.2	0.0	0.0	3,937.4
Q-factor 1.69	190.0	112.5	66.5	39.4	23.3	13.8	8.2	4.8	2.9	1.7	1.0	1.0			

[a] Diameter class n contains trees from n.0-(n+1).9, inclusive.
[b] The diameter for stems < 1.6 inches was measured at the root collar and for stems ≥ 1.6 inches was measured at breast height.

Other research on various oak species has suggested that shade tolerance may not be as fixed as often suggested (Johnson and others 2002). McGee (1976, 1988, 1997) has shown that oaks adjust to variation in light conditions by shifting the timing of their spring budbreak, based on their exposure to light during the previous year. Seedlings and saplings beneath a forest canopy begin growing earlier in the spring than open-grown oaks when light and moisture conditions are the most favorable. McGee (1997) found this same response in several oaks—namely, white, black, scarlet, post (*Q. stellata* Wangenh.), chestnut (*Q. prinus* L.), and northern red oaks. McGee (1986) also found this same response in hickories, red and sugar maple, and white ash (*F. americana* L.).

The highly irregular but constant provision of direct light through single-tree selection management may be the key to understanding the positive response of many species to this method of forest management in the Missouri Ozarks.

Regeneration

Single-tree selection on central hardwood sites, by its nature, is sustained by the accumulated regeneration of desirable species. The ability of oaks to accumulate in the understory has been well documented. As Johnson and others (2002) have pointed out, the early development of a large taproot and delayed shoot growth are characteristic of all oaks. Previous research has shown that oak seedlings sprout and grow, and then die back, repeating this response for many years while building a taproot (Johnson and others 2002). Dey and Guyette (2002) offer a brief review of oak regeneration ecology, pointing out that oaks are well adapted to repeatedly produce new sprouts from dormant buds located at the root collar. This root collar is often located beneath the soil surface and is naturally protected from such disturbances as low-intensity fire and some herbivores. With this adaptation, oak seedlings sprouted from acorns can develop beneath a forested canopy for decades, capable of rapid response to changes in light availability. Their response is to re-allocate energy from root into shoot development (Johnson and others 2002, Dey and Guyette 2002).

The cutting cycle used in single-tree selection harvests on Pioneer Forest is not long enough to allow the canopy to completely close, a condition that could, over long enough periods, result in a loss of oak regeneration and therefore a change in canopy species composition. Each cutting cycle reopens the canopy whereupon seedlings and stump sprouts, with well-developed taproots, are ready to capture the hole created in the canopy. Since the canopy gaps resulting from single-tree selection harvesting are small, the recruitment and regeneration present on the floor at any given time may number only a few saplings with perhaps a higher number of seedlings and sprouts. These numbers are small when compared to reproduction numbers using even-aged forest management. However, the young seedlings and saplings survive in sufficient numbers to replace the correspondingly smaller number of individual trees that are removed during each harvest.

Unlike even-aged management, where establishing regeneration is a one-time event, single-tree selection harvests provide for regeneration with each entry. This maintains the range of age classes characteristic of this technique of management.

Reducing Disturbance Effects and Harvest Damage to the Residual Stand

Under uneven-aged forest management, abiotic variables, such as percent canopy coverage, temperature, and humidity show measurably fewer changes among the trees than in forests under even-aged management (San Diego 2001). This reduced environmental variability provides for increasing stability to forest structure through time (when compared to the change created from even-aged management methods) and represents a unique opportunity to restore and then maintain a forest condition in the landscape. However, protecting leave trees during successive harvests and until maturity requires deliberate and careful application of specific cutting and removal techniques when compared to other methods of forest management. Table 3 describes such techniques for reducing damage from harvesting within the forest.

Age, Composition, and Resistance of the Canopy

Successful use of single-tree selection depends on the continual development of all of the age classes present within the forest. The oak-hickory-pine forests in the Ozarks represent one of the oldest natural communities within the region. The biological lifetimes of dominant canopy species range from scarlet oak and black oak at 80 to 100 years, and northern red oak at 90 to 130 years, to shortleaf pine at 200 to 300 years, to white oak exceeding 350 years (Personal communication. Richard P. Guyette, Associate Professor, University of Missouri, School of Natural Resources, Columbia, MO 65211). Runkle (1990) studied the spatial pattern of disturbance in old-growth forests and found the annual rate of canopy gap formation ranged from 0.4 to 0.2 percent for various temperate hardwood forests. Dey and Guyette (2002) estimated from these data that the turnover of the canopy in these forests studied by Runkle would occur in less than 250 years. Similarly, here in the Ozarks, LaVigne (2002), using a life history table, calculated the statistical range of age for the forest canopy on Pioneer Forest between 189 to 228 years. The range LaVigne describes is comparable to a 95-percent confidence interval with single-tree selection harvesting as the only source of mortality for trees that form the canopy. Rather than prescribing an arbitrary canopy rotation, single-tree selection harvesting allows individual species, as well as individual trees, to fully develop and mature within the forest over rather long periods of time, while providing managers the opportunity to utilize potential mortality.

Furthermore, these forests, which are managed using single-tree selection harvesting, seem to provide for a more natural composition of species, indicative of a particular site's capability. Our own sampling data from the Continuous Forest Inventory show that among various canopy species those most characteristic of pre-European settlement conditions are

Table 3—Techniques for reducing damage within the forest

1. Require that the felling and skidding operations work together, beginning at the bottom of a hill and proceeding to the top.
2. Mark each tree to be removed on both its uphill and downhill sides. Mark the uphill side at chest height and mark the backside at the base of the tree. Marking the backside of the tree allows the skidder driver to use marked trees as pivot points when a load needs to be turned, thereby reducing or eliminating damage to higher quality leave trees remaining in the forest.
3. Have sawyers trained in using directional felling. This is the ideal cutting technique for single-tree selection harvests, significantly reducing damage to the residual stand, as well as improving both production and safety. Directional felling reduces damage within the forest, as well as the potential danger from hanging up, as well as fiber pull, and splitting. An especially good overview of these ideas and the technique are found in Maine Employers' Mutual Insurance Company's Production Felling Through Safety (1994).
4. Reuse ridge roads and skid trails for removing logs and for equipment access. Require single lane for skid trails and keep improvements to a minimum.
5. Avoid late winter and early springtime operations while the sap is moving or when roads and skid trails are particularly subject to rutting and erosion. This simple technique will minimize rutting of roads and excessive bark damage on leave trees.

regaining a stronger presence in the canopy. Shortleaf pine and white oak, which were the focus of the earliest cutting in the Ozark Region, have shown a marked increase in the volume of saw log trees per acre (Iffrig and others 2004). White oak, perhaps the most impressive Ozark forest canopy species, has increased slowly, but over the past 25 years has more than doubled in its volume per acre (Iffrig and others 2004).

The nature of periodic entries used during single-tree selection cutting also seems to provide a more favorable environment where competition is substantially and regularly reduced. This is accomplished during each entry, which removes approximately 40 percent of the standing volume and 60 percent of the annual growth. Jenkins (1992), in studying oak decline on this and another forest, suggested that the factor of reduced competition might be advantageous, particularly in situations where mortality affects a particular age or species class. In other words, "at risk trees" are continuously removed from these forests and the variability, which is maintained through this method of management, thereby greatly reduces certain risk factors of catastrophic oak decline and mortality.

CONCLUSION

In addition to researching the many silvicultural aspects of single-tree selection management, there is also a body of other research demonstrating positive conservation, social, and economic influences that have resulted from its use. Over the past 50 years, uneven-aged management and the use of single-tree selection harvesting have proven to work, both as being ecologically and silviculturally appropriate, and as providing a strongly positive forest management application for the central hardwoods region.

ACKNOWLEDGMENTS

Whereas the forest takes its name from its many pioneering efforts, the real pioneer in the story of this forest is its owner, Leo Drey. To him we are grateful to have been able to participate in, work on, study, and write about such a grand experiment. Since 1951, a number of staff members have worked on Pioneer Forest, and each of them has either developed, or assisted in the development, discussion, and continuing refinement of the field prescription we describe herein. To each of them, our thanks.

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PIONEER FOREST: IN THE HEART OF ROUGHNESS

Richard P. Guyette and Michael C. Stambaugh[1]

Abstract—Landscapes in the Ozarks vary greatly with respect to surface topography. Some are very rough and steep, while others are rolling and smooth. Landscape roughness or *topographic roughness* mitigates and slows the movement and propagation of humans, fire, and commerce across the land. The degree of landscape roughness can be quantified as indices of topographic roughness, calculated here as the ratio of the surface of the earth measured with large and small surfaces. Maps of indices of topographic roughness indicate that Pioneer Forest is one of the roughest landscapes in the Ozark Highlands region of Missouri. Topographic roughness insulates forests from many types of human and natural terrestrial disturbances such as wildland fire. Here, we define and calculate topographic roughness and discuss the relevance of topographic roughness to the natural heritage and silvicultural practices of Pioneer Forest.

PROLOGUE

On the road to Mauser Mill one gets a feel for landscape roughness. The road is bumpy and rocky in every sense of the word. Sharp curves and steep short hills slow the rate of travel, accelerate vehicle wear and tear, and turn back the faint and ill-provisioned. Forests on each side of the road drop down out of sight and define a landscape almost intimidating to the social psyche. Here lies Pioneer Forest 'in the heart of roughness'; a landscape that has resisted the pressures of human population and disturbance for millennia.

INTRODUCTION

Some two decades ago at the Missouri Botanical Garden's Ridgeway Center, an exhibit described the art and sciences that use old trees and tree-rings, in particular eastern red cedar (*Juniperus virginiana*). This exhibition was inspired by the many old eastern red cedars of the Leatherwood Creek area located on Pioneer Forest. We thank Leo Drey for the preservation of such wildlands and forests and for the opportunity to work in this great natural library. Research on landscape ecology that is published and stored in the human libraries of the world and partially derived from the tree rings and forests of Pioneer Forest and the Missouri Ozark Forest Ecosystem Project (Guyette and others 2002) is presented in this paper.

Dendrochronology is the technique of using the annual woody growth increments (e.g., tree rings) of trees to date wood, interpret the information contained in the rings, and answer environmental and cultural questions. Crossdating is the crux of dendrochronology and allows for annual precision in the dating of tree rings and injuries from both live trees and long dead wood. The research presented here began with a tree-ring data base of fire scar occurrence from Pioneer Forest, State forestlands, and the Ozark National Scenic Riverways. A landscape analysis of tree rings, wildfire, and topography is used to address the effects of topographic roughness on Pioneer Forest. We show in a quantitative manner why Pioneer Forest is the 'heart of roughness', and how this has affected its forests. This rough landscape has likely slowed the propagation of people, disturbance, and particularly wildland fire for thousands of years. Topographic roughness inhibits many of the most important causes of disturbance to forest canopies.

If forest management objectives include understanding or mimicking processes of past ecosystems, then an analysis of the topographic roughness of this landscape can yield insightful conservation and silvicultural guidelines. The objectives of this research are to define and calculate topographic roughness in and around Pioneer Forest and to discuss the relevance of topographic roughness to the natural heritage and forestry of Pioneer Forest.

METHODS

Topographic roughness is a relative measure of variability in a landscape surface. Irregularities in the landscape influence the propagation and behavior of fire, particularly in the highly dissected landscape of the Current River region (Guyette and others 2002). In highly dissected landscapes, the propagation of low intensity surface fires across hills and valleys is lessened as the spread rate is slowed and as fire moves downslope because preheating of fuels is less than preheating as fires move upslope. In addition, ravines, creeks, and rivers break fuel continuity, and fuel moisture content increases on northern aspects. We used indices of topographic roughness to reflect topographic inhibition of the propagation of fire across the landscape.

Indices of topographic roughness were developed using Geographic Information Systems (GIS) by comparing surface area measurements made with two different sized scales. A circle, 5000 meters in diameter, is identified on a digital elevation model (DEM). The surface area of the earth circumscribed by this circle is calculated using a 30-m cell (i.e., small scale). Cell slope and a trigonometric conversion are used to estimate the area of the uneven land surface. The cell surface areas are summed and used as an estimate of the uneven surface area of the landscape enclosed by the circle. This estimate is divided by the planimetric surface area (i.e., large scale) of a circle that is 5000 meters in diameter. This ratio of the small-scale surface area to the large-scale surface area is the Index of Topographic Roughness. In short, the topographic roughness value of an individual place represents the amount of variability in the landscape surface around that place. We describe the relationship between historic mean fire intervals and their respective topographic roughness indices using correlation analysis.

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RESULTS AND DISCUSSION

Topographic roughness index values are classed and mapped for the region in and around the Current River Hills (Nigh and Schroeder 2003) and Pioneer Forest (fig. 1). Topographic roughness increases from horizontal and rolling landscapes (fig. 1, lighter shaded areas) to rough and steep landscapes (fig. 1, darker shaded areas). Index values range from approximately 1.000 (i.e., perfectly smooth and level) to 1.044 (i.e., rough) in this region.

The topographic roughness map (fig. 1) illustrates that Pioneer Forest is one of the roughest regions in the Current River Hills and located within a topographically rough region, the Ozark Highlands. The topographic roughness of the region is due to the erosion of bedrocks and soils by precipitation and the down cutting of streams and rivers. Complex subsurface geology, such as the near surface Precambrian geology that underlies the Current River Region, can create variable uplifting and fracturing of surface sedimentary rocks. Surface and ground water hydrology may cause variable patterns of erosion and topographic roughness. For example, just southeast of Van Buren (fig. 1) is an area of topographic roughness we termed the "Big Springs butterfly", a pattern in topographic roughness that is underlain by a peak in subsurface Precambrian igneous rock (Kisvarsanyi 1981). Pioneer Forest just south of Mauser's Mill is anomalously topographically rough. This area is underlain by a ring intrusion of granite that may contribute to increased

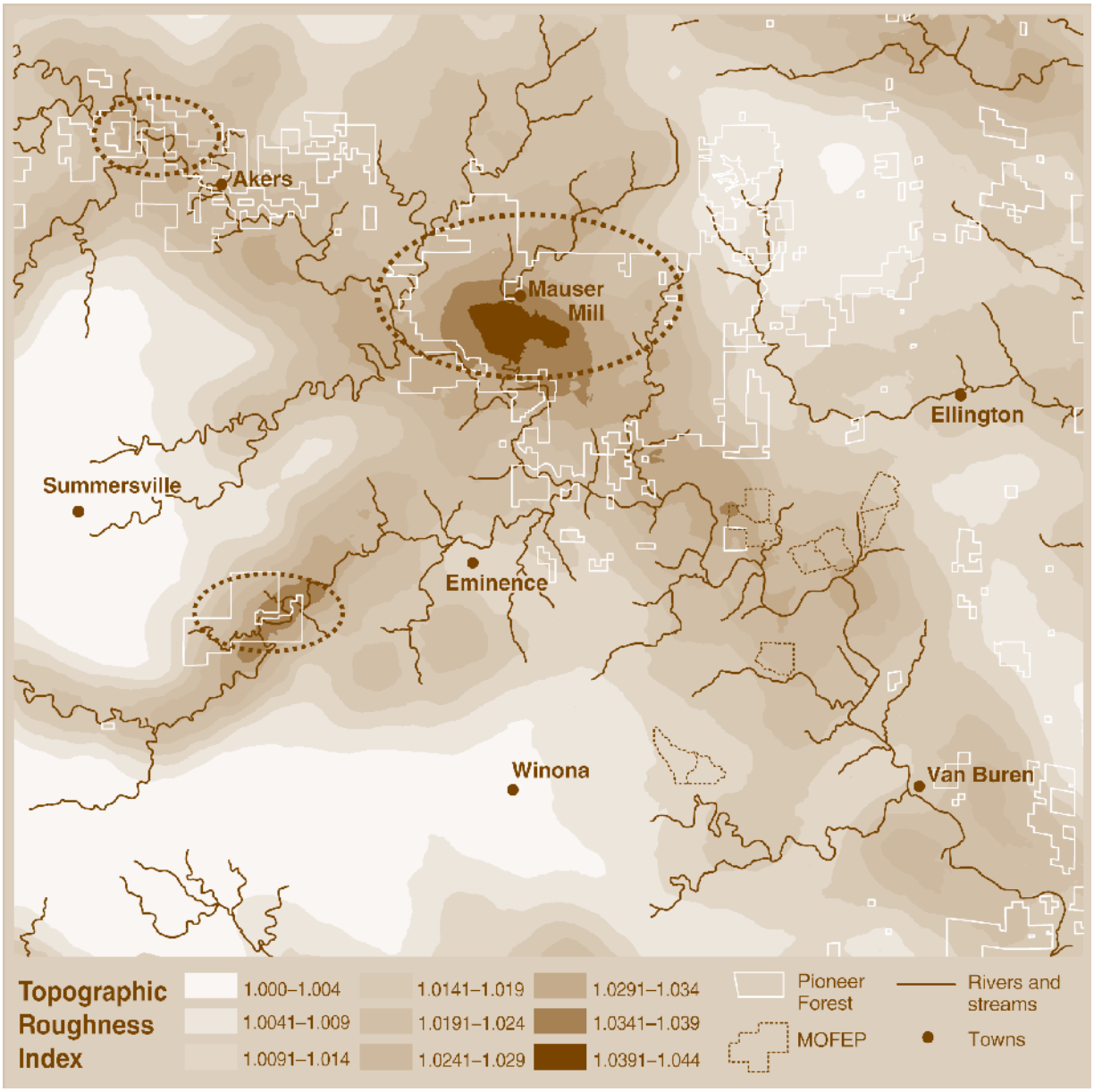

Figure 1—Variation in topographic roughness in the Current River region. The lighter shades represent topographically smooth landscapes, whereas the darker shades represent rough landscapes. The regions of large Pioneer Forest holdings are circled with dashed ellipses and have some of the highest calculated topographic roughness indices values.

topographic roughness. These examples are evidence that riparian erosional processes, surface bedrock, and subsurface geology influence topographic roughness.

Topographic roughness mitigates the rate and movement of fire, vehicles, commerce, and human travel. This mitigation is evident in fire history data (Guyette and Dey 2000) and the speed limits, curvature, surface type, and distribution of roads. Thus, many of the anthropogenic disturbances to the forest canopies are minimized by the reduced fire frequency and access in areas surrounded by landscapes with high topographic roughness. Topographic roughness is likely associated with many biological processes. The association with different variables is both causal and incidental. For instance, topographic roughness may be associated with the slope of a site but has little to do with slope effects on soil hydrology that influence the abundance of certain plants. On the other hand, there are causal relationships, such as the direct effect of topographic roughness on the rate of propagation of surface fires, which are the primary objective of quantifying and mapping topographic roughness. There are also the secondary effects of topographically mitigated disturbance, such as the size of a canopy disturbance, canopy density, and forest structure.

Topographic roughness has been associated with mean fire intervals (Guyette and Dey 2000, Guyette and others 2002). The relationship between topographic roughness and the time between fires was positive, particularly when human population densities were low (Guyette and Dey 2000). Fire scar chronologies within Pioneer Forest have some of the longest mean fire intervals in the Current River region during the period just before Euro-American settlement circa 1820 (Batek 1999). For example, the mean fire interval between 1620 and 1700 for Big Creek (16 years) in the heart of Pioneer Forest is 3 times longer than that of Hartshorn State Forest (5.3 years), a more topographically smooth region to the east. During more recent and more densely populated periods, this difference disappears, and fire intervals at both sites shorten to 2.8 years by the late 1800s.

A portion of Pioneer Forest (fig. 2) was mapped for mean fire intervals (average time between fires in a 1.5-km area) during the period 1700 to 1820. This map was calculated from regression equations that used several thousand fire scars, indices of topographic roughness, fuel quantity, fuel moisture, and human population density (Guyette and others 2003). Modeled mean fire intervals on this part of Pioneer Forest ranged from about 10 to 50 years. These intervals are up to 10

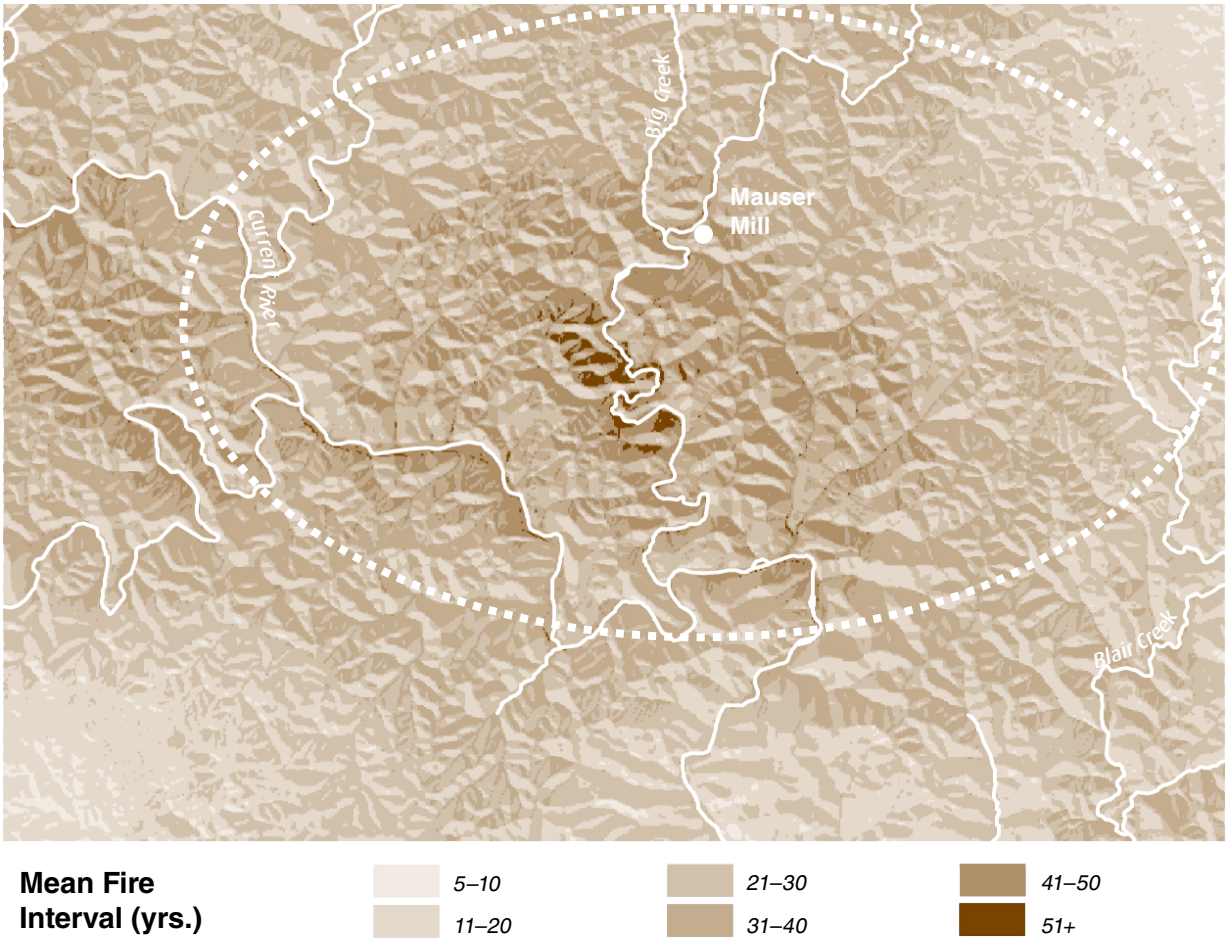

Figure 2—Reconstructed mean fire intervals for part of Pioneer Forest between 1700 and 1780 that are partially modeled with topographic roughness. *(Guyette and others 2003)*

times longer than those calculated for less topographically rough areas of the Ozarks.

The topographic roughness map (fig. 1) shows that Pioneer Forest is in one of the most topographically rough landscapes in the Ozarks. This has several implications for conservation plans and forest management practices given that management goals are designed to mimic the historic disturbance regimes, such as the frequency of fire. Three important points may be considered when comparing forest management to forest disturbance with the disturbances estimated from pre-Euro-American fire frequency and topographic roughness.

1. Fire disturbance was less frequent at Pioneer Forest in comparison to much of the greater Current River Hills region because of the relatively high degree of topographic roughness. This was particularly the case prior to 1820 when the propagation of fire contributed greatly to the fire frequency in a given location. The role of fire in influencing vegetation was reduced, particularly in the Big Creek vicinity of Pioneer Forest, because of the low frequency of fire. A reconstruction of the vegetation in this area from General Land Office Survey notes (1815-1850) showed a dominance of white oak (*Quercus alba*) in a closed canopy forest structure (Batek and others 1999, Hughes and Nigh 2000) relative to many adjacent forests. White oak, which is shade tolerant and fire sensitive, was competitive in this low frequency disturbance regime. Forest management that mimics the historic frequency and size of canopy disturbance would likely maintain a more closed canopy structure. For example, tree harvesting would be limited to small areas where there were single-tree or small group canopy disturbances. The removal of one to several trees from any given area is a management approach already employed by Pioneer Forest's single tree selection practices. The silvicultural practice used on Pioneer Forest mimics the scale of the pre-Euro-American canopy disturbance regime as predicted by corollaries of topographic roughness and as supported by studies at the MOFEP sites (Guyette and Kabrick 2002).

2. Topographic roughness and legacies of its effects likely have long-term influence on forest communities, particularly resident populations of forest interior wildlife. At Pioneer Forest, conservation and temporal continuity of certain indigenous species would be maintained or promoted with small-scale disturbances as they would represent the long-term disturbance frequency related to topographic roughness. Topographic roughness may be positively correlated to forest bird territories in the Ozark region (Guyette and Kabrick 2002).

3. If Pioneer Forest lies in the most topographically rough region of the Ozarks and has the least often disturbed forest canopy and litter layer in the Current River Hills, we would expect to find an abundance of species that are sensitive to disturbance, particularly to fire. This hypothesis has been tested and seems plausible for many ecosystem variables measured at the MOFEP sites (Guyette and Kabrick 2002).

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INVERTEBRATE COMMUNITY STRUCTURE AND FOREST MANAGEMENT IN THE MISSOURI OZARK LANDSCAPE

Gerardo Camilo and Nick San Diego[1]

Abstract—Disturbance is important in the context of ecosystem diversity, but little is known about the effects of forest management on invertebrate insect communities. We estimated arthropod species diversity in terms of species richness, abundance and evenness at several spatial scales under clearcutting, single-tree selection, and preservation management regimes in the Missouri Ozarks. A total of 121 taxonomic groups and 22,000+ arthropods were identified and catalogued. Overall species diversity among treatments was not significant either at the micro-scale or meso-scale level. However, principal components analysis effectively segregated the clearcut community from the other two communities. Results suggest that the type of forest management practiced does significantly affect overall forest and leaf litter arthropod community structure in terms of scale and diversity. The single-tree selection harvest within Pioneer Forest generates a spatial gradient throughout the landscape, creating conditions most suitable for diversity to be maximized.

INTRODUCTION

The current paradigm in ecology is that disturbance plays a critical role in maintaining diversity within ecosystems (Sousa 1979, Pickett and White 1985, Willig and others 1998, Schowalter 2000, Camilo and Zou 2001). Too little disturbance may displace poor competitors whereas too much may create conditions unfavorable for most organisms (Sousa 1979, Runkle 1985, Filser and others 1995, Bengtsson and others 1997). The scale, intensity, and frequency of disturbance, then, contribute greatly to how communities are structured (Willig and others 1998). Less commonly known is how disturbance is transferred into spatial gradients (Wootton 1998). Macroscale studies have illustrated that change in the plant community along environmental gradients also induces change in the composition of the microarthropod community (Hagvar 1982). On a smaller scale, the arthropod community in microclimate conditions is affected by spatial heterogeneity (Poole 1962).

Critical to a forest ecosystem is the role that the invertebrate community plays in the decomposition of organic matter and maintenance of soil structure. It is estimated that up to 90 percent of a forest's net primary production returns to the soil where leaflitter and topsoil faunas aid microbial and fungal decomposers (Swift and others 1979, Coleman and Crossley 1996, Weaver and Heyman 1997). Biological and biochemical energy can be dissipated back into the soil along shorter time scales than by chemical or physical avenues that, via soil formation processes, may take at least 10,000 years. The specific properties of soil invertebrates, as well as environmental factors, determine the rates at which this energy flows through the soil ecosystem (Swift and others 1979, Jenny 1980, Lavelle and others 1995). By studying the ecology of these animals, scientists have come to understand that there are suites of interaction integral to maintaining forest processes (Swift and others 1979, Faber and Verhoef 1991, Ananthakrishnan 1996).

Forested systems are under extreme pressure to be harvested (Annand and Thompson 1997, Herbeck and Larsen 1999, Guyette and Larsen 2000). In western Oregon, the impact of clearcutting has had an effect on the spatial patterns of soil arthropods. Forest stand composition appeared to contribute significantly to the spatial structuring of soil properties and, therefore, invertebrate spatial structuring (Torgersen and others 1995). It is the purpose of this research to analyze how various forest management practices have affected the community composition of leaflitter invertebrates over ecological time. Our working hypothesis is that the type of forest management practiced over recent history has shaped the structure of the leaflitter arthropod communities. Our objectives are to characterize leaflitter invertebrate communities at each site and to determine how changes in scale affect community parameters.

MATERIALS AND METHODS

Study Sites

The Ozark Highlands are characterized by high plateaus, carved by centuries of erosion; spring-fed streams have cut deeply into the plateaus, shaping moderately rolling hills with local relief of 50-150 m, sometimes reaching 300 m. Soil composition ranges from shallow unconsolidated materials over bedrock to very deep, highly weathered soils in hillslope sediments or residuum or both (Kabrick and others 2000). Oak-hickory and oak-shortleaf pine forests and woodlands, oak savannas, bluestem prairies, and glades make up the natural vegetation of the Ozark Highlands. Bottomland and mixed upland hardwood forests reside in large valleys and on adjacent sideslopes whereas the prairies and savannas are situated on gentler slopes (Kabrick and others 2000).

We sampled three forest management regimes in the Missouri Ozarks; preservation (Current River Natural Area, 37°15′N, 91°15′W), single-tree selection (Pioneer Forest, Inc., 37°18′N, 91°23′W), and clearcutting (Reis Biological Station, 37°56′N, 91°10′W), each of which has maintained their respective treatments since the early 1950s.

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Experimental Design

Within each site, three 20- by 20-m (= 400 m^2) plots were demarcated with flags and PVC stakes. Each plot was further subdivided into 16 smaller subplots (5 by 5 m). Forest structure was estimated measuring abiotic parameters, vegetative composition, and understory vegetation profiles. Ambient temperature (°C) and percent relative humidity were recorded at the base of each subplot corner using a digital thermometer. Percent canopy cover, using both convex and concave mirrored densiometers, was also estimated for each point. Within every 5- by 5-m subplot, trees were identified to species and diameter at breast height (d.b.h.) was measured. Foliar volume was measured using a 3-m PVC pole with 0.5-m dowels attached perpendicularly at 0.5-m intervals along the length of the pole. Rotating the pole 360° at each flag, the number of touches made at each height increment was recorded (Secrest and others 1996).

Within each 400-m^2 quadrat, we collected litterbag samples at random from 10 of the 16 subplots. The sampling area in each subplot was approximately 0.25 m by 0.25 m (or .06125 m^2). Within each transect, 20 of the 32 subplots were randomly sampled in the same manner. These leaflitter collections were taken once each summer for 1999 and 2000. Each leaflitter sample was processed through Berlese funnels, a high-gradient extractor (Winter and Voroney 1993), which separates the fauna from the litter. Eventually, the litter desiccated, and the fauna dropped down into a 70- percent ethanol solution. After separation, these specimens were identified and cataloged to at least family. Mites, an ubiquitous group of organisms with up to 50,000 described species (Walter and Proctor 1999), easily qualified as a candidate for morphospecies identification (Camilo and Zou 1999). The concept of "taxonomic sufficiency" identifies organisms to a level of taxonomic resolution adequate enough to satisfy a study's objectives (Ellis 1985). Studies have shown that this concept can be applied to ecological studies of terrestrial invertebrate communities without sacrificing estimates of species diversity or species turnover (Pik and others 1999).

Species Diversity Estimates

Analyzing arthropod species diversity in terms of species richness, abundance, and evenness provides baseline descriptions about community composition. In community order studies, there are two types of information collected: (1) the number of species and (2) the number of individuals in each species. The Shannon-Weiner Index takes into account the proportional abundance of species within a community giving more weight to rarer species (Magurran 1988, Krebs 1989). This function assumes that all species are represented from random samples and measures the uncertainty of correctly predicting the species of the next individual collected (Krebs 1989). Although the experimental design does not randomly distribute subplots throughout the forest stands, the sampling area used (0.0625 m^2) is small enough relative to the landscape that it could be considered random. Information indices such as Shannon-Weiner are widely used because no assumption is made about the underlying species abundance distribution curve (Magurran 1988). Rank abundance curves, on the other hand, plot the proportional abundance against rank of abundance utilizing all the information gathered about the community (Magurran 1988). This provides a more complete picture of species abundance distribution among treatments than using diversity indices alone (Krebs 1989, Stiling 1996). Distribution curves can be likened to one of four main models (log normal distribution, log series, geometric series, broken-stick) with each highlighting a specific pattern of species richness and evenness (Magurran 1988, Stiling 1996).

Ordination Analyses

Ecological data are often multi-dimensional and can be arranged in a matrix (e.g., with species as rows, treatments as columns, and abundance as entries). Because there may be a lot of redundant information (e.g., many species responding to the same environmental gradient), only the most crucial dimensions must be extracted. These techniques can provide diagrammatic expressions of species composition pattern variation as well as the relationship between species and environmental variables (Palmer 1993). Principal Components Analysis (PCA) is an indirect ordination method that is used to order arthropod species and the three forest treatments in successive dimensions without regard to environmental variability (Digby and Kempton 1987).

Canonical Correspondence Analysis (CCA) is a direct ordination technique that was used to directly relate arthropod species composition to the abiotic and vegetation gradients (Palmer 1993). CCA overlays the arthropod data onto the abiotic and vegetation data resulting in a direct ordination of the environmental factors that shape community composition (Digby and Kempton 1987). What is generated, then, is a diagram termed a tri-plot in which the environmental variables that explain most of the variation within treatments are represented by arrows. The length of the vector represents the loading (i.e., how much is the arthropod community responding to the environmental gradient). The direction is the level of correlation, and the thickness is an estimate of the variation (Palmer 1993).

RESULTS

Species Diversity Estimates

A total of 121 taxonomic groups and 22,000+ arthropods were identified and catalogued from 112 out of 120 leaflitter collections (table 1). Overall species diversity among treatments was not significant among logging treatments either at the micro-scale (0.0625 m^2) level or the meso-scale level (1600 m^2; fig. 1). Rank abundance analysis revealed more insight into community structure (fig. 2). The clearcut site had a total of 104 species and followed a log series distribution (R^2 = 0.82). Note, however, that many of these species were rare with low abundances. The preservation site had 81 species and also followed a log series distribution (R^2 = 0.88). The single-tree selection site had a total of 80 species and followed a log normal distribution (R^2 = 0.69), suggesting that the total

Table 1—Taxonomic listing and abundance of leaflitter invertebrates collected from three forest stands under three management regimes in the Missouri Ozarks [a]

Taxonomic classification	Clearcut	Preservation	Selection
Class Arachnida			
Order Aranae			
Dictynidae	4	31	0
Pholcidae	4	1	0
Thomisidae	6	86	41
Clubionidae	115	248	104
Pisauridae	3	0	0
Lycosidae	1	19	1
Salticidae	11	3	7
Pirate spiders	1	0	0
Order Opilionida			
Palpatores sp 1	1	0	0
Order Acari			
Suborder Ixodida	1	0	0
Suborder Prostigmata			
Tetranychidae	4	0	5
Suborder Oribatida			
Oribatid sp 1	296	988	1980
Oribatid sp 2	29	337	833
Oribatid sp 3	3	19	0
Oribatid sp 4	81	244	342
Oribatid sp 5	2	15	3
Oribatid sp 6	13	12	14
Oribatid sp 7	52	224	511
Oribatid sp 8	7	0	4
Oribatid sp 9	2	0	4
Oribatid sp 10	6	22	165
Oribatid sp 11	15	14	75
Oribatid sp 12	23	38	61
Oribatid sp 13	2	2	5
Oribatid sp 14	1	8	18
Oribatid sp 15	0	3	22
Oribatid sp 16	0	0	1
Oribatid sp 17	0	2	7
Oribatid sp 18	1	0	0
Oribatid sp 19	0	8	68
Oribatid sp 20	0	3	68
Oribatid predator sp 1	6	22	17
Oribatid predator sp 2	15	43	299
Oribatid predator sp 3	21	60	3
Oribatid predator sp 4	12	0	12
Oribatid predator sp 5	12	49	59
Oribatid predator sp 6	1	0	12
Oribatid predator sp 7	15	83	121
Oribatid predator sp 8	114	200	313
Oribatid predator sp 9	257	217	342
Oribatid predator sp 10	12	12	75
Oribatid predator sp 11	1	0	2
Oribatid predator sp 12	72	43	20
Oribatid predator sp 13	1	0	0
Oribatid predator sp 14	1	0	0

continued

Table 1—Taxonomic listing and abundance of leaflitter invertebrates collected from three forest stands under three management regimes in the Missouri Ozarks [a] (continued)

Taxonomic classification	Clearcut	Preservation	Selection
Oribatid predator sp 15	6	59	214
Oribatid predator sp 16	5	100	238
Oribatid predator sp 17	1	1	4
Oribatid predator sp 18	14	11	41
Oribatid predator sp 19	0	4	0
Oribatid predator sp 20	0	2	1
Oribatid predator sp 21	0	2	188
Oribatid predator sp 22	0	0	14
Oribatid predator sp 23	0	0	1
Order Pseudoscorpiones			
Morphospecies 1	3	32	0
Morphospecies 2	45	338	206
Morphospecies 3	20	0	25
Class Diplopoda	2	9	4
Class Chilopoda	1	128	76
Class Insecta			
Order Collembola			
Entomobryidae	53	1,239	1,254
Isotomidae	27	690	599
Onychiuridae	22	462	217
Order Orthoptera			
Gryllacrididae			
Raphidophorinae	0	0	3
Order Blattaria	21	1	0
Order Isoptera			
Kalotermidae	16	18	13
Order Psocoptera	397	0	0
Order Hemiptera			
Immature sp 1	1	1	1
Suborder Cimicomorpha			
Tingidae	3	47	26
Reduviidae	10	1	1
Suborder Pentamomorpha			
Lygaeidae	1	2	0
Order Homoptera			
Immature sp 1	3	0	0
Immature sp 2	3	8	2
Immature sp 3	177	8	0
Immature sp 4	5	1	0
Immature sp 5	1	4	4
Suborder Auchenorrhyncha			
Superfamily Cicadoidea			
Cercopidae	1	0	1
Suborder Sternorrhyncha			
Superfamily Aphidoidea			
Aphidae	1	0	0
Phylloxeridae	2	31	0
Superfamily Coccoidea			
Coccoidae	2	0	12

continued

Table 1—Taxonomic listing and abundance of leaflitter invertebrates collected from three forest stands under three management regimes in the Missouri Ozarks [a] (continued)

Taxonomic classification	Clearcut	Preservation	Selection
Order Thysanoptera			
Thysanoptera sp 1	38	0	606
Phlaeothripidae	529	4	0
Order Coleoptera			
Coleoptera immature	112	1	0
Suborder Adephaga			
Carabidae	0	428	0
Suborder Polyphaga			
Superfamily Staphylinoidea			
Staphylinidae	3	6	23
Superfamily Cucujoidea			
Nitidulidae	1	1	27
Byturidae	3	26	17
Superfamily Tenebrionoidea			
Ciidae	3	46	1
Melandryidae	1	0	194
Superfamily Curculionoidea			
Anthribidae	7	23	0
Curculionidae	4	5	0
Scolytidae	10	0	0
Order Diptera			
Diptera immature	30	0	0
Suborder Nematocera			
Infraorder Bibionomorpha			
Superfamily Sciaroidea			
Mycetophilidae	10	148	1
Sciaridae	1	0	1
Cecidomyiidae	2	0	67
Infraorder Culicomorpha			
Superfamily Culicoidea			
Culicidae	1	111	0
Order Trichoptera	12	3	33
Order Lepidoptera			
Lepidoptera immature	44	1	0
Moths	52	0	5
Order Hymenoptera			
Hymenoptera immature	477	0	97
Suborder Apocrita			
Superfamily Ichneumonoidea			
Ichneumoid sp 1	321	2	4
near Eulophidae	52	0	1
Superfamily Chalcidoidea			
Chalcidoidea sp 1	2	1	0
Chalcidoidea sp 2	1	0	0
Chalcidoidea sp 3	1	0	8
Chalcidoidea sp 4	2	0	0
Chalcidoidea sp 5	0	4	0
Chalcidoidea sp 6	1	1	0
Chalcidoidea sp 7	1	0	0
Encyrtidae	7	0	0

continued

Table 1—Taxonomic listing and abundance of leaflitter invertebrates collected from three forest stands under three management regimes in the Missouri Ozarks [a] (continued)

Taxonomic classification	Clearcut	Preservation	Selection
Torymidae	7	147	1
Pteromalidae	20	57	0
Superfamily Formicoidea			
Formicidae			
Aphenogaster	31	4	0
Crematogaster	1	0	60
Iridomyrmex	2	6	0
near *Iridomyrmex*	0	33	0
near *Forelius*	0	0	44
Procertium	0	0	1
Prinopelta	0	27	0

[a] Forty (0.0625 m^2) samples were collected from each study site and processed via Berlese funnel extraction. Specimens were counted and identified to at least family.

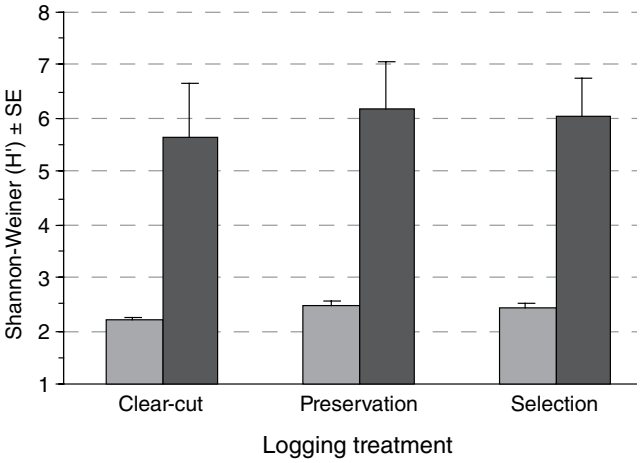

Figure 1—Leaflitter arthropod diversity of three forest management regimes in the Missouri Ozarks.

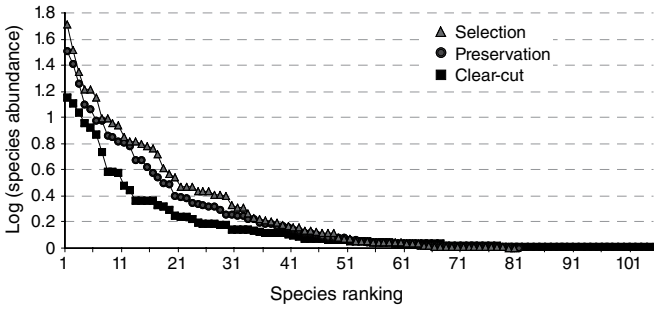

Figure 2—Rank abundance curve of arthropod species abundance for three forest management regimes in the Missouri Ozarks (1999).

number of species was large and that the community was well established (May 1975, Magurran 1988).

Arthropod Community Structure

Principal components analysis effectively segregated the clearcut community from the other two communities along two principal components (fig. 3). Based on a loading of three Oribatid morphospecies and three families of Collembola, 42.4 percent of the variability was explained along the first principal component and 11.5 percent was explained by the second component. However, no clear separation could be made between the single-tree selection and preservation communities along either of these axes.

CCA revealed that percent relative humidity was the most important environmental gradient in the clearcut to which the arthropod communities were responding (fig. 4). Foliar density at 0.5 m and 1.0 m was the most important gradient within the preservation treatment. For the single-tree selection, wood volume (i.e., diameter at breast height) was the most important environmental gradient.

DISCUSSION

Many studies have focused on the effects of disturbance on forest arthropod communities (Swift and others 1979, Schowalter 1985, Torgersen and others 1995, Greenberg and McGrane 1996, Bengtsson and others 1997, Camilo and Zou 2001). This study assumed that three different logging practices would generate three specific forest structures, thereby creating spatial heterogeneity gradients to which species communities would respond over ecological time. Results suggest that the type of forest management practiced does significantly affect overall forest and leaflitter arthropod community structure in terms of scale and diversity.

The invertebrate community analyses suggest that communities are significantly affected by the type of forest management practiced (figs. 2, 3, and 4). The purpose of this study was to look at overall community structure. Therefore, all organisms were counted and sorted. Trying to visualize what factors explain most of the variability within community ecology data sets is a daunting task (Digby and Kempton 1987, Palmer 1993). The use of ordination techniques was especially helpful in assessing how the environmental gradients and arthropod communities could be segregated by treatment and uncovering how they relate to each other. This lends itself to ask the question, "What else could be responding to these treatments?" Principal component analysis (fig. 3) sorted through an extensive data set (of richness and abundance) and determined which taxa explain most of the variability within the data set. Because this is an indirect ordination method, the relationship between species distribution and the underlying environmental gradients is not determined (Digby and Kempton 1987). CCA superimposed the arthropod data on top of the environmental data. By performing a direct gradient analysis we were able to generate a clear separation of arthropod communities and identify the most important environmental gradients to which they were responding (fig. 4).

Given these results, it seems evident that the single-tree selection and harvest within Pioneer Forest generates a spatial gradient throughout the landscape creating conditions most suitable for diversity to be maximized. Research by Iffrig and others (2004) concluded that over a 30-year period, six of seven species groups have maintained their relative proportions within the 486 (0.2 acre) permanent research plots. A study on songbird populations in the Missouri Ozarks also suggests that this type of management treatment can contribute greatly to species abundance (Annand and Thompson 1997).

This research has provided some baseline data upon which several interesting hypotheses may be tested. The scaling results suggest that the plots could be expanded in all directions to see if bigger "window sizes" will detect spatial patterns at greater scale levels. Conversely, subplots could be further divided (i.e., increase the spatial resolution) to determine if indeed the critical window size transitions around the 5- by 5-m grid level. Specific guilds or functional groups of arthropods could be studied on a more detailed level with questions relating to emergence, trophic levels, or species turnover. Litter quality and decomposition is yet another aspect to be examined. Studies have shown that nutrient cycling is highly influenced by litter inputs to the soil (Blair 1988, Blair and Crossley 1988).

Recent advances in spatial ecology have demonstrated that scale is critical to detecting and interpreting ecological patterns (Gardner 1998). Scale is crucial to analyzing community stability and persistence (Rahel 1990) and may have significant implications when it comes to sampling and conservation strategies (Milne 1992). Any efforts to preserve biodiversity must have an ecosystem level approach (Franklin 1993). Forested systems are no exception (Lertzman and Fall 1998). This study has shown that the scale at which forest management took place had significant effects on both overall forest structure and the leaflitter arthropod communities in the Missouri Ozarks. Management and research entities must work interactively to achieve conservation objectives (Hobbs 1998).

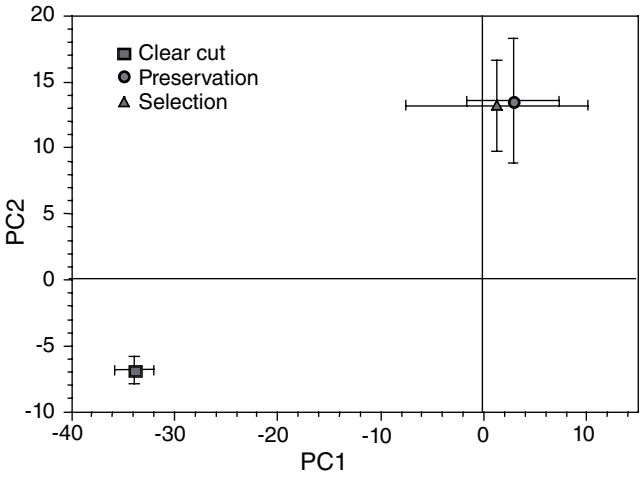

Figure 3—Principal Components (PC) analysis of arthropod species and abundance for three forest management regimes in the Missouri Ozarks.

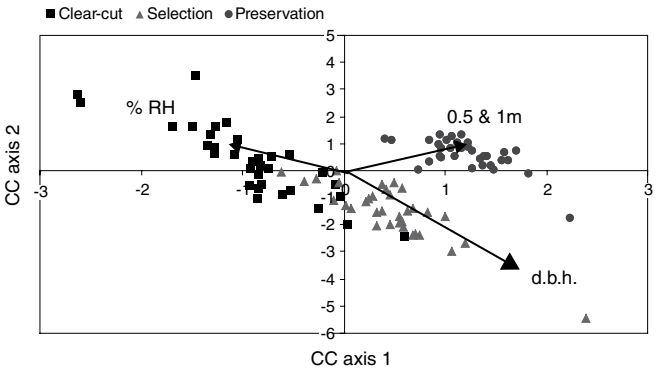

Figure 4—Canonical Correspondence Analysis (CCA) of arthropod data and forest structure variables for three forest management regimes in the Missouri Ozarks. Arrows represent the main abiotic gradient that explains the greatest amount of variation within a community.

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ECONOMIC & SOCIAL VALUES

Roger Pryor Pioneer Backcountry overlooking the Current River at Bee Bluff.
(Photo by Bob Gestel)

AN ANALYSIS OF THE BENEFITS AND PROFITS OF SINGLE-TREE SELECTION SILVICULTURE: A CASE STUDY OF PIONEER FOREST IN MISSOURI'S OZARKS

Makoto Hamatani and Katherine M. Goslee[1]

Abstract—The profitability of single-tree selection is analyzed using Pioneer Forest as a case study. Uneven-aged management has resulted in an increase in standing volume over time, but stands have not yet attained their maximum volume. The 2000 asset value in real terms is three times higher than in 1980 and nine times higher than in 1960 due to an increase in volume per acre and a real increase in stumpage price. Whereas there are both advantages and disadvantages to uneven-aged management, particularly for small, nonindustrial private forest landowners, it is clear that single-tree selection is profitable for landowners, and may even compete financially with even-aged management. Ultimately, the combination of ecological benefits, continuous forest cover, and economic incentives make single-tree selection a valuable tool.

INTRODUCTION

Pioneer Forest is a 154,000-acre privately owned forest, established in 1951. These woodlands are located in Missouri's Ozark region, within the Jack's Fork, Current, and Black River watersheds, and have a canopy dominated by oak, hickory, and pine. Pioneer Forest, under the ownership of the L-A-D Foundation, is the largest private landbase in Missouri. The forest is a working landscape, managed for timber, as well as many other purposes, including preservation of unique features in natural areas and forest reserves, watershed protection, and recreational activities such as hunting, fishing, camping, and hiking. Forest staff also use the forest as a model for other private timberland owners.

Since its establishment, Pioneer Forest has been under a method of uneven-aged management called single-tree selection. Uneven-aged forests contain trees in all age and size classes, with at least three age classes present on any given acre. Each harvest removes some of the financially mature trees and thins other trees from the forest structure. With each entry, only 40 percent of standing volume may be harvested, which allows the forest to maintain continuous forest cover of a variety of tree species over multiple generations. The residual trees are generally healthier than harvested trees and have increased space, light, water, and nutrition available for growth. Using these methods, any given area of the forest may be harvested approximately every 20 years.[2]

The purpose of this paper is to examine the profitability of single-tree selection using Pioneer Forest as a case study. First, the biological effects of Pioneer Forest's management over the last 50 years are described, including change in volume and tree growth on the forest. Next, the resulting asset value, sales, and profitability of Pioneer Forest are addressed, along with the economic potential for single-tree selection on private land in general. Finally, uneven-aged management and even-aged management are compared and advantages and drawbacks of uneven-aged management for small landowners are discussed in this paper.

CHANGE IN VOLUME OF STANDING TREES

Since 1952, Pioneer Forest has carried out a Continuous Forest Inventory (CFI), measuring and recording tree species, diameter, height, health/vigor, volume, and quality of standing trees every 5 years.[3] There are 486 2/10-acre permanent plots in which all trees 5 inches in diameter and greater at breast height (d.b.h.) are measured. For the past three inventories, all trees 1.6 inches to 5.0 inches in d.b.h. also have been measured in order to provide a better indication of the size and species composition of regeneration. Through single-tree selection, the volume of standing trees has been increasing over time. The annual rate of increase in standing volume was an average of about 2 percent through 1987 (aside from the period between 1972 and 1977). Since 1987, volume has been increasing at a rate of nearly 4 percent per year (fig. 1). Due to these increases, current volume of standing trees is more than three times higher than when Leo Drey acquired the land. Volume reached 3,680 board feet per acre in 2002 from 1,128 board feet per acre in 1952. Uneven-aged management at Pioneer Forest has resulted in an increase in standing volume over time, and ultimately the forest will reach its potential maximum volume. This increase in standing volume is due partly to the reallocation of resources to healthy trees by focused cutting on poor quality trees. However, based on the trend of a continued increase in standing volume, the forests on Pioneer Forest have not yet reached their maximum volume and may continue to increase for some time into the future.

[1] Makoto Hamatani, Graduate Student, Nicholas School of the Environment and Earth Sciences, Duke University, Durham, NC; Katherine M. Goslee, Director, Appalachian Voices, Boone, NC, now with the U.S. Forest Service, Cooperative Forestry, Washington, DC.

[2] Over the more than 50-year existence of Pioneer Forest, it has been determined that 20-25 years is the best rotation period. This interval allows maximum growth and minimum mortality, resulting in an increase in standing volume. It is important to note that rotation is determined by climatic and topographic conditions and will vary in different environments.

[3] Volume of trees is measured in board feet, the volume of wood in a board 1-inch thick by 1-foot wide by 1-foot long. (MBF = 1,000 board feet.) Size of trees refers to diameter at breast height (d.b.h.), which is the diameter of the tree trunk 4.5 feet above the tree base.

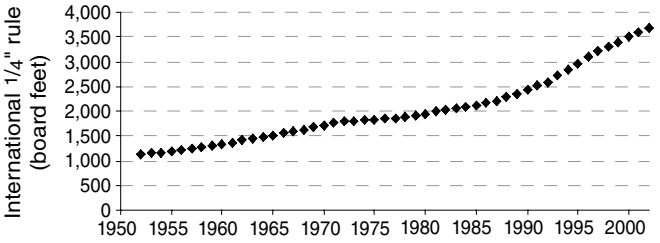

Figure 1—Change in volume of standing trees per acre.

TREE GROWTH

Annual increment is the net annual increase in volume of standing trees per acre after mortality and sales are taken into account. Average annual tree growth is the gross increase in volume and is calculated by adding annual increment and the volume harvested for timber sales. Figure 2 shows average annual increment of standing volume, sales proportion, and annual tree growth. Because volume is measured every 5 years, the rate of annual increment appears to be stable. However, the ratio of sales to total volume fluctuated substantially every year until the 1990s.[4] It is important to note that growth rate is likely to be stable, whereas annual increment is actually likely to change every year, although the average of each of these rates should be very close to the actual rate.

The ratio of sales to total volume fluctuated until the middle of the 1980s, and has since been decreasing, as seen in figure 2. Whereas sales volume has remained relatively constant over time, total volume has risen incrementally until reaching a relatively stable level. Average annual net volume of standing trees has remained higher over the last decade because the ratio of sales to total volume has decreased. Prior to 1985, sales averaged 2.4 percent of total volume, tree growth rate was 4.3 percent, and net growth was nearly 2 percent. After 1985, sales averaged 1.5 percent of total volume, growth rate was 5.1 percent, and net growth was 3.6 percent.

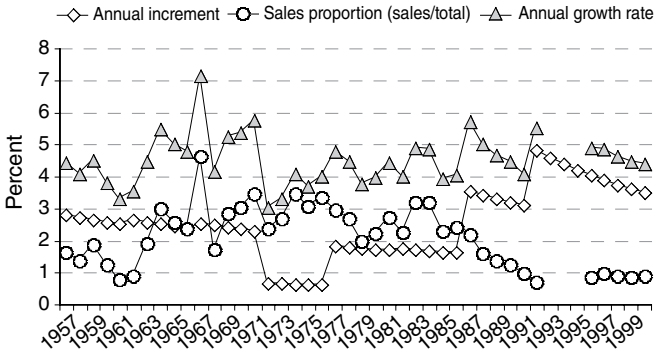

Figure 2—Timber sales relative to tree growth rate.

Whereas growth rate has not changed very much over time (3 percent to 7 percent), annual growth in volume has increased yearly. As shown in table 1, the annual increase in volume of standing trees in 1957 was only 54.4 board feet per acre. Over the past 50 years, annual volume increase has become 2.5 times as high as that of 1957, based on an average growth rate of 4.4 percent. Continuous uneven-aged management improves the quality of forests and has led to an increase in annual growth every year thus far. However, it is unclear how long this trend will continue, and it is necessary to continue to analyze results from the forest inventory in order to pinpoint the maximum annual growth on Pioneer Forest.

CHANGE IN VOLUME PER ACRE BY DIAMETER CLASS

Figure 3 shows increases in volume per acre for all measured diameter classes; the highest increase in volume is seen in trees with a diameter between 11 and 16 inches.[5] The volume of trees with a diameter greater than 21 inches increased by less than 100 board feet per acre for 45 years. This is due to the fact that it takes larger diameter trees more time to grow,

Table 1—Annual volume increase

Year	Annual increase
	bd ft/acre
1957	54.4
1962	62.0
1967	70.2
1972	79.1
1977	81.6
1982	89.1
1987	96.8
1992	113.9
1997	141.3
2002 [a]	134.76

[a] The slight drop in annual increase for 2002 is attributed to mortality from drought.

[4] Because of the different intervals of sampling data and heavy harvesting in terms of ratio of sales volume on total volume, the data in the early 1950s are eliminated to avoid distortion of the average growth rate. Also from 1993 to 1995, sales data is not available; the tree growth in the 3 years is not calculated.

[5] For hardwood species in Missouri timber markets, merchantable size is 11-inch d.b.h.; for softwood species, merchantable size is 9-inch d.b.h.

and harvesting only a few of these trees as they reach financial maturity greatly affects that particular class average. In addition, the number of trees per acre decreases with increasing size, explaining much of the variability in the larger diameter classes because fewer trees sampled leads to a higher variation in statistical results. Despite the slower increases in volume of larger trees, it is clear that in all diameter classes, there has been an increase in volume over the past 50 years (fig. 4). Additionally, figure 5 shows the percentage of volume per acre by diameter class, indicating that 11- to 16 -inch diameter trees have comprised a significant and stable proportion of total volume over time.

CHANGE IN ASSET VALUE

The relative value of the standing trees per acre on Pioneer Forest has been increasing steadily over the past 50 years. As seen in figure 6, these values slowly changed until the 1980s, when the relative value of standing volume per acre began increasing dramatically. The circles represent actual or nominal value, and the squares represent the relative value adjusted

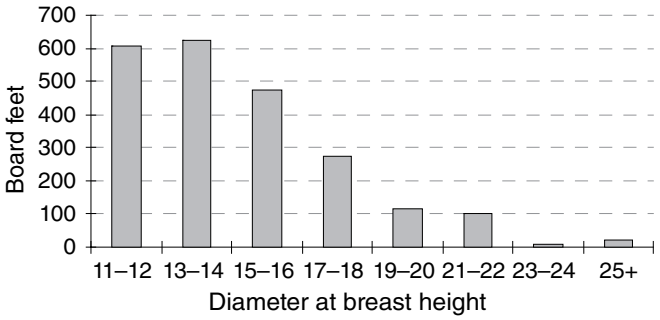

Figure 3—Increase in volume per acre by diameter class from 1952 to 2002.

for inflation.[6] The 2000 asset value in real terms is three times higher than in 1980 and nine times higher than in 1960. There are two reasons for this increase in the value: an increase in volume per acre as previously described and an increase in timber price.

Though there have been some fluctuations, overall stumpage price has been rising since 1970. The current price for stumpage is 4.3 times higher than that of 1970. In figure 7, the lower line and the upper line represent nominal and real prices of stumpage from Pioneer Forest, respectively.[7] Until 1970, an increase in timber price was lower than inflation, which indicates that price of timber in real terms decreased.

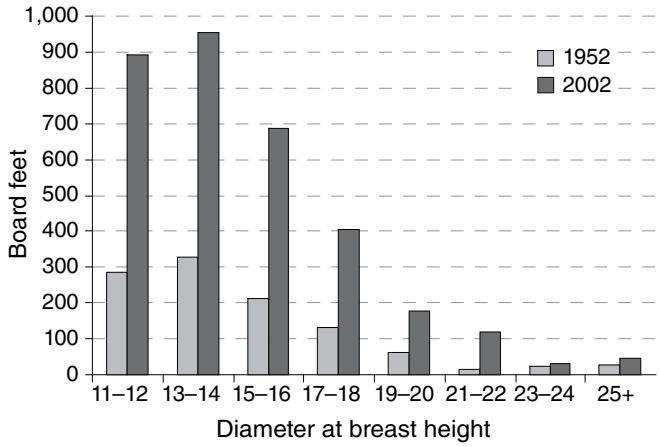

Figure 4—Distribution by diameter class in 1952 and 2002.

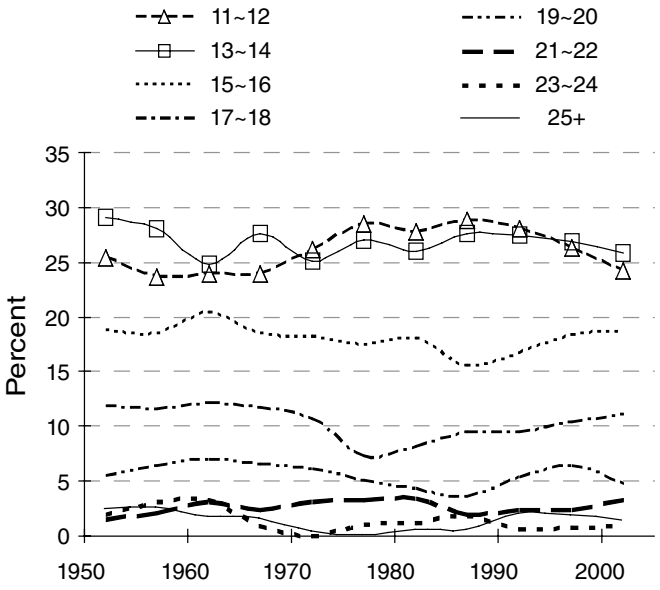

Figure 5—Percentage of volume by diameter class.

Since there have been simultaneous large increases in both price and standing volume per acre for the last 30 years, the value of standing trees has risen significantly. In 2001, Pioneer Forest had 2.47 times more volume at 4.3 times higher price than in 1972. This results in an average value per acre approximately 9 times higher in 2001 than in 1972.

[6] In this paper, the base of real term is the price in 2002. Real term value allows for a comparison of prices over time, as the value of the dollar changes.

[7] The prices in the graph are not average prices in this region; prices for Pioneer Forest are set higher than average prices in almost any year. The trend of average price in this area must be very similar to that in the graph. There are many related price determinants such as timber supply, quality of timber, and market power.

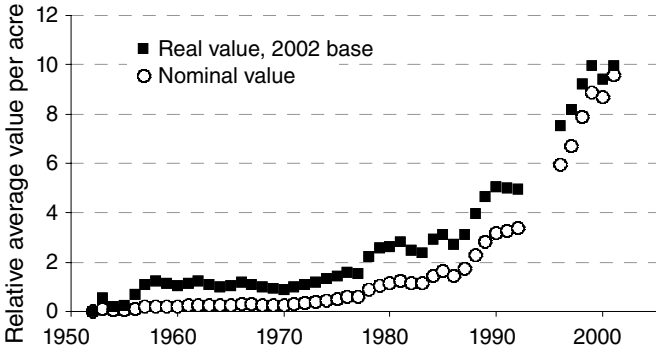

Figure 6—Value of standing trees.

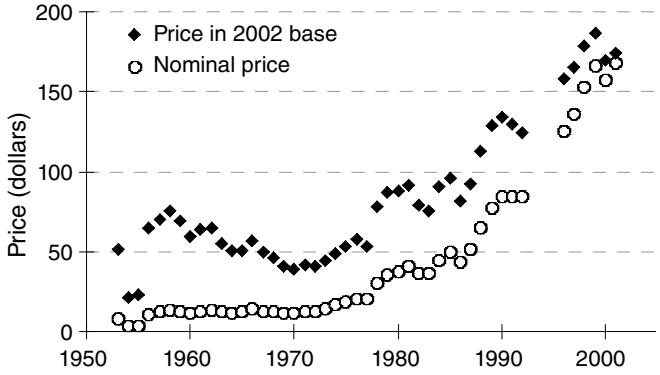

Figure 7—Price trends for stumpage from Pioneer Forest.

There are a number of factors that can impact asset value. Purchasing land has an effect on total asset value, and Pioneer Forest has purchased a large amount of land. However, over the past 30 years, the contribution of acquisition to the change in asset value is not significant. Timber grade also has an effect on asset value; the range of veneer timber price is from 3 times to 10 times as high as that of saw log price.[8] Assuming that the veneer price in this region of Missouri is just $600 per thousand board feet (MBF), and 1 percent of the standing volume of Pioneer Forest is classified as veneer-quality timber, the total asset value including veneer-quality logs is 30 percent higher than the value in the graph.[9] However, it is often difficult to separate veneer-quality timber from saw logs, and this distinction is not generally made in timber sales. A final consideration is the inherent flaw in the concept of asset value, which is a hypothetical figure that cannot be accurately assessed until assets are actually sold.

SINGLE-TREE SELECTION AND MARKET COMPETITION

In order to understand the economic benefits of single-tree selection, it is necessary to know how much timber per acre has been harvested from Pioneer Forest and the level of earnings from harvests over time. Since 1952, Pioneer Forest has made two or three entries into each harvest unit of their land,[10] although the intervals for entry differ depending on site conditions. This difference does not affect the number of board feet per acre that has been harvested, but it does affect profit because the same price in different years has different purchasing power due to inflation. Using actual data since 1952, adjusted to a 2002 base price, the average per acre volume of harvested timber and average sales per acre for 50 years are 2,708 board feet and $238.85, respectively.

Based on the average volume of timber sold and the average profit over a 50-year period, the price of timber per MBF at a 2002 base is $87. Compared to the current saw log price, this price is quite small. However, an advantage of uneven-aged management is that selling timber in several different market periods significantly reduces market risk to the landowner by making it possible to avoid selling all of the timber at the lowest price. By selling timber regularly, expected sales price is closer to actual average price, and variance of sales, the range of money you can earn from one sale, is less than it would be from fewer timber sales. Selling most of the timber in the 1950s would have led to lost opportunity for higher incomes because of high prices over the last 20 years. However, the range in price of saw logs was from $20 to $170 (2002 base), indicating that by selling timber regularly, Pioneer Forest avoided selling significant volumes of timber at a lower price. Uneven-aged management has proven to be an excellent method of avoiding market risk because landowners can harvest multiple times, thus avoiding risks of price fluctuation over time.

MANAGEMENT COSTS AND PROFITS

Table 2 shows incomes and expenses from 1996 to 2001. The figures cited do not include certain sale expenses such as miscellaneous and consulting fees; rather, most are sales from saw log timber.[11]

Over the last 6 years, Pioneer Forest has netted profit constantly at an average of 57 percent of the total expenses. The largest portion of annual expenses is labor-related, which accounts for 70 percent to 80 percent of the annual costs. The second largest cost is taxes, with property tax the highest, at 10 to 20 percent of the annual costs.

[8] http://www.conservation.state.mo.us/forest/products/prices/, Missouri Timber Price Trends-Quarterly Market Report Index, Missouri Department of Conservation.

[9] [(Asset Value in 2001)*99 percent +(Asset Value in 2001)*0.1 percent/(Real Price in 2001)*(Price of Veneer=600)]/(Asset Value in 2001) nearly equal to 1.3.

[10] As mentioned previously, Pioneer Forest does not harvest timber from all of their land but manages some areas as old growth or for their unique ecological characteristics.

[11] Since no compatible data exists earlier than 1995, the ratio of incomes on expenses until 1996 is not clear.

Table 2— Incomes and expenses of Pioneer Forest

Year	Nominal		Ratio (incomes: expenses)
	Incomes	Expenses	
	- - - - - - *dollars* - - - - - -		
1996	499,391.19	360,873.43	1.38
1997	651,860.91	393,089.17	1.66
1998	700,890.23	398,466.46	1.76
1999	766,041.26	456,050.14	1.68
2000	784,299.67	470,014.35	1.67
2001	645,897.21	490,205.54	1.32
2002	731,525.75	490,878.21	1.49
Average			1.57

FINANCIAL CONSIDERATIONS FOR SMALL LANDHOLDINGS

Having developed an understanding of the methods, benefits, and drawbacks of single-tree selection on Pioneer Forest, it is possible to draw some inferences about the economic potential for single-tree selection in general, and particularly on private land. There are a number of components to consider in the differences between a large landholding such as Pioneer Forest and smaller private landholdings that do not employ full-time foresters. First, it is important to note that because of overhead costs, it is not always economically feasible for a logger to enter a small acreage; whereas there are possible solutions to this problem, namely landowner cooperatives, they are beyond the scope of this paper. Additionally, because most landowners do not employ or need to employ a full time forester, the associated costs include fees charged by consulting foresters.

The charges that a landowner will incur from a forester usually include a flat rate for a stewardship management plan, a per-hour fee for appraisal, boundary marking, and other nonsale services, and a percentage of any timber sale. These fees approximate the costs to Pioneer Forest, which average approximately 12 percent of income and will account for fixed costs and salary, which will not need to be calculated separately. Based on this, it is possible to estimate the potential income for an individual private landowner using the approximate per-acre per-year income earned by Pioneer Forest, which was $4 for the past 25 years. This means that if a landowner harvests 40 acres on a 20-year cycle, each harvest will gross $3,200. This is likely to be an underestimate since it is based on the entirety of Pioneer Forest's acreage although not all of their land is harvested. One potential source of additional income from forestland that is not addressed is nontimber products. Individual private landowners might consider such activities as annual hunting leases, growing other commodities such as mushrooms or, depending on the size and location of the forest, ecotourism.

In addition to costs, landowners face a number of obstacles when managing their forests using single-tree selection. The most noteworthy of these is the difficulty of finding a forester who is knowledgeable about single-tree selection and a logger who is willing to harvest in this manner. However, it is possible to ask a forester for references from previous clients and to look into the types of management he or she has utilized. Additionally, consulting foresters work directly for landowners, not logging companies, and are typically able to find an appropriate logger and manage the sale to ensure that all recommendations are followed.

COMPARISON OF UNEVEN-AGED MANAGEMENT WITH EVEN-AGED MANAGEMENT[12]

To determine whether uneven-aged management is economically competitive with even-aged management, it is necessary to determine the volume of harvested trees. Assuming that approximately 6,000 board feet per acre can be harvested out of one clearcut, what volume of standing trees per acre is required to harvest an equal amount from uneven-aged forests?[13] The clearcut rotation in the Missouri Ozarks is estimated as roughly 80 years for oaks, although no forested tract in Missouri has been regrown through that suggested rotation period, and it may possibly be longer. However, during that period, uneven-aged management allows Pioneer Forest to harvest 40 percent of total volume at four different periods.

The CFI data reveal that on the whole, the harvests on Pioneer Forest compare quite favorably to those of even-aged management. On average, about 2,700 board feet per acre have been harvested, and, at this rate, it is possible to harvest 4,333 board feet per acre over 80 years[14] while still retaining an average standing volume of 3,700 board feet per acre. The last 50 years have been, in part, a transition period, during which time the volume of standing trees has been increasing. However, if all of the trees on Pioneer Forest were cut now,

[12] This comparison is hypothetical because Pioneer Forest has no areas managed using even-aged management. However, another study offers a direct comparison of low-impact methods and clearcutting methods. A 45-year study undertaken in New Brunswick by the New Brunswick Federation of Woodlot Owners and the University of New Brunswick compared three similar stands, two managed using low-impact, selection forestry and the other managed through clearcutting (http://www.lowimpactforestry.com/doesitpay/study2.htm). The results show that low impact forestry provided an average of 74 hours per acre of employment, whereas clearcutting provided 35 hours per acre. The sites managed using selection forestry yielded an average of 35 cords per acre, and the clearcut sites yielded 22 cords per acre. The total stumpage value, in 1996 dollars, averaged $1,350 per acre from the low-impact site and $550 per acre from the clearcut site. In addition, the site managed using low-impact methods had twice the standing volume of the clearcut site when the study was published in 1996, with a wood of higher value, red spruce, than the clearcut site, poplar.

[13] Clinton E. Trammel, Personal Communication, 1310 Hillview Drive, Rolla, MO 65401

[14] 4,333 board feet per acre is calculated simply by multiplying 2,708 by 1.6 (80 years/50 years). The amount of harvest for the 80 years will exceed 4,333, because volume of standing volume now is higher than 2,708 board feet per acre.

the harvest would be 6,400 board feet for 50 years; the volume of timber that has been produced for 50 years, on average, is 5,270 board feet. In an 80-year rotation, 8,480 board feet would be produced assuming that the volume of standing trees increased at the same rate. If the volume of standing trees does not increase, a conservative estimate, the amount of harvested trees will be 2,700 board feet multiplied by 80/50 years. The volume produced would be 6,920 board feet; therefore, even the conservative case is competitive with even-aged management. Another important consideration is that when a landowner clearcuts, land costs have to be carried 60 to 80 years with little or no revenue from that land.

The principal economic advantages of uneven-aged management, compared to even-aged management, are (1) financial diversification, (2) annual value added, (3) constant income, (4) continuous forest cover, and (5) a long-standing relationship with sawmills. As explained through this paper, uneven-aged management enables diversification in two ways. One is diversification by more sales opportunities, and the other is diversification by holding several different investments. This combination allows landowners to be exposed to less risk. Second, as shown previously in table 2, annual growth of standing volume on Pioneer Forest has increased under uneven-aged management, and annual average volume growth per acre is 106 board feet for 50 years compared to 75 board feet under even-aged management.[15] This shows that the value added annually for uneven-aged management is greater than that of even-aged management. Of course, these numbers are averages, and trees do not grow at the same rate all the time, although overall, if landowners keep forest in uneven-aged management and even-aged management for the same period, forests in uneven-aged management produce more timber.

Third, uneven-aged management provides landowners with an income from their land every 20 years rather than once every 80 years. Consider a hypothetical example of two identical sites; one is managed using even-aged management, the other using uneven-aged management. On both sites, 6,000 board feet can be harvested for 80 years, and the price of timber is constant at $170 (real) per MBF. Table 3 shows the schedule of harvests. Based on both stumpage values and nominal values, uneven-aged management yields a higher profit than even-aged management over the duration of the 80-year cycle. In the case of high inflation or an increase in expected timber price, nominal values for uneven-aged management would be even higher. How the cash flow is ranked depends on individual preference, and some prefer the constant cash flow and value provided by uneven-aged management. Additionally, the maximum yield for uneven-aged management on Pioneer Forest has not yet been determined. Furthermore, in uneven-aged forests, multiple uses such as hunting, camping, and hiking are continuously possible, and landowners may derive some income from these activities.

Finally, since there are more opportunities to sell timber using uneven-aged management, it could be possible to have long-term relationships with sawmills. These relationships help to establish trust between landowners and sawmills because they offer a more continuous timber transaction for both the buyer as well as the seller. Actually, Pioneer Forest has such long-term relationships with sawmills extending over generations of mill owners, which helps the business of Pioneer Forest to run smoothly.

CONCLUSION

It is clear that there are both advantages and disadvantages to uneven-aged management, particularly for small, nonindustrial private forest landowners. However, it is also clear that single-tree selection is profitable for landowners and may even compete financially with even-aged management. Whereas the economic aspects of uneven-aged management are primarily addressed in this paper, there are numerous ecological factors that should be considered for a complete comparison to even-aged management. Ultimately, the combination of ecological benefits, continuous forest cover, and economic incentives make single-tree selection a valuable tool.

[15] [2,600(an increase in standing trees per acre)+2,700(average harvest per acre)]/50 years=106.

Table 3—Investment value of even-aged and uneven-aged management

Year		Tract 1—Even-aged management			Tract 2—Uneven-aged management		
		Volume/acre	Stumpage	Nominal	Volume/acre	Stumpage	Nominal
			- - - - - *dollars* - - - - -			- - - - - *dollars* - - - - -	
0	Original volume	6,000 bd ft			6,000 bd ft		
	Harvest, [a] bd ft	6,000 @$6/mbf	36.00	343.61	2,900 [b] @$6/mbf	17.40	166.06
	Retained volume	0			3,100		
	Bd ft growth	0			2,900 [c]		
20	Volume, bd ft	0			6,000		
	Harvest, bd ft	0			2,900 @$6/mbf	17.40	201.32
	Retained volume	0			3,100		
	Bd ft growth	800			2,900		
40	Volume, bd ft	800			6,000		
	Harvest, bd ft	0			2,900 @11/mbf	31.90	181.64
	Retained volume	800			3,100		
	Bd ft growth	1,000			2,900		
60	Volume, bd ft	1,800			6,000		
	Harvest, bd ft	800 @ $72/mbf	57.60	107.74	2,900 @$57/mbf	165.30	309.20
	Retained volume	1,000			3,100		
	Bd ft growth	2,000			2,900		
70	Volume, bd ft	3,000					
	Harvest, bd ft	1,000 @$100/mbf	100	124.87			
	Retained volume	2,000					
	Bd ft growth	2,900					
79	Volume, bd ft	4,900			6,000		
	Harvest, bd ft						
	Retained volume	4,900			6,000		
	Volume	4,900 @$170/mbf	833.00	833.00	6,000@$170/mbf	1,020.00	1,020.00
Total harvested volume		7,800			11,600		
Total residual volume		4,900			6,000		
Total volume		12,700			17,600		
Total value of harvested and remaining volume			1,026.60			1,252.00	
Nominal dollars reinvested using CPI [d]				1,409.22			1,878.22

[a] Harvests begin immediately and assume 80 year investment.

[b] Harvest no more than the annual growth.

[c] 145 board feet annual growth per acre per year.

[d] Consumer Price Index of 2.86.

NATURAL AREAS PROTECTION AND RECREATION OPPORTUNITIES ON PIONEER FOREST AND OTHER PROPERTIES OF THE L-A-D FOUNDATION

John A. Karel[1]

Abstract—The lands of Pioneer Forest and the L-A-D Foundation comprise more than 150,000 acres. Pioneer Forest is located within the Current, Jacks Fork, and Black River watersheds in the Ozarks. The other L-A-D Foundation properties are broadly distributed from north-central Missouri to extreme southern Missouri, with a primary concentration in the Ozark region. Both Pioneer Forest and the L-A-D Foundation are life-long projects of Leo Drey, a conservationist and businessman from St. Louis, MO. On these lands are important natural and cultural resources as well as interesting and unique outdoor opportunities. A number of landmark achievements in the fields of natural areas protection and outdoor recreation have resulted from the leadership of Leo Drey. The principal developments in these fields that have occurred here over the past half-century are chronicled in this paper.

INTRODUCTION

During the 1950s, Leo Drey, a conservationist and businessman from St. Louis, MO, assisted by foresters Lee Paulsell, Ed Woods, and Charlie Kirk, came to understand that Ozark forests could recover from the more intensive cutting, which began at the turn of the century, and, by the use of conservative and thoughtful harvest practices, could be restored to provide continuous economic productivity. Pioneer is widely known for its system of timber management, but Leo, with advice from his early foresters and along the way from other advisors, also has been a leading steward for a very broad range of natural and recreational resources on Pioneer Forest and beyond.

One cannot purchase 150,000 acres of undeveloped land in the Ozarks without, at the same time, acquiring important natural features and lands that are important for outdoor recreation. Stewardship of these resources is also part of the Pioneer story—and the Leo Drey story.

CONTRIBUTIONS RECOGNIZING NATURAL AREAS IN MISSOURI

Participation in Society of American Foresters Natural Areas Program

In 1947, the Society of American Foresters (SAF) began a program to recognize the value of setting permanently aside certain tracts of high-quality, unique, or otherwise special lands as a reference for study and comparison—an outdoor library of original forest and natural community types. During its first 2 years, the SAF Natural Areas Program had registered 153 areas on either U.S. Forest Service or USDI Fish and Wildlife Service lands, many located in western states, particularly in Arizona, Oregon, and Washington, although none had been designated in Missouri. To encourage even greater participation, the April 1952 issue of the *Journal of Forestry* issued a call for foresters to locate and register virgin type associations in this new program. The philosophical rationale for these areas has evolved since that time, and the importance of such areas has now been almost universally acknowledged throughout the natural resource professions. Today's consensus, however, required yesterday's pioneers.

In 1951, Leo Drey acquired his first tract of land in the Ozarks of southern Missouri and, in 1954, he acquired the nearly 90,000-acre holding of National Distillers land. Foresters Ed Woods and Charlie Kirk had already begun working with the SAF to establish a virgin hardwood area on the National Distillers property (file correspondence of Pioneer Forest, August and October 1953). On the advice of both Woods and Kirk, now foresters with his newly created Pioneer Forest, Drey recognized the value of the natural area concept and approved registration of a 10-acre tract of old-growth white oak forest as an SAF Natural Area. SAF Natural Area Committee Chair John Shanklin reported on the designation of the Current River Natural Area in the March 1955 issue of the *Journal of Forestry*.

This particular white oak forest had previously been identified as a significant site for Missouri. The first list of Missouri sites to be considered for preservation included 121 areas and was compiled sometime prior to 1953 by well-known botanist Julian Steyermark (The Nature Conservancy 1954). Steyermark's list of areas was then annotated by field visits conducted by Nevins (1953) for The Nature Conservancy. Nevins's shorter list of 55 sites described the virgin white oak forest owned by National Distillers. The *St. Louis Post-Dispatch* interviewed Drey in May 1954 and reported on the setting aside of "two tracts of virgin white oak estimated to contain 300,000 board feet of timber. Drey says these trees will not be harvested, but kept in their virgin state as a sort of monument to past greatness of Ozark forests and an object lesson as to what a fine forest can become if permitted to do so. . . . Some of the trees . . . measure almost 4 feet in diameter. Many of them may have been vigorous saplings at the time of the Revolutionary War." Clearly this was not a tentative inauguration of natural areas at Pioneer Forest—Leo Drey had become fully engaged. Current River Natural Area was the first such area designated in Missouri and Drey was

[1] John A. Karel, President, L-A-D Foundation, and Director, Tower Grove Park, St. Louis, MO 63110.

undoubtedly looking for other ways he might participate in this evolving effort.

Drey was active in SAF programs throughout the 1950s and worked on several committees as a member of that professional association. As late as 1960, the Current River Natural Area remained the only SAF area designated on public or private lands in Missouri. Despite this relatively slow progress in his home state, Leo continued to be a supportive voice for identifying and protecting natural areas on his and other lands.

In 1964, negotiations were completed for the second SAF natural area on the forest (correspondence February-April 1964). The site, Pioneer Natural Area, was a mixed forest site with old-growth eastern red cedar on a ridge directly adjacent to the Current River. The files of Pioneer Forest for both areas include correspondence, field measurements, notes, and land survey information contributed by several of the staff who were also members of the SAF, including Ed Woods, Charlie Kirk, and Steve Lindsey. In the December 1964 issue of the SAF's *Journal of Forestry*, D.W. Lynch (1964) noted that both areas "are examples of outstanding contributions by a private timber landowner in which he relinquishes the management of the areas to a board of trustees under legal indenture."

Missouri Natural Area Survey and L-A-D Foundation

By this time, the Nature Conservancy and the University of Missouri also had become more active, conducting studies and identifying priority sites for protection. Drey became involved in both, and his association with this early natural areas work proved fruitful.

By 1958, Drey had already joined the board of trustees for the fledgling Missouri Chapter of the Nature Conservancy. Drey participated in discussions regarding purchase of the Jam Up Bluff area (Hath 1958). Then, Dr. William H. Elder, also a member of the board and professor at the University of Missouri, began more formal study of natural areas in the state (Sherman 1965). Other surveys for natural areas were being planned, using graduate students at the university.

The L-A-D Foundation was formed by Drey in 1962 and became the primary vehicle for pursuing his goal of protecting natural areas, parallel and complementary to his forestry goals on Pioneer Forest. From 1971 to 1973, Drey's L-A-D Foundation contributed to the university's work through financial support of a second survey of natural areas (Fadler and Elder 1973) in six counties in the Ozarks.

During the 1970s, two separate but complementary efforts worked to complete the first statewide inventory for natural areas. The University of Missouri effort completed four additional studies (Mechlin and Elder 1974, Muser and Elder 1975, Karel and Elder 1976, Iffrig and Elder 1978) through funding from the State Inter-Agency Council on Outdoor Recreation. The L-A-D Foundation initiated an inventory of remaining unsurveyed counties, plus a statewide summary of previous work. The foundation's project was known as the Missouri Natural Area Survey and was underway from 1974 to 1978 under the direction of R. Roger Pryor of St. Louis (Pryor 1980).

These combined efforts during the 1970s produced the initial comprehensive inventory of potential Missouri Natural Areas. The listing of evaluated sites proved immediately useful as acquisition priorities were developed. Leo himself joined government agencies and other private conservation groups in various committees and study groups to determine which natural areas most deserved preservation. Each participating organization accepted responsibility for certain areas. The L-A-D Foundation stepped forward to purchase priority areas where there was no public agency in a position to do so.

Participation in the Missouri Natural Areas System

The Missouri Conservation Department initiated their Natural Areas Program for agency-owned properties in 1970. The first natural areas were approved in 1971, including two L-A-D Foundation sites, Clifty Creek Natural Bridge in Maries County and Piney River Narrows in Texas County. Then, in 1976, by cooperative agreement, the Missouri Departments of Conservation and Natural Resources joined forces to form a truly statewide effort. This was known as the Missouri Natural Areas System, and it is now a multi-agency program of great strength and vigor administered by the Missouri Natural Areas Committee (MoNAC). Shortly after the agencies combined efforts, Leo Drey was asked to include the two L-A-D Foundation-owned areas previously registered with the Society of American Foresters, the Current River and Pioneer Natural Areas, in the state system. MoNAC chairman Allen Brohn, in a memo to the Natural Areas Committee, said, "designation of these tracts would be breaking new ground for our system" (Brohn, correspondence, 1977). Other L-A-D sites followed, including classic Missouri landmarks such as Grand Gulf in Oregon County, Hickory Canyons in Ste. Genevieve County, and Rocky Hollow in Monroe County. A total of 11 areas have been thus permanently protected as Missouri Natural Areas (table 1). Drey had acquired his interest in protecting important Missouri places on Pioneer Forest first, but it became a lifelong passion with enormous public benefit throughout much of Missouri.

Over the years, leaders of the Missouri Natural Areas Committee came to realize that protecting the biodiversity of natural areas usually required sizeable acreage. Some began to question whether the earliest small areas, such as Current River Natural Area at only 10 acres, really belonged in the system. L-A-D Foundation leaders, noting that it was the first designated area in the state, asked a team of naturalists to examine Current River Natural Area in person. Once on site, the naturalists reported their astonishment that the Pioneer Forest land surrounding the tract was equal in quality to the original natural area. As a consequence, Drey agreed to add additional land to the natural area, and on April 30, 2005, the L-A-D Foundation celebrated the rededication of Current River Natural Area by adding 255 acres on the occasion of the area's 50th anniversary (fig. 1). The nomination for the expansion (Drees and others 2004) states: "CRNA (Current River Natural Area) is one of the few old-growth white oak forests in the Missouri Natural Areas System . . . . The 255-acre addition protects more of the landscape—the natural integrity of the original natural area is strengthened by the high natural integrity of the addition.

Table 1—L-A-D Foundation lands recognized by various State or national programs

Name	County	Recognition	Date	Size
				acres
Ball Mill Resurgence	Perry	Missouri Natural Area [a]	1979	19.7
			2007	183.2
Total				202.9
Clifty Creek	Maries	Missouri Natural Area	1971	230
Current River	Shannon	SAF Natural Area [b]	1955	
		Missouri Natural Area	1977	10
		Addition, Missouri Natural Area [d]	2005	255
Total				265
Dillard Mill	Crawford	Missouri Historic Site [c]	1977	130
Grand Gulf	Oregon	National Natural Landmark	1971	
		Missouri State Park [c]	1984	159
		Missouri Natural Area	1986	(portion) 60
Hickory Canyons	Ste. Genevieve	Missouri Natural Area	1973	420
		Addition, Missouri Natural Area	1979	530
Total				950
Horseshoe Bend	Texas	Missouri Natural Area	1973	69
Lily Pond	Reynolds	Missouri Natural Area	1975	8
Piney River Narrows	Texas	Missouri Natural Area	1971	50
Pioneer	Shannon	SAF Natural Area	1964	
		Missouri Natural Area	1977	20
Rocky Hollow	Monroe	Missouri Natural Area	1973	
		National Register of Historic Places	1974	191
Roger Pryor Pioneer Backcountry	Shannon	Lease to Missouri State Parks	2002	56,675
Scenic Easements	Shannon, Carter	National Park Service		
		Ozark National Scenic Riverways	1970	951
Triple Sink	Shannon	Missouri Natural Area[d]	1980	23
		Addition, Missouri Natural Area	2007	19
Total				42

[a] The Missouri Natural Areas System began in 1971 with the first areas owned by the Missouri Department of Conservation. Beginning in 1977 the Missouri Natural Areas Committee was established by agreement of the Missouri Department of Conservation and Missouri Department of Natural Resources to review and approve natural areas throughout the State under a variety of public and private ownerships.

[b] The Society of American Foresters Committee on Natural Areas was organized in 1947.

[c] State historic sites and State parks are managed by the Division of State Parks, Missouri Department of Natural Resources.

[d] Originally designated as a Missouri Natural Area under the ownership of the Frank B. Powell Lumber Company; acquired by the L-A-D Foundation in 2006.

The nomination includes three additional terrestrial natural communities . . . [as well as an] Ozark Faunal Region headwater stream. The contribution of these four natural communities to the overall biodiversity within the natural area is very significant." The role of Current River Natural Area in tracing Missouri's own natural areas history along with the institutionalizing of state programs around the country testifies to the good judgment and lasting value of once novel efforts.

Cooperation with Other State and Federal Agencies

In 1964, the Ozark National Scenic Riverways was established by Congress for management by the National Park Service. It was intended to protect the free-flowing Current and Jack's Fork Rivers by purchasing or acquiring scenic easements on a corridor extending at least 300 feet back from the banks of the two streams. Pioneer Forest includes more than 35 miles of frontage along the riverways, so Drey was faced with a major challenge to the integrity of Pioneer Forest. Though the

Figure 1—Richard Smith and Leo Drey at the April 2005 dedication of the expanded Current River Natural Area. Smith was a forestry professor at the University of Missouri who was involved in the SAF designation of the original area in 1955. *(Courtesy of Pioneer Forest)*

National Park Service insisted on outright purchase of some lands, especially in the vicinity of Round Spring, it was willing to accept scenic easements on the remainder, totaling nearly a thousand acres. Drey subsequently donated the easement lands to the L-A-D Foundation, which oversaw the lands in cooperation with the National Park Service. The easement lands include a number of noteworthy natural and cultural features, including Medlock Cave, which harbors several endangered species; Bluff School, fondly remembered by many older Ozarkians; and Cave Spring, a karst geology masterpiece immortalized in a haunting riverside painting by Thomas Hart Benton.

Among the many outstanding sites Leo Drey helped protect were Dillard Mill and Grand Gulf, both now leased to the Missouri Department of Natural Resources for state parks (Flader 1992). One of Missouri's most picturesque gristmills, Dillard Mill, was to have been acquired by the U.S. Forest Service and then leased to the state, but the U.S. Forest Service appropriation fell through, so Drey stepped in to acquire the site through the L-A-D Foundation and complete the lease agreement with the state. There had also been interest in a state park at Grand Gulf near the Arkansas border, known to many as "Missouri's Little Grand Canyon," since at least 1959. Drey finally stepped in to save the property in 1970 by purchasing it for the L-A-D Foundation, and, in 1971, it was recognized by the U.S. Department of Interior as a National Natural Landmark. After the successful lease arrangement for Dillard Mill, Drey concluded a lease agreement with the state for Grand Gulf State Park in 1984.

Drey also stepped into north Missouri to save Rocky Hollow in Monroe County. Shortly after it had been included in Missouri's Natural Areas System in 1973, it was also approved for listing on the National Register of Historic Places in recognition of its highly significant Indian petroglyphs. Rocky Hollow is now managed by the Missouri Department of Conservation, along with nine other L-A-D Foundation natural areas.

For many, the most dramatic single episode in the saga of Drey's one-man rescue squad for at-risk natural areas came during the 1980s when he purchased Greer Spring in Oregon County. Greer Spring is the most unspoiled of the large freshwater springs of the Ozarks, a region known around the world for its abundance of such treasures. Rising from the floor of a thickly vegetated dolomite canyon, Greer Spring is a feature of extraordinary beauty, scientific importance, and symbolic value.

In the 1980s, various circumstances combined to put this landmark at grave risk. Drey was a key player in the campaign to protect the area, and when all other strategies seemed about to fail, he knew he was the only one who could save the day—so he did. He put $4.5 million on the table to purchase the spring and the surrounding 7,000 acres. This bought the time needed to have Congress authorize purchase of the tract, by now with the generous assistance of one of Missouri's most widely known corporations, Anheuser-Busch. The tract was then added to the Eleven Point National Scenic River, managed by the U.S. Forest Service.

Beginning in the 1990s, Pioneer Forest also began more thoroughly to review its own resources. This has led to the designation of a series of Pioneer Forest Reserves, each recognizing special or unique features and habitats. So far, there are seven such areas totaling more than 1,500 acres. They include a significant cultural feature as well as forests, caves, fens, hollows, and sinkholes. The largest and most important area, Leatherwood Creek Forest Reserve, protects an unspoiled tributary of the Jacks Fork River—a wonderland of dissected Salem Plateau geology, topography, flora, and fauna.

DEVELOPING RECREATIONAL OPPORTUNITIES ON PIONEER FOREST

Pioneer Forest stretches across large blocks of contiguous and appealing Ozark land; it includes major stretches of the Current and Jacks Fork Rivers, plus smaller stretches of the Black and Little Black Rivers. The forest includes dozens of miles of permanent tributary streams, caves, springs, natural ponds, forests, bluffs, and hills. This expansive landscape is, and always has been, a compelling place for outdoor pursuits, not only for local residents but also, especially on the Current River, for the many outside visitors to the region.

From the time of his first purchase, Leo has welcomed visitors on Pioneer land, making it available for traditional hunting and fishing, swimming, hiking, and horseback riding. There is also the seasonal gathering of such Ozark delicacies as mushrooms, paw paws, persimmons, walnuts, blackberries, dewberries, and huckleberries.

The swift clear waters of the Current and Jacks Fork Rivers have drawn locals and visitors alike since the 19th Century, even though old-time jon boats have generally given way to canoes, inner tubes, and modern fishing boats. On the Current River alone, as noted above, Pioneer Forest borders or surrounds the river for more than 35 miles.

When the Ozark National Scenic Riverways was established under the National Park Service in 1964, public use dramatically increased. This led Drey to reflect on how he might more actively accommodate access to, and enjoyment of, Pioneer lands in the vicinity and be responsive to the growing public interest in such outdoor activities as long-distance hiking, nature study, and photography.

During the 1970s, the National Park Service was well underway with its own planning, and at least some of its thinking involved connections between the park and Pioneer Forest (Bruff 1977), but the service decided to confine its efforts to the riverways corridor. Drey, meanwhile, had invited the then Bureau of Outdoor Recreation to study how Pioneer Forest could encourage more outdoor recreation in a manner that would be compatible with his ongoing forestry programs. This resulted in a recreation plan (U.S. Department of the Interior 1976) authored by BOR staffer Gerald Stokes. Noting that the plan was well done but also very ambitious, Drey then asked two experienced Missouri conservationists, David Bedan and Bob Goetz, to boil that federal plan down into projects that were feasible and consistent with his approach to things: understated and to the point. Their resulting study (Bedan and Goetz 1976) outlined a program that continues today to serve as a blueprint for recreational programs on Pioneer Forest.

The Ozark Trail and Other Trail Development on Pioneer Forest

Also during the 1970s, state and federal agencies were in the formative stages of planning for a Missouri Ozark Trail, a 150-mile-long hiking trail through the Missouri Ozarks. With the exception of Pioneer Forest, the projected route was almost entirely on public land. These efforts quickly gained momentum, aided in December 1978 by a Trail Agreement between Leo Drey and the Missouri Department of Natural Resources that provided for the establishment, construction, and maintenance of 13 miles of the Ozark Trail through Pioneer Forest. This stretch of trail, designated as the Blair Creek Section, is a key link amid the state and federal lands that connect the Ozark borderlands near St. Louis, MO with the Boston Mountains of Arkansas.

One feature of this effort has been the nearly three-decade-long relationship between Pioneer Forest and the Sierra Club. Largely through a dedicated crew of volunteers from the club's Ozark Chapter, extensive trail construction and maintenance have been carried out. In addition to the Blair Creek valley, tributary trails now lead through Laxton Hollow, Brushy Creek, and Satterfield Hollow. Plans are also underway to establish another moderately long-distance hiking trail through the Current River Valley in cooperation with the Ozark National Scenic Riverways. Newly completed, also in cooperation with the National Park Service, is a route linking Devil's Well by way of Pioneer Forest with Cave Spring on L-A-D Foundation easement lands along the Current River. Today, there are a hundred or more volunteers visiting Pioneer Forest each year to assist in trail-building efforts; they come from counties surrounding the forest as well as from around the state and beyond. All together these volunteer labors have added more than 35 miles of hiking trails to Pioneer Forest, all of which are available to the public.

Pioneer Forest and L-A-D Foundation staff have also completed a Forest Interpretive Drive open to the public. Accessed from Highway 19 just south of Round Spring, this drive uses a brochure-based auto tour format, introducing motorists to Pioneer Forest, the Ozarks, and the Current River country using a combination of marked stops and explanatory text. The brochure also describes an interpretive walk through a remnant stand of virgin shortleaf pine forest that borders Highway 19 in this vicinity. Originally part of the large block that Drey acquired from National Distillers, the tract had been purchased for Highway 19 right-of-way in 1940 and then about 40 acres of it resold to the L-A-D Foundation by the Missouri Department of Transportation in 1996. Although the corridor of old growth pine is quite narrow, it nevertheless conveys a moving and evocative glimpse of the original Lower Ozark landscape.

Roger Pryor Pioneer Backcountry

Drey had continued thinking about and working on ways in which his Pioneer Forest lands could contribute toward outdoor recreation. He was especially keen to find a way to take advantage of the unique size of the Forest.

After several unsuccessful attempts to work out a cooperative arrangement with the National Park Service and the state park system, in 1998 Drey presented to his staff an idea for a large area of Pioneer Forest to be managed for primitive outdoor recreation while also serving as a working forest. The largest contiguous area of Pioneer became the focus, including Pioneer and L-A-D Foundation lands along Current River between Round Spring and Two Rivers and extending north for 5 to 6 miles, an area of almost 61,000 acres. This breathtaking expanse includes much or all of the watersheds of three tributary streams to the Current River: Blair Creek, Brushy Creek, and Big Creek. The L-A-D Foundation's board of directors enthusiastically endorsed the concept, and, in fall 1999, Drey publicly announced his intent to establish the Roger Pryor Pioneer Backcountry in honor of one of Missouri's foremost conservationists.

In October 2001, amid much celebration, Pioneer Forest dedicated this landmark tract; the Pryor Backcountry is now the largest Missouri area dedicated to primitive outdoor recreation. At the same time, discussions began in earnest with the Missouri Department of Natural Resources for park division management of the area's recreational component while Pioneer Forest would demonstrate sustainable management of the model working forest. Together they would cooperatively manage the Backcountry under a lease agreement that breaks new ground for that agency as well as for Pioneer Forest. The Department of Natural Resources has provided staffing for trail and trailhead development as well as law enforcement. The Pryor Backcountry is not a wilderness—the forestry program in the area will continue—but its large, wild, and undeveloped character will be managed to provide visitors a primitive experience as free as possible from the intrusions of motorized vehicles.

CONCLUSION

In both natural areas and outdoor recreation, Leo Drey has built an extraordinary record. He has demonstrated that responsible forestry is perfectly compatible, in fact works best, as part of a broad program of resource stewardship. As Donald Jackson observed in 1988 in *Audubon Magazine*, "Every state should have a Leo Drey." That is true, and we hope that other states can get somebody like him to help them out. But they cannot have Leo Drey; he belongs to Missouri.

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PERSONAL REFLECTIONS[1]

Glenn D. Weaver

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I grew up on a farm east of Winona, MO in Shannon County. As with many of the farms in the area, when my dad bought the farm, the previous owner had cut every tree that would make a tie or fence post. This practice continued for many years. Then in the mid-1960s I flew over Texas, Shannon, and Reynolds counties studying the forest and wildlife habitat. The forest that was managed for a continuous, sustainable harvest, as Pioneer Forest is, was easy to identify from the air. I have known Leo since early 1970, when I spent a great deal of time in the Ozarks with University Extension. My dad and granddad also knew Leo. My dad worked for Kerr McGee in their forest products division and admired the philosophy and management practices used on Pioneer Forest.

Pioneer Forest has set an example through its management practices that assure continuous sustainable harvest. These practices of cutting only a few of the trees on each acre while always leaving the forest intact have had a profound economic impact throughout this region of the Ozarks.

The direct economic impact of Pioneer Forest includes the continuous sale of timber over more than 50 years. This influence alone is significant. For example, since 1960 the annual volume produced from the forest averaged 4.5 to 5 million board feet. Since 1960, the price for timber has risen from $12 to $165 per thousand board feet. This overall economic activity is notable in an area which, measured by Missouri standards, has been generally depressed throughout this period. The cumulative effect of Pioneer Forest's activity since 1951 has been significant.

The real impact of the business of Pioneer Forest is measured by the accumulation of effects as the direct income produced is trickled back through the forest to its employees and their families, as well as from the forest directly through the sawmills to their crews and families. Pioneer Forest employs six full-time staff, but including the crews responsible for contract sales, the direct collective economic activity reaches from 60 to 82 people each year (Figure 1).

Secondary impacts include the taxes paid, equipment purchased, and the living expenses of employees and contract personnel. Businesses in the community and surrounding areas benefit directly and indirectly from purchases of gasoline, food, recreation, insurance, clothing, etc.

Many latent benefits exist as a result of Pioneer Forest and its management practices. We recognize many examples when we raise the question of the beauty and value of a forest to tourism as compared to the perceived values of clearcuts, or the quality of a river that is protected from erosion by continuous and well-established woodlands. Leo Drey, through Pioneer Forest, has demonstrated that the practice of selective cutting can produce continuous economic benefits for the landowner and area economies while at the same time protecting the many qualities of our woodland resource.

Figure 1—Harvest activity on the Pioneer Forest, ca. 1940–50. *(Courtesy of Pioneer Forest)*

Beyond today's economy and for much longer than even one man's lifetime, this enterprise of Leo's will continue. Leo has demonstrated that generations will enjoy the benefits of never removing the forest from the land. I think this point is best illustrated by the Spencer family, which has had three generations working on the forest since the 1950s. In one section of Pioneer Forest, the grandfather cut beginning in the 1950s, then his son cut in the same section of land during the 1970s, and now the grandson is cutting through this same section of the forest. Because every acre of Pioneer Forest is continuously forested, continuously growing, and periodically harvested, there will be lifetimes of folks like us who will always benefit from this unique resource.

Bill Terry

National Park Service
Ozark National Scenic Riverways
Salem, MO

It was the early 1970s when I personally developed a little sweat equity with Pioneer Forest. I was a young seasonal ranger working for the Ozark National Scenic Riverways. The riverways was, at that time, actively involved in open field management in the old fields along the Current River. We had taken them over and we were actively manipulating old fields, planting food plots, and doing habitat improvement for small game species. I'll never forget, I got an assignment from my supervisor for old field management at a place near Cedar Grove, called the Osborne Riley place. We were to take the Ford tractor up there

[1] The following reflections were prepared by Hank Dorst and the editors, working from a videotaped recording of presentations at the symposium, as well as prepared drafts and notes. For citations, see the annotated bibliography in the appendix.

and put some food plots in. I checked with my supervisor about the boundaries. He said we border Leo Drey there so don't worry; as long as we were on the inside of the fence it was the National Park Service property purchased from Osborne.

Well, Rex Innis and I went up there. We took about 3 days to plant several nice food plots. Being avid bird hunters and quail hunters, we thought we had done a really good job. About 3 days after that I was talking to Charlie Kirk, the forester for Leo Drey at the time, and Charlie was not so happy about our resource management efforts. He felt that inside that fence was Leo Drey's property. My supervisor and Charlie had several heated discussions that ended up at our park's Van Buren headquarters. The bottom line was, that was Leo Drey's field and Leo wasn't that interested in food plots; he and his foresters were interested in timber.

The solution was that another ranger and I spent the better part of several days planting pine seedlings through those food plots. My supervisor and Charlie Kirk had a running jab at each other at the coffee shop in Salem, MO. My supervisor had some of the guys at the sign shop in Salem make a sign that read 'The Charlie Kirk Memorial Forest, established 1974'. I'll never forget Rex Innis and myself standing there in the middle of that memorial forest next to that nice big redwood sign and those little pine seedlings about 6 inches tall. Those trees in the Charlie Kirk Memorial Forest are now about 20 to 30 feet tall. It's a living memory to a time in my life and I am glad it's a part of Pioneer Forest.

I also wanted to say that I am an avid outdoorsman. I don't think many people in the last 30 years, other than Leo's professional foresters, have tramped over as much of his land more than I have, hunting, hiking, camping, enjoying pawpaws, and seeing the beauty. I have really felt a fondness for those woods. People who work there, like Terry Cunningham and Clint Trammel, have told me about beautiful stands of timber and I have gone and looked at many of them.

It has been a fortune for me to have access to the lands of Pioneer Forest. I am a spiritual man and I often thank God for the things that I have been given. Driving through St. Louis traffic I think about Missouri's Ozarks—what a great place to live. My life has been enhanced to be in the presence of Pioneer Forest and to think that a far-sighted man like Leo Drey is so willing to share his land with the people of this State and this Nation.

David Bedan

Conservationist
Columbia, MO

Like so many people, I have had the privilege of benefiting from Leo's generosity, in my case primarily through backcountry recreation. In the 1970's, while teaching classes at St. Louis University, I led a number of Sierra Club backpackers into Pioneer Forest, leading mostly urban students who had some real life-changing experiences in those wild places.

I think Leo decided that since I was using the place so much I should do something for it. He asked me to write a report, along with Bob Goetz, *Pioneer Forest Recreation Study* (1976). This was a follow-up to a Bureau of Outdoor Recreation study, completed earlier in 1976, that identified a huge smorgasboard of potential projects that could be done on the forest. Our assignment was to narrow that down to some specific and doable things. I was really thrilled when the Roger Pryor Pioneer Backcountry was finally dedicated down at the Himont Tower site in October 2001, because it seemed like concrete proof that some of the ideas in our report 25 years ago were being implemented on the ground.

We have heard a lot of talk about how Pioneer Forest has shown that timber harvesting is compatible with a long-term sustainable management that can maintain or improve the ecology of the forest. I think Pioneer Forest can also be applauded for showing that timber harvesting can be compatible with a true backcountry experience. Pioneer Forest is not a wilderness area in the sense that the term is defined by the Wilderness Act of 1964, in which you can't have any timber harvest entry of any kind. However, the timber management practices on Pioneer Forest are very compatible with backcountry experience, especially since they only go back into a given area every 20 years. It is easy to lay out trails in such a way that there is almost no conflict between the primitive backcountry recreation experience and timber harvesting.

I'm talking here about what I call 'self-propelled' recreational experiences—hunting, dayhiking, backpacking, nature study, nut and fruit gathering, fishing, horse-riding. There can be too much of any good thing, so I think there has to be some management because we don't want too much impact in any one area or from any single use. I think that's not too difficult to manage and that the Pioneer staff is well on top of managing it.

The biggest challenge in management, though, is limiting motorized access, because with motorized access you can have several orders of magnitude greater impact in terms of soil erosion, littering, spotlighting of deer, and conflicts with other recreationists. One off-road vehicle can ruin the experience of dozens of other back-country recreationists. In a large area like this, with a small staff, it's a very hard thing to do, but I know Pioneer staff is aware of this challenge. I think that we can probably never eliminate unauthorized motorized access, but it can be kept down to an acceptable level.

I see the back-country concept on Pioneer Forest as one of the great experiments in our country about how timber management can be compatible with back-country recreation.

David R. Larsen
Professor, Department of Forestry
The School of Natural Resources
University of Missouri-Columbia
Columbia, MO

Pioneer Forest has from the beginning maintained an openness and willingness to collaborate with students and researchers, serving as a veritable outdoor laboratory. Its staff understands the unique opportunities that they provide and they want others to learn from their forest.

Students have visited the region of the Ozarks in which Pioneer Forest is located since the start of forestry schools in the United States. The first forestry summer camp in the area was led by Dr. H.H. Chapman of Yale University, who brought his 1907 forestry class to study southern pine forests near Grandin in southern Carter County (fig. 2). This was the home of the largest sawmill in the Nation at the time, and some of the lands then owned by the Missouri Lumber and Mining Company and likely studied by Chapman's students are now part of Pioneer Forest. Chapman reported on this and subsequent summer camps in the Ozarks in *Yale Bulletin 2* in 1913.

The University of Missouri held its first forestry summer camp in the woods near West Eminence in 1912, also on land that belonged to the Missouri Lumber and Mining Company. Summer camps after 1912 were held in Butler County on land that is now University Forest Conservation Area until the Department of Forestry was terminated in 1921. In 1947, the School of Forestry was re-established and resumed summer camps. The camps were directed for many years by Lee Paulsell, who had helped Leo Drey buy his first forest land during 1951-54 before rejoining the university.

Paulsell, Dick Smith, and others began a tradition of taking forestry students on field trips to Pioneer Forest, as did other universities and colleges over the years (fig. 3). These trips, hosted by Ed Woods and Charlie Kirk and later by Clint Trammel and Terry Cunningham, often included picnics on the Current River after a hard day visiting numerous sites on the forest. The Pioneer staff has always been willing to lead tours for forestry students whenever asked, and Woods and Kirk also contributed articles to the *Missouri Log*, a publication of the University of Missouri Forestry Club.

I know from personal experience that Pioneer Forest has hired many college students to work on the forest over the years. Having grown up in Salem, MO, where the forest has its headquarters and where my father was a friend of Woods and Kirk, I learned about forestry and Pioneer firsthand as a child. When I was in forestry school at the University of Missouri, I spent the summers of 1976 and 1977 contract thinning in pre-commercial stands on the forest. I also spent the fall of 1977 working on the remeasurement of the continuous forest inventory. Those experiences added greatly to the sum of my forestry background.

The continuous forest inventory in particular yielded large rewards scientifically. Many of the research studies associated with Pioneer Forest have strongly depended on this dataset. I myself collected site index on 482 CFI plots in 1979-80 and used

Figure 2—H.H. Chapman and his Yale Forestry Class in Grandin, Missouri, in 1907. *(Missouri Lumber and Mining Co. photographs, 1906–1916, Western Historical Manuscript Collection, Columbia, MO)*

Figure 3—Ed Woods measuring a large white oak. *(Courtesy of Pioneer Forest)*

the data to develop a whole stand forest growth model for my 1980 master's thesis. The U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station also used this data to calibrate the STEMS/TWIGS forest growth model, and it was further used to develop a matrix transition model (Lootens and others 1999).

In the early 1990's, the University and the North Central Forest Experiment Station initiated a project to describe the method of cutting implemented on Pioneer Forest so that others might try the method (Loewenstein 1996), and a number of graduate students and other researchers focused on related studies of forest management, structure, and reproduction. Larsen, Metzger, and Johnson (1997) asked the question 'what are the probabilities for understory reproduction given various overstory densities?' Larsen, Loewenstein, and Johnson (1999) summarized these results and gave specific recommendations for those interested in managing other forests in the Missouri Ozark Highlands with methods similar to those used on Pioneer.

Numerous other students and researchers in forestry, ecology, and related fields have sampled sites across the Ozarks, including Pioneer Forest, for studies of forest composition and plant communities, fire history, and the relationship of wildlife and insect communities to forest structure.

The willingness of Pioneer staff to share its management philosophy, and to explore the benefits and limitations of that management through scientific research, speak eloquently about the commitment of Pioneer Forest not only to share with but also to learn from others.

David Hamilton[1]

Wildlife Research Biologist
Missouri Department of Conservation
Jefferson City, MO

I'm interested in black bears, which I regard as integral to the look and feel of a Missouri oak woodland. Bears are native to Missouri. At settlement thousands of black bears roamed the Missouri and Arkansas Ozarks. Bears provided early settlers their primary source of meat, hides, and grease. It was believed that bears were gone from the Ozarks by 1920; however, a 1950 *Missouri Conservationist* article included a photograph of a bear cub shot near Salem, MO. This strongly suggested a breeding population nearby, while another large bear was shot in Reynolds County in 1954. Missouri may always have had small numbers of resident bears. In addition, the first large program to restore black bears occurred in Arkansas in 1956. This program used bears from northern Minnesota, and once released, many moved into Missouri and Kansas, though undoubtedly many were shot.

Leo Drey showed a strong interest in black bears years ago, writing to the Missouri Conservation Department at least two times, first in 1972 and again in 1978, suggesting Pioneer Forest as a place to help maintain or restore black bear populations. The Department decided both times against it. The belief was that Missouri probably didn't have very good habitat and since bears occurred in Arkansas, Missouri would naturally benefit. Thus, without direct intervention, there has been a resurgence of black bears in Missouri with sightings increasing. Between 1990 and 1993 we recorded about 600 sightings in Missouri; there are now, on average, about 200 to 300 sightings a year with bears scattered occasionally over 54 counties.

What does a bear look for? Does Pioneer Forest have the bear necessities? Bears like a large block of forest. Pioneer Forest has excellent habitat, with heavy forest density, low traffic volume, few people, no resident livestock, and ongoing conservative forest management. The most important food source is acorns, although only seasonally available, and bears may feed 20 hours a day in preparation for hibernation. Areas of oak-hickory forest under management such as that on Pioneer Forest also produce berries. Berries are an important summer food. While blueberries were thought to be a historically important food source, today blackberries are an important substitute. Pioneer's single-tree selection management produces openings where sunlight reaches the forest floor, stimulating fruit production. In addition, the number one prey item in their diet is ants, and, seasonally, tent caterpillars.

Food availability and quantity dictate the size of individual bears, and in turn influence the size of the litter and fitness of the cubs as well as the size and age of the female at first reproduction. While we do not have much data from Missouri,

[1] David Hamilton passed away on September 8, 2007.

we do know that in Arkansas bears begin to reproduce at 2 and have cubs every year. Bears in Missouri are mid-range in size, with males up to 500 pounds, compared with an average of 250 pounds in the Southwest and up to 700 to 800 pounds in Pennsylvania and the Adirondacks.

In the Missouri Conservation Department, we began looking closely at the distribution of bears in Missouri in 1991. To do this we used bait station surveys where at each station we hung sardine cans from trees. Each station was revisited to collect data on the presence of black bears. There were 50 stations on each route and about 60 routes region wide. In addition, motion-sensitive cameras have been used, especially to determine differences in bears and whether reproduction is occurring in Missouri.

Using the black bear occurrence records, we have developed a habitat model of southeast and southwest Missouri by also adding forest cover information and human population density. Bears like at least 80 percent canopy cover and 10 or fewer people per square mile; in a lot of bear areas there are several square miles per person. By combining several layers of information we now estimate there are 2.9 million acres of adequate habitat for bears; much of it is in the eastern Ozarks, and the particular region that stands out is where the large block of Pioneer Forest occurs. This is where Richard Guyette describes from his data the diversity and roughness of topography and thus a region showing the least disturbance. In this region, around the Current and Jacks Fork Rivers, bordered by several exterior blacktop roads, is a large block of habitat that is probably the best in the State.

Gerardo Camilo

Associate Professor of Biology
Saint Louis University
Saint Louis, MO

Several years ago my graduate student Nick San Diego and I began to look for sites closer to home in order to pursue research on questions raised by our earlier work in tropical ecology. We were interested in how management practices translate to ecological patterns and whether forest management that is profitable can also enhance biodiversity. The staff on Pioneer were happy to cooperate with us, so we began to do research there.

We set out to analyze how various forest management practices have affected the composition of leaf litter invertebrate communities, and especially how these communities are influenced by the scale of disturbance. Two of our sites, an unharvested site in the Current River Natural Area and an area subject to single-tree selection harvest, were on Pioneer Forest, and the third, a site that had been clearcut, was at the Reiss Biological Station.

What we found is that tree species diversity and spatial heterogeneity were greater on the site harvested by single-tree selection than in either the uncut or the clearcut sites, thus creating conditions for maximum diversity in leaf litter communities. At a scale of 100 square meters, the clearcut and selectively cut sites were similar, but at 250 square meters, the spatial heterogeneity of the selectively cut site on Pioneer was three times the heterogeneity of the clearcut or the uncut sites, even though one might expect the uncut site to be highest.

Trees, a forest do not make. We wanted to look at differences in scale from the perspective of an insect. Clearcuts even as small as 2 or 3 acres are mammoth for an insect, compared with the scale of heterogeneity in single-tree selection. The insects seem able to tell Pioneer Forest from everything else. They respond better to the distribution in tree sizes there. Single-tree selection thus seems to be the management regime with the greatest health and diversity in the leaf litter community.

The staff on Pioneer Forest may have difficulty describing just what they are doing when they practice single-tree selection, but we can measure the effect of what they do by looking at the insects.

David Russell

Trees L.C.
Van Buren, MO

I have been working for Mr. Drey, indirectly, since 1981. I was raised in St. Louis, MO but moved to the Ozarks when I was 14 years old. I had a pickup truck, a new wife, and a new chainsaw. Cutting sawtimber was the way we derived our living in the Ozarks. We had worked on the national forest and on private forest land, doing logging operations. It was cut everything that you see—all you had to do was find a tree and cut it.

In 1981, the logger I worked for was cutting a tract for Pioneer Forest and I found myself standing on a south hillside in the middle of a hollow called Round Pond with a chainsaw thinking 'what in the world am I doing here?' I remember that because there was a different concept being placed in my mind; it was the beginning of my education in the timber business. I was beginning to realize what was appropriate and how things were to be done. We didn't just go out and look for trees to cut. There was a management plan being implemented, even though at that time I didn't realize what it was.

I look back now, decades later, operating a sawmill producing close to 3 million board feet per year, cutting roughly 1.3 million off of Mr. Drey every year. I look at that and I can see there is a right way to do things and a wrong way to do things, and I have done both. Because of the way Pioneer Forest does things I look out there and I say, 'this is the right way.' Now I have loggers working for me who probably would not have to be told which tree to cut because of the educational process they have been through and because they have worked on Pioneer Forest.

When we do private timber sales now we can take the approach Pioneer Forest does, that is, we should be doing uneven-aged management. We know the forest product can be pulled off without destroying the environment, without destroying the ecological benefits, without destroying the recreational benefits, and when we leave we try to do it in the least intrusive way.

Now you will look at me today and think there's a logger. No, I'm a businessman who tries to do things right, and working for Pioneer Forest has been a right fit for my business.

We sell every product that we produce today—the lumber, the bark, we even sell our sawdust. There is no waste to what we harvest from Pioneer Forest. We leave the forest better. I'm very quickly approaching being able to go in on the same tract that I logged decades ago. I can't think of another process, or another place, where I can go back 20 years later, where the timber will be better, the ecology will be better, and the environment will be more protected than it was 20 years ago. Mr. Drey, I thank you for allowing us to work on your forest.

Gene Maggard

Akers Ferry Canoe Rental and
Jacks Fork Canoe Rental
Salem, MO

My wife, my son, and I own two canoe rentals in Shannon County, one called Akers Ferry Canoe Rental, the other around Eminence called Jacks Fork Canoe Rental. We also have about a 1,500-acre farm that is almost surrounded by Pioneer Forest. We have enjoyed our relationship with Leo and Kay and Pioneer Forest as neighbors over the years. Really, each year the hunters from our part of the Ozarks, which is northern Shannon County, should send a thank you letter because they really enjoy your property and their access to it. But more than that it's beautiful land—and in my business, canoe rentals need trees for their beautiful scenery.

Hank Dorst

Mark Twain Forest Watchers
Elk Creek, MO

I'm going to discuss a chronology of learning and activism on public forest land in which Pioneer Forest was instrumental. The year 1988 saw rebellions against clearcutting by residents near the Willow Springs and Poplar Bluff Ranger Districts of the Mark Twain National Forest. At that time the Forest Service was getting most of its timber volume from clearcuts. Good young white oak poles were routinely dropped in the name of creating an even-aged stand and immature sawtimber was indiscriminately cut before its time. The forest plan was new and language about using uneven-aged management in certain situations was not being implemented.

We were researching forest management alternatives to clearcutting. One day a silviculturist at the Houston District recommended getting in touch with the Pioneer Forest folks, saying they'd show us their system, and mentioned it was 'brushy woods' and that it wouldn't look as good as we expected. (Of course, clearcuts are entirely brush!)

In December 1988, we visited Pioneer along B Highway near Current River with Clint Trammel. Photos taken that day of recently harvested stands and stands cut in the 1970's are still in our slide show today. We learned that uneven-aged management is a dynamic system requiring regular but infrequent entries, perhaps 20 years on average. (A major flaw of the highly touted Missouri Forest Ecosystem Research Project (MOFEP) conducted by the Missouri Department of Conservation is that the uneven-aged management prescription there plans entries every 10 years.)

The opened canopy after selective harvest allows more vigorous growth of the residual stems and recruitment of seedlings and pole size trees into gaps. As the canopy closes, growth slows and eventually it is time to cut again. This system helps minimize oak decline, as less vigorous and older offsite trees that typically decline are often removed in uneven-aged harvests. It could be said that the Forest Service, with its over-reliance on clearcutting in the 1970s and 1980s, set up an age class homogeneity with too many stands of older trees, rather than tending larger acreages with partial cuts each year, thus exacerbating oak decline. The 1990s saw a change in Forest Service management away from complete reliance on clearcutting to more balance in management methods.

Over the years we were constantly able to point to Pioneer as a model of another way. Pioneer has also been our learning place where we could go and talk with staff and see examples in the field of different conditions. For that, we are thankful.

Today we look back on Pioneer's accomplishments. But we also must look ahead to the challenges and opportunities of the future. Just as it played a role in public forest management changes, Pioneer Forest is uniquely positioned to occupy a leadership role in the effort to increase the use of good forest management on our private forests. Through its participation in Value Missouri, an organization of industry, landowners and environmentalists working to promote FSC forest certification and better private forest management, Pioneer is once again playing a leading role.

Victoria Grant

Landowner
Reynolds County, MO

Though I work for the National Park Service, I speak as a private landowner who happens to live next to Pioneer Forest. I live in southern Reynolds County near the top of the Current River watershed. My husband and I have a 90-acre farm, half-timbered and half-pastured, nestled at the end of a county gravel road. It's a beautiful spot. We are bordered on two sides by Leo Drey's Pioneer Forest. We drive through the forest everyday to the blacktop and we are really happy about having Leo Drey as a neighbor.

First of all, as a private landowner, there is a wonderful sense of security that you know your neighbor. When you look at a plat book and you see that Pioneer Forest owns a section of property, you know what to expect; you can see in your mind that it will be a mature forest, it's going to stay a mature forest, and if there is timbering done it's going to be done in a certain fashion. So you're not worried that it will be divided into 10-acre parcels, sold, or clearcut. It's an intangible benefit we have as a neighbor of Pioneer Forest.

The section of Pioneer Forest we drive through every day was cut in 1998, and we owned our land before, during, and after the cut, so we've seen what happened during and we've seen what happened afterward. As my husband likes to say, 'when Leo Drey cuts, it still looks like a forest afterward, there are still big trees, big enough that a man can hardly get his arms around.' My husband is 6'4" and he has pretty long arms.

When I look at it now, particularly during fall color, it is a forest with every layer or structure that is giving me those blazing colors, from a canopy to a subcanopy, to ground layer, down to the soil layer. I think the management on Pioneer Forest is wise enough to know they have invested in preserving the soil structure, and Lord knows we don't have enough soil in the Ozarks to begin with. But I think they see that soil structure as the placenta for growing the forest, taking care to preserve that. It's been said many times down there that if everyone cut their forest like Leo Drey, the Ozarks would never run out of timber. I've been able to see that every day as I drive back and forth on my little gravel road. We consider ourselves extremely fortunate to live next to that kind of a good neighbor, with that kind of philosophy.

Caroline Pufalt

Ozark Chapter, Sierra Club
St. Louis, MO

I come primarily from the perspective of activism through the Sierra Club, although it is really hard to capture everything Pioneer Forest and Leo and Kay Drey's environmental activism has meant to us.

To start out with a downer, the United Nations recently released a report on the threats to the worldwide closed canopy forests and it was pretty disturbing. We in the United States have 8.2 percent of the closed canopy forest. It seems like a small percentage, but it is important and we are responsible for it. That responsibility has inspired a lot of us to work on forests and forest management over the years. When I think back to the time Hank referred to in the early 1980s, and what the conflicts and the agenda were like then, I remember all the hectic, disruptive activity in the Pacific Northwest, with demonstrations and tree sitters, some of which is still going on— conflicts between jobs and the environment. Then, here in Missouri we had our own smaller but very important issues involving clearcutting and public lands. We all knew then that the method of forest management used on Pioneer Forest was an example we wanted to emulate.

The folks at Pioneer were very welcoming and shared their information with us. It was a real frustration that some of the managers of public lands and those that even advised private landowners didn't seem to be too receptive to that. So, it is really gratifying to know that the studies have been done, the results are in, and we can see what a contribution Pioneer Forest has made.

As I think about the Pioneer Forest and Leo and Kay Drey I remember the movie 'It's a Wonderful Life.' I think of Leo and Kay Drey like Jimmy Stewart and Donna Reed. Pioneer Forest is like the Building and Loan, their forest, our natural resources, and they preserve them, keeping them available to us for value added for the community. Imagine Jimmy Stewart's nightmare if there were no more Pioneer Forest, if there were no model. It is a wonderful forest, and so, Leo and Kay, it's a wonderful life (fig. 4).

Mary Chapman

Director, Forest Stewards Guild
Santa Fe, NM

The Pioneer Forest is not the only example for sustainable uneven-aged management across the United States. But it is among the largest, the longest in tenure, the most firmly grounded in research and inventory, and the most progressive in outreach and education efforts. Moreover, the land ownership ethic of the Pioneer Forest exemplifies the concept that productive forestry can go hand in hand with ecological responsibility. In this, the Pioneer Forest provides a valuable model for private and public forest landowners across the Nation.

Two definitions of the word Pioneer make its selection as the name of these lands very prescient and fitting:

1. One that originates or helps open a new line of thought or activity

2. An early settler in a new territory

It seems to me that accomplishments of Pioneer Forest demonstrate both of these meanings.

Pioneer Forest is recognized for having bucked trends and for crafting a style of uneven-aged forest management using selection silviculture that is in the forefront of ecologically and economically sustainable forestry. Is Pioneer Forest all alone on this path?

In 1995, several foresters began identifying the best examples of forest management from around the country by asking the question: what does 'sustainable forestry' look like on the ground, and who is doing it? After interviewing a wide range of forest managers and getting a sense of their philosophy, meetings were held around the country inviting these foresters to come together to discuss their management perspectives and practices. Many of these foresters felt quite isolated as a result of the general view of their concerns and techniques held by the mainstream forestry sector. As Pioneer staff know well, the refrain was 'that won't work here' and 'you can't do that, and don't talk about it, either.'

Participants were surprised and energized through contact with like-minded foresters. They wanted an organization that would preserve that spark, so they formed the Forest Stewards Guild, which now has over 400 members managing 5.5 million acres in the United States and Canada. Guild members share a mission to promote an alternative vision of forest management. Clint Trammel is a founding member, and we're proud to have had him on our Board of Directors.

Figure 4—Leo and Kay Drey. *(Photo by Cliff White, Missouri Department of Conservation)*

For most guild members, seeing is believing—a trait we share with residents of the 'Show Me' state. Demonstration of silvicultural practices and impacts is a major focus of the guild, from northern hardwoods in the Upper Peninsula of Michigan, where individual tree selection harvests without changing stand composition towards increasingly shade tolerant trees, to oak and pine forests of southern New Hampshire, and from redwood in California to Douglas fir and mixed conifer in the Willamette Valley and pine forests of southern Oregon, where uneven-aged techniques are being used successfully to manage and regenerate forest types that have traditionally been clearcut and replanted.

Selection silviculture is a forte of our membership. A U.S. Fish and Wildlife Service biologist visited a member's forest on a California field tour and commented, 'if all of our forests were managed this way, we could de-list most of our endangered species.' Nevertheless, we face considerable challenges in researching, quantifying, documenting, and publicizing these success stories, since selection silviculture is not the style of forestry traditionally applied to most managed forest land today.

Pioneer Forest is to be commended for its considerable proactive efforts to demonstrate economical and ecological viability. Pioneer's research program is truly a model for the country. But is Pioneer all alone? Not anymore.

APPENDIX

Cave Spring along the Current River. *(Photo by G.F. Iffrig, courtesy of Pioneer Forest)*

ANNOTATED BIBLIOGRAPHY OF RESEARCH AND INFORMATION ON PIONEER FOREST

Greg F. Iffrig[1]

Abstract—A bibliography of research and other scholarly activity undertaken on Pioneer Forest is presented. This bibliography contains the information that managers of Pioneer Forest believe is of greatest importance to them as they refine their management practices to meet the varied objectives that the Drey family and the L-A-D Foundation have had for ownership of Pioneer Forest and natural areas.

INTRODUCTION

Altogether the lands of Pioneer Forest and the L-A-D Foundation total nearly 160,000 acres and are open for research and independent study with permission. Over the years a variety of university and public agency-directed research has been completed. There also has been a significant amount of non-technical information written about individually significant areas. These writings and research include both natural and cultural history and span biological, geological, cultural, and economic aspects of the properties of Pioneer Forest. We have attempted to compile and then annotate these writings and research since our own review and understanding of this information assists in our forest stewardship programs. We also hope that it may help current researchers or those intending to do research on Pioneer Forest to know what kinds of research and information have already been completed here.

This bibliography is periodically updated; copies of most entries are found at the Pioneer Forest office in Salem, MO. There are 170 works listed here.

Aley, T. 1980. Cave management investigations on the Ozark National Scenic Riverways, Missouri. Ozark Underground Laboratory contract report to the National Park Service. 111 p. + appendix. On file with: Pioneer Forest, Highway 19 N., Salem, MO 65560.

The first cave management study of Ozark National Scenic Riverways' caves, reporting on 19 caves including at least one reference to a Pioneer Forest cave, Albert Reinhold Cave (named in this report as Rockclimb Cave).

Aley, T. 1981. Cave management investigations on the Ozark National Scenic Riverways, Missouri; Phase 2. Ozark Underground Laboratory contract report to the National Park Service. 151 p. + appendix.

Follow-up to the 1980 study, here reporting on an additional 60 caves, including Devils Well.

Aley, T.; Aley, C. 1989. Final Report—delineation of recharge areas for four important cave streams, Ozark National Scenic Riverways, Missouri, August 25, 1989. Prepared for the Ozark National Scenic Riverways under Purchase Order PX6640-7-0556. 28 p.

Two of the four studied caves are on L-A-D property—Flying W Cave and Medlock Cave.

Annand, E.M. 1995. Habitat relationships of migrant songbirds in a managed forest. Columbia, MO: University of Missouri. 73 p. MS Thesis.

Annand studied migrant songbird response to managed forest treatments from 58 sites (12 clearcut, 12 shelterwood, 12 group selection, 10 single-tree selection, and 12 unharvested mature even-aged sites). Using the point count method, relative abundance of all occurring species were measured. Habitat measurements were gathered to assess vegetation characteristics of all sites. Analysis of variance models and multiple regression models were used to analyze habitat relationships. Chapter 2 of the thesis is the manuscript for the paper published in 1997 by Annand and Thompson.

Chapter 3, another manuscript, discusses the relationship of songbirds to vegetation characteristics in regenerating forest stands. Models for six individual bird species (acadian flycatcher, red-eyed vireo, blue-winged warbler, ovenbird, hooded warbler, and the yellow-breasted chat) were established using variables such as basal area, canopy closure, and understory cover. Acadian flycatchers prefer large trees, dense understory, and closed canopy. Red-eyed vireos prefer high basal area and a high percent canopy closure. Ovenbirds preferred high percent canopy closure and short tree regeneration height. Hooded warblers prefer high density of smaller trees, relatively low density of large diameter trees, high shrub stem counts, and high canopy closure (all four of these variables fairly describe single-tree selection treatments).

[1] **Greg F. Iffrig**, Liaison to the Board, L-A-D Foundation, 705 Olive, Room 724, St. Louis, MO 63101.

Annand, E.M.; Thompson, F.R. 1997. Forest bird response to regeneration practices in Central Hardwood Forests. Journal of Wildlife Management. 61(1): 159-171.

Study of breeding songbird populations in managed forested landscapes in southern Missouri; includes clearcut, shelterwood, group selection, single-tree forest regeneration methods of harvest, and mature unharvested even-age stands.

Pioneer Forest transects represent the single-tree selection portion of the study. Hooded warblers and northern parulas were more abundant in the selection treatments than other harvest treatments (hooded warblers have been found to nest in gaps in Illinois in another study). Parula warbler numbers were greater in single-tree selection treatments. Species such as the red-eyed vireo, worm-eating warbler, and acadian flycatcher, which are usually associated with mature forests, were abundant in group and single-tree selection treatments. Species usually associated with mature forest were likely abundant in the selection treatments due to the presence of intermediate- and large-diameter trees.

Autry, D.C. 1988. Plant communities on riparian limestone bluffs in Ozark National Scenic Riverways. Carbondale, IL: Southern Illinois University. 139 p. Ph.D. dissertation.

Extensive site sampling from more than 90 bluff transects; includes species lists for each sample and located by latitude, longitude. Includes Pioneer Forest bluff sites in Bay Creek and Leatherwood Creek.

Baigell, M. 1974. Thomas Hart Benton. New York: Harry N. Abrams, Inc. 281 p.

Author describes four periods of Thomas Hart Benton's life. The work, *Cave Spring* is from the 'World War II and Postwar Works' period. Cave Spring is located on the Current River, is owned by the L-A-D Foundation, and was visited by Thomas Hart Benton who depicted the scene in a color painting in 1963. There are 229 plates included in this volume, including numerous color plates. In describing this period of work in general, the author notes "In many ways, though, his more remarkable achievements are the landscapes of this period. In these, it would appear that Benton's overwhelming love for America found its true outlet—in the streams, hills, and mountains of the country, populated by people unsuspectingly living out their time, quietly enjoying themselves, living easily on the land, celebrating nothing more than their existence. Perhaps cumulatively these works glorify "America the Beautiful," a dream America where every prospect pleases. Individually they describe, sometimes with great succulence, a particular segment of that landscape."

"In the scenes painted from landscapes closer to Benton's home the effect is more intimate. The sky appears to be closer, the horizon is nearer at hand, and the vegetation grows more lushly (plate 136, compiler's note: "Cave Spring. 1963. Polymer tempera on canvas mounted on panel, 30 x 40". Field Enterprises Educational Corporation Collection). The streams, gullies, and soft hills of the Middle West - the vacation lands of the artist's mature years - become idyllic haunts of weekend fishermen and Sunday boatmen. The tumult of spirit in earlier paintings has given way to the continuous, easy pulsation of curving water banks, clumps of trees, and those familiar Middle Western clouds. The richness is sometimes overwhelming as one senses that Benton is reaching out to encompass all that he sees in a scene. It is as if he were making love to the trees, bushes, grasses, sandy spots, rocks, and pebbles. Other American artists have celebrated the American landscape, but few with such joy and innocence. Benton painted these works, one imagines, to please himself, and, even if they are stylistically related to earlier paintings, their mood is entirely personal."

"Yet they are personal in a way easily accessible to anybody. Their meanings are still American. Benton is still a painter of the American scene.

Batek, M.J. 1994. Presettlement vegetation of the Current River watershed in the Missouri Ozarks. Columbia, MO: University of Missouri-Columbia. 264 p. + 4 colored maps. M.A. Thesis.

This geography thesis reconstructs early nineteenth-century vegetation from Public Land Survey notes and other sources. The watershed includes a major portion of Pioneer Forest land.

Batek, M.J.; Rebertus, A.; Schroeder, W.A. [and others]. 1999. Reconstruction of early nineteenth-century vegetation and fire regimes in the Missouri Ozarks. Journal of Biogeography. 26: 397-412.

Study area is 26 complete and 4 partial townships in the Current River watershed including the Jack's Fork, from about Welch Spring in the Northwest to Van Buren in the Southeast, including three nearly complete townships of the big block on Pioneer Forest and about 9 partial townships. Combines analysis of early nineteenth-century Public Land Survey notes and dencrochronology-based fire histories to reconstruct vegetation and disturbance regimes of pine-oak woodlands. Vegetation patterns are also related to geological parent material, topography, and mean fire intervals. Reveals a distinct fire shadow east of the Current River.

Beckman, H.C.; Hinchey, N.S. 1944. The large springs of Missouri. Rolla, MO: Missouri Geological Survey and Water Resources. 2nd serial, 141 p. Vol. 29.

Summarizes the geology of the big spring country in Missouri, includes a short description of Cave Spring. Reports the only flow measurement made on the spring at that time, a low stage reading and another at high stage, both by the U.S. Geological Survey.

Bedan, D.E.; Goetz, R.E. l976. Pioneer Forest recreation study. St. Louis, MO: Coalition for the Environment. 54 p. + maps.

Detailed recommendations for lands of Pioneer Forest including trail development, recommended protection for Laxton Spring, Leatherwood Creek, and Rough Hollow as natural areas, and wildlife management recommendations.

Beveridge, T.R. 1966. Grand Gulf . . . Missouri Conservationist. 27(10):12-13.

This is an excellent overview of the area written by a geologist with insightful commentary. Beveridge reviews the stream piracy and cave roof collapse. As if this were a long-term geological combat he adds "...the Grand Gulf drainage system represents the greatest booty of any Stygian pirate in the Ozarks, and the battle area records the most extensive, dramatic, and scenic preservation of geological conflict in Missouri."

Beveridge, T.R. 1978. Geologic wonders and curiosities of Missouri. (Vineyard, J.D., revised edition, 1990). Rolla, MO: Missouri Department of Natural Resources, Division of Geology and Land Survey. 400 p.

Includes specific descriptions of the Narrows, Ball Mill Resurgence, Clifty Hollow Natural Bridge, Grand Gulf, and Leatherwood Arch.

Bolon, H.C. 1935. A study of Missouri springs. Rolla, MO: University of Missouri. 77 p. Thesis.

Author tabulated all state and federal records of the time regarding size of Missouri springs and determined relative mean flow. Twenty-seven Ozark springs (Mammoth Spring in Arkansas is the only non-Missouri spring included) are listed with Cave Spring at an estimated 45 cubic feet per second ranking twenty-one. The measurement for Cave Spring is from a single record taken June 22, 1924 and represents 46,600,000 gallons per day. Since it was taken during what would normally be a wet season it probably represents nearly maximum flow. Interestingly the author included black-and-white photographs of the time for some springs (Alley, Bennett, Big, Blue, Greer, Ha Ha Tonka, etc.) though none of Cave Spring.

Bretz, J.H. 1953. Genetic relations of caves to peneplains and big springs in the Ozarks. American Journal of Science. 251: 1-24.

Presents the theory of cave formation in the Ozarks. The origin of most Ozark caves is from circulating water below-ground. When the hydrostatic head disappeared as the uplands continued to age, these water-filled spaces then began to accumulate red clay from the soil above. Uplift caused further dissection on the upland, lowered the water table and drained these spaces. Bretz cites several Ozark caves where streams now flowing on the cave floor are not responsible for the solutional features on the cave walls and ceiling since the present stream is younger than the cave itself. Then Bretz describes four large Ozark springs [Greer, Roaring River, Welch, and Fishing Cave (now more commonly referred to as Cave Spring)] which still function as cave-makers.

Bretz, J.H. 1956. Caves of Missouri. Rolla. MO: Missouri Geological Survey and Water Resources. 490 p. Vol. 39.

Includes a discussion of the nature of Cave Spring, pages 441-444. Bretz considered Cave Spring to be an excellent, functioning example of cave origin in the phreatic (water-filled) zone. Big Creek Cave on the Current River in S36, T30 R4W also is noted and briefly described. Medlock Cave, S10 T31 R6 is briefly noted. Author includes a brief note regarding Cookstove Cave on page 444 and Grand Gulf on pages 350-355.

Broadhead, G.C. 1873. Maries County. In: Broadhead, G.C.; Meek, F.B.; Shumard, B.F. Reports on the geological survey of the State of Missouri, 1855-1871. Jefferson City, MO: Bureau of Geology and Mines. Regan and Carter Printers and Binders: 7-25.

Mentions Clifty Hollow Natural Bridge from fieldwork of 1857 as "a perfectly clear stream of water courses through this valley. The bottoms near are spread with a dense growth of trees and vines, among which I noticed the Muscadine grape. The valley at this point, being shut in by its perpendicular cliffs, with not a path to guide the traveler through the dense thickets, is wildly picturesque and romantic in its loneliness."

Bruff, G.L. 1977. Preliminary trail study for Ozark National Scenic Riverways. Van Buren, MO: National Park Service, Ozark National Scenic Riverways. 55 p.

Describes the setting for the lands of the national park and the cultural activities in the context of potential trail development. The report emphasizes the discussions which were ongoing at this time regarding Missouri's Ozark Trail under the Ozark Trail Steering Committee. Pioneer Forest is specifically mentioned in the recommendations here, including reference to the Bureau of Outdoor Recreation study (1976). Under a section titled 'Cooperative Efforts' Bruff discusses a meeting with Pioneer Forest staff in March of 1977.

Buckman, R.E.; Quintas, R.L. 1972. Natural areas of the Society of American Foresters. Washington, DC: Society of American Foresters. 38 p.

Brief introduction of SAF system with definition, criteria for selection, and procedure for designation. This report then details the name, location, size, owner, and representation of forest type for 281 areas. This is the fourth published list of SAF Natural Areas. As of this listing there are four Missouri areas, the Current River and Pioneer natural areas on Pioneer Forest, and Cupola Gum Pond and Haden Bald on the Mark Twain National Forest. The Pioneer Forest areas are identified here as under indenture and administered by the University of Missouri, School of Forestry.

Burghardt, R. 2003. Missouri's little grand canyon. Missouri Life. 30(2): 20-21.

This is an overview article. This issue of the magazine included a cover photograph of Grand Gulf State Park; other photos published with the article. All of the photos here by Don Kurz.

Chapman, H.H. 1951. Report on examination of forest property in Shannon County, Missouri, for the National Distillers Products Corporation, July 5-15, 1951. Typed manuscript on file with: Pioneer Forest Archives, Salem, MO 65560. 8 p.

This study of National Distillers' lands was to determine a method for securing maximum yields from white oak timber for barrel manufacturing, the practicality of managing these forest lands for continuous yield of forest products, and desirable data for a cruise including estimates of standing timber, rates of growth, and yield. Chapman provides an overview of recommended management practices especially with regard to the continuous production of white oak, appraisal of stocking from earlier work completed in 1949, establishment of sample plots for future inventory, economic return, silvicultural practice including the role of natural pine sites, and a discussion of oak wilt.

Comer, M. 1993. Resources to explore—Dillard Mill State Historic Site. Missouri Resource Review. 10(3): 28-30.

Brief historical sketch plus present day character of mill and surrounding land/buildings.

Curtis, M. 1981. The Ozarks' grandest canyon. The Ozarks Mountaineer. 29(4,5): 44-47.

Descriptive article highlighting geology and natural features of Grand Gulf, also explores management alternatives between state, federal, and private administration.

Davis, M.B. 1993. Old growth in the east, a survey. Richmond, VT: Cenozoic Society. 150 p.

Missouri listings are included in the southern Midwest section. Hickory Canyons Natural Area includes 190 acres of old-growth forest. The Virgin Pine Forest along Highway 19 also is included here. Age notation for the Virgin Pine Forest from this 1993 publication is an estimated 150 to 190 years (Richard Guyette established the canopy here at 200 to 225 years). Interestingly the Current River Natural Area (whose canopy is estimated at 400 years) is not included in this particular study.

Diaz-Granados, C. 1983. Rocky Hollow revisited. Further investigations, update, and recommendations for preserving and maintaining the integrity of a Woodland petroglyph site in Monroe County, Missouri. 76 p. (On file with: The L-A-D Foundation, 705 Olive Street, Room 724, St. Louis, MO 63101.)

Documents petroglyph symbols from Rocky Hollow including thunderbirds, serpents, human figure, turkey tracks, deer, turtle, fish, moon, comet, hunters, elk; they seem to reflect the earlier Woodland period and possibly a transitional period between the Woodland and Mississippian cultures. This report further documents and details features of the site and develops a list of recommendations for preservation including shelter protection, possible chemical treatment of the stone, photogrammetry, permanent castings, and an interpretive center.

Diaz-Granados, C. 1990. Tracking the A.D. 1054 supernova in Missouri's petroglyphs and pictographs. Paper presented at the Annual joint meeting of the Missouri Association of Professional Archaeologists and the Missouri Archaeological Society, May 5, Sedalia. (On file with: The L-A-D Foundation, 705 Olive Street, Room 724, St. Louis, MO 63101.)

The only anthropomorphic figure at Rocky Hollow on the west wall has both arms raised in the "shaman" position. The left hand is open and upright, but the palm is obliterated by a perfect circle. This author has reported that from the earliest work here that circle was believed to be an eclipse being "perpetrated" or a sun "being stopped" by a priest or shaman.

Diaz-Granados, C.; Duncan, J.R. 2000. The petroglyphs and pictographs of Missouri. Tuscaloosa, AL: University of Alabama Press. 333 p.

Presented here are the findings of a survey conducted between 1987 and 1992 to document all known and identifiable petroglyph and pictograh sites and analyzing the variety of ritual activities represented. The result is an inventory of 14 rock art sites. The context along with analysis of two predominant style groupings and ten minor styles are presented. The book's cover illustration is from Rocky Hollow Natural Area, from a photo by Richard C. Smith, the 'hands panel, plate 18 in the book (apparently misidentified as a bird motif from Washington State Park). The antlered animals depicted at Rocky Hollow represent wapiti (elk) rather than deer because of their backward configuration. Nine bird figures are noted. Fish are rare in Missouri and Rocky Hollow is one of only two in the State, and, as noted by this author, carved in considerable detail. Turtles are even less common but also represented. Rocky Hollow portrays the only certain prehistoric fish known from Missouri. Anthropomorphic figures are common at Rocky Hollow with "shaman" figures known because both hands are raised, one obliterated by a circular disk. There are other human figures, most likely hunters who appear to be on their knees and likely shooting with bows.

Diaz-Granados describes the Eichenbarger (1944) investigation among the early projects in Missouri and as a precious record from avocational archaeologists. Thirty-two plates are included as illustrations, three from Rocky Hollow. The Marion-Ralls Archaeological Society work discovered a tool believed to have been used to produce the carvings. In addition the Rocky Hollow site is believed to have been painted (with red or black

pigments). Rocky Hollow was repainted in the 1940's. Rocky Hollow is classified here as the Northeastern style, carvings are more or less sequential on a vertical shelter wall.

Doll, W.L. 1938. Hydrography of the larger springs of the Ozark region of Missouri. Rolla, MO: University of Missouri. 106 p. Thesis.

Presents evidence against stream piracy by springs. A series of discharge measurements were made on the Current River (several miles above a spring and immediately below the spring) and no evidence was found that springs carry an appreciable amount of water from the river. Uses streamflow and rainfall records to outline drainage areas of many Ozark springs. Estimates (see table 5, "Effective Drainage Areas of the Largest Springs in MO", p. 57) the effective drainage area of Cave Spring at 50 square miles. In discussing the Gasconade limestone whose thickness can be as much as 500 feet, author notes it is frequently cavernous and has some of the largest springs in the United States. Includes an estimate that 80 percent of Ozark springs flow from the Gasconade formation. Grand Gulf is specifically mentioned (page 13) as "3/4-mile long and 200 feet deep" and "from the bottom of this chasm a cave leads into a more recent channel exposing the stream, which flows out at Mammoth Spring."

Drees, D.; Flader, S. 2005. Current River Natural Area: Missouri's first designated natural area is bigger and better at 50. Missouri Conservationist. 66(5): 4-7.

Discusses history and natural history of Missouri's first designated natural area (1955) and a 255-acre expansion (2005), located in the big block on Pioneer Forest.

Drees, D.; Hughes, L.; Flader, S. 2005. Missouri natural area nomination form: Current River Natural Area (expansion). Missouri Natural Areas Committee, Nomination Date March 14, 2005. 14 p. + six appendices.

The natural area, originally established in 1955 at 10 acres, was expanded by 255 acres from adjacent land in Pioneer Forest. The nomination details the history and natural history of the area and includes discussion of principal features and management considerations, a plant list, and maps.

Dwyer, J.P.; Dey, D.C.; Walter, W.D.; Jensen, R.G. 2004. Harvest impacts in uneven-aged and even-aged Missouri Ozark forests. Northern Journal of Applied Forestry. 21(4): 187-193.

While the introduction notes that poorly managed selection harvests may increase damage to residual trees, these authors point out the more than 50 years of management experience on Pioneer Forest and the recent research of Lowenstein and others showing that individual-tree selection harvest can be a sustainable management method for xeric oak-hickory forests. This particular study was conducted entirely on sites, which are part of the Missouri Forest Ecosystem Project and analyzing the effects of clearcut and selection harvests. Few trees suffered bole wounds from either method, 5 percent in the clearcut sites and 8 percent in the selection sites. Crown damage from either method was insignificant. The conclusion is that well-supervised logging operations can minimize damage to the soil as well as leave trees.

Eddleman, W.R.; Clawson, R.L. 1987. Population status and habitat conditions for the red-cockaded woodpecker in Missouri. Transactions, Missouri Academy of Science. 21: 105-117.

Interesting overview, including comment on the historical records of this bird in Missouri. The red-cockaded woodpecker was first recorded in Missouri in 1907 as fairly common in Shannon and Carter counties. Around 1940 all subsequent records were from what was then a virgin pine forest just south of Round Spring (most likely the tract of Pioneer Forest we call the Randolph tract and from the virgin pine forest along Highway 19, now owned by the L-A-D Foundation). Three birds were observed in June of 1940; four in June of 1941; and five in June of 1946. The area was logged in 1946 except for the narrow virgin pine forest. No sightings have been recorded from Missouri since 1946.

Paper also briefly explores management strategies if these birds were to be re-introduced to the State: understory control is essential, rotations of 80 to 100 years would allow continuous production of mature pines needed by the birds, suggested minimum viable population size of 500 birds (250 clans) would be an eventual goal with a minimum area of 80 to 160 ha (200 to 400 acres) needed to support one clan, mature pine along highway right-of-ways could provide links between management areas.

Eichenbarger, J.A. 1944. Investigations of the Marion-Ralls Archaeological Society in Northeast Missouri. The Missouri Archaeologist. 10: 1-68.

This paper provides a detailed description of investigations during 1941. Titled Holliday Petroglyph Site MN 1, this article lists petroglyph groupings for four separate features and artifacts from two test trenches. The author provides extensive description of petroglyphs along with illustrations and photographs. Associated artifacts recovered from the site include potsherds, gouge, flake or flake knife, a scraper or graving tool, and chert spalls.

Everson, A.R.; Chilman, K.C. 1987. Final report—Cave recreation at Ozark National Scenic Riverways. Contract No. PX-6640-6-0285. U.S. Department of the Interior, National Park Service.

Includes a review of Medlock Cave.

Fadler, G.; Elder, W.H. 1973. A natural area survey of six eastern Ozark counties—Final report to the L-A-D Foundation. Columbia, MO: University of Missouri Cooperative Wildlife Research Unit. 98 p.

Includes natural area descriptions for Carter, Dent, Reynolds, Ripley, Shannon, and Texas counties. This report also includes specific discussion of Lily Pond (p. 68), Bowles Pond (p. 69), Cave Spring (p. 79), Pioneer Natural Area and Current River Natural Areas (p. 82), bluff at Two Rivers where we have a scenic easement (p. 93) and Dripping Spring (p. 94).

Fan, Z.; Shifley, S.R.; Spetich, M.A. 2003. Distribution of cavity trees in Midwestern old-growth and second-growth forests. Canadian Journal of Forest Research. 33: 1,481-1,494.

This paper provides an interesting analysis for predicting cavity trees, using variables such as diameter, species group, and decay class. Although to our knowledge none of the results reported here are from Pioneer Forest there are interesting implications. These authors suggest that thinning and selection harvests repeated over several decades may reduce the cavity tree population but following one harvest may have little net effect. This study points out that for old growth sites there are five times as many cavity trees as there are from mature, second growth sites (generally greater than 110 years old). As a supplement to the information presented here, Thompson's graduate student Elizabeth Annand reported on the similarity of the structural characteristics of Pioneer Forest plots comparing them more closely to mature and old growth forests. Given that the average turnover of the canopy on Pioneer is much greater than 200 years, the management strategy emphasizes leaving trees to fully mature and marking instructions leave wildlife trees may combine to maximize cavity opportunities. This study also points out that greater tree size and greater abundance of cavity-prone species (for Missouri, white oak and red oak have the highest probability) on old growth sites may have the greatest effect on cavity tree presence, characteristics of the forest structure on Pioneer Forest as well.

Fan, Z.; Shifley, S.R.; Spetich, M.A. 2005. Abundance and size distribution of cavity trees in second-growth and old-growth Central Hardwood forests. Northern Journal of Applied Forestry. 22(3): 162-169.

This discussion is more focused on grouping stands into broad size classes, specifically seedling/sapling-pole-sawtimber-old-growth. The authors suggest that the values for old growth forests serve as a reference for comparing conditions in other managed forests for this region. Uneven-aged forests such as those resulting from Pioneer's management, where at least three different age classes are the goal, should be ideal for producing and maintaining cavity trees across the forested landscape.

Faulkner, J.; White, J. 1991. Feasibility study for an Ozark Man and the Biosphere Cooperative. Urbana, IL: Ecological Services. 137 p.

Discusses potential biosphere reserve sites and outlines a specific area of managed use to include Pioneer Forest among other private conservation and preservation lands. See page 39.

Flader, S. 2004. Missouri's pioneer in sustainable forestry. Forest History Today. Spring/Fall 2004: 2-15.

Flader presents a history of Leo Drey's influence in Missouri forestry and conservation efforts. The piece is nicely illustrated with many of the photographs coming from the archived Pioneer Forest collection. Flader traces Leo's first acquisition in 1951 to his largest, nearly 90,000 acres from National Distillers in 1954. The various periods of Pioneer's more than 50-year history are traced beginning with its role in regional development (1955-1976), Pioneer's method of forest management (c. 1970), the silvicultural revolution (1965-1985), Pioneer's role in the controversy over public land management (1985-1990), and vindication (1990-2000). Throughout these five decades Leo's vision and adherence to the goals he and his earliest staff had established in the 1950's have always served as the stabilizing influence with Leo and Kay's gift of nearly all of Pioneer Forest in 2004 to the L-A-D Foundation "perpetuating the Pioneer tradition."

Flader, S., ed. 1992. Exploring Missouri's legacy: state parks and historic sites. Columbia, MO: University of Missouri Press. 352 p.

This extensive review of the Missouri State Park System includes essays and photographs on Dillard Mill State Historic Site and Grand Gulf State Park, both properties of the L-A-D Foundation.

Flader, S.L. 2004. History of Missouri forests and forest conservation. In: Flader, S.L., ed. Toward Sustainability for Missouri Forests. Gen. Tech. Rep. NC-239. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 20-59.

This extensive and well-documented paper mentions Leo Drey's leadership organizing the Missouri Forest Resource Conference held in October 1958; his founding of Pioneer Forest in 1951 and his vision "to restore a profitable forest by conservative single-tree selection uneven-aged management that would be productive also of wildlife, recreation, and other social and scientific values."; Pioneer Forest's comprehensive forest inventory and the fact that this ownership proved especially significant in comparison to the more widespread use of even-aged management by clearcutting begun in the 1960's; Leo Drey's position favoring U.S. Forest Service administration of the proposed Ozark National Scenic Riverways, as well as his later support for the Natural Steams Act proposed in 1990; Pioneer Forest's participation in the proposed Ozark Highlands of the Man and the Biosphere project.

Fritz, E.C. 1989. Clearcutting: a crime against nature. Austin, TX: Eakins Press. 124 p.

Examines the practice of clearcutting, reviews alternatives such as individual tree selection. Pioneer Forest cited as "selection forest" and includes photograph from 1987 at unknown location.

Gardner, J.E.; Taft, J.B. 1983. Cave resources of Ozark National Scenic Riverways, an inventory and evaluation. A preliminary copy of a final report submitted to Ozark National Scenic Riverways, National Park Service in compliance with contract CX-6000-2-0075.

Description and management recommendations for several caves on Pioneer Forest and L-A-D Foundation lands including Flying W Cave, Medlock Cave, Conglomerate Cave, and Wind Cave.

Grant, C. 1967. Rock art of the American Indian. New York: Promontory Press.

Mentions Rocky Hollow and includes an illustration (fish and elk) from the site.

Gremaud, G. 1995. The treasure hunters. Missouri Conservationist. September 1995: 56(9).

Overview article of the Missouri Natural Features Inventory. Running from 1980-1995, the article includes several examples of areas found and mentions the benefits provided from earlier inventories, specifically those counties inventoried by the L-A-D Foundation and graduate students of the University of Missouri. The L-A-D Foundation supported the work of one of the first university students (see Fadler and Elder 1973).

Guyette, R.P.; McGinnes, E.A., Jr.; LeDuc, S. 1982. Climatic history in the Ozark region as reconstructed from the tree-rings of eastern red cedar and white oak. Occasional Paper 7. In: Proceedings of the Cedar Glade Symposium, School of the Ozarks. Point Lookout, MO: Missouri Academy of Science: 80-111.

The period of analysis for this study was 1700-1980. Results show two drought cycles of 2.3 and 6 years. Chronologies for white oak include samples from Current River Natural Area, owned by the L-A-D Foundation.

Guyette, R.P.; Cutter, B.E.; Henderson, G.S. 1991. Long-term correlations between mining activity and levels of lead and cadmium in tree-rings of eastern red cedar. Journal of Environmental Quality. 20(1): 146-150.

Examines lead and cadmium concentrations in growth increments from lead-mining areas compared to control sites. Chronologies from Jerktail Mountain on Pioneer Forest were used as a control.

Guyette, R.P.; Henderson, G.S.; Cutter, B.E. 1992. Reconstructing soil pH from manganese concentrations in tree-rings. Forest Science. 38(4): 727-737.

Uses tree-ring chronologies from Jerktail Mountain area including nearby Asher Creek and Thompson Creek, all on Pioneer Forest.

Guyette, R. 1993. Fire history of the Eck Tract on the Big Piney River. 20 p. Unpublished report. Report for the project, pre-settlement fire history of oak-pine forests in the Ozarks, dated November 22, 1993. On file with: Pioneer Forest, Highway 19 N., Salem, MO 65560.

Tree ring sampling study which compares results on this tract with preliminary sampling of shortleaf pine from the virgin pine tract along Highway 19. Six tree ring samples from the virgin pine tract indicated even-age structure, however, all samples were specifically selected from the largest pine. Twenty-six samples were collected from the Eck Tract and indicated a wider range of ages for dominant canopy trees.

Guyette, R.; Muzika, R.M.; Dey, D.C. 2002. Dynamics of an anthropogenic fire regime. Ecosystems (2002). 5: 472-486.

The highly dissected nature of this study area has been shown to inhibit the occurrence of fire. Of an average of 108 fires annually in the region, less than 1 percent were from lightning, leaving the majority to be human-caused. The context for this paper then is the apparent relationship here between humans and fire. This study area, especially the northeastern quarter, is largely under the ownership of Pioneer Forest. Especially interesting here is the color map that depicts the forest types, topography, and the average fire or disturbance intervals. Shown on the map are intervals ranging from 10 to 29 years between 1700 to 1850.

Overall, the study area is more than 80 percent forested and located near the western edge of the eastern deciduous forest and dissected by steep ridges and numerous streams. Slopes here average 18 degrees. Considering fire history development, topographic roughness, and human population information these authors have developed a four-stage sequence of the fire regime: ignition-dependent, fuel-limited, fuel-fragmentation, and culture-dependent stages.

Guyette, R.P.; Stambaugh, M.C.; Dey, D.C. 2003. A riparian fire history along the Current River corridor. National Park Service report for the Ozark National Scenic Riverways. Van Buren, MO.

Details the fire history of the Current River corridor from dendrochronology and other records. The L-A-D Foundation (and Pioneer Forest) owns substantial land in the corridor and about 35 miles of L-A-D frontage along the river is under scenic easement to the Ozark National Scenic Riverways.

Haefner, R.A. l983. A survey of sinkhole pond natural communities in Missouri. Columbia, MO: University of Missouri. 205 p. MS Thesis.

Includes descriptive information and comparative notes for Bowles Pond, pages 138-144, 189 and mentions Vinson Pond, page 189.

Hall, L. 1958. Stars upstream, life along an Ozark river. Chicago, IL: University of Chicago Press. 252 p.

Hall compares the "little rivers of the Ozarks" against any streams in America, his two "favorites by far are the Current and its tributary Jacks Fork". Hall credits Ed Woods (Chief Forester for Pioneer Forest at that time), among others, for teaching him about Ozark timber. In his essay on the Ozark Mountains, Hall cites nine of the large springs, including Cave Spring saying "the location is extremely scenic but difficult to reach except by river, so that it is seldom visited". In his discussion of open range Hall mentions Spencer Jones, who strongly advocated closing the range in the Ozarks, and whose farm is now part of Pioneer Forest. Describing the float from Cedar Grove to Round Spring Hall mentions several of the tributary hollows which include some of the lands of Pioneer Forest, Fishtrap, and Lewis; Hall also writes about entering Cave Spring by canoe.

Hall also recounts the 80,000 acres of cooperage company land, reportedly the largest stand of virgin white oak remaining in America and when they decided to liquidate some of their assets they cut most of the white oak of 14 inches in diameter. Hall's description includes the note that even with this cut, "there were a great many trees left" including "smaller white oak, but there were also extensive stands of pine seedlings, some pine of larger size, and other species of hardwoods such as scarlet oak and black oak, hickory and sour gum". Randolph Hole, a bank along the Current River, is mentioned, where an agreement was made to leave some of the largest white oak uncut, "these will be preserved so that future generations may know what our forests looked like before they were despoiled by the lumberman" Hall mentions the young St. Louis businessman, Leo Drey, who purchased these lands from National Distillers for a long-range forestry project.

Hall, in his description of the Current River from Big Spring to Doniphan floats with canoe enthusiasts, Leo and Kay Drey.

Hawksley, O. 1976. Missouri Ozark Waterways. Jefferson City, MO: Missouri Conservation Commission. 114 p.

Notable features of interest to floaters along Ozark rivers in Missouri; references along the Current River include the following from Pioneer Forest Medlock Cave and spring (mile 12.6), Cave Spring (mile 21.9), and on the Jacks Fork River Leatherwood Creek (mile 22.2) and Bay Creek (mile 25.2).

Hebrank, A.W. 1989. Geologic natural features classification system for Missouri. Natural Areas Journal. 9(2): 106-116.

Geologic natural features are classified according to the physical processes that formed them. They are categorized into fluvial (stream-related), erosional, solution/groundwater, gravity, glacial, eolian (wind-related), oceanic, igneous, tectonic, and 'features of problematic origin'. The classification system published here serves as the standard for the classification of geologic natural features in Missouri. Several of the L-A-D Foundation properties and one area on Pioneer Forest are cited as examples. The Narrows along the Big Piney River in Texas County is cited as one of two examples of a narrows, a fluvial feature. Grand Gulf in Oregon County is cited as one of two examples of a collapse canyon, a solution/groundwater feature. Ball Mill Resurgence in Perry County is the example of an estevella (a reversible swallow hole/spring), a solution/groundwater feature. Clifty Hollow Natural Bridge is cited as one of two natural tunnels/bridges/arches of lateral piracy origin, a solution/groundwater feature. Grand Gulf's natural bridge is the example of an uncollapsed segment of a cave roof collapse. The Leatherwood Natural Arch is cited as an example of solution enlargement of a joint usually adjacent or parallel to the face of a bluff or cliff. Grand Gulf is one of three karst complex sites.

Hedden, W.J. 1968. The geology of the Thayer area emphasizing the stratigraphy of the Cotter and the Jefferson City formations. Rolla, MO: University of Missouri. MS Thesis.

Discusses geology of Grand Gulf, description of faulting, formation of the gulf, suggests cave entrance resulted from a tornado which uprooted trees upstream during the early 1920's. Author describes isolated karst features of the area of several square miles immediately west of Koshkonong. Pages 112-123.

Hensold, N.C.; Leoschke, M.J.; Morgan, S.W. 1986. Rare plants of the Ozark National Scenic Riverways. Jefferson City, MO: Missouri Department of Conservation. 200 p.

Because the Congressional boundary for the Ozark National Scenic Riverways includes a significant amount of privately-owned property, this report includes a number of plant records for Pioneer Forest and L-A-D Foundation properties. Nineteen species are reviewed from their occurrence along both the Jacks Fork and Current rivers. Part II of the report is a descriptive exemplary natural community survey. Among sites detailed in this survey are Jerktail Mountain (high quality dry-mesic igneous forest on the south end of the mountain crest) and an extensive, high quality igneous glade (five distinct large glades occur along all sides of Jerktail Mountain, Cave Spring dolomite glade (the only significant glade on the Lower Current District), Rough Hollow fen (high quality deep muck fen, three rare species known from the site), and Thompson Creek seep fens (a series of four small fens along 3/4-mile of the stream valley). For the specific references here see pages 177, 181, 183, and 190.

Herbeck, L.A. 1998. Ecological interactions of plethodontid salamanders and vegetation in Missouri Ozark forests. Columbia, MO: University of Missouri. 78 p. MS Thesis.

Salamanders alone are the most abundant vertebrate animals, and their annual production of biomass exceeds that of birds or small mammals. This thesis reports research results on plethodontid salamander densities. Relationships between coarse woody debris, canopy cover, ground area cover, herbaceous vegetation, woody vegetation, and plethodontid salamanders occurring among 42 sample plots distributed within three distinct forest structural stages were determined. Second growth and regeneration sites were located on Missouri Department of Conservation lands in Reynolds and Shannon counties, while old-growth sites were located on National Park Service lands in Carter County and on Pioneer Forest land (the uncut Current River Natural Area and the surrounding old-growth forest on that same north-facing hillside) in Shannon County.

During 1995 and 1996 three species and 348 individuals were captured; southern redback salamanders (84 percent) and slimy salamanders (16 percent), and one individual of longtail salamander were captured. Estimated mean densities were 1422.7 salamanders/hectare for old-growth, 287.5 salamanders/hectare for second growth, and 14.87 salamanders/hectare for clearcut. Regeneration cutting reduces microhabitats for salamanders through increased temperatures and decreased moisture availability from the elimination of the forest canopy. This study found 5 times more salamanders in old-growth than in second growth and 20 times more salamanders in second growth than in regeneration cuts.

Forest management focused on rotations of 75 to120 years may truncate succession and prevent development of structural characteristics associated with older, mature forests, including development of larger trees, accumulation of down wood, and development of high density foliage layering.

Herbeck, L.A.; Larsen, D.R. 1999. Plethodontid salamander response to silvicultural practices in Missouri Ozark forests. Conservation Biology. 13(3): 623-632.

Authors present data on salamander densities from regeneration cuts (<5 years old), second-growth cuts (70 to 80 years old), and old growth sites (>120 years old). Among the old growth sites is the Current River Natural Area on Pioneer Forest. Salamander populations were reduced to very low numbers when mature forests had been intensively harvested. Plethodontid salamanders (those species of salamanders which are purely terrestrial and lack an aquatic larval stage; plethodontids lack lungs and exchange gases almost entirely through the skin) appear to be best adapted to conditions characteristic of older, mature forests and management can affect their abundance. During the spring season of 1995 and 1996 the authors found five times more salamanders in second growth forests than in regenerating forests. Increasing the rotation length in managed forests would provide older, mature forests that play a critical role in maintaining relatively high densities of plethodontid salamanders.

Hobbs, H.H., Jr.; Hobbs, H.H., III; Daniel, M.A. 1977. A review of the troglobitic decapod crustaceans of the Americas. No. 244. Smithsonian Contributions to Zoology. 183 p.

Detailed review of 55 species in 8 families, includes notes on karst regions, adaptations, as well as detailed scientific illustrations and a key. *Cambarus hubrickti*, a white cave crayfish, was collected from Medlock Cave in 1941 (see page 82).

Holst, S. 1991. Resources to explore—Grand Gulf State Park. Resource Review. 8(1): 28-31.

General write-up on the park, includes description of geology, relationship of surrounding lands, hydrology; specific mention of L-A-D Foundation ownership.

House, S. 1985. Cave maps as management tools. Missouri Speleology. 25(1-4): 68-77.

House discusses various uses for cave maps including land management, inventory, visitor management, interpretation, and scientific; several maps are included as illustrations. Under the discussion of interpretation are comments about Cave Spring and Devil's Well where the author notes that the National Park Service brochure uses the mapped plan and profile views of Devil's Well to help explain the relationship to the Cave Spring supply system. The suggestion is made here that these two features should be connected with a trail as a further aid in explaining these geological relationships. This issue of Missouri Speleology is the Proceedings of the 1984 National Cave Management Symposium.

Iffrig, G.F.; Trammel, C.E.; Cunningham, T. 2004. Pioneer Forest: a case study in sustainable forest management. In: Flader, Susan L., ed. 2004.Toward sustainability for Missouri forests. Gen. Tech. Rep. NC-239. St. Paul, MN: USDA–FS, North Central Forest Experiment Station. 913–204.

Detailed overview of the design and description of single-tree selection forest management as used on Pioneer Forest. Data for the period 1957 to 1997 are presented showing volume measurements for seven major species groups and basal area by diameter class from 6 inches to 24 inches or greater. Economic advantages of this system of forest management are demonstrated by looking at market price increases from Pioneer Forest for the period 1950 to 1999. Using this information an economic model is applied to an average acre of Ozark forest land managed for the most recent 24-year period (1975 to 1999) using clearcutting versus single-tree selection harvest. From the two management scenarios, including management costs for conducting each sale, the authors showed a nearly doubled rate of return by using single-tree selection harvests.

Jackson, D.D. 1988. Every State should have a Leo Drey. Audubon. 90: 78-83.

Interview article discussing background of Leo's acquisition of Pioneer Forest and other lands. Includes management style; relationships with Department of Natural Resources, Missouri Department of Conservation, private conservation groups. Discusses L-A-D Foundation.

Jeffries, J.M. 2004. Community composition, species richness, and abundance of oak herbivore insects in a chronoseries of temperate forests. St. Louis, MO: University of Missouri. 65 p. MS Thesis.

Jeffries' work provides companion research to that reported by Robert Marquis at the University of Missouri-St. Louis (Marquis and Le Conff in 1997 and then Marquis and others 2002) regarding insect herbivore diversity and abundance. Those results indicated increasing rates of diversity and abundance as the age of Missouri Ozark forests increased, however, the range of difference in age from their study was only 25 years. Jeffries' interesting addition of Current River Natural Area as a sampling site has provided a much longer chronoseries, extending beyond 300 years. Her results provide strong evidence that increasing structural diversity within forests influences herbivore success. Older forests are not as dense and therefore provide a quite different forest architecture from their canopy layers, multiple diameter classes, shrubs, and forest floor debris. Jeffries discusses the implications for conservation suggesting modifications in forest management which would extend rotation periods for even-aged forests and leaving more, larger diameter trees uncut.

Jenkins, M.A. 1992. A study of oak decline and vegetation dynamics in the forests of the southeastern Missouri Ozark Mountains. Columbia, MO: University of Missouri. 244 p. MS Thesis.

Describes oak decline, traces history and factors involved. Study sites were located on Pioneer Forest, Mark Twain National Forest, and University State Forest. Discussion of once-dominant *Pinus echinata* now found only on the driest sites and replaced by *Quercus coccinea*. This occurred after large scale harvest and subsequent fire suppression, resulting in an apparently even-aged stand of scarlet oak (*Q. coccinea*). Over the decade of the 1980's mortality of *Q. coccinea* in the Ozarks may have resulted from synchronized effects on this particular age class and spread over a vast area of the Ozarks. Also traces changes for *Q. alba* and *Q. velutina*; notes Pioneer Forest showed no major decrease in frequency of *Q. velutina* or *Q. coccinea* and the author suggests that selective cutting and the resulting reduced competition may explain the different vegetational dynamics at play here than in Ozark forests elsewhere.

Jenkins, M.A.; Pallardy, S.G. 1993. A comparison of forest dynamics at two sites in the southeastern Ozark Mountains of Missouri. Gillespie, A.R.; Parker, G.R.; Pope, P.E., eds. In: Proceedings of the 9th Central Hardwood Conference. Gen. Tech. Rep. NC-161. St. Paul, MN: U.S. Forest Service, North Central Forest Experiment Station: 327-341.

Data from established plots at Pioneer Forest and University State Forest studying mortality and decline of red oak species. Similar mortality rates for *Quercus coccinea*; University Forest exhibited higher mortality rates for *Q. velutina*. Importance value (IV) for *Q. velutina* declined (1962 to 1991) on University forest but remained stable at Pioneer Forest. IV for *Q. coccinea* decreased on both areas 1980 to 1987, increasing after that on Pioneer Forest, while gradually declining at University Forest.

Authors suggest selective cutting at Pioneer Forest may be creating more uneven-aged stands which are less susceptible to synchronous mortality. Results of this study report "oak regeneration on Pioneer Forest is certainly comparable, and perhaps superior, to that of University Forest. Pioneer had significantly greater density of *Q. alba* seedlings; significantly greater *Q. coccinea* and *Q. alba* sapling densities. Again, suggesting "uneven-age management of oak-hickory forests in the Ozarks might provide sufficient regeneration to perpetuate oak species in subsequent stands."

Johnson, C.; DeLano, P. 1990. Missouri: off the beaten path. Chester, CT: Globe Pequot Press. 166 p.

Mentions the town of Dillard and specifically Dillard Mill State Historic Site.

Johnson, P.S. [n.d.]. Uneven-age management of oaks in the Ozark Highlands: is it sustainable? Unpublished report. On file with: Pioneer Forest, 2814 Highway 19 N., Salem, MO 65560.

Uses data exclusively from Pioneer Forest; discusses regeneration dynamics of oaks, the "accumulation" of reproduction over several decades; presents plot data from Pioneer Forest suggesting single tree selection method of harvest can work. Forest-wide size structure conforms to the reverse-J distribution curve; in addition to plot data a limited analysis of the age structure indicates the uneven-aged condition has been created and occurs at a relatively small spatial scale.

Johnson, P.S. 1992. Perspectives on the ecology and silviculture of oak-dominated forests in the central and eastern states. Gen. Tech. Rep. NC-153. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 28 p.

Describes the historical and ecological relations between oaks, fire, and humans and reports the consequent silvicultural options and limitations in managing and sustaining oak-dominated forests. Includes a discussion on the history of clearcutting, beginning in the 1960's, noting clearcutting on public lands (especially the national forests) has declined in favor of forest

management less focused on commodity production and more focused on the total of forest values. The overview and history here is interesting. Johnson includes options to clearcutting and discusses the single-tree selection method. Pioneer Forest is mentioned though no specific data is presented. General discussion of the method notes that survival of understory oaks (regeneration) is substantially greater than for trees of the same size in an even-aged forest at the same overall stocking level.

Johnson, P.S. 2004. Thinking about oak forests as responsive ecosystems. In: Spetich, M.A., ed. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 13-18.

Important review of forests as continually responsive to forces from within and outside. While presenting a four-stage development process for even-aged forests, Johnson discusses the development of uneven-aged characteristics resulting from stand maturation and gap formation and filling. Johnson also suggests that in the Ozark Highlands oaks are "usually not successionally displaced by other tree species and the relative permanence of oaks is reflected by their relatively high abundance in the smaller diameter classes, even in old-growth stands." Under natural conditions the persistence of diameter distributions often approaches a reverse-J shape, in other words having a greater number of smaller diameters and increasingly fewer numbers of larger diameter trees. In pointing out that specific characteristics of such diameter distributions and their natural occurrence and silvicultural maintenance, depend on species composition and stand density and cites the work of Larsen, Loewenstein, and Johnson in 1999 where the basis for the silvicultural recommendations was the Pioneer Forest dataset, and the work of Loewenstein, Johnson, and Garrett in 2000, which also examined the Pioneer Forest plot data during the thirty-year period 1962 through 1992 declaring the method of management here as strongly positive in maintaining a healthy and sustainable forest.

Johnson, P.S.; Shifley, S.R.; Rogers, R. 2002. The ecology and silviculture of oaks. New York: CABI Publishing. 503 p.

A thorough treatment of the genera, this is primarily a silvicultural approach to managing and sustaining oak forests. The treatment here extends across six regions within the United States where various oak species occur. Included are ecological aspects of oak-dominated ecosystems, regeneration ecology, site productivity, development of natural stands, self-thinning and stand density, even-aged and uneven-aged silvicultural methods, silvicultural methods for multi-resource management, and growth and yield. Of particular interest here is the authors' discussion of uneven-aged silvicultural methods where they credit and reference Pioneer Forest data. Although certainly favoring group selection, and unnecessarily critical, the discussion of the principles and theory of the single-tree selection method are quite important, and notably the most extensive we have seen.

Karel, J.A.; Elder, W.H. 1976. A natural area survey of the Southeast Missouri Regional Planning District—Final report to the Missouri Inter-Agency Council for Outdoor Recreation. Columbia, MO: University of Missouri, Cooperative Wildlife Research Unit. 151 p.

Includes descriptions for natural areas in Bollinger, Cape Girardeau, Iron, Madison, Perry, St. Francois, and Ste. Genevieve counties. The report describes Ball Mill Resurgence (pages 108-109), Hickory Creek Canyon (pages 133-134), and Lower Rock Creek (pages 93-94).

Kirk, C. 1979. I think on it often. Missouri Conservationist. 40(7): 20-23.

Musings on forest management and the natural world, incorporates observations from several decades of work on Pioneer Forest and Cal Stott's Newsletter on Continuous Forest Inventory. This same article was reprinted in American Forests 85(12): 34-35, 55-57.

Kramer, K.; Thom, R.; Iffrig, G. 1996. Directory of Missouri Natural Areas. Jefferson City, MO: Missouri Natural Areas Committee. 156 p.

This is the updated version of the 1985 publication (see Thom and Iffrig, 1985).

Kurz, D. 1996. Scenic driving in the Ozarks including the Ouachita Mountains. Helena, MT: Falcon Publishing. 274 p.

Details the natural and cultural highlights along some of the most inviting roads in Missouri, Arkansas, and Oklahoma. The "Two Rivers" drive in Missouri, a 64-mile route between Salem and Blue Spring, includes a description of the virgin pine forest and the 2-mile long Pioneer Forest interpretive drive.

Larsen, D.R. 1980. A growth and yield model for managed upland oak-shortleaf pine stands in Missouri. Columbia, MO: University of Missouri. 83 p. MS Thesis.

Study completed entirely on Pioneer Forest; discusses and uses CFI data, establishment plots, develops growth and yield model for oak-pine modified from published work of Sullivan and Clutter in Forest Science, 1972.

Larsen, D.R.; Metzger, M.A.; Johnson, P.S. 1997. Oak regeneration and overstory density in the Missouri Ozarks. Canadian Journal of Forest Research. 27(6): 869-875.

Using data from Pioneer Forest research plots, the authors present models for reducing overstory density to increase the regeneration potential of oak forests. In general, oak reproduction increases as residual stand basal area decreases. Authors note that due to the nature of this relationship, the predictability of individual stands is low, however, these models describe average trends for the highly stochastic regeneration process.

Larsen, D.R.; Johnson, P.S. 1998. Linking the ecology of natural oak regeneration to silviculture. Forest Ecology and Management. 106 (1998): 1-7.

Authors provide a useful interpretation to the regeneration requirements of oaks and point to the need for ecologically sound silvicultural prescriptions. While oaks are often classed as mostly shade intolerant, Larsen and Johnson point out that oaks have successfully adapted to and survive during extended periods of shade within the forest. The habit of oaks to grow up from seedlings, survive for a few years, dieback, and then repeat this process for many years is well known. This ability of oak seedlings to persist declines with increasing stem sizes. From unpublished oak root data at the North Central Forest Experiment Station, belowground portions of seedling sprouts can live up to 50 years. This paper notes Lowenstein's work (1996) on Pioneer Forest, identifying the success of selection harvesting of oaks in xeric forests resulting from minimal non-oak competition and the ability of moderately tolerant oak species such as white oak to reproduce and grow in the understory. This paper briefly discusses the shift in silviculture from the traditional expectation to control most ecological processes to the role of creation and maintenance of ecologically 'natural' forests. They discuss the move of the Forest Service during the mid-1990's to ecosystem management. Single-tree selection is discussed as one successful cutting method for the drier forests of the Missouri Ozarks but suggest that it may not be successful where it encourages other more shade-tolerant non-oak species.

Larsen, D.R.; Loewenstein, E.F.; Johnson, P.S. 1999. Sustaining recruitment of oak reproduction in uneven-aged stands in the Ozark Highlands. Gen. Tech. Rep. NC-203. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 11 p.

This paper describes the relationship between overstory density and oak reproduction. Criteria are presented for selecting a residual stand structure and density appropriate to the single-tree selection method in the Ozark Highlands and consistent with the regeneration ecology of oaks and thus sustaining a forest dominated by oaks. The basis for the silvicultural recommendations in this paper is the Pioneer Forest dataset.

LaVigne, E.M. 2002. Heterogeneity within and among selectively harvested forest stands in the Missouri mountains. St. Louis, MO: Saint Louis University. 94 p. MS Thesis.

A study of the change in forest structure and composition on Pioneer Forest using a space-for-time substitution. To accomplish this, the author established plots from within the forest representing harvest entries throughout the past twenty-year cutting period. Three stumps were identified at each site. Using stumps as plot centers, data was collected on percent canopy coverage, stem abundance, species abundance, and species diversity. Analysis of the data provided information on heterogeneity among the cuts. Canopy cover was the only significant difference measured across the landscape; ecological heterogeneity occurred at scales smaller than 0.0017 km^2. Heterogeneity produced from single-tree selection harvesting occurs mainly at smaller spatial scales within the forest understory.

A measure of the canopy cover and turnover ranged from 189 to 228 years and provides further indication that disturbance within the forest is in fact minimized from use of the single-tree selection technique. Yet another indication of this is that the measure of species richness did not significantly change over time, in other words change from sites recently harvested to those measured immediately prior to harvest activity was not significant. LaVigne found there was no consistency as to which species would fill a particular gap that was created; her results indicate this is more a matter of chance events determined largely by the existence of previously established individuals. The interesting analogy established by SanDiego (2000) about opening windows within the forest is further explained here by LaVigne as the canopy gaps created by single-tree selection harvesting act as moving windows that shift in time and space, while varying the concentration of light availability over space and time.

Lewis, D. 1978. The Current River and tributaries (Montauk to Lower Big Creek). Eminence, MO: Ozark Custom Printing Co. 47 p.

Author grew up along the Current River and these writings are an effort to preserve some of the area's history and culture. Mentioned are a number of the hollows, springs, and caves on Pioneer Forest, often including derivations of particular place names. Included within the text are Razor Hollow, Medlock Cave, Bluff Schoolhouse, description of a float trip in 1908 by Governor Herberet S. Hadley and stop at Cave Spring, Kelley Hollow, Capps Hollow, and Big Creek Cave. Also included is an interesting historical sketch of the settlement of Big Creek Valley and briefly of Brushy Creek.

Lewis, N. 2005. Couple's giving is rooted in their passion for the great outdoors. The Chronicle of Philanthropy. March 3: 7, 22.

Profiles Leo and Kay Drey's conservation and philanthropic interests and activities over the years, with special reference to their gift of 146,000 acres of Pioneer Forest to the L-A-D Foundation, the sixth largest philanthropic gift in the nation in 2004.

Loewenstein, E.F. 1996. An analysis of the size- and age-structure of a managed uneven-aged oak forest. Columbia, MO: University of Missouri. 167 p. Ph.D. Dissertation.

There are two aspects to this study. One is an investigation of age-structure and age/diameter relationships from a random sample of 600 oaks from a one-square mile area of Pioneer Forest. Sample data from ten one-acre plots from a one square mile area of the forest showed that seven of the ten plots were uneven-aged, two were two-aged, and one was even-aged.

This research also investigates the long-term trends in species composition, basal area, density, and quadratic mean diameter using data from the 370, 1/5-acre permanent plots. During the period from 1952 through 1992 the average basal area increased by 68 percent and average density by 89 percent. Ingrowth of trees into the 5-inch diameter class was sufficient to maintain or increase density for all principle species, even after accounting for harvested trees. No compositional shift toward shade-tolerant species was noted. In addition a chi-square test showed that the diameters from the plot data conformed to the forest-wide average at a scale of 0.6 acres.

Loewenstein, E.F.; Garrett, H.E.; Johnson, P.S. 1995. Changes in a Missouri Ozark oak-hickory forest during 40 years of uneven-aged management. Gottschalk, K.W.; Fosbroke, S.L.C., eds. In: Proceedings, 10th Central Hardwood Forest Conference. Gen. Tech. Rep. NE-197. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 159-164.

Examines changes in basal area, density, and average diameter from Pioneer Forest plot data from 1962 through 1992. Describes the forest, management strategy, and methods of data collection from the permanent plots. Basal area and density are increasing. Forest composition has not changed measurably during the data collection period; the seven species prominent in the forest 40 years ago still comprise the same relative proportion on the forest today. *Quercus alba* has increased its density three-fold and its basal area has more than doubled. Conclusions are that the management "appears to be maintaining a healthy, sustainable forest...ingrowth into the five-inch diameter class is occurring at a rate sufficient to maintain or increase density for all of the principal forest species even after accounting for harvested stems."

Loewenstein, E.F.; Johnson, P.S.; Garrett, H.E. 2000. Age and diameter structure of a managed uneven-aged oak forest. Canadian Journal of Forest Research. 30(7): 1060-1070.

Discusses age and diameter structure on one section of Pioneer Forest. Authors note advance oak reproduction in the Ozarks and cite the evidence that "this relatively shade-tolerant oak can survive beneath a forest canopy for up to 90 years." Using ten study plots these authors data confirmed a reverse-J shaped diameter distribution, however, diameter measurement alone can be a result of variation in growth rates among similar aged trees or especially among different species expressing varying growth rates. When the data was analyzed by species alone, the study area population of red oak as well as the population of white oak each expressed uneven-aged distribution based on diameter. Analysis of actual age distributions showed the forest conforms to an uneven-aged state at a scale of 0.4-ha on 70 percent of its area. Interestingly, this same analysis of actual age showed a range from 12 to 233 years and the authors suggested that a significant proportion of these trees were already established by 1954. Only 13 percent of the population of trees from this study have been established since 1954.

A fundamental conclusion is that just as a reverse-J shaped diameter distribution does not confirm an uneven-aged state, a bell-shaped age distribution does not preclude its existence. Therefore, when managing forests using uneven-aged silvicultural systems, diameter structure should be the primary factor to consider.

Loewenstein, E.F.; Guldin, J.M. 2004. Conversion of successionally stable even-aged oak stands to an uneven-aged structure. Spetich, M.A., ed. In: Upland oak ecology symposium: History, current conditions, and sustainability. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 264-268.

Authors present four conversion prescriptions targeting mostly fully-stocked even-aged stands of varying ages into an uneven-aged forest structure. They note the experience of Pioneer Forest in creating well-structured uneven-aged upland oak stands from poorly stocked, cutover stands through judicious tending of residual growing stock. Furthermore, authors note this pattern has also been common for southern pine.

Lootens, J.R.; Larsen, D.R.; Loewenstein, E.F. 1999. A matrix transition model for an uneven-aged, oak-hickory forest in the Missouri Ozark Highlands. A paper presented to the 1999 Missouri Natural Resources Conference. Haywood, J.D., ed. In: Proceedings of the Tenth Biennial Southern Silvicultural Research Conference. Asheville, NC: U.S. Forest Service, Southern Research Station: 536-538.

Authors present a matrix growth model for an uneven-aged, oak-hickory forest in the Ozark Highlands of Missouri. The model was developed to predict ingrowth, growth of surviving trees and mortality by diameter class for a 5-year period. Tree removal from management is accounted for. The model is based on Pioneer Forest data from 400 0.2-acre permanent plots, measured over eight, 5-year periods from 1957 to 1992. Variables include basal area, site index, and species group. Models were evaluated using 100 reserved plots and comparing predicted and actual diameter-distributions over 5-, 15-, and 35-year periods.

Love, K. 2003. Building natural wealth. Missouri Conservationist. 64(11): 8-11.

A personal look at Leo's many accomplishments over the years, including recollections about people he acquired land from, his forest managers, particularly about building and managing Pioneer Forest for more than 50 years, acquiring and preserving natural areas, and working on various conservation issues (for example, founding the Open Space Council, Ozark National Scenic Riverways, founding the Coalition for the Environment, and acquiring Greer Spring).

Lynch, D.W. 1964. Report of the Committee on Natural Areas. Journal of Forestry. 1964 (December): 916-918.

Report on Pioneer Natural Area as one of three added during the year. Reference to the establishment in 1955 of the Current River Natural Area. Both "are examples of outstanding contributions by a private timber landowner in which he relinquishes the management of the areas to a board of trustees under the protection of legal indenture." Measurements of eastern red cedar at approximately 30 percent of the basal area in age classes ranging from 20 to 80 years old. Individual red cedar trees were measured at 18 inches d.b.h.

Marling, K.A. 1985. Tom Benton and his drawings—a biographical essay and a collection of his sketches, studies, and mural cartoons. Columbia, MO: University of Missouri Press. 224 p.

See page 8 of this book for the sketch of Lyman Field, friend of Thomas Hart Benton, on a river float on the Buffalo River in Arkansas. This sketch was later incorporated into the painting of Cave Spring that Benton completed in 1963 (see also Baigell 1974).

McKee, J. 1998. Milling around. Missouri Conservationist. (January 1998): 4-9.

This is a story about Russ Noah, retired forester from Pioneer Forest. During the 34-year portion of his career in the Missouri Ozarks Noah acquired an extensive knowledge of old forestry equipment. Russ began working with Pioneer Forest in 1951. Here is an inside look at the collecting and restoring of antique logging equipment. The article mentions the 1800's portable railroad tie mill he restored and pictured is the restored 1906 Case steam engine (see also Santhuff 1998).

McPherson, A. 1997. One hundred nature walks in the Missouri Ozarks. Vienna, IL: Cache River Press. 327 p.

The author includes trails at Dillard Mill State Historic Site and Grand Gulf State Park. Devils Well is written up and includes reference to our planned 2-mile trail to Cave Spring. The Blair Creek Section of the Ozark Trail is also reviewed by McPherson with notes on the mileage, maps, trailheads, and descriptions.

Melick, R.A. l989. Uneven-aged management opportunities in upland oak-hickory stands in the Missouri Ozarks, with silvicultural prescriptions for three stands near the Mill Creek Recreation Area. Mark Twain National Forest, Rolla Ranger District. A paper presented to the U.S. Forest Service Region 9, to meet one of the requirements for the Program for Advanced Silvicultural Studies and Silvicultural Certification. 103 pages with literature cited and appendices.

This paper presents some of the earliest work in the Mark Twain National Forest' consideration of uneven-aged management. References Pioneer Forest work and specific discussions in June of 1987. Mention of Pioneer Forest, see pages 52, 59, and 66 for general advantages of uneven-age management, see Table 11 on page 68, also page 54.

Meyer, A.B. 1949. Pioneer Forest. Missouri Conservationist. August: 1-3, 16.

Interesting review of "Pioneer Forest of National Distillers Products Corporation." Summarizes early history prior to National Distiller's ownership when Current River Land Company owned part of the property and when ancient white oaks and shortleaf pine were common; discusses both companies conservative management practices. Mentions Ed Woods and Charlie Kirk and their forest inventory and leaving seed trees for shortleaf pine.

Millman, E. [n.d.]. A history of Deloss Lovine Millman and Millman Lumber Company. Unpublished printed manuscript. On file with: Pioneer Forest, Highway 19 N., Salem, MO 95560.

This is an interesting historical overview of a company working on the lands which would become Pioneer Forest during the 10 to 20 year period before Leo's purchase of these lands from National Distillers. This work was compiled by Ellen Millman with contributions by family members and others associated with Millman Lumber Company and Great Western Lumber Company. This work explores the family's long history of operating sawmills in southern Missouri and northern Arkansas.

In 1937 Millman Lumber Company purchased all of the yellow pine timber (from what was then Pioneer Cooperage Company, later purchased by National Distillers and then sold to Leo) estimated at 60,000,000 board feet and requiring 9 separate sawmill locations and 11 years to cut. In 1935 to 1937 they established a sawmill on Blair Creek (perhaps in Spring Hollow near Spout Spring). In 1938 they located a sawmill at Himont and then on Big Creek. The Big Creek mill was probably located near the creek and just north of the current Pioneer Forest property and included a steam-powered sawmill, dry kilns, planing mill, several houses, bunkhouse, and store. In 1939 the author notes "final cut of virgin pine forest in the State of Missouri." Author notes that D. L. Millman sold the 200-foot wide strip of virgin pine to the state, however, our records show Pioneer Cooperage sold the land to the State, Millman may have agreed to sell their rights to the yellow pine timber here at the same time.

Missouri Department of Conservation. 1993. Management plan for the black bear in Missouri. Jefferson City, MO: Missouri Department of Conservation. 50 p.

L-A-D Foundation listed, among others, for forest management for black bears and landscape level conservation needs. See page 11.

Missouri Department of Natural Resources. 1991. Challenge of the 90's—Our threatened state parks; park threat summaries. Jefferson City, MO: Missouri Department of Natural Resources. 155 p.

Park-by-park overview for eight broad threat categories: air pollution, aesthetic degradation, physical removal or loss of resources, exotic encroachment, visitor physical impacts, water quality changes, park operations, and ecosystem degradation. L-A-D Foundation properties, Grand Gulf State Park and Dillard Mill State Historic Site, are reviewed.

Mohlenbrock, R.H. 1983. Botanical inventory of the Ball Mill Resurgence Natural Area. Unpublished manuscript submitted to the L-A-D Foundation, November 1, 1983. 28 p. On file with: Pioneer Forest, Highway 19 N., Salem, MO 65560.

Brief overview of the area with a description of dominant vegetational communities (upland woods, floodplain forest, old field, and disturbed areas). Included is a complete list of taxa observed from the site during the late spring, summer, and autumn of 1983, totaling 339 ferns and flowering plants. No specimens were collected.

Mohlenbrock, R.H. 1984. Biological inventory of the Clifty Creek Natural Bridge Natural Area. Unpublished report submitted to the L-A-D Foundation, June 20, 1984. 43 p. On file with: Pioneer Forest, Highway 19 N., Salem, MO 65560.

Overview of the area including description of the dominant vegetational communities (upland woods, mesic woods, stream and streambank, glade, bluff faces, and disturbed). The study was conducted during late summer and autumn of 1983 and early and late spring of 1984. Included is a listing of 458 taxa of ferns and flowering plants recorded from the site. Collections were made during the 1984 visits.

Mohlenbrock, R.H. 1985. First interim report on botanical inventory of Hickory Canyons Natural Area. Report prepared for L-A-D Foundation by Biotic Consultants, Inc. June 20, 1985. 7 p. On file with: Pioneer Forest, Highway 19 N., Salem, MO 65560.

Details plant communities listing dominant species; estimates as many as 700 species of ferns and flowering plants.

Nelson, P. 1985. The terrestrial natural communities of Missouri. Jefferson City, MO: Missouri Natural Areas Committee. 197 p.

Specific mention of Dripping Springs (Texas County) as a type example of moist limestone/dolomite cliff; Rocky Hollow as type example for dry sandstone cliff; Grand Gulf as type example for influent cave. Each of these areas is owned by the L-A-D Foundation.

Nelson, P.W. 2005. The terrestrial natural communities of Missouri. Jefferson City, MO: Missouri Natural Areas Committee. 550 p.

Nelson's 1985 work was revised in 1987 and this latest revision has been greatly expanded. In a table showing Missouri Natural Areas ownership (table 6, page 71) there are 10 L-A-D Foundation natural areas totaling 1,637 acres. Several of the Foundation's natural areas are noted as type examples. In the terrestrial natural communities discussion of forests, a photo of Current River Natural Area shows at least four large white oak trees, each exceeding 20 inches in diameter. Hickory Canyons Natural Area is referenced as a representative example of both dry-mesic and mesic sandstone forest, and dry sandstone cliff; Rocky Hollow Natural Area is referenced as a representative example of both moist and dry sandstone cliff; Clifty Creek Natural Area is referenced as a representative example of gravel wash.

Nevins, R.B. 1953. Report of Missouri Natural Area Survey. Report to the Nature Conservancy. Columbia, MO: University of Missouri, Department of Horticulture. 12 p.

Nevins, a graduate student at the University of Missouri, took a list of 121 areas in Missouri prepared earlier by J.A. Steyermark, then during July and August of 1953 reviewed their potential for nature preserves. This listing included 57 sites, which were visited and assessed. This listing references the National Distilleries virgin hardwood stand, noting that the exact location for a preserve had not been determined. Nevins indicated its size was expected to be about 15-20 acres, surrounded by an appreciable buffer, and that some of the stands on this land are pure white oak, averaging 200 years of age. Nevins last entry for the National Distilleries site is that the contacts are Ed Woods and Charlie Kirk, both very interested in conservation.

This listing includes Bowles Pond and Vinson Pond, both on Pioneer land, and Lily Pond, which has been acquired by the Nature Conservancy and is surrounded by Pioneer land.

This list is annotated with remarks and landowner names. This copy on file with Pioneer Forest was obtained from the collection of Steyermark's papers at the Missouri Botanical Garden, St. Louis, MO and has a handwritten note at the top, "Mr. Nevins Report". At least two other versions of the list were produced and distributed, each either containing less information or less specific information. One dated January 1954 is noted as an abridged report of Mr. Nevins findings and is titled Missouri Natural Area Survey and dated January 1954. Another abbreviated listing bears the title 'Missouri Areas in Need of Protection'.

Nigh, T.A. 1984. An ecological assessment of sugar maple in the upland oak-hickory forests of Missouri. Columbia, MO: University of Missouri. 191 p. MS Thesis.

Study includes three sites: Current River Natural Area (L-A-D Foundation), Sugar Tree Hollow, and West Fork of Black River (Pioneer Forest).

Nigh, T.A. 1988. Final report on the Missouri natural features inventory: Carter, Oregon, Ripley, and Shannon counties. U.S. Forest Service, Rolla, MO and Missouri Department of Conservation, Jefferson City, MO. 286 p.

Thompson Creek, Leatherwood Creek, Bay Creek, Cave Spring, others listed by county; properties of both Pioneer Forest and the L-A-D Foundation.

Nigh, T.A.; Pallardy, S.G.; Garrett, H.E. 1985. Sugar maple-environment relationships in the river hills and central Ozark Mountains of Missouri. American Midland Naturalist. 114: 235-251.

Study includes research sites on Pioneer Forest. Conclusions are that sugar maple is reproducing more rapidly than oak throughout the western portion of the eastern deciduous forest, even forests with a predominant oak canopy. Authors largely attribute this to reduced site disturbance and suggest that lack of oak regeneration on all but the driest sites will result in a profound shift in species composition within future forests of this region. Sites sampled include western, central, and southern Missouri.

Opton-Himmel, J. 2001. Black bear survey on Pioneer forest, Shannon County, Missouri. Unpublished report. 19 p. On file with: Pioneer Forest, Highway 19 N., Salem, MO 65560.

Summary report of a bait station survey modeled after Missouri Department of Conservation (MDC) surveys statewide. In 1992 the MDC statewide effort consisted of 1,062 stations where 13 confirmed black bear visits. Six of these 13 were from Pioneer Forest. However, for the past 3 years (1999 to 2001) no black bear visits have been reported from bait stations on Pioneer Forest. This study by Opton-Himmel used the same methodology to more intensively sample a roughly 80 square mile area of Pioneer Forest. The results confirmed the presence of black bear on the forest. Six percent (5) of the established stations (80+) from this work received visits and all of these were within a 4 square mile area.

Orr, L.S. 1990. The vascular flora of Grand Gulf State Park, Oregon County, Missouri. Springfield, MO: Southwest Missouri State University. 37 p. MS Thesis.

A floristics survey of the park's 160 acres, conducted from July 1987 through July 1990. The collections numbered 346 species from three plant communities. Voucher specimens are deposited in the Ozarks Regional Herbarium at Southwest Missouri State University.

Orzell, S.L. 1983. Natural area inventory and floristics analysis of fens in selected southeastern Missouri counties. Carbondale, MO: Southern Illinois University. 202 p. MS Thesis.

General overview of Missouri Ozark fen hydrology and especially floristics as well as community structure; contains information from specific localities on Pioneer Forest, although these are hard to pinpoint from looking at the thesis alone. From Shannon County site #40 is either Fishtrap Hollow Fen or Marshy Spring Hollow Fen, others from maps pages 58-73.

Owen, L.A. 1898. Cave regions of the Ozarks and Black Hills. Cincinnati, OH: The Editor Publishing Company. 228 p.

In the first chapter Owen compares the southern half of Missouri with the Black Hills of South Dakota as "delightful regions for the study of caves." She quotes geologists of her day in relating the complexities of cave formation and the diversity of their decoration. Owen also quotes Broadhead's report in Broadhead, Meek, and Shumard (1873) regarding "natural bridges worthy of special notice" and specifically Clifty Creek Natural Bridge west of the Gasconade. She quotes Broadhead's entire description of the bridge (see entry for Broadhead (1873) in this bibliography). Chapter 7 of Owen is about Grand Gulf. It is interesting, knowing that today the cave entrance is blocked by debris, that Owen reports walking perhaps 600 feet into the entrance before reaching "the end of dry land at an elbow of a silently flowing river". Owen reports using a boat to travel a channel no more than 6 feet wide and for some distance. Owen mentions visiting Mammoth Spring in Arkansas just 9 miles to the south.

Owen, L.A. 1968. Cave regions of the Ozarks. Missouri Speleology. 10(2): 22-86.

Reprint of part of the 1898 work pertaining to Missouri and including an introduction by J.D. Vineyard nicely describing the life and work of Owen.

Owen Gallery. 2000. Thomas Hart Benton, exhibition of paintings, October 14 – December 15, 2000. Notes and research by Andrew Austin Thompson. Owen Gallery. 104 p.

This nicely illustrated publication includes a written overview of Benton's career as an artist, including discussion of his earliest modern art period, the years during which he produced mural paintings, and the influences during his later work. There is also a Catalogue of the Exhibition, which appeared at the Owen Gallery in New York City in 2002, with 39 images of the work of Thomas Hart Benton. For each image there is documentary information including the title of the work, the year completed, size, materials used in creating each work, its provenance (source), and exhibition history. Benton's Cave Spring, completed in 1963, was part of this exhibition and is presented twice in this work, on page 28 (a close-up from the center of the painting) and pages 90-91. Although Benton frequented the Ozarks and floated both the Current River in Missouri and the Buffalo River in Arkansas, the actual location of the subject of this painting is misidentified here as being along the Buffalo River. Certain elements in the painting itself offer unmistakable evidence of the location of Cave Spring along the Current River in Missouri, one of the properties owned by the L-A-D Foundation.

Pallardy, S.G.; Nigh, T.A.; Garrett, H.E. 1991. Sugar maple invasion in oak forests of Missouri. In: Burger, G.V.; Ebinger, J.E.; Wilhelm, G.S., eds. Proceedings of the Oak Woods Management Workshop. Charleston, IL: Eastern Illinois University: 21-30.

Study sites include Pioneer Forest for the Ozark portion of the study, map included.

Panno, S.V.; Weibel, C.P.; Wicks, C.M.; Vandike, J.E. 1999. Geology, hydrology, and water quality of the karst regions of southwestern Illinois and southeastern Missouri. ISGS Guidebook 27. Champaign, IL: Illinois State Geological Survey.

Guidebook for a geological fieldtrip as part of the 33rd Annual Meeting of the North-Central Section of the Geological Society of America. Includes description of a stop at Ball Mill Resurgence in Perry County and photo (pages 34-35). Also notes that the cobbles lining the resurgence scoured the dolomite bluff in a manner similar to the bowl-shaped features of Illinois Caverns.

Powell, R.L. 1970. A guide to the selection of limestone caverns and springs in the United States as Natural Landmarks. Bloomington, IN: Indiana Geological Survey.

Brief mention of the collapse cavern structure of Grand Gulf and its association with Mammoth Spring, AR.

Pryor, R.R. 1980. Natural areas in Missouri—Report of the Missouri Natural Area Survey. L-A-D Foundation, St. Louis, MO. 381 p. On file with: Pioneer Forest, Highway 19 N., Salem, MO 95560.

Extensive report in two volumes covering 67 counties in Missouri listing noteworthy natural communities and geologic areas. Numerous sites are described. Includes illustrations of Grand Gulf and Clifty Creek and each of these areas is also described in the report.

Reiter, S.R. 1991. Woody invasion onto glades of the Ozark National Scenic Riverways, Missouri. Ames, IA: Iowa State University. 80 p. MS Thesis.

Includes Cave Spring Dolomite Glade where NPS/Pioneer Forest boundaries join. Study also includes some work on Jerktail Mountain, a rhyolite glade and Thompson Creek Dolomite Glade. Overall study results show loss of open area at 32.4 percent for Gasconade dolomite areas and 22.9 percent from rhyolite areas. Measurements were taken from aerial photographs from 1955, 1966, and 1984.

Rennicke, J. 1995. Wild at heart. Backpacker. April 1995: 48-56.

Featured trails from the Heartland of the Midwest; included among the 10 listings is the Ozark Trail, the description which highlights the Blair Creek section which "offers solitude, ridgewalking, Blair Creek's scenic deep valley, and great views of the Current River."

Rossiter, P. 1992. A living history of the Ozarks. Gretna, LA: Pelican Publishing Company. 487 p.

Discussion of Dillard Mill, pages 439-442, with specific mention of L-A-D Foundation, history of ownership and operation, with notes on the cultural importance of the mill.

Rothwell, T.W. 1993. Missouri pine. Missouri Conservationist. 54(6): 22-25.

Overview article, includes introductory mention of the "one-mile long virgin pine strip" indicative of "a common site before the turn of the century (photograph of the Virgin Pine accompanies the article). Discusses companies operating in the Ozarks around the turn of the century including Grandin Timber Company and the Missouri Lumber and Mining Company. Wildlife benefits are discussed. Young dense stands of pine are favored by Cooper's and sharp-shinned hawks; older pine trees provide cavity nesting for the red-cockaded woodpecker.

Rucker, B.H. 1993. With a little help from our friends. Missouri Resource Review. 10(1): 8-13.

This article presents an overview of philanthropic assistance to the Missouri State Park System, from organizations and businesses to individuals from across the state. Includes mention of L-A-D Foundation contributions with respect to Dillard Mill State Historic Site and Grand Gulf State Park; author notes that "Perhaps at opposite ends of the cultural-natural dichotomy, each is a masterpiece of its own genre."

Ryan, J.; Smith, T.E. 1991. Final report on the Missouri natural features inventory of Howell, Texas, and Wright counties. Missouri Department of Conservation, Jefferson City, MO and U.S. Forest Service, Rolla, MO. 149 p.

Records on Horseshoe Bend, Piney River Narrows, and Dripping Springs natural areas, each of these areas is owned by the L-A-D Foundation.

San Diego, N.M. 2001. Management regime, scale, and the diversity of leaflitter arthropod communities of an Ozark forest. St. Louis, MO: Saint Louis University. 56 p. MS Thesis.

Analysis of how various forest management practices have affected the community composition of leaflitter invertebrates over ecological time. This study characterized communities at each site, determined how changes in scale affect community parameters, and compared scaling effects, both within and among three management treatments. The three treatments were an area not subject to harvest (Current River Natural Area), an area subject to single-tree selection harvest (Pioneer Forest), and an area cleared of trees (Reiss Biological Station). The arthropod data suggests that communities are significantly impacted by the type of forest management practiced. Abiotic variables (percent canopy coverage, temperature, humidity) showed significant spatial patterns at the 5 x 5 meter grid level.

As for abiotic variables the scale in variance for the clearcut is one to two orders of magnitude greater than the same measures on Pioneer Forest or at Current River Natural Area.

Author uses an interesting window analogy (see pages 47) where the forest canopy is the window. Harvesting a significant number of trees (clearcut) is akin to opening the window wide. The result is that for the clearcut, a suite of disturbance effects sets in leaving a footprint which is still being felt (25 years after the disturbance), particularly in measures of increased relative humidity.

Results of this study indicate that single-tree selection harvests on Pioneer Forest generate a spatial gradient throughout the landscape creating conditions most suitable for diversity to be maximized.

Santhuff, C. 1998. Noah's mill. Missouri Conservationist. January 1998: 9.

A look at the restoration and operation of Noah's early 1800's up-and-down sawmill. (see also McKee 1998).

Sarvis, W. 2000. Old eminent domain and new scenic easements: land acquisition for the Ozark National Scenic Riverways. Western Legal History. 13(1): 1-37.

Interesting historical analysis of the eminent domain concept and its use during creation of the Ozark National Scenic Riverways (ONSR). Sarvis points out that until the early 1960s, NPS acquisition practices had rarely required eminent domain (the 1961 establishment of Cape Cod National Seashore set an important precedent in this regard). Introduction to this essay portrays local sentiment squarely against establishment of the ONSR, thought of as taking of property rights. Much of the information in this area originates from papers of Leo A. Drey, collection no. 531, Western Historical Manuscript Collection, University of Missouri, St. Louis, MO.

There is also background on scenic easements beginning in California in the 1930s. The concept of using scenic easements for establishing the ONSR was introduced during the early 1960s, as one supporter put it to preserve "a living landscape" of bucolic beauty and as an alternative to fee simple title acquisition and certainly acquisition by eminent domain. With the power of eminent domain, land was acquired for the ONSR. Sarvis documents the complications and oftentimes unfairness in appraising property values and truthfully approaching the large number of landowners here with the acquisition and condemnation process.

Sarvis concludes by noting that further use of the scenic easement option was "the most successful broad-based phenomenon to arise out of ONSR land acquisition." Further stating "this innovative concept was admirable and remarkable for its adoption at such a relatively experimental stage...". It was the sort of bitter feelings generated by the ONSR condemnation experience that contributed to congressional reform in Public Law 91-646 (Uniform Relocation Assistance and Real Property Acquisition Policies Act) in 1971. The essay suggests that occurrences of the sort experienced here helped inspire the libertarian "property rights movement" of the 1980s and 1990s.

Sarvis, W. 2002. A difficult legacy: Creation of the Ozark National Scenic Riverways. The Public Historian. 24(1): 31-52.

An interesting and well-documented look at how the Ozark National Scenic Riverways was first proposed. Sarvis discusses at length the influence and feeling of the proposals' supporters as well as its opponents. He traces the discussion of the idea from its infancy, through its successful passage as federal law (Public Law 88-492). Sarvis documents his discussion with references to Leo's papers that are part of the Western Historical Manuscripts Collection, University of Missouri-St. Louis. Other individuals mentioned here are then acting NPS Director Hillory A. Tolson, Leonard Hall, Shannondale Mission Reverend Vincent Bucher, Sigurd F. Olson of Wilderness Society and National Parks and Conservation Association fame, and Richard Pogue then with the Natural Areas Council and later with The Nature Conservancy. Leo's role during this period and his opposition to the plan are a significant part of this discussion.

Sarvis mentions the September 1961 float trip down the Current River where Leonard Hall accompanied Secretary of the Interior Stewart Udall and NPS Director George Hartzog. Concluding the discussion are references to the many controversies which have arisen over the years, from the very beginning with local resistance to land acquisition (see Sarvis 2000) to canoe traffic, horsepower limits on motorboats, trapping, and most recently feral horses. An interesting contrast is offered recognizing the intrusion of the NPS into Ozark culture and society to their lasting service in documenting and preserving area history, ethnology, and folkways.

Schaper, J.; Wicks, C. 2004. Aqueous geochemical study of a calcite-depositing Ozark creek: Tufa Creek, Shannon County, Missouri. Columbia, MO: University of Missouri. Speleology. 42(3/4): 1-38. Senior Thesis Study.

With a calcareous fen providing year-round water, Tufa Creek becomes a tufa depositing cold-water stream. Tufa is a thin, soft, spongy, cellular or porous, semi-friable incrustation around or along a stream or spring. Analysis of six sample sites provided for such measurements as water temperature, chemistry, alkalinity, hardness, etc. from this small, spring-fed tributary to Current River. Carbon-dioxide off-gassing from agitation of stream water as it falls 25 m in elevation over a distance of 583 m is considered the mechanism for calcite deposition. By comparing nearby Ebb and Flow Spring and Thompson Creek, these authors suggest that sufficient stream mineralization and optimal stream geometry are necessary for freshwater calcite deposition.

Schnack, D. 1994. The Ozark Trail. Missouri Resource Review. 11(1): 28-31.

General write-up on the Ozark Trail. This article notes Pioneer Forest as members of the Ozark Trail Council; it also includes a descriptive section about the trail and mentions Blair Creek and Harper Spring.

Scott Consulting Engineers. 1988. Grand Gulf Cave, Interim Report, October 21, 1988. Project No. 10-799-9-0005. 10 p. + exhibits. Unpublished report. On file with: Scott Consulting Engineers, Springfield, MO 65806.

Discusses work and feasibility of opening the cave entrance at Grand Gulf State Park.

Scott Consulting Engineers. 1989. Grand Gulf Cave-Interim report, October 21, 1989. Project No. 10-799-9-0005. 10 p. + exhibits. Unpublished report. On file with: Scott Consulting Engineers, Springfield, MO 65806.

Discusses work and feasibility of opening the cave entrance at Grand Gulf State Park.

Scott Consulting Engineers. 1991. Grand Gulf State Park, Final Report-Cave exploration phase, February, 1991. Project No. 10-799-9-0005. 12 p. + exhibits. Unpublished report. On file with: Scott Consulting Engineers, Springfield, MO 65806.

Companion to this report is a video-taped report prepared by team members from the High Pressure Water Jet Laboratory, University of Missouri, Rolla, MO.

Shanklin, J.F. 1955. Current River Natural Area. Journal of Forestry. 53(7): 532-536 (July 1955).

In the April 1952 issue of the Journal of Forestry the Society of American Foresters' Committee on Natural Areas issued a request for locations of virgin type associations. This note, published 3 years later, highlights negotiations begun with National Distillers Products Corporation of New York City and completed between the SAF and the new owner, Leo Drey. Area established in March 1955 to fill the need of all practicing foresters for a comprehensive knowledge of natural developments within virgin forest associations. The indenture is also printed as it was legally established.

By the agreement Leo granted to himself and John F. Shanklin (Chairman, Committee on Natural Areas) as Trustees for the administration of the natural area by "remise, release, and quit-claim" the area of approximately 10 acres.

Shanklin, J.F. 1960. Society of American Foresters Natural Areas. Journal of Forestry. 58(11): 905-917.

The third printing of the Society's approved natural areas. The first list was printed in the journal in 1949, another in 1952. One hundred and twenty-eight natural areas in 34 states and Puerto Rico are listed here; the Current River Natural Area is the only Missouri site.

Steyermark, J.A. 1963. Flora of Missouri. Ames, IA: Iowa State University Press. 1,728 p.

Notes occurrence of *Decodon verticillatus* at Lily Pond and Bowles Pond (page 1090). Also mentions Lily Pond as the only known location for *Potamogeton epihydrus* var. *nuttallii* "growing close to another sinkhole pond where *Decodon verticillatus*, also an isolated relict in Missouri, occurs" (page 54). On page 1,172 Steyermark notes *Hottonia inflata* from Vinson pond, remarkably isolated from where it is more common in swamps and low ground. Bowles Pond, Lily Pond, and Vinson Pond are all on Pioneer Forest land (Lily Pond is a Missouri Natural Area).

Still, M. 1983. Profile - Leo Drey: land magnate of the Ozarks. Missouri Resource Review. 2(1): 24-26.

Highlights the establishment of Pioneer Forest, style of land management, and formation of the L-A-D Foundation.

Stroh, E.D.; Struckhoff, M.A. 2002. Exotic species invasion and structural damage along horse trails in sensitive natural areas at Ozark National Scenic Riverways. 36 p. Unpublished research report. On file with: USGS Northern Prairie Wildlife Research Center, Missouri Field Station, University of Missouri, Columbia, MO 65211.

Two-year study with the first year sampling six vegetation communities in order to determine which had the greatest frequency of exotic species associated with horse trails. Of upland waterways, glades, south/southwest slopes, north/northeast slopes, ridges/shoulder slopes, and river bottoms, the results reported here show that exotic species associated with horse traffic were more commonly recorded from river bottoms, upland waterways, and glades. Nine study sites were chosen and a total of 66 plots were sampled. A number of sample plots were located on Pioneer Forest lands including those around Eminence and the Sinks (WC01-02, WC01-03); Round Spring (RS01-05, RS01-06, RS01-03, RS01-04, RS01-07, RS01-01, and RS01-02); Jerktail Landing (JT01-17, JT01-18, JT01-19, JT01-20, JT01-21, and JT01-22), and Two Rivers (TR01-01 and TR01-03). The management recommendations include either eradicate or control the most troublesome exotic species (fescue, sweet clovers, garlic mustard, and Chinese yam) in the highest quality natural areas; monitor along horse trails for new infestations; monitor for leafy spurge, as yet unknown to the area; and utilize horse riders to help scout and monitor new occurrences.

Suggs, G.G. 1990. Water mills of the Missouri Ozarks. Norman, OK: University of Oklahoma Press. 204 p.

Discussion and illustrations (2) of Dillard Mill, pages 69-71.

Sutton, M.; House, R.S. 2003. Ozark National Scenic Riverways Bat Survey, Winter 2002-2003. 40 p. Unpublished Report. On file with: Cave Research Foundation, Missouri.

Report on the field inventory of 44 caves, including Medlock Cave on Foundation easement property and Wind Cave on Pioneer Forest. At one time reports of the gray bat population at Medlock had been estimated at 36,000, down as of this inventory to 5,000-9,000. With human visitation heavy, obvious trails developing, and controlling access difficult, the recommendation is that Medlock Cave be gated. Wind Cave had been noted as a minor summer site for gray bats, however, this inventory recognized increased guano accumulation leading to estimates of at least 26,500 bats and possibly double that depending on the occupation patterns of the bats. In either case it appears this is one of the largest summer gray bat colonies in the lower Ozarks. Gating the entrance is not recommended here, although blocking the road and obliterating the trace leading motorized vehicles to the site are recommended.

Taylor, R.L. 1977. Cookstove cave (SHN 018). Missouri Speleology. 17(1-2): 32-35.

Description of Cookstove Cave in Shannon County, map, and discussion of geology and speleogenesis. From the article "there are 3,400 feet of mapped passage in the cave, with most of that passage having large dimensions...the passage is nearly 100 feet wide." Cookstove Cave is also known as Holmes, Stovepipe, Squaredance, and Big Dixon Cave. The conjecture is that Cookstove was once a major spring which flowed away from the cave's present entrance, generally to the northwest into Blair Creek.

Thom, R.H.; Iffrig, G.F. 1985. Directory of Missouri natural areas. Jefferson City, MO: Missouri Natural Areas Committee. 115 p.

Specific listing and description of Clifty Creek, Rocky Hollow, Ball Mill Resurgence, Hickory Canyons, Current River, Pioneer, Piney River Narrows, Dripping Springs, and Horseshoe Bend natural areas.

Trammel, C.E. 1996. Pioneer Forest: a kinder, gentler way. International Journal of Ecoforestry. 12(2): 235-237.

Overview of history of the Ozarks and establishment of Pioneer Forest, the management system, and why uneven-aged harvest works.

U.S. Department of Agriculture, Forest Service. 2002. Draft Environmental Impact Statement, Pineknot woodland restoration. Carter County, MO: Doniphan/Eleven Point Ranger District, Mark Twain National Forest. 277 p. + appendices.

Proposal to develop a shortleaf pine woodland community similar to those known to exist in Missouri during the 1800's and known to exist at this particular site. Several stages of restoration are proposed. The area includes 10,831 acres of the Mark Twain National Forest. Our comments on this document are strongly supportive; of particular interest here is that lands of Pioneer Forest occur within the project area, to the far eastern edge of the site. In addition to being supportive we have suggested that our lands here be included with our role being a cooperating partner.

U.S. Department of the Interior. 1976. A recreation plan for Pioneer Forest, Missouri. Salem, MO: Mid-Continent Regional Office, Bureau of Outdoor Recreation. 41 p. + maps.

Report includes recommendations for trails, primitive camping facilities, retention of old growth forest, self-guiding auto tours, interpretive shelters, and various cooperative projects with Federal and State agencies whose lands join Pioneer Forest.

U.S. Department of the Interior. 1979. Executive summary, new area, study of alternatives—Grand Gulf, Missouri. May 1979. National Park Service 1420. 8 p. + map.

Broad overview of the significance, status, and alternatives for management of the site. At the time of the report the L-A-D Foundation had acquired the property. Management alternatives include continuing the sites unimproved state under foundation ownership, private/state administration, state ownership and administration, and federal administration. Costs for operation and maintenance are drawn from comparison with Timpanogos Cave National Monument located near American Fork, Utah and Elephant Rocks State Park here in Missouri.

U.S. Department of the Interior. 1979. Study of alternatives, new area—Grand Gulf, Missouri. May 1979. National Park Service, Denver Service Center. National Park Service 1421. 49 p.

Study of alternative strategies for the protection, interpretation, use, and management of Grand Gulf to the National Park System. Described here are the regional and local environment, cultural resources, recreational resources, significance of the resource (a superlative geological and ecological entity; comparisons to three other natural landmarks: Grassy Cove, TN, Germany Valley, WV, and Newsome Sinks, AL; comparison to Natural Bridge and Natural Tunnel in Virginia, neither are comparable in size or nature) (discusses limit of feasibility for development as a major park). This report details each of the four management alternatives listed in the Executive Summary (see listing above) keeping in mind the natural preserve concept, limited development, and interpretation of the geologic resource.

Vandike, J.E. 1985. Movement of shallow groundwater in the Perryville Karst Area, southeastern Missouri. Water Resources Report No. 40. Rolla, MO: Missouri Department of Natural Resources, Division of Geology and Land Survey.

Detailed discussion of the intensely karstified Perryville sinkhole plain. No other area in Missouri contains more extensive karst development. Blue Spring Branch is the western boundary of this study area and within this watershed lays Ball Mill Resurgence. Several maps delineate Blue Spring Branch where Ball Mill Resurgence occurs along with the several perennial

springs and intermittent resurgences: Blue Spring, Keyhole Resurgence, Keyhole Spring, Blue Spring Resurgence, and Blue Spring. There is a brief discussion of the Moore Cave System and its relationship to the features which overlie it. The specific recharge area for Ball Mill Resurgence was not established in this study.

Vandike, J.E. 1997. Karst in Missouri, an overview. MCKC Digest. 4(2): 32-42.

Part 1 of a series of articles which provide an overview of our state's caves, springs, sinkholes, losing streams, and the land and water that gives them form and function. Included here are a brief review of geology (illustrated by a three dimensional figure of the origin of geologic features of the landscape), karst features of Missouri, and map of Missouri's major karst regions. This article highlights karst features of the Salem Plateau, commonly considered Missouri's premier karst region. Interestingly Logan Creek is described as a classic example of an Ozark losing stream. Several areas of Pioneer Forest are within the upper watershed, between Highway 72 to the north and Highway 106 to the south. Perhaps for 10 or more miles, Pioneer Forest land lies directly adjacent to the creek on one or both sides, mostly in the section which is the gaining part of the creek. Below this, Logan Creek is a losing stream, with a gravel-filled channel which can be more than 200 feet wide.

In describing sinkholes, Grand Gulf is called the "Cadillac" of Missouri sinkholes, a spectacular center piece of Grand Gulf State Park. This article includes two photographs illustrating the natural bridge at Grand Gulf as well as an aerial view of the gulf itself.

Vandike, J.E. 2000. Southeast Missouri karst region. MCKC Digest. 7(2): 17-30.

Article contains specific information on this particular karst region, essentially within Franklin, St. Louis, Jefferson, Ste. Genevieve, Perry, and Cape Girardeau counties and the city of St. Louis. This author attributes this karst region with the most varied geology and hydrology. This review describes in some detail resurgences of eastern Perry County, including a good overview of the functioning of Ball Mill Resurgence. There is an interesting observation that Ball Mill Resurgence "can mutate from a dry, rock filled basin to a spring rivaling the first magnitude springs of the Salem Plateau in size."

Ver Hoeff, J.M. 1991. Statistical analysis of spatial pattern in ecological data. Ames, IA: Iowa State University. 147 p. Ph.D. dissertation.

Three-part study dealing with estimation and prediction for spatial processes, especially for ecological data using (1) variogram under aggregation, (2) estimation of average patch size for transect data, (3) simultaneous prediction of several variable types for a vector-valued process. Data collected from several Pioneer Forest Ozark glades including Cave Spring, Thompson Creek, and Jerktail Mountain.

Vineyard, J. 1958. The reservoir theory of spring flow. National Speleological Society. Bulletin 20: 46-50.

Describes Cave Spring, Wallace Well, and Devil's Well and presents results of dye-tracing from Wallace Well to Cave Spring which support theory of the supply system of submerged conduits and reservoirs (Wallace Well and Devil's Well), the reservoirs serving as settling basins, flood control agents, and storage for waters which ultimately empty into the Current River at Cave Spring.

Vineyard, J.D. 1963. Origin and development of Cave Spring, Shannon County, Missouri. Columbia, MO: University of Missouri. 81 p. MA Thesis.

Detailed investigation and discussion of the Cave Spring system including spring orifice (Cave Spring), Wallace Well, and Devil's Well. Discusses and maps subwater-table conduits and ongoing transition from the phreatic (deep, water-filled) to the vadose (above water, air-filled) zone. Initial development of Cave Spring was in a shallow, water-filled zone but the current deep, water-filled erosion cycle continues to enlarge the spring supply system. Estimates flow at 30 to 32 million gallons per day.

Vineyard, J.D. 1985. Guidebook to the geology of springs in the Ozarks of south-central Missouri. Viburnam, MO: Association of Missouri Geologists. 61 p.

See "Geology of Springs in the Jacks Fork-Current River Area, Day 2" pages 25-56. Mileage log from Salem including a note about the pair of sinkholes on Pioneer Forest immediately west of the Highway 19/KK junction; Devil's Well on the Ozark National Scenic Riverways and its role in the Cave Spring recharge system; and brief description of the Virgin Pine Forest.

Vineyard, J.D.; Feder, G.L. 1974. Springs of Missouri. Rolla, MO: Missouri Geological Survey and Water Resources. 266 p.

Extensive discussion of Cave Spring (pages 90-103), includes relationship to Devil's Well and nearby Wallace Well, the latter also on L-A-D Foundation property.

Ball Mill Resurgence, a L-A-D Foundation property in Perry County, is reviewed on pages 244, 246-247. Ball Mill Resurgence is a spring rise basin at the base of a steep hill along the south side of Blue Spring Branch. Figure 90 is a photo of Ball Mill and includes a close-up of the milling action which gives the resurgence its name. Review notes five such spring rise basins in the Blue Spring Branch.

Walter, H.D.; Johnson, P.S. 2004. Sustainable silviculture for Missouri's oak forests. In: Flader, S.L., ed. Toward Sustainability for Missouri Forests. Gen. Tech. Rep. NC-239. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 173-192.

These authors present background on Missouri's oak forests and silvicultural prescriptions including reviewing uneven-aged silviculture and the single-tree selection and group selection methods. These authors note the experience with single-tree selection in Missouri oak forests shows the method is sustainable citing the research from Pioneer Forest (Larsen and others 1997, Larsen and others 1999, Loewenstein 1996, Wang 1997). They also suggest the method may be applied in other regions with similar oak forests. Walter and Johnson point out that the method is regaining some of its former prominence although it is widely misunderstood. These authors point to research from Ohio which suggests its use there has resulted in the displacement of oaks by more shade-tolerant species.

Wang, Z. 1997. Stability and predictability of diameter distributions in a managed uneven-aged oak forest. Columbia, MO: University of Missouri. 147 p. Ph.D. Dissertation.

Using two diameter-distribution models, the negative exponential model and the power function model, this study used information from the 40-year inventory records of Pioneer Forest. All data were averaged across the site and diameter distribution patterns were compared without consideration of site differences. Pioneer Forest data included measurements for all trees equal to or greater than 5 inches in diameter. Our forest-wide data clearly demonstrates the classic reverse J-shape curve. This study added measurements of all trees from 1.6 inches (white oak stems outnumber red oak stems in the smaller diameters by almost three-to-one) to the entire data set. Wang observed instability of diameter distributions explained by the effect of our minimum cutting threshold (11-inch diameter for oak species). Partial cutting initiates a steepening of the distribution curve, there is an increase in the number of trees below the threshold (i.e. reduced mortality of the small diameters, increase in recruitment rate of reproduction, and reduced density of trees above the threshold). Steepening of the curve eventually reverses as density of diameters above the threshold gradually rebounds.

Wang, Z.; Johnson, P.S.; Garrett, H.E.; Shifley, S.R. 1996. Stability of diameter distributions in a managed uneven-aged oak forest in the Ozark Highlands. Proceedings, Central Hardwood Forest Conference 11. Unpublished draft. 23 p.

Using the Pioneer Forest dataset, these authors assess the sustainability of the diameter distributions (the reverse-J curve) found on Pioneer to oak forests in the Ozark Highlands in Missouri. The single-tree selection system seems to be maintaining relatively high densities of white oak at or below 10 inches d.b.h. which may compensate for a decrease stocking of small-diameter red oaks; there may be a dynamic adjustment associated with the replacement of red oaks by white oaks as well as a relatively uneven spatial and temporal nature to that process. All evidence suggests that the system used on Pioneer Forest will sustain a balanced uneven-aged forest.

Weaver, D. 1990. Caves, Missouri's growing natural resource. Missouri Resource Review. 7(2): 16-21.

Brief note of Grand Gulf as mammoth breech in the earth, three-fourths of a mile long with walls 120 feet high. Collapse estimated at less than 10,000 years ago.

Weaver, H.D. 1992. The wilderness underground; caves of the Ozark Plateau. Columbia, MO: University of Missouri Press. 113 p.

Grand Gulf noted on page 11 as chasm on Salem Plateau. Also see page 27.

Weaver, H.D. 2000. The significant caves of Missouri. Missouri Caves and Karst Conservancy Digest. 7(1): 1-15.

Review of the project along with the alphabetical listing of unrestricted significant caves of Missouri, compiled by H.D. Weaver and J.B. Beard. The listing includes the following caves on Pioneer Forest and L-A-D Foundation properties: Cave Spring Cave, Cookstove (Squaredance) Cave, Flying W Cave, Grand Gulf Cave, Medlock Cave, Sugar Tree Hollow Cave, and Wind Cave.

Weigel, D.R.; Johnson, P.S. 1998. Stump sprouting probabilities for southern Indiana oaks. TB-NC-7. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station.

Regeneration of oaks in southern Indiana is largely limited to sprouts originating from stumps. Johnson's work (1977) in the Missouri Ozarks found that oak sprouting here was related to age and diameter as well as site quality. For the five species tested in Indiana, sprouting decreased with increasing age and d.b.h. of the parent tree and increased with increasing site index (site quality). The sprouting results reported here for five oak species were found to generally parallel sprouting probabilities for white oak and black oak in Missouri. Populations can be either even-aged or multi-aged. These authors reference the work of Loewenstein (1996) on Pioneer Forest where oaks form uneven-aged populations and where age and d.b.h. may be poorly correlated.

Wheeler, H. 1991. Along the Ozark Trail, notes from a backpacker's journal. Missouri Conservationist. October 1991: 10-13.

Journal from a hike in November 1990 along the Blair Creek section of the Ozark Trail. Article begins at Cedar Point which is part of Pioneer Forest, located just above Laxton Hollow.

White, C.M. 1985. Caves and canoes: managing cave resources in a recreational park. Missouri Speleology. 25(1-4): 191-200.

White provides a historical overview of cave management efforts at Ozark National Scenic Riverways. He reports on an earlier work (MS Thesis, University of Missouri, Columbia, MO) by Sutton (1976) which details floater impacts on the riverways, in particular Cave Spring and Pulltite Springs "which have become traditional stopping points for canoeists" and where "major change in the vegetation and soil have been caused at these landings". White also mentions the National Park Service brochure produced by the National Park Service in 1984 and that at the time of this writing, Wallace Well (L-A-D Foundation ownership) was among only four caves that had been gated.

White, L.C. 1993. Ozark hideaways: twenty-seven day trips for hiking and fishing. Columbia, MO: University of Missouri Press. 244 p.

The second edition of this book (1998) has been revised to omit reference to lands of Pioneer Forest, however, the first edition includes specific discussion of Pioneer Forest lands in these areas, although there is no mention of ownership: Upper Sinking Creek (pages 11-17, would include lands above The Sinks in Sections 14 and 23, T31N R4W which extend to Sinking Creek); Sinking Creek—Highway 19 to The Sinks (pages 18-24, routes users through Pioneer Forest, along the creek in Sections 4, 5, and 8 T30N R4W); Big Creek Northeast of Eminence (pages 27-33, includes extensive sections of the forest along this entire section of the creek); Big Creek County Road 3710 to the Current River (pages 62-65, Sections 7, 8, 9, and 10 T31N R6W focuses not only on Big Creek but routes users overland through lands in Section 15 to Current River and mentions an old school which is Bluff School and Medlock Cave); Leatherwood Creek (pages 73-80, essentially the entire ownership of Pioneer Forest along Leatherwood Creek).

Wilson, S. 1993. The lady was a caver. Missouri Conservationist. 54(3): 4-9.

Interesting sketch of Luella Agnes Owen, author of 1898 book "Cave Regions of the Ozarks and Black Hills". Article mentions her account of exploring the cave at Grand Gulf.

Wylie, J. 1979. Devil's jump off. Missouri Conservationist. 40(7): 8-9.

Tall tale on the origin of Ball Mill Resurgence.

Guldin, James M.; Iffrig, Greg F.; Flader, Susan L., eds. 2008. Pioneer Forest—a half century of sustainable uneven-aged forest management in the Missouri Ozarks. Gen. Tech. Rep. SRS–108. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 123 p.

This collection of papers analyzes the Pioneer Forest, a privately owned 150,000-acre working forest in the Missouri Ozarks, on which the science and art of forest management has been practiced for more than 50 years. The papers discuss how this half century of management has contributed to forest restoration and sustainability on the forest itself and, through its example undergirded by a remarkable body of research, throughout the Ozark region and beyond.

Keywords: Pioneer Forest, L-A-D Foundation, Leo A. Drey, uneven-aged forest management, single-tree selection, natural areas, oak-hickory, Ozark highlands.

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