MISSOURI Natural Areas NEWSLETTER

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Editor's Note

Beyond *Quercus alba:* Missouri's Tree Diversity

At the time of the General Land Office Survey which ran from 1816 through 1851, one out of every four trees documented in Missouri were white oak *(Quercus alba)*[1]. White oak is included in 15 of the 20 modeled tree associations. It is dominant among four of them. White oaks occur in most upland natural community types that harbor trees. Valued for its wood quality in building, staves, and more, logging removed nearly all sizable primary trees, historically considered "virgin trees." More than 50 species of moths including luna moth *(Actias luna)* and imperial moth *(Eacles imperialis)*, and three species of butterflies (Juvenal's duskywing *[Erynnis juvenalis]*, white m hairstreak *[Parassius m-album]*, and banded hairstreak [*Satyrium calanus*]) use white oak as a host plant.

In *Trees of Missouri* by Don Kurz (2003), he describes 149 trees native to Missouri. In this issue, read on to learn about the devas-

Photo by Allison Vaughn, Missouri Department of Natural Resources

Figure 1. Scattered white oak leaves litter the woodland floor at Harry S Truman State Park in Warsaw, Missouri. Thinning projects and regularly occurring prescribed fire events at Harry S Truman SP began in the early 1980s, and the canopy composition today is remarkably similar to what it was at the time of the General Land Office Survey.

1 Harlan, Jim. 2021. Missouri Historic Landscape Project, Early 19th Century, Geographic Resources Center, Department of Geography, University of Missouri. Jim Harlan, Project Manager.

tating impacts of an invasive forest pest to our ash populations *(Fraxinus* sp.), the importance of tree canopies in urban areas to reduce heat islands, and the largescale restoration of shortleaf pine *(Pinus echinata)* in the southern Ozark Highlands. The first article by Paul Nelson is a deep dive into the historic tree associations as they shape current definitions of terrestrial natural communities as well as the differences between old growth, ancient and primary trees (and where to find them on the landscape today). Retired Missouri Department of Conservation forester Steve Paes writes about Sand Ponds Natural Area and the amazing tree diversity housed within.

Finally, in Natural Areas News, the longtime Missouri Department of Natural Resources Natural Areas Chair, Ken McCarty, retired December 31, 2024. Having served on MoNAC throughout his 38-year career with Missouri State Parks as either a coordinator or chair, his wise ecological insight into all facets of nature in Missouri will be missed.

I hope you enjoy this issue and learn more about Missouri's rich diversity of trees and how they contribute to the overall splendor of our state.
— Allison J. Vaughn, editor

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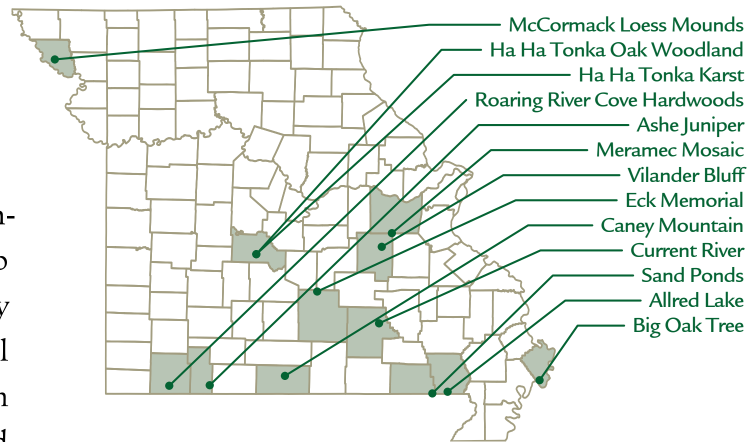
NATURAL AREAS FEATURED IN THIS ISSUE



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Cover page photo: Standing sentry on a loess hilltop at the Columbia Audubon Nature Sanctuary is a sprawling white oak aged to over 200 years old. This tree is commemorated with a large rock and plaque from the City of Columbia's 200th Anniversary of founding event in 2019. The nature sanctuary is home to many of these old growth white oaks, with little regeneration due to deer herbivory and lack of woodland fire. The Columbia Audubon Society is partnering with Columbia Parks and Recreation to continue hosting managed deer hunt seasons at the adjacent Bonnie View Nature Sanctuary to help mitigate this issue. Photo by Bill Mees, Columbia Audubon Society

The ***Missouri Natural Areas Newsletter*** is an annual journal published by the Missouri Natural Areas Committee, whose mission is identifying, designating, managing and restoring the best remaining examples of natural communities and geological sites encompassing the full spectrum of Missouri's natural heritage. The Missouri Natural Areas Committee consists of the Missouri Department of Natural Resources, the Missouri Department of Conservation, the U.S. Forest Service, the U.S. Fish and Wildlife Service, the National Park Service and the Nature Conservancy.

Missouri's Pre-Colonial Tapestry of Ancient Virgin or Primary Trees, with Character

By Paul W. Nelson

Introduction

The purpose of this article is to compare the characteristics of "old growth" trees (often referred to as old growth forest) primary trees and ancient trees, historically called "virgin trees." Less than 800 acres of unlogged or 'primary' timber remain in Missouri today, mostly in isolated relict parcels and scattered "Legacy" individuals (discussed later). Disagreements abound among foresters, loggers, nature enthusiasts, and politicians over old growth forest definitions. These differences are subject to biases and competing values whether viewing old growth as timber resources or conservation/preservation for wildlife, wilderness, and natural areas. Currently the U.S. Forest Service and Bureau of Land Management are working on various definitions of old-growth in response to the Executive Order 14072 issued by the Biden Administration in 2022 (U.S. Forest Service, U.S. Department of Agriculture 2023).

This article expands upon the characteristics and distinction between old growth, primary, and ancient trees. The significance of primary trees is elucidated by examining the witness tree dataset, a shapefile of over 450,000 tree points developed by the Geographic Resources Center at the University of Missouri (Harlan 2021). Most of the trees measured by land surveyors in the early 1800's predates the devastating logging period to follow; thus, these trees are considered all in the primary state.

The US Forest Service describes a "forest" where trees cover 10 to 100 percent of the land. This definition meets their criteria for managing trees as timber resources. However, from an ecological perspective, old growth and primary trees also occur on prairies, glades, savannas, woodlands, swamps, and forests alike. All are distinctive and their structure is inherent in the natural community's name (Nelson 2010). Within each natural community, the age, structure, and species of trees varies according to surrounding natural environment, disturbance processes and quality of the natural vegetation.

People are fascinated when in the presence of a big tree of unusual enormity, or an ancient tree of memorable character. The larger the tree, the more popular it becomes. An even greater experience is seeing the rich diversity of herbs, shrubs, and vines associated with these old trees; qualities we look for in designated natural areas.

As European settlement commenced across the Midwest in the early 1800s, settlers experienced the raw wilderness of primary trees and vibrant native vegetation. Unfortunately, greed, the drive to meet world demands for dwindling lumber, wildlife desecration, and rapid human immigration to the new world resulted in the destructive exploitation of tree resources. The most profound was the near complete annihi-

Definitions

Primary forest: An area of land, typically 5 acres or greater (Illinois Natural Features Inventory standard), that has never been logged. These sites are also known as "virgin" forest. In a primary forest, there are typically ancient trees, but not always[1].

Old-growth forest: An area of land, typically 5 acres or greater that supports a canopy dominated by trees over 120 years old (Illinois and Missouri Natural Features Inventory standards).

Ancient trees: Also known as "virgin" trees, these are trees 200+ years old.

[1]For example, a stand of ancient trees in a primary forest could get hit by a tornado and all the ancient trees are felled. In the aftermath, the site is still primary forest but for a long time would lack ancient trees.

lation of primary timber across the US. This era of exploitation (lacking conservation measures) eliminated primary trees, leaving the hills barren excepting a few areas of scattered "undesirable" woods. The original natural cover of grasslands, shrublands, marsh, and woodland groundcover (then devoid of invasives) gave way to severe open-range overgrazing, and rapid tilling (destruction) of ancient soils. Logging and overgrazing were two of the many factors that destabilized ancient ecosystems.

Given the rarity of primary trees today, or protected trees that will someday attain great age and character, I recommend that public land agencies should designate remaining significant primary stands or select old growth areas as "permanent old growth," and that timber management agencies should increase their respective rotation ages for old growth areas where trees are logged.

Most people across the eastern United States are unaware of what a forest or woodland of enormous ancient trees looked like. So unimaginable the size of such trees, people attending the 1897 Chicago World's Fair referred to the reassembly of a magnificent giant sequoia stump on display as a hoax. They were skeptical that a species as big as the giant sequoia ever existed.

Foresters define "old growth" as trees attaining 100 to 200 years old; this range varies widely. Unfortunately, ecologists looking for examples of high quality timbered natural communities are left with a few fragments and must choose among second growth trees (preferably old growth) to best attain the desired qualities of old growth structure. However, what of "primary tree" and "ancient tree" characteristics? Were they significantly different than designated old growth?

When I was born in 1948, logging companies were finishing off logging the primary timber across Missouri and the southeast swamplands in the Bootheel. Dr. Milton Rafferty (1992) provides an in-depth account of the logging era and its exploitation/removal of Missouri's vast primary timber. Second growth trees are protected in state parks, some conservation areas, L-A-D lands, natural areas, national parks, and lands owned by private conservation organizations.

Most states maintain champion tree lists, designating the largest of respective tree species based on a point system. The American Forest organization tracks 761 tree species on the National Register of Big Trees. These lists exist because of the interest of society in seeking and experiencing them. I compare the dimensions of these listed big trees to primary trees recorded by land surveyors. Many trees on the champion list feature atypical individuals due to their rapid growth and younger age provided by favorable conditions found in yards, parks, cemeteries, and other cultural sites. These lists include a mix of rapidly growing cultural trees, and a few remaining older or legacy trees found in natural settings.

Missouri's trees before the big cut as seen by an early explorer, and land surveyors

Early explorers, naturalists, and botanists, along with land surveyors, were all experiencing the tapestry of primary and ancient trees (before the logging era) as shown on the map in Figures 5 and 6. Many people today sense something amazingly different about the character of primary trees when experiencing them in a natural and rare undisturbed setting.

In 1818–1819 early explorer Henry Rowe Schoolcraft journeyed across Missouri's unbroken pristine Ozark wilderness, starting in Potosi, and traveling to southwest Missouri. Schoolcraft (1821) writes in his monumental journal as he traveled (over 90 days and 900 miles) on foot and horseback across the Missouri Ozarks: "The sleep of the hunter is not sound, neither is his vigilance to be eluded: and the anxiety be kept in, from the fear of the Indian on the one hand, and the approach of wild animals on the other, produce constant wakefulness during the night."

Bears, wolves, lions (cougars), and the Osage Indian are mentioned in the journal as subjects to fear. This fear is heightened by Schoolcraft's (and settlers') encounter with the unfamiliar wildness of enormous trees; albeit as a naturalist, they fascinate him. He writes about experiences on the wild character of the landscape; his citations help visualize what Missouri's vast natural wilderness once looked like. Missouri's landscape evoked a sense of untamed wilderness where reaching emerging settlements were days apart by horseback.

Schoolcraft writes in his journal: "One of the most conspicuous objects among the trees and vegetables that skirt the bank of the North Fork River (in Missouri), is the sycamore, rearing its lofty branches into the air, and distinguished from other forest-trees by its white bark and enormous size." Among the land surveyors systematically surveying Missouri's lands, sycamore is the largest of the over 453,800 trees recorded in the early to mid-1800's. In 1817 Land Surveyor Lionel Browne measured a sycamore in St. Francois County with a 13-foot diameter at 4.5 feet high, like the giant sycamore shown in Figure 1.

Photo by Robert Ridgway

Figure 1. In 1876, naturalist Robert Ridgway (left) along with brother James documented giant primary trees along the Wabash River bordering Illinois and Indiana (Ridgway 1872). This sycamore tree *(Platanus occidentalis)* measured fifteen feet in diameter.

Trees in Natural Communities

Trees of Missouri by Don Kurz (2003) lists 149 native tree species (illustrations by Paul Nelson) presumed to occur in Missouri prior to the arrival of European settlers. Kurz defines a tree as being 13 feet or more tall, and three or more inches in diameter at 4.5 feet above ground. These species often occur in associations, which are groupings of species that share mutual adaptations to their surrounding environment, whether a savanna, woodland, or forest. Factors determining the presence of certain tree species and associations include topography, soil moisture, soil substrate, geographical location, and past land history.

Primary & Ancient Tree Characteristics

Many definitions abound for primary trees, often referred to as "primary forests." A primary forest (region or area of trees regardless of ecosystem type) contains trees (and other plants and animals) undisturbed before European colonization. Old growth definitions, however, are a bit more elusive depending on the biases of the developer. Roget's Thesaurus defines old growth as a "forest or woodland having a mature ecosystem more or less uninfluenced by human activity." Unfortunately, as discussed earlier, commercial interests and those wanting to manage ecological and wilderness values debate the definition.

The purpose of my discussing the difference between primary, old growth, and ancient trees is to explain the primary characteristics of historical primary and ancient trees before the European logging industry and modern-day commercial logging entities (early logging barons, logging companies, developers clearing trees, governments, and politicians) crafted old growth definitions as compromise between profiteers and conservationists.

These differences are as follows:

EQUILIBRIUM

Equilibrium is the ability of an ecosystem to maintain a healthy and balanced state among all species (especially predators and prey) living in their respective environment. While there are no written records of precisely the impact that Native Americans and early colonists made on the landscape, it is commonly accepted that before the onset of European colonial settlement, Missouri harbored a matrix of predator-prey relationships to the degree that the landscape was not destabilized from overbrowsing. This was the Missouri of pre-colonial times up to the early 1800's. Inherent in this equilibrium are the ancient processes from which soils and vegetation evolved complex molecular interactions between soil microorganisms, fungi, invertebrates, and vertebrates.

The following are components that make up this equilibrium relative to trees. I first discuss the desired attributes, then examine the destabilizing factors:

STRUCTURE

Primary forest structures contain trees of various ages. This paper examines trees that are of old age and maximum girth for the species. Trees age to the maximum extent of growth and life expectancy, to a point of death by senescence or killing. The life span of trees varies by species. For example, persimmon trees *(Diospyros virginiana)* may live 100 years while bald cypress *(Taxodium distichum)* may live 1,000 years, and more. In an ecosystem driven by millennia of equilibrium, trees grew slowly due to competition between other trees, herbaceous plants, and climate. For example, note the pine trees in Figure 13. Their diameters vary, signifying different ages. Some even-aged groups of trees did exist. Severe winds, tornados, and intense fires killed local expanses of trees resulting in a flush of emerging seedlings or stump sprouts, all the same age. Prior to settlement, large hollow fallen logs provided hibernacula or food for bears, mountain lions, reptiles, and many other animal species. Bacteria, fungi, insects, microbes, small vertebrates, and other animals thrived in this decaying material that is part of the soil development process.

In contrast, the logging era decimated the ancient structural character of virgin forests, leaving Missouri's landscape covered in stumps and rutted eroding soil. This was the first step in destabilization of natural community equilibrium. Quickly following the logging era, open range livestock grazing was the second significant destabilizing factor. Overgrazing led to substantial soil loss across the now barren landscape. Today's tree regrowth and woodland structure is what emerged from the barren, cut-over forests during lumbering exploitation. This second growth forest is a mix of post logging legacy trees and tree regeneration. Legacy trees are scattered to isolated trees of an older generation left after logging primary trees. Tapper (2022) discusses the importance of legacy trees.

Tree cover density has expanded in the absence of historical fires and reduced competition from overgrazed herbaceous plants. Vast portions of the present-day, still maturing second growth forests are lacking abundant decaying wood and will take decades to accumulate. Rebuilding soil quality will take much longer. The most effective means of accelerating recovery is to place expanses of native woodlands and forests into permanent old growth protection. Historical wildfires in open woodlands limited the accumulation of downed wood. Soil building occurred at and below ground in the form of decaying deep rooted perennial grass and forb species, and ash/detritus left behind after fire. This ebb and flow of rotting logs and fire-mediated detritus varied according to fire frequency and intensity subject to variations in topography.

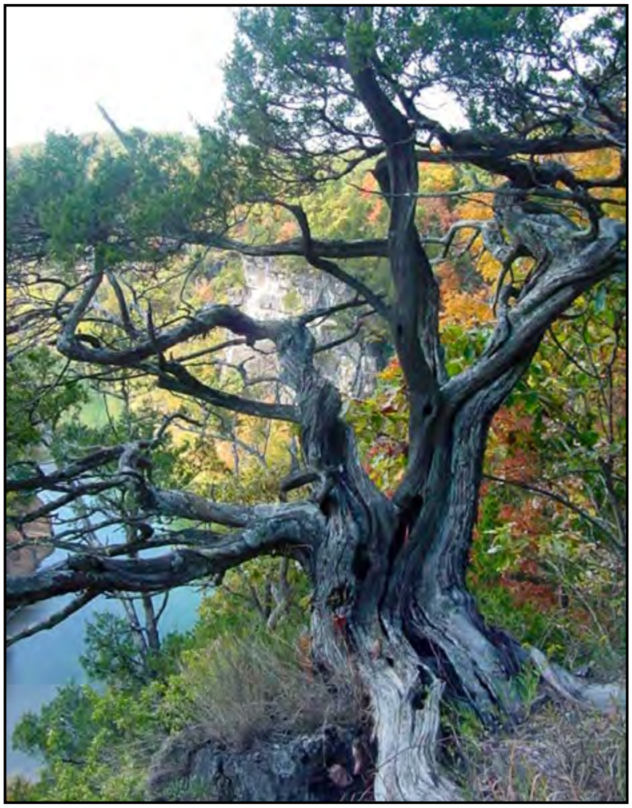


Photo by Paul Nelson

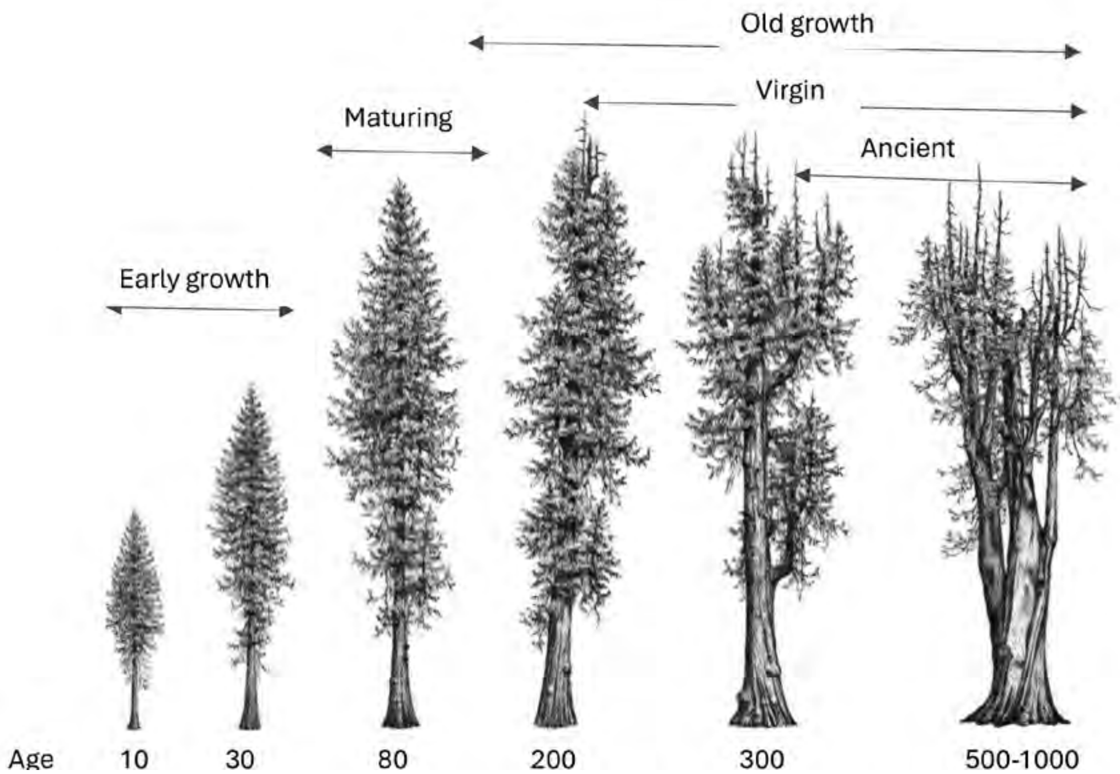
Figure 2. Perched on a cliff high above the Meramec River, this estimated 800-year-old ancient eastern red cedar *(Juniperus virginiana)* can only attain this gnarly shape with great age. The oldest eastern red cedars occur where historical wildfire effects were absent, especially along cliffs and on rocky barrens. This tree grows at Vilander Bluff Natural Area in Onondaga State Park.

ATTAINING GREAT AGE AND INDIVIDUAL CHARACTER

A substantial difference exists between old growth, primary, and ancient trees. It is not until trees reach at least 200 years old that they begin attaining individual character and, depending on the species, enormous size. As trees age beyond maturity, particularly long-living trees, they reach a late stage in life where declining features appear before they die. Their life span and character is random based on weather, disease, fire, and human disturbance. The properties of ancient trees can only emerge over centuries, especially long-lived species (Cannon 2022). An ancient Missouri tree species is often very old, but the age varies in accordance with the species. A birch tree may acquire late growth at 80 years old. I do not consider a tree "ancient" at that age. This paper uses the term ancient to apply to trees of greater age (more than 200 years old) and living before or at pre-colonial settlement. What are the features of "ancient trees?" The tree crown size and height diminish from that of a mature tree with an often pointed or rounded crown of still competing and growing branches. These crowns often take on distinctive and unique staghead appearances when limbs die as shown for the crowns in Figures 14, 15 and 18. They may attain large girth, but the trunk accumulates physical damage, bark loss, crevices, and can be hollow. Old growth trees at 100 years can show some of these features, such as in decay holes, woodpecker holes, and living snags, but ancient trees often show all the features. These features become important as habitat for a myriad of plants and animals. Hundreds of invertebrates and other animal species seek out nooks, crannies, cavities, hollows, and dead/decaying wood on them. Aging reduces seed and fruit reproduction, and parts of the tree die as they adapt to living longer. Epiphytes, especially lichens, fungi, bryophytes, ferns, and select vascular plants appear in bark crevices and horizontal old limbs acquire soil-like deposits.

Nearly all of Missouri's primary trees were cut by 1950. Subsequently, the term old growth and second growth, as it applies to Missouri, was created to favor emerging, desirable qualities of maturing trees following the cutover of primary forests. Exceptions include setting aside lands for wilderness, wild areas, natural areas, and ecological restoration in which ancient trees will eventually attain prominence.

Shifley (2000) defines old growth as trees 100 to 200 years old and without severe disturbances such as fire or drought. Missouri has about 62,000 acres of forests with some trees greater than 130 years old. Of this number, fewer than 8,000 acres are considered good examples. Only about 800 acres are excellent, and this number is divided into remnant tracts between 15 and 300 acres. This is less than five hundredths of one percent of the state's fourteen million acres



Drawings from Van Pelt 2007

Figure 4. Changes (variable) in crown form of hypothetical eastern red cedar over time. Note that trees remain simple for the first three decades (my yard, old fields, etc.).

of forestland (Shifley 2000). This generalization does not account for the great diversity and distinctive characteristics of old trees in savanna, glade, cliff, swampland, and woodland natural communities. Remember that these ecological non-forest natural communities harbor distinctive variations in tree species diversity and distinct assemblages of grasses, sedges, flowering herbs, ferns, and mosses.

Red cedar begins to develop crown maturity and is suitable for cedar logs at approximately 100 years old. Trees older than 200 years are primary (predating logging and colonial settlement). Only at great age (300 years) does individual character emerge (Figures 2 and 21). The above growth stages serve as a surrogate for several Missouri tree species (bald cypress, for example) but vary according to species and life span. According to the 80- to 100-year-old rotation ages for old growth shortleaf pine, white and red oaks on the Mark Twain National Forest, their crown form makes them best suited for desirable wood products. However, note in Figure 4 that this falls short of the old growth to ancient features desired by many more wildlife and plant species (200-300 years old for shortleaf pine).

Photo by Paul Nelson

Figure 3. One of the characteristics of virgin or ancient wood is the tight rings signifying slow growth resulting from competition in stable ecosystems and/or very dry conditions often found in dry woodlands and atop bluffs. Dr. Richard Guyette examined ancient red cedars growing at the base of Vilander Bluff at Onondaga State Park for evidence of tree ring damage caused by rocks falling from the cliff. He found this small 450-year-old six-inch piece of red cedar. Guyette said it was the oldest, smallest cross section of wood he has seen in Missouri.

BIOLOGICAL AND NATURAL DIVERSITY

Missouri's 149 native tree species make up only seven percent of all the physiognomic types of Missouri's 2,055 native plant species present on the landscape prior to European settlement. Natural areas should contain relative abundances and viable populations of all plant types across the area or landscape, at least to some extent.

Unfortunately, much of today's Missouri landscape lacks the full spectrum of quality historical plant and animal diversity. Homogenization of Missouri's landscape (unraveling of the historical tapestry) has destabilized most of Missouri' natural communities (Nelson 2018). It is especially difficult to grade the quality of potential natural areas based on whether environmental plant physiognomy resembles what we believe to be the optimal life form structure.

As the result of the globalization of the world, humans and societies are translocating thousands of non-native plant species to the countries they have now immigrated to and colonized. In my experience, no other country has suffered greater impacts to native flora and fauna than New Zealand. Much like North America, the progress of British colonization of a California-sized island was wrought with disputes and battles with the native Māori, as well as political power fueled by exploitation of natural resources, especially primary forests. Throughout this process, British colonizers, far removed from their homeland England, yearned to import the best-remembered and most cherished objects (non-native plants and animals) from the lands which they came. This zeal was unfettered by scientific knowledge of the deleterious effects of invasives on the new country's ecosystems (a similar pattern occurred in North America). For example, 44 mammal species were introduced purposefully, primarily as game but some to control introduced animals, then only to later become pests (Thomson 1922). While visiting New Zealand I learned of the disastrous destruction of native vegetation and soil caused by the burgeoning introduced populations of white-tailed deer, elk, thar, red deer, dozens of game bird species, and other non-native species (Fleet 1986).

Food chain equilibrium— Balance between predators and prey

Keystone predators including mountain lions, wolves, and bears were present in sufficient numbers to ensure that white-tailed deer, elk, and bison populations did not overbrowse or graze native herbaceous and woody vegetation. Early explorers and travelers recorded numerous predators across a landscape mantled in a vast harmonious cover of healthy natural communities.

By the early 1800's, trappers and hunters were impacting the balance of predators and other wildlife. Settlers persecuted predators to the point of near extinction in Missouri. The numbers that remained were ineffective in controlling expanding deer numbers as conservation measures regulated uncontrolled hunting. Studies demonstrate the world-wide impacts of removing keystone predator species. Having recently visited Scotland, I learned that the tragic loss of the once diverse Caledonian Forest that mantled the Scotland Highlands was due to the extinction of wolves and bears, ending in a massive overpopulation of red deer and grazing sheep that prevented tree regeneration.

Native Americans then Europeans inhabit the Americas

The Kathyrn Buder Center for American Indian Studies at Washington University in St. Louis published a book titled *Indigenous Lands, People, and History of Missouri* (2021). This book helps bridge the gap between the more biased Euro-American teachings in schools in contrast to the history and contributions of Native American indigenous peoples. It captures the incredibly diverse cultural history of the hundreds of indigenous tribes inhabiting the Americas for over 12,000 years. In Missouri, the evolution of these cultures across time is reflected in land use changes such as advancements in building cities, villages, structures, practicing agriculture, hunting, and interactions of societies. These activities affected the vegetation and wildlife in Missouri, and the distribution and presence of trees (and other vegetation), especially hickories, pecans, some oaks, and black walnut. However, the differences between the utilization of natural resources by indigenous people and exploitation/destruction of natural resources of old-world civilizations is dramatically different. We know from all the known habitations and artifacts that Native Americans used portions of the land for timber, wildlife, and agricultural resources. Only plants native to North America existed at the time. New evidence, fiercely debated, suggests that a combination of a warming climate, changes in vegetation, and arrival of humans, all led to the extinction of Pleistocene megafauna animals.

Pre-Columbian population figures are difficult to estimate because of the fragmentary nature of the evidence. It is difficult to determine exactly how many people lived in North America before Columbus. Estimates range from 3.8 million, as mentioned above, to 7 million. Archaeologists associated with Missouri universities have documented over 13,000 archaeological sites in the state. Indigenous people affected the distribution and assemblages of trees in two major ways: first was their widespread use of fire across the North American landscape, which subdued the formation of forests where trees would otherwise form a complete closed canopy in Missouri. Second, there were local effects resulting from agriculture, hunting, building shelters, and local cities (especially in rich river bottomlands). The extent of this disturbance destabilized isolated portions of Missouri's natural communities, especially where early people cleared fields for agriculture, and timber/wood for villages and encampments. Missouri's natural vegetation and most primary trees remained intact.

Presettlement is the reference point by which we best evaluate the modern altered landscape and understand the complexity of diverse native ecosystems (Noss 1983). Natural area professionals accept that the complex assemblages of native plants and animals in pre-European times evolved over thousands of years commensurate with the local disturbances by Native Americans. The pre-colonial tapestry of trees modeled in the tree associations map (Figure 5) is more closely aligned with the ancient stable landscape in which Native Americans lived. The early 1800's period marks the initiation of European resource exploitation and industrialization that created a cultural landscape far different than that of the early 1800's.

Missouri's Historical Land Surveyor Records (GLO Notes; 1816–1851) converted to historical tree associations

In 1815, the U.S. Government Land Office (GLO) hired land surveyors to methodically subdivide the land into townships and one-mile sections to aid in the accurate sale of land during settlement. At each square mile (a section) surveyed, they recorded notes on changes in land cover, vegetation, wetlands, other natural features, and tree species along section lines and corners. James Harlan of the Missouri Geographic Center at the University of Missouri commissioned students and others to enter the data collected by land surveyors in the early 1800's into a GIS-based shapefile (Harlan 2021). That shapefile contains geo-referenced point data for 453,892 trees, a project taking over ten

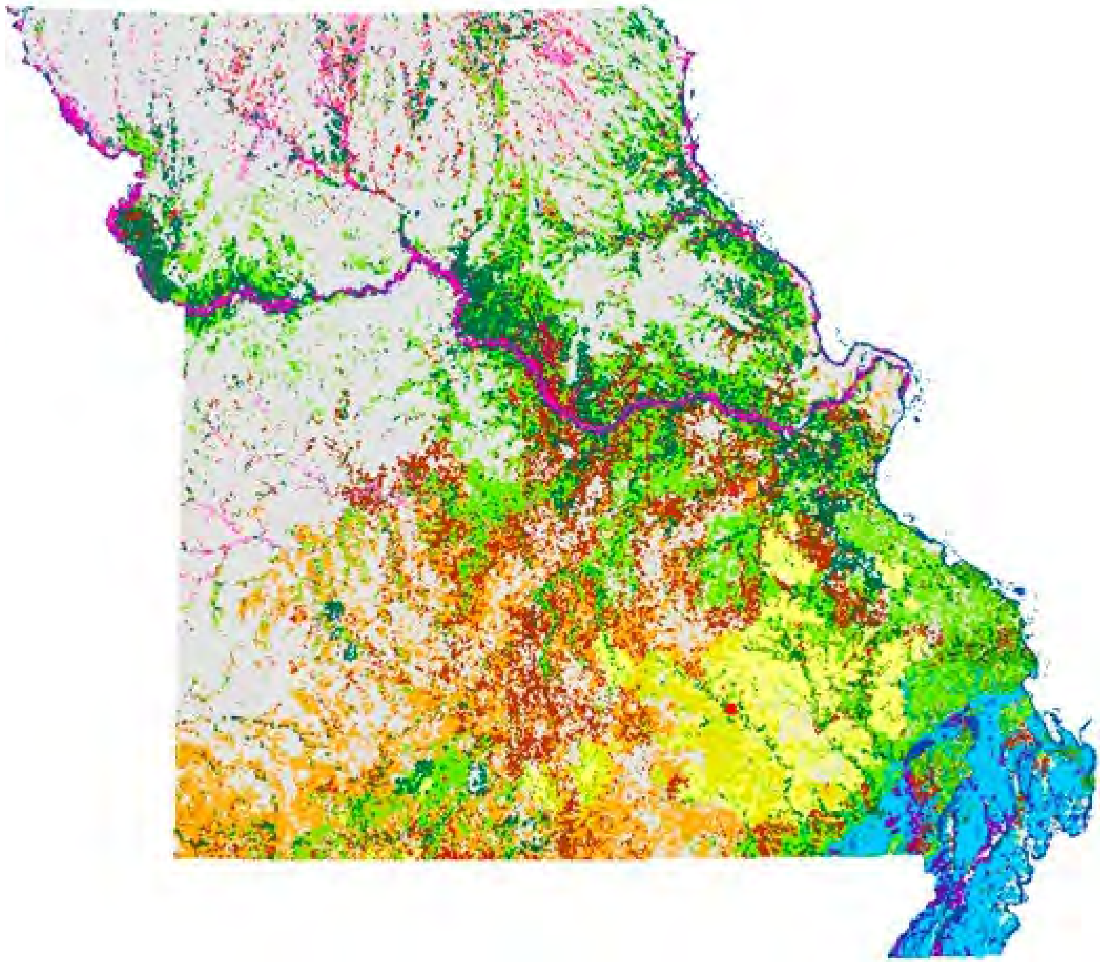


Image by Paul Nelson

Figure 5. The map color patterns match the legend in Figure 6 below showing 20 modeled tree associations that occurred 200 years ago. The light gray color matrix is prairie-barrens; orange and brown represent post oak variations associated with savannas and dry woodlands; light yellow and light green in Southeast Missouri are pine associations; medium to dark greens are more forested associations found in hills along rivers and steep valleys; pinks in Northern Missouri are bur oak associations; and the blues and purples of the Southeast Missouri Bootheel are wetter bottomlands and swamps. The cedar associations are barely visible along the southern Missouri border associated with rock outcrops of bluffs and some glades.

Figure 6. This list of associations (Harlan 2021) gives us a snapshot in time of primary forest prior to the big cut that removed nearly all merchantable timber from Missouri by the mid-1950s. Some overlap occurred in the effects of European settlement, especially for newly established towns along major rivers.

Pine—White Oak w/Black Oak, Post Oak

Pine—Post Oak w/Black Oak, White Oak

White Oak—Black Oak w/Hickory, Elm, Walnut

White Oak—Black Gum—Black Oak w/Elm, Hickory

White Oak—Ash w/Elm, Black Oak, Hickory

Post Oak—Black Oak w/White Oak, Hickory, Blackjack Oak

Post Oak—Blackjack Oak w/Black Oak, White Oak, Hickory

Red Oak—White Oak—Black Oak w/Hickory, Elm, Walnut

Bur Oak—Elm w/Pin Oak, White Oak, Black Oak, Hickory, Walnut, Red Oak, Swamp White Oak

Pin Oak—Elm w/White Oak, Black Oak, Bur Oak, Hickory, Walnut, Red Oak, Swamp White Oak

Sugar Maple—White Oak w/Elm, Hackberry, Black Oak, Hickory, Maple

Elm—White Oak—Black Oak w/Hickory, Walnut, Red Oak, Sycamore, Hackberry, Ash, Maple

Elm—Ash w/Sycamore, Hackberry, Cottonwood, White Oak, Hickory, Maple, Willow

Elm—Hackberry w/Cottonwood, Sycamore, Ash, Maple, Willow

Sweet Gum—Elm—Maple w/White Oak, Hickory, Ash, Black Gum, Sycamore, Black Oak

Cypress—Sweet Gum w/Water Tupelo, Overcup Oak, Maple Ash, Elm, Black Gum

Open (Prairie, Barrens/Scrub)

Water

Post Oak—Chinquapin—Black Oak w/White Oak, Spanish Oak, Blackjack Oak

Cedar—Oak

Cedar—Pine—Oak

years to complete. Interpretation and limits of the GLO data: Land survey records used for interpreting presettlement vegetation do have errors in accurate species identification. Common names are assumed to mean certain tree species. For example, all of Missouri's 9 hickory species are combined and recorded as "hickory or hicky". Land surveyors also chose the most suitable tree species to blaze (mark with an axe or sharp tool to help delineate a survey section corner or line) as witness trees over larger and older species that may not live as long.

GLO notes are invaluable in providing tree diameter dimensions. The shapefile for trees recorded by early land surveyors reveals many trees that exceed even the largest state champion dimensions of today. While some limitations of GLO notes are recognized, the sheer number of large diameter trees recorded far exceeds any statistical margin of error. It is also important to note that many trees were selected for the survey process, not their size, resulting in bias against large (and unsuitable) trees. Land surveyors only recorded trees along the lines of the square mile; not the vast interior of each square. If we assume land surveyors recorded section and line witness trees within a 200-foot margin of each section, this will omit the vast number of large trees within a remaining 460 acres (70 percent) inside each square mile.

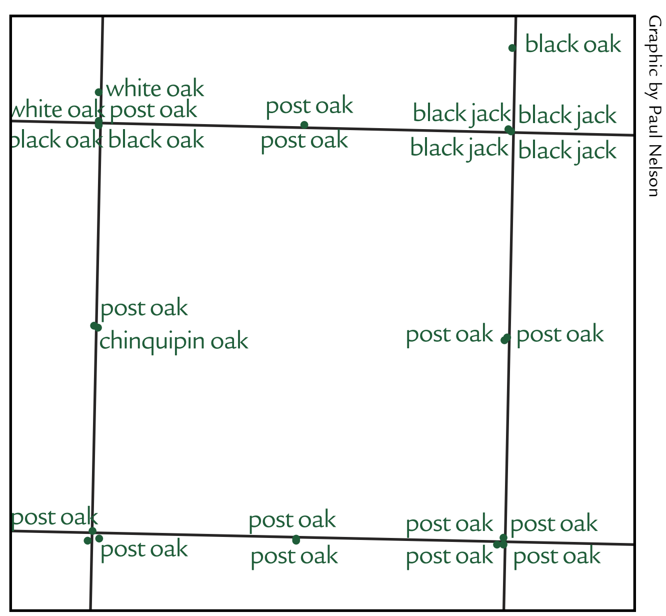
The following are descriptions and images of the most prominent tree associations that should elucidate the difference between what is considered old growth, primary, and ancient trees.

As a disclaimer or for clarification, this paper focuses only on the data presented in the historic tree associations shapefile by Harlan (2021). Ecologists also use other ecologically based plant association systems. These include the 119 Missouri plant associations posted on NatureServe (Jennings 2009), and the 86 natural community descriptions in Nelson (2010). The work by Harlan is just one of many model variations depending on the variants programmed for data analysis. Tree sampling and observations also show that many other tree species combinations were present across the landscape.

Fire-adapted and mediated tree associations:

Fires set by Indigenous people profoundly influenced the distribution of trees across Missouri's varied landscape. Adaptation and tolerance to fire are primary determinants in shaping tree associations. Historically, the frequency of wildfires influenced the openness of tree spacing. Wildfire burned more intensely and frequently on the prairies and savannas of dissected plains, and open woodlands over hills leaving more widely spaced trees. Figure 5 shows the influence of frequent (near annual) fires on prairies shown in gray and where fire tolerant post oak, black oak, bur oak, white oak, and shortleaf pine associations occur.

Figure 7. This figure shows a typical one-mile square surveyed and established by land surveyors in the early 1800s. Witness (section corners) and line trees were recorded along the section boundaries. These tree points are modeled as tree associations shown in the variously colored map in Figure 5.



Select Tree Associations:

POST OAK — WITH BLACK OAK, BLACKJACK OAK, HICKORY, AND PINE

Post oak *(Quercus stellata)* makes up 15 percent (68,616 records) of the total witness trees in Missouri. Surprisingly, the largest recorded GLO post oak was an astounding 7.4 feet DBH. Eleven other post oaks exceed six feet in DBH. Today's state champion post oak is 5.7 feet DBH; the national champion post oak from Texas is 7.3 feet DBH. This species is among a few growing in harsh sites (dry woodlands, savannas, and scattered across prairies). These conditions and the growth nature of post oak produces trees of poor wood quality making most economically unsuitable for harvest. As a result, many isolated virgin post oak groves (mingled with second growth post oak) predating the logging era occur in the Ozark Highlands and Osage Plains. While studying the flora of the Ozark Underground Laboratory, the author located several section corners where primary post oak witness trees remain. Guyette (1989) also substantiated the presence of primary post oak in nearby Caney Mountain Natural Area

Note in the legend for the tree associations (Figure 6) that post oak can also co-dominate with other fire-tolerant species including black oak *(Quercus velutina)*, Spanish oak *(Q. falcata)*, blackjack oak *(Q. marilandica),* black hickory *(Carya texana)*, shortleaf pine *(Pinus echinata)*, and white oak *(Q. alba)*. These species mix in with post oak groves in more dissected plains and hills across Missouri.

Figure 8. In 1983, the author accompanied Dr. Richard Guyette to age post oak trees at Ha Ha Tonka State Park, Ha Ha Tonka Oak Woodland Natural Area. Several individual trees were found to exceed 400 years old, as represented by the trees in this image. Note the grass/forb groundcover resulting from historical and present-day fires, and the varied ages and openness of the woodlands.

Missouri Department of Natural Resources photo by Ken McCarty

Figures 9 & 10. These 300-year-old primary post oak witness trees (right) remain near the survey marker (**Figure 10**, inset) following the GLO note survey records of 1847 (177 years ago) when the surveyor measured six trees ranging from 12 to 16 inches DBH. During the study of the flora of the Ozark Underground Laboratory in 2022, the author relocated and measured them at 22 to 24 inches (DBH).

Photo by Paul Nelson

Photo by Paul Nelson

POST OAK-CHINQUAPIN OAK-BLACK OAK —WITH WHITE OAK, BLACKJACK OAK, SPANISH OAK

Chinquapin oak *(Quercus muehlenbergii)* makes up only one tenth of a percent of the total witness tree records. Their growth forms were gnarly with multiple trunks and spreading lower branches. The witness tree map reveals that most are associated with post oaks found along dolomite glade borders, and dolomite outcrops in open dry woodlands. Larger diameter trees grew in deep calcium rich loess soils along forested hills east of the Missouri River in Buchanan County where 18 trees were at least 3 ft. DBH.

Photos by Paul Nelson

Figure 11. Shaped by rocky excessively drained soils and frequent fire, these old growth chinquapin oaks *(Quercus muehlenbergii)* dominate amidst a diverse herbaceous groundcover. Meramec Mosaic Natural Area, Meramec State Park.

Figure 12. Typically gnarly, these ancient chinquapin oaks found on the Ozark Underground Laboratory were likely unsuitable for logging due to often hollow and twisted trunks. These trees are surrounded by younger eastern red cedar, having emerged following intensive open-range grazing.

SHORTLEAF PINE—WITH POST OAK, BLACK OAK, WHITE OAK

Before the logging era, primary shortleaf pine *(Pinus echinata)* woodlands covered over six million acres of the southern Ozarks south of Interstate 44. The most expansive "pineries" extended 20 miles either side of Highway 60 between Poplar Bluff and Birch Tree (Figure 13). The 19,562 witness tree records make up about four percent of Missouri's total GLO records. The largest shortleaf pine recorded was 8.1 feet DBH, with an additional 650 trees greater than three feet DBH. The state champion, located in an open cemetery, is 3.8 feet DBH while the national champion known from Texas is 4 feet DBH.

Its dominance is determined by the steepness of the landscape, with pine especially prominent on drier, more exposed south facing slopes of steep hills and valleys. It also occupies exposed rocky soils on top of cliffs and bluffs where historical fire was less prominent. Dey (2022) and Stevens (1991) detail the establishment of logging camps targeting shortleaf pine in and around the Ozark National Scenic Riverways. The documents provide excellent discussion on the harvesting of Missouri's original pine woodlands by lumber barons in the late 1800s.

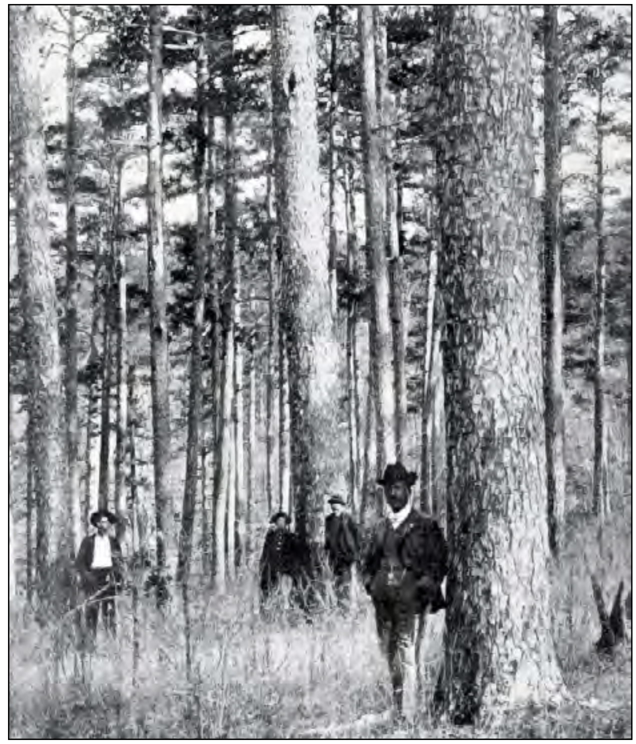


Photo from American Lumberman magazine, May 9, 1903.

Photo by Paul Nelson

Figure 13. This original shortleaf pine grove near Birch Tree was typical of the extensive pineries of southern Missouri. Note trees are of assorted sizes, attesting to the frequent ground fires and stable natural community structure that existed for hundreds of years.

Figure 14. Right, the three ancient shortleaf pine trees in the immediate foreground show characteristic variation in their canopy tops. Each tree's canopy limbs differ following 300 years of natural disturbances including high winds, lightning, ice storms, damage from wildlife, and fires. Fewer limbs in the canopy may mean less damage by the wind.

BUR OAK—ELM, PIN OAK, WHITE OAK, BLACK OAK, HICKORY, WALNUT, RED OAK, SWAMP WHITE OAK

Land surveyors recorded 10,439 bur oak *(Quercus macrocarpa)* witness trees. Of that number, 74 trees were four feet DBH or greater. Bur oak grows in several natural communities. It occurs in groves in northern Missouri (Figure 18) where it is associated with widespread prairies and savannas. Due to frequent fires in once widespread prairie natural communities, it is an open-grown tree with spreading crowns. In contrast, bur oak also frequents large streams and river floodplains across most of Missouri. In the swamplands of the southeastern Bootheel, where competing with surrounding mixed hardwoods, it attains great heights (Figure 16) in forest structure.

Bur oak associates include white oak and post oak on prairies and savannas. In bottomland woodlands and forests, associates include slippery elm *(Ulmus rubra)*, swamp white oak *(Q. bicolor)*, bald cypress, sweet gum *(Liquidambar styraciflua)*, black walnut *(Juglans nigra)*, red oak *(Q. rubra)*, and hickory species *(Carya* ssp.*)*.

Figure 15. This state champion bur oak *(Quercus macrocarpa)* measures 7.6 feet in DBH, nearly the same as the largest historic GLO tree. Note the person standing next to the tree for scale. The open grown crown easily qualifies it for primary and ancient tree characteristics, and points to its association with prairie or savanna conditions. At 400 years old, it was a sapling when the first great wave of immigrants left England. It has endured many lightning strikes, ice storms, wind, historical fires, and vandalism.

Photo by Paul Nelson

Missouri Department of Natural Resources file photo

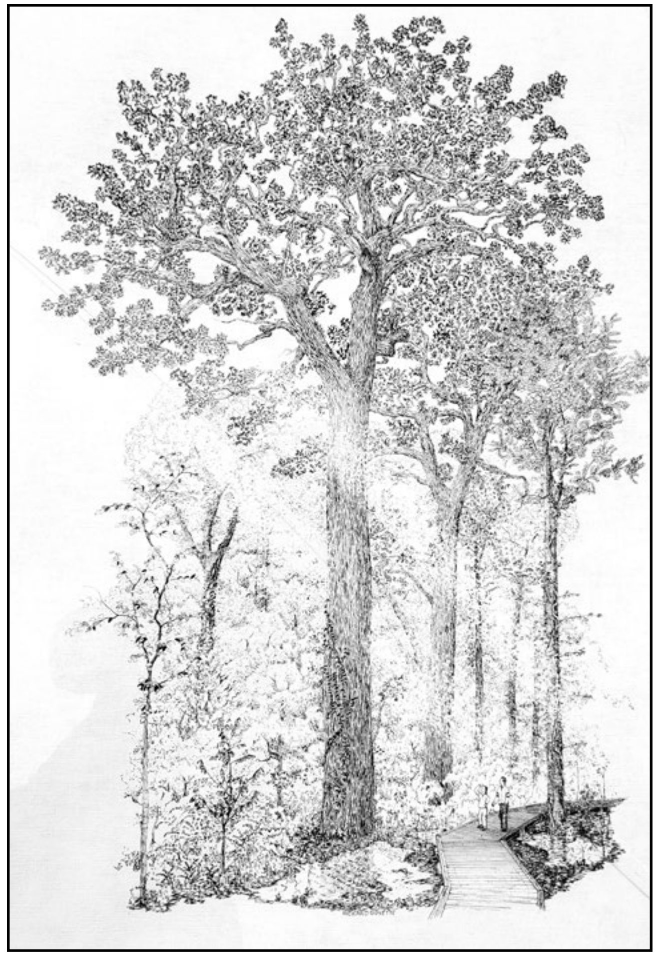


Illustration by Dr. Richard Guyette

Photo by Tom Nagel

Figures 16. (upper left) Note the editor standing next to the former state champion bur oak in Big Oak Tree Natural Area, Big Oak Tree State Park. This portion of the park contains primary forest as attested by the surrounding large trees with characteristically twisted crowns. At 400 years old, the tree stood over 140 feet tall, with a diameter of six feet. A catastrophic ice storm in 2009 damaged or destroyed many primary trees. High winds later felled this giant bur oak.

Figures 17. (upper right) Dr. Richard Guyette is known for his stellar pen and ink drawings of ancient Missouri trees. To commemorate the significance of Big Oak Tree State Park, he chose to illustrate the park's signature giant bur oak tree, the same tree shown in the photo. His artwork shows the dramatic character of the tree's ancient canopy sprawling 130 feet above the ground.

Figure 18. (lower left) Less rainfall, past fires, and well-drained soils of dry loess hills shaped the ancient look of these twisted bur oak trees. Their appearance requires greater than 200 years of growth. McCormack Loess Mound Natural Area, Jamerson C. McCormack Conservation Area.

WHITE OAK, WITH A VARIETY OF MIXED TREE ASSOCIATES ACROSS MANY NATURAL COMMUNITIES

Of the 149 Missouri native tree species, white oak is the most prominent in Missouri. 103,889 witness trees are white oaks, representing 23 percent of the total. Of this number, six trees are over 12 feet DBH. The largest known state champion is 5.5 ft. DBH, smaller than 59 historic witness trees measured at 6 ft. DBH. Twenty-eight trees were larger than the current national champion, which is 8.75 ft. DBH.

Relict legacy trees are scattered across Missouri, especially on dry, rocky hills and around glades.

SWEET GUM AND BALD CYPRESS ASSOCIATION

Both species co-exist in lowlands and swamps of southeastern Missouri. Sweet gum also grows in drier bottomland forests and mesic valleys of the hills in the southeastern Ozarks, and to a lesser extent in uplands. Today, sweet gum and bald cypress are more widespread across the state, favored as ornamental trees planted in parks, yards, along streets, around lakes and ponds.

Historically, bald cypress occurred in southeast Missouri where they are confined to wet lowlands, along sluggish rivers, and swamps where associated with water tupelo *(Nyssa aquatica)*, overcup oak *(Quercus lyrata)*, Drummond's maple *(Acer rubrum* var. *drummondii)*, pumpkin ash *(Fraxinus profunda)*, and slippery elm. Primary bald cypress is one of the most iconic tree species of the southern United States. Large trees of distinctive shapes and character are so impressionable as to receive distinctively famous names, like the Senator in Florida. It was the largest bald cypress growing in Eastern North America. One bald cypress tree along the Black River of North Carolina is at least 2,624 years old. In Missouri, bald cypress trees greater than 500 years old are located at Allred Lake Natural Area, and Big Oak Tree State Park. Less than one percent of Missouri's recorded witness trees are bald cypress (1,586 trees). The largest historical GLO tree is 12 feet DBH, with over 500 trees more than 5 feet DBH. The present-day state champion tree is 8.5 DBH.

Figure 19. Current River Natural Area is known for its primary white oaks, determined to be around 300 years old. Members of the L-A-D Foundation stand among white oaks dominating north-facing upland dry-mesic forest. Note the rich herbaceous groundcover, a signature attribute of high-quality natural communities.

Photo by Paul Nelson

ELM AND MIXED HARDWOOD ASSOCIATIONS

Next in the line of significant and distinctive tree associations are those occurring in mesic to wet river bottomlands, deep valleys along streams, and mesic sheltered ravines. These associations show up on the map in deep blue and purple. Elm (most likely slippery elm) was dominant. Large expanses occupied the floodplains of the Mississippi and Missouri rivers. Unfortunately, those groves and remnants that survived succumbed in huge numbers to Dutch Elm disease.

Mesic forests found in floodplains, deep valleys, and ravines were cited by early explorers for harboring trees of enormous size. The largest diameter trees recorded by land surveyors found in these rich habitats include pin oak *(Quercus palustris)* at 10.75 feet DBH, cottonwood *(Populus deltoides)* at nine feet DBH, sycamore *(Platanus occidentalis)* at nine feet DBH, silver maple *(Acer saccharinum)* at eight feet DBH, and ash (undetermined species) at seven feet DBH, among other species. All of these species and others attain impressive diameters ranging from two to six feet found commonly within rich mesic habitats. One of the best examples of primary mixed mesic hardwoods is the 40 acre Wegener Woods National Natural Landmark near Hermann.

Figure 20. The author stands next to the state champion slippery elm tree in a mesic dolomite forest at Ha Ha Tonka Karst Natural Area.

Missouri Department of Natural Resources file photo

OTHER ASSOCIATIONS

ASHE JUNIPER (NOT SHOWN ON MAP)

Ashe juniper *(Juniperus ashei)* is restricted to southwest Missouri where found on dolomite glades and dry exposed bluffs.

FLOWERING DOGWOOD *(CORNUS FLORIDA)*

Many other tree species recorded in the GLO notes reflect primary forest characteristics. A few included flowering dogwood *(Cornus florida)* with the largest recorded tree an astounding 4 feet DBH (national champion is 3 feet).

HICKORY SPECIES

Hickory (hicky) as recorded by land surveyors shows up in 12 of the 20 Harlan associations. Land surveyors did not attempt to identify any of the nine Missouri hickory species *(Carya* sp.*)*. Despite this, they recorded 32,100 hickory witness trees (seven percent). Of this number, the largest were around 7.5 feet DBH. Missouri's state champion is a water hickory *(Carya aquatica)* closely followed by shagbark hickory (*Carya laciniosa)*, both around 3.7 feet DBH, much smaller than the historical GLO trees.

Conclusion

The Missouri Natural Areas Program designates public or private lands to restore and protect our states distinctive, high quality natural

Figure 21. Here, a band of ancient ashe juniper trees has endured 500 years along a steep dolomite bluff above Table Rock Lake. Note the entanglement of dead trees (perhaps lying there hundreds of years) intermingled among ancient trees. This location is at Ashe Juniper Natural Area.

Photo by Paul Nelson

communities. Tree associations are managed in special areas for designated or de facto "permanent old growth" protecting valuable plant and animal species diversity in natural areas, state parks, national parks, and private organizations. We may not know how much of these types to designate and protect, but what we do know is that the current acreage is quite small when compared to the potential for protecting old growth on a reasonable and necessary landscape scale.

Developing "old growth" definitions across various states is of limited consistency. The U.S. Forest Service has adopted working old growth definitions applied to tree species and forest types for each U.S. Forest Service region (USDA 2023). These vary according to the history of timber management, public use, forest types, and culture of the respective region. Many definitions accommodate the rotation/cutting of trees when they maximize their favorable growth and value. Age is often the determinant but falls short of ancient tree characteristics.

The 2005 Land and Resource Management Plan for the Mark Twain National Forest (USDA 2005) includes considerable discussion regarding the definition, delineation, and management of old growth forest (remember, a forest according to the Forest Service includes trees covering ten percent or more of the landscape). The qualifying age to permanently protect stands is more than 175 years old. Unfortunately, very few tree groupings between 15 to 100 acres contain trees of this age on the Forest. The Plan identifies the rotation age in Management Prescriptions for Ecosystem Restoration between 80 and 120 years old. At this maturing age, trees begin attaining old growth characteristics. However, these characteristics are not those of ancient primary forests.

Changes in the Missouri Department of Conservation's and Mark Twain National Forest's, (Missouri's largest public timberland management areas) objectives can greatly influence the future direction of protecting old growth and ancient natural communities. Public review comments of U.S. Forest Service documents on the topic (USDA 2023) mention the need to manage various forest types to meet primary forest (and tree) characteristics. In this regard, Missouri land managing entities should reconsider primary tree characteristics, and implications for management and designation of "permanent old growth" to achieve them as follows:

1. Change desired conditions and the definition for old growth to achieve ancient forest characteristics. Cutting (rotating) trees less than 100 years old does not reach ancient structural features.
2. Inventory and designate portions of public lands that meet quality standards to best attain these desired conditions, especially where ecosystem restoration is a priority. Distribute them across the landscape at various ecological scales.
3. Create naturral areas that harbor sizable acreages of distinctive tree associations in their respective natural community environment such as Pineknot on the Eleven Point Ranger District of the Mark Twain National Forest.
4. The Mark Twain National Forest should query data for the presence of permanent old growth (stands with 175 year old trees), and inventory remaining areas for ancient trees.

Threats will continue pressing the quality and viability of tree associations, and their respective natural communities. It will take decades to recover natural organic matter in the form of characteristic standing dead trees, and downed logs. Timber managing entities should consider resting large tracts of land for decades to recruit old growth trees with their inherent benefits, especially rebuilding soil, and accumulating woody debris.

Presently, the detrimental effects of overbrowsing by white-tailed deer are spreading across Missouri, especially in urban areas, city parks, state parks, and other areas where deer control measures are difficult. This overbrowsing leaves the ground barren with an increasing growth of undesirable plants avoided by deer. Tree regeneration is affected when too many deer browse twigs, tree seedlings, and small trees. It will take decades to recover the once rich native herbaceous vegetation destroyed by livestock grazing. High deer density will not aid in this recovery.

Introduced plants, diseases, and many exotic invertebrates continue to impact various tree species. Fungus is killing off slippery elm and butternut *(Juglans cinerea)*, with few large living trees remaining. Recently, emerald ash borer has caused the rapid decline of five ash species now listed as Critically Endangered on the IUCN red list in the United States. Tens of thousands of infected dead and dying ash trees cover forests and woodlands, city parks, yards, and streetsides in the eastern U.S. The introduction of non-native, and relocation of native tree and shrub species has and will continue to transform and move Missouri's tree presence away from historical conditions. Bush honeysuckle *(Lonicera maackii)* and autumn olive *(Elaeagnus umbellata)*, among many others, are aggressively expanding their range, spreading outward from cities and along highways. Where at their densest cover, they inhibit tree seedling growth and regeneration. More foreign introductions will likely continue unabated.

Climate change is extremely alarming. A 2024 study conducted by a team of international scientists (Pihu Ke et al. 2024) concluded that last years world record warmth led to the inability of vegetation worldwide to absorb CO2. Johan Rockström, director of the Potsdam Institute for Climate Impact Research warns that plants seem to be losing their ability to uptake carbon, and it is anticipated that 2025 will be a record year for warmth. He further warns that nature has so far balanced some of this CO2 abuse, but that it is coming to an end. The loss of this carbon absorption mechanism (among others) was not factored into the carbon buildup models and could accelerate global warming.

A list of areas with primary and ancient tree characteristics follows: Readers should consult with the appropriate owners who will point them to specific locations within each area. Ancient trees can be found in other places. For example, ancient eastern red cedar is widespread where it holds on precariously to the tops of cliff ledges and bluffs along larger streams and rivers and even large reservoirs like Harry S Truman Lake. The list includes:

- **Ashe Juniper Natural Area** for 500 year old Ashe Juniper trees
- **Mudlick Mountain Natural Area** for old growth white oak, black oak, and shortleaf pine
- **Ha Ha Tonka Karst Natural Area** for old growth/primary mixed hardwood forest
- **Ha Ha Tonka Oak Woodland Natural Area** for old growth and primary post oak woodlands
- **Engelmann Woods Natural Area** for mixed hardwoods in a mesic river ravine
- **Roaring River Cove Hardwoods Natural Area** for mixed oaks and hickories, some over 250 years old
- **Allred Lake Natural Area** for primary bald cypress and tupelo gum exceeding 500 years old
- **Caney Mountain Natural Area** for primary post oak in dry woodlands and glades
- **Eck Memorial Natural Area** for old growth shortleaf pine
- **Virgin Pine Randolph Tract** along Highway 19 featuring Missouri's only unlogged pine woodland
- **Big Oak Tree State Park** for primary mixed bottomland hardwoods

Photo by Paul Nelson

Figure 22. Wegener Woods National Natural Landmark (NNL) in Warren County is distinguished for its mixed oak, hickory, and ash-dominated primary forest. Designated in 1975, the NNL website states the site is an example of an oak-hickory forest undergoing succession/replacement by sugar maple *(Acer saccharum)*. John Wylie (former Director of the Natural History Section, Missouri Department of Conservation) provides an in depth accounting of the area, emphasizing how sugar maple will replace trees in 40 years (Wylie 1991). My recent visit revealed many primary oaks and hickories still remain. This image shows the ancient gnarly character of white oak (center of image with a 4 foot DBH) and hickory crowns. Unfortunately greater destabilizing forces now threaten its character. Multiple threats include die off of large 300 year old white ash *(Fraxinus americana)* killed by emerald ash borer, intensive overbrowsing by white-tailed deer with a groundcover devoid of diverse herbs, and invasion by bush honeysuckle, Japanese honeysuckle, and garlic mustard *(Ailliaria petiolata)*. The area is worth a visit to discover how these threats are degrading its quality.

- **Wegener Woods National Natural Landmark** featuring 40 acres of primary mixed mesic hardwood forest (Figure 22).

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Photo by Robbie Doerhoff

Figure 1. Enhanced-color aerial photo of ash die off: dead and dying ash trees can be noticed in the woodland canopy in stark contrast to the living trees in the growing season.

The Future of Ash in Missouri

by Robbie Doerhoff

Are there any live ash out there?

Across the state, dead and dying ash trees are a common sight thanks to *Agrilus planipennis,* a.k.a. the emerald ash borer (EAB). This shiny green invader from Asia has now been confirmed in all but three of Missouri's 114 counties. The voracious larvae of this wood-boring beetle kill trees by feeding just under the bark and disrupting the flow of water and sugars. With varying success, EAB can attack all four of our native ash species: white ash *(Fraxinus americana),* green ash *(F. pennsylvanica),* pumpkin ash *(F. profunda),* and blue ash *(F. quadrangulata).* They are also able to infest a close relative of ash, the white fringetree *(Chionanthus virginicus).*

Overall, ash make up roughly 3% of Missouri's forests but can be 10–90% of the canopy cover in localized areas. Ash can be scattered throughout the stand, like white ash growing in upland forests, or concentrated in large stands, especially in riparian and bottomland areas like we see with green and pumpkin ash. Blue ash tends to grow in patches and on drier soils with higher calcium content. USDA Forest Service Forest Inventory and Analysis (FIA) data estimate over 50 million green and white ash trees in the state (≥5 inches in diameter at breast height (DBH)), with an annual mortality rate steadily increasing in the last five years (Thomas Goff pers. comm. 2024). Over four billion white ash seedlings are growing in Missouri, a billion more than what FIA data estimate for white oak.

Figure 2. EAB on an ash leaf. The infestation of this metallic beetle has caused widespread mortality of ash species in Missouri and many other states.

Photos by Robbie Doerhoff

Figure 3. Photo of blonding tree: This photo shows the telltale signs of EAB infestation as the bark damage caused by birds foraging for the EAB. The advanced blonding such as this does not appear until five to seven years after EAB has been introduced.

The EAB Invasion Cycle

EAB was first found in the US in 2002, infesting green and white ash trees near Detroit, Michigan. While devastating to most of North America's 16 ash species, it was a rather unimportant insect in its native range in Asia since it only infested stressed and dying ash. Asian species of *Fraxinus* have evolved resistance over time (Wang et al. 2010), but the first ash trees EAB encountered in the US, our green and white ash, were naïve to this pest and had no defenses. Once established, EAB was here to stay and spread, both on its own and with the help of firewood-hauling humans. In 2008, Missouri's first known EAB population was detected in a Wayne County public campground, near Lake Wappapello. The likely pathway was infested ash firewood brought from Michigan by unsuspecting campers.

With several years of EAB observations, we've learned some things about the invasion cycle of this pest. The most reliable sign of EAB infestation is woodpecker blonding of ash bark. This bark damage is caused by the birds foraging for tasty EAB larvae and popping off the outer bark of ash trees. We usually don't notice woodpecker blonding on ash until five to seven years after EAB has been introduced; mortality rates of ash are still relatively normal at that point since the EAB population is still low. But by eight years post-invasion, many trees are showing signs of damage and 10% are dead (see figure adapted from Dr. Dan Herms at the Davey Tree Expert Company). From there, the EAB populations explodes and ash mortality also hops on an exponential curve, reaching 95% by year 14, post-invasion. Then the EAB population begins to decline rapidly as fewer large trees are left to support the pest. By year 16, all susceptible trees have died, and only stems less than one inch in diameter remain.

Once the ash resource is gone, EAB has nothing to eat, right? Not exactly. It's true that EAB won't switch to new host species, like oak or walnut. However, it will persist on new ash seedlings growing into the one-inch-diameter size range. This so-called "aftermath" forest will allow EAB populations to fluctuate over time, but at levels far more manageable by biological control agents.

The Future of Ash is Complicated

Early observations have given us some hope that we will see ash remain on the landscape, like how we see American elm persist through the continual cycles of Dutch elm disease. Like with elm, long-term survival of ash depends on there being established seedlings and saplings present prior to the death of the larger, seed-producing trees. Since EAB populations will decline but persist, ash survival also depends on how the EAB population rebounds as smaller trees grow into a size usable by EAB larvae. If young trees can survive long enough to bear seed, then ash will likely persist. Biological control, in the form of native woodpeckers as well as some tiny, non-native, stingless wasps, will be critical in protecting those younger trees from EAB damage.

Missouri's native woodpeckers, especially red-bellied and downy woodpeckers, are doing a great job of eating 40–85% of the EAB larvae from infested trees (Flower et al. 2014). Researchers have noted increases in winter populations of woodpecker and nuthatch species—all thanks to the plethora of EAB larvae (Koenig and Leibhold 2017). However, by the time a woodpecker finds an EAB larva and eats it, the tree has already suffered extensive vascular damage from larval feeding. Woodpeckers can't keep up with high-density EAB larval damage and prevent the death of large overstory ash in the initial wave of invasion, but they may be crucial in the battle to keep smaller trees alive long enough to produce seed.

The second part of biological control is winged but not feathered. Tiny, stingless wasps, brought from the native range of EAB in China and Russia, were tested for release in North America in the mid-2000s. Researchers concluded with high confidence that these species, including one egg parasitoid and three larval parasitoids, would only parasitize EAB eggs and larvae and were unlikely to attack native wood-boring insects (Bauer et al. 2007). After approval, the USDA's Animal and Plant Health Inspection Service (USDA-APHIS) began rearing the wasps in their biocontrol lab in Brighton, Michigan, and eventually offered them to state agencies for release on public lands. The plan was to get these parasitoids established during the invasion phase of EAB, when lots of larvae are present. However, we knew they wouldn't prevent the decline and death of large, overstory trees. Instead, these wasps are great at controlling low populations of EAB in young, thin-barked ash, like what we will see in the aftermath forest.

In 2012, the Missouri Department of Agriculture (MDA) began releasing parasitoid wasps in Wayne County. Since then, nearly a half million wasps have been released at 53 sites in 40 counties across the state. USDA-APHIS staff have confirmed establishment of one or more of these parasitoid species at 11 locations, including the original release site. Back in 2019, nearly 20 years after EAB was introduced to the Lake Wappapello area, it was easy to find small ash trees that were still alive and relatively healthy, likely in part to the parasitism of EAB larvae by these wasps.

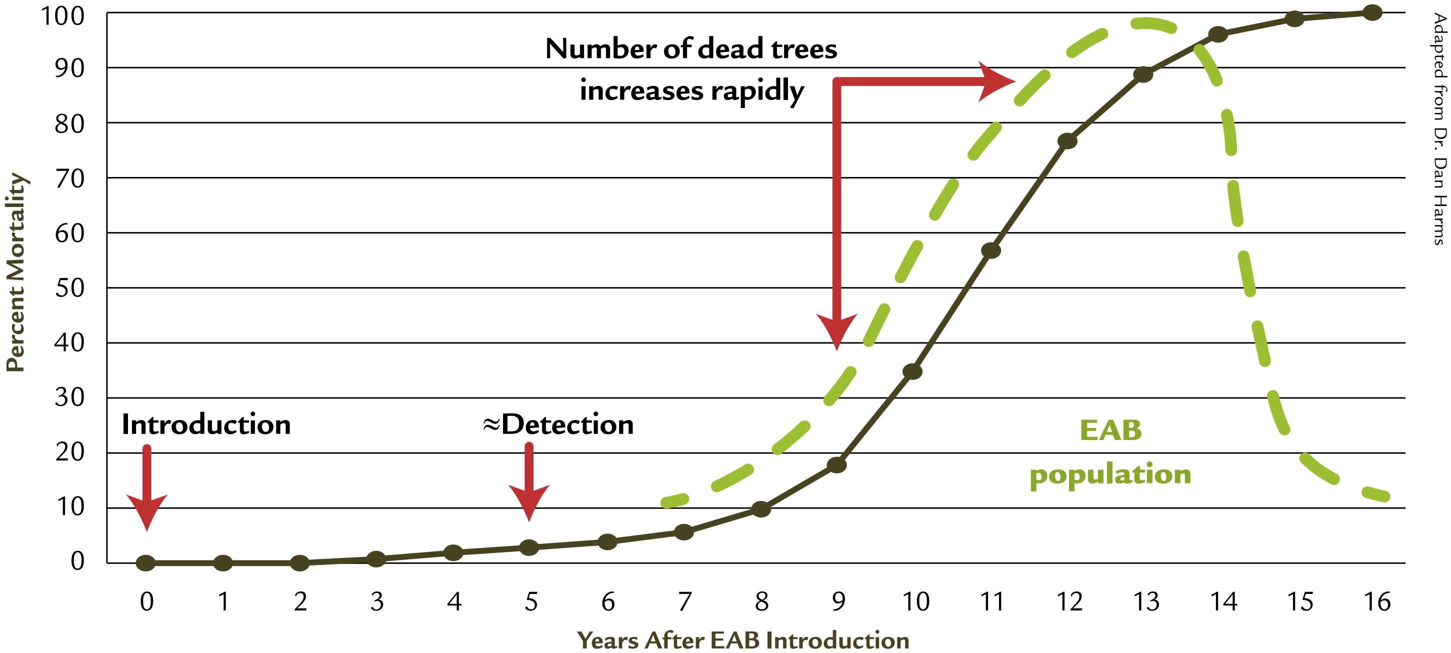

Figure 4. Chart indicating tree mortality and the EAB populations. As the ash die off, the beetle population declines.

While there are glimmers of hope for ash populations, there is also research indicating the future for ash could be grim. States that have had EAB for a few decades—beyond the initial 16-year invasion cycle timeline—are reporting 99% mortality in ash trees over 10 inches DBH. In a 2020 study conducted by Ward et al., researchers used forest inventory data across the eastern US to look at ash regeneration and recruitment in areas known to have EAB. They found that the mortality rate of younger overstory trees—those capable of producing seed—is increasing over time. This leads to a negative population trajectory for ash and suggests that over several decades and multiple cycles of EAB population changes, we will likely see fewer ash on the landscape due to the lack of seed-producing trees. Once ash is no longer able to reproduce and or influence their ecosystem as before, they are considered functionally extinct.

If this pattern eventually holds true in Missouri, white, green, and pumpkin ash are all on the path to functional extinction in the coming decades. Functional extinction is devastating, it doesn't mean the complete extinction of our ash species. We are also unlikely to see ash extirpated from the state in our lifetimes, but they will become increasingly difficult to find and much smaller in size. I'm still hanging on to the hope that ash-dependent insects will have enough host trees to persist, pending adequate biological control by Missouri's woodpeckers and our introduced parasitoid wasps. And, fingers crossed, we see some EAB-resistant trees left standing in the coming years.

Fortunately, there have been many EAB-resistant green and white ash trees identified in the Great Lakes states. Federal and state partners there are actively pursuing a breeding program with the ultimate goal of ash restoration. Roughly one in a thousand trees shows resistance to EAB, and that resistance can range from "slightly better than susceptible ash" to "EAB-proof". Tree breeders then take those genetics from across the resistance spectrum and breed for progeny that are highly resistant to EAB yet also carrying regional genes (no Asian ash genes used). Currently, there isn't an ash breeding program in the lower Midwestern states, but we are starting to look for these "lingering" ash. To qualify as a potentially EAB-resistant individual, a tree needs to be over 10 inches DBH and live two or more years after the other nearby ash have died from EAB. You can report these trees to the MDC Forest Health Program: Forest.Health@mdc.mo.gov

Another piece of good news is that blue ash was left out of that prediction for functional extinction. Yes, blue ash might just make it through the EAB invasion! Research conducted in Michigan has shown that blue ash mortality rates post-EAB invasion are generally less than 40% and can be as low as 7% (Spei and Kashian 2017; Tanis and McCullough 2012). Research into the mechanisms of resistance for blue ash leans toward this cool tree being North America's most naturally EAB-resistant species (Deb McCullough pers. comm. 2024). This trend seems to hold true in Missouri where we continue to see healthy blue ash growing in proximity to dying and dead white ash, even in urban areas. Keep your fingers crossed that blue ash will remain a healthy, overstory tree for the foreseeable future!

Ash are like giant Styrofoam cups… that can kill you!

In the last 20 years, dozens of people have been hurt or killed by ash trees falling unexpectedly along roads or during removal operations. EAB-infested ash trees have reduced wood strength (Persad et al. 2013), because larvae feeding under the bark increase the drying of the wood and create entry points for wood decay fungi (Simento et al. 2023). Ash commonly shatter during high winds or in response to vibrations from chainsaws or heavy equipment. The safest option is to remove ash that might pose a hazard to life or property before they are completely dead. Dead ash in the forest can be left to fall naturally, as removing and destroying dead trees will have no effect on the local EAB population.

Things to Remember

- Keep an eye out for larger ash trees (≥10 inches DBH) that are surviving after all the other nearby ash have died. Report these lingering ash to Forest.health@mdc.mo.gov
- If you are managing a forest that has pockets of surviving, small-diameter ash, consider allowing those to persist and provide a food source for ash-dependent insect species.
- Ash trees infested and killed by EAB are incredibly brittle, so plan to remove trees that might pose a hazard to life or property before they die!
- If you lost an ash in your yard, replace that tree with a native species, preferably an oak such as bur oak or overcup oak. Both species tend to tolerate the compacted clay soils found in yards and urban areas across the state.

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Land Management and Climate Impacts on Missouri Forest Insects

by Robert J. Marquis

Insect declines

Over the last 50 years, entomologists, ecologists, naturalists, and conservation biologists have been shining a light on the problem of declining insect populations. Of the estimated 10 million or so insects on Earth today, about 1.1 million species have been described. Of those species, population trends in butterflies and bees are the most well-known. Unlike the more diverse moths, which are mostly active at night, butterflies and bees are active during the day, when humans are most often out observing in nature. In North America, there is a manageable number of species of both butterflies and bees at any one location. With the help of guidebooks, one can learn to identify most if not all the species in a given location with a little effort, and thus contribute to our understanding of population trends through participation in citizen science studies. Forty to 80 species of butterflies might be found commonly in a given location in Missouri, while bumble bees in Missouri number about 10 species total.

Aquatic insects, especially caddisflies, mayflies, midges, and stoneflies, are also particularly well known. Because these insects are prey of fish, they are of great interest to fishermen. Tie flying, the creation of artificial lures that mimic insects, is an art form and an entire cottage industry unto itself. These aquatic insects are of great import to stream ecologists and water quality managers because the particular composition of the aquatic insect community at any one location is an excellent indicator of water quality.

Dragon- and damselflies span the terrestrial and aquatic habitats. Juvenile forms are aquatic while adults are terrestrial. Adults are often brightly colored, live a relatively long time, hold territories, and are fierce predators of other insects. Naturalists and insect behavioral ecologists often spend much time observing them, and there are also field guides dedicated to the identification of dragon- and damselflies of many regions.

These various insects are all under threat. The main cause of population decline and ultimately extinction is the alteration of the natural habitat of these animals, mostly by conversion to agriculture, grazing, logging, draining of wetlands, and urbanization. Also implicated are pesticides, climate change, disease, imported parasites, and nutrient and light pollution. As so aptly put in a recent review article on the causes of insect declines, it is a 'death by a thousand cuts' (Wagner et al. 2021).

Two relatively local studies provide evidence that the effects of habitat destruction have been going on for some time. A survey conducted in 1908 of butterflies in Winneshiek County, Iowa, documented 73 species. Ninety years later, only 55 species could be found (Larsen and Bovee 2001). Similarly, 50% of the bee species documented in the late 1880's in the Carlinville, Illinois, area, could not be found 120 years later (Burkle et al. 2013). In both cases, loss of natural habitat was implicated, while in the Illinois study, there was a shift in the timing of bee activity and flowering phenology of the plants on which the bees depend, suggesting an additional impact of climate change.

A recent study in Germany brought to the forefront the issue of declining insect populations. These researchers sampled flying insects over the years 1989–2016 in various locations in Germany. They found more than a 75% decline in flying insect biomass over these 27 years (Hallman et al. 2017). Increased temperatures and reduced rainfall were implicated as the probable causes for change (Welti et al. 2022). This Hallman study led to the first use of the term 'Insect Apocalypse' in the popular press (Jarvis 2018), which in turn led to a special session on insect decline at the annual meeting of the Entomological Society of America, held in St. Louis, in November, 2019. Since that conference, numerous data papers, reviews, and meta-analyses have been published, only supporting the earlier reported trends.

Habitat alteration in Missouri: Logging in the Ozarks

The history of logging in Missouri and in most forests of the United States is one of over exploitation and habitat alteration. In Missouri, almost all forested land had been logged by the early 1900's with just a few stands of virgin timber left uncut (Flader 2004). Most timber harvested was oak, while pine was prized to such a degree that only one-tenth of the original pine forest acreage exists today (Guyette et al. 2007). Erosion following logging and farming in river bottoms of the Ozarks filled many channels with excessive sands and gravels (Jacobsen and Primm 1997). Both deer (Budd et al. 2018) and turkey (Clawson et al. 2015) were imported from surrounding states to make up for the loss following complete alteration of the landscape. Historical and first-hand accounts and photos attest to the devastation (e.g., Jacobsen and Primm 1997). Given that today there is much continuous forest, broken up by openings of natural glades, towns, and scattered farmlands, it is difficult to imagine the extreme loss of forest cover that occurred. Today, 34% of Missouri is covered in forest, while in the 1880's it is estimated that 70% of the state was in some form of wooded cover including forest, woodland and savanna (Goff 2018).

The Missouri Department of Conservation (MDC), founded in 1937, realized that by the late 1980's the second growth forests were maturing, and at some point in the near future, trees would be old enough to harvest once again. The question was, 'How was logging to be conducted in a more sustainable way?': that is, in a way that will ensure forest productivity long into future? One measure of sustainability is an economic one: can current extraction of resources be continued into the distant future without decreased productivity? One parameter to consider is the economic benefit to humans through timber production, recreation, and protection of water quality of the streams and rivers that drain the forest watersheds. It is likely that complete clear-cutting of the state once again would not be sustainable by this definition as the ecosystem would unable to provide sufficient resources to maintain forest productivity. But of course, we value forests more than just for their wood volume. We value the insects, birds, reptiles and amphibians, the mussels and fish of the streams and rivers, and all plants that are not trees. We have little data that might tell us what the impact of this original devastation might have had on the biodiversity of region, but this is where the Missouri Forest Ecosystem Project becomes relevant.

Missouri Ozark Forest Ecosystem Project

The MDC initiated a 100–200 year experiment, the Missouri Forest Ecosystem Project or MOFEP, in 1989, in the Current River Watershed in southeastern Missouri (Shifley and Brookshire 2000). The MOFEP is one of the best well-kept secrets among experimental forest ecosystem studies in North America. The goal of this experiment was to quantify the relative sustainability of two contrasting tree extraction regimes on 1) timber production, and 2) maintenance of non-tree components (i.e., birds, insects, aquatic biota, etc.). Two treatments or management regimes were applied: clear-cutting in small patches or thinning of forests in the same size patches. Measures for the two experimental types would then be compared to non-harvested (control) forests. The designers of the project wanted to know both the local impacts of cutting (comparing logged forests vs. nearby unlogged forest), but more importantly how clear-cutting vs. thinning affects processes at the landscape level, across multiple units of the same treatment or management type. Harvest would take place every 10–15 years, depending on how fast trees were growing. A full cycle of cutting would be completed after 100–150 years. Data collection would be by teams of researchers focusing on particular components of the ecosystem: trees, birds, amphibians, soil invertebrates, forest insects, acorn and berry production, and many others.

Our group focused on insects feeding on white and black oak trees, two of the dominant tree species in southern Missouri. Most of these are caterpillars, the immature stages of butterflies and moths. These insects consume much leaf tissue of Missouri trees, in certain years reaching high enough numbers that large tracts of forest are completely defoliated. One concern was that forest management regime might influence the abundance of these insects, perhaps increasing them, and in so doing, cause widespread defoliation and a resultant decrease in tree growth. These insects, however, also serve as food for the vertebrate animals that consume them, mostly birds, bats, and rodents. Finally, as adults many are pollinators of the flowers of understory shrubs and the ground flora. The Missouri Ozark forests probably house a large percentage of the total 2,280+ species of moths and butterflies known for Missouri (P. E. Koenig, pers. comm.). Thus they represent a major portion of the state's biodiversity in terms of sheer numbers, but also are a component that is key to important ecological processes, predation and pollination, and parasitism, which promote the maintenance of other diverse components of the Ozark ecosystem.

When we first began this project, we had little idea which species of caterpillars we would encounter and how many of each, let alone what the effects of timber harvest might be on caterpillar abundance. In fact, we were being extremely optimistic that we could identify the insects we encountered. There was only a single guidebook to caterpillars of any location in North America, and many of the descriptions and photographs were scattered throughout the primary scientific literature and "gray" publications of the U.S. Forest Service and state forestry agencies. A further obstacle was that available descriptions were of economically important species (outbreak species) and usually of last instars, the last caterpillar stage. But we were sampling many species that caused little damage by themselves, so they had not been studied in any depth, and we were encountering them in early as well as late instars. It was not unusual to find that caterpillars change morphology and color pattern as they go from one instar stage to the next. Prior to starting, we conferred with a number of caterpillar experts, many of whom had sampled in various parts of the country, on oaks, focusing on their particular specialty group of caterpillars. When we described the project, the general reaction was a sarcastic "Good luck!" We also had to deal with the fact that most of the foliage of oak trees is located in the canopy, to which there was no easy access. Finally, even prior to our starting, oaks were thought to harbor an inordinate amount of caterpillar diversity, something that we took to be an exciting challenge rather than an excuse not to be involved or to study tree species with less diverse faunas.

Photo by R.J. Marquis

Figure 1. Using a boom truck with attached bucket to census insects in the oak canopy of the Current River Watershed, Missouri Ozark Forest Ecosystem Project.

Photo by J. Fabara-Rojas

Figure 2. Censusing insects on understory white oak in the Missouri Ozark Forest Ecosystem Project

Many of these problems that we encountered have been resolved. There are now a number of guidebooks that allow identification of forest caterpillars, including the one that we published with the goal of alleviating this problem for future researchers (Marquis et al. 2019b). In addition there are now a number of dependable websites that can aid identification and provide geographic information based on museum specimens. Finally, most butterfly and moth species of North America have been genetically bar-coded, so it is possible to send extracted DNA from unidentified individuals to a Canadian lab for identification based on matching genes of the unidentified individuals to the lab's identified specimens. To solve the issue of tree canopy access, we rented a bucket truck with a 35-foot boom to get us in the canopy in a few selected locations where the terrain was flat. It became a real art to maneuver this huge truck amongst trees without damaging them, and getting the boom in position to sample branches with sufficient numbers of leaves.

Missouri Ozark Oak Caterpillar Fauna

We sampled caterpillars for twenty years within the MOFEP experimental study (Marquis et al. 2019a). We recorded leaf-chewing insects encountered on marked branches of marked trees. All insects were left on trees, unless we could not identify them, in which case we took them to the lab for rearing to adults. Adult moth and butterflies are easier to identify than their larval counterparts. We sampled four times during the growing season, up until the last two years when we only sampled during the spring. Four of our findings are relevant to the question of the past and future effects of land use on current and future insect diversity and abundance in a rapidly changing world.

First, we found a very high diversity of caterpillars, and other insect herbivores, on these two tree species. Our current list includes approximately 228 species of moths, 5 species of butterflies, 12 species of beetles, 2 species of walking sticks, 4 species of grasshoppers and katydids, and 14 species of sawflies (related to bees and wasps). This is not all of the diversity of oak-feeding moths known to occur in Missouri. We did not encounter caterpillars of 193 species of moths whose caterpillars are known to feed on oak trees in locations outside of Missouri but have been collected only as adults in Missouri. We know they occur or occurred in Missouri because J. Richard Heitzman kept records of moths and butterflies collected in Missouri until his death in 2013, with Phillip E. Koenig continuing this effort today. It is a mystery why we have not seen these species after sampling tens of thousands of caterpillars (220,000+ in the first 10 years). Perhaps some of them occurred in the state prior to the logging of the late 1800s but now are extinct in Missouri as a result of the logging.

Photos by R.J. Marquis

Figure 3. Common caterpillar species encountered in the Missouri Ozark Forest Ecosystem Project on white and black oak trees. *(top to bottom)* **Green Oak Caterpillar** (*Nadata gibbosa,* Notodontidae). Note the sub-dorsal yellow lines running the length of the body. Mandibles are yellow with black tips. **Banded Tussock Moth Caterpillar** (*Halysidota tesselaris,* Erebidae). Found on a wide variety of tree species, often on tops of leaves, the mature larvae come in either a yellow or gray form. **Variable Oakleaf Caterpillar** (*Lochmaeus manteo,* Notodontidae). This species has a dorsal gland that emits acetic acid when disturbed. **Spiny Oak Slug** (*Euclea delphinii,* Limacodidae). This is the green form of this caterpillar. Also seen in Missouri are orange and white forms. All have urticating spines. **Common Lytrosis Caterpillar** (*Lytrosis unitaria,* Geometridae). A spectacular twig mimic.

Second, we found a very strong effect of forest age on the insects associated with them in the nine MOFEP study sites prior to the first forest harvest in 1996. We first found that older forests, that is, forests that had been longer in the possession of the Missouri Department of Conservation, had more insects on white and black oak trees. There was about a 27-year difference in age from the youngest forest (1953, Peck Ranch Conservation Area) to the oldest (1926, Deer Run State Forest, which was 57 years old at the time of sampling) (Marquis and Le Corff 1997). When we expanded this sampling to white oaks outside of the MOFEP study sites to include forests 2 years to 300 years of age, we found that species numbers and insect density were higher in the oldest forests, and insect composition in older stands of white oak differed from that on younger stands (Jeffries et al. 2006).

To explain the above result, we suggest that older forests contain unique habitats and resources that some insects may require that are not otherwise found in younger forests. For example, there may be particular micro-niches necessary for pupation and overwintering of caterpillars, such as large logs; crevices in bark in which caterpillars can hide during the day to escape predators; and sites for background matching of adults to avoid predation, true for many underwing moths (genus *Catocala*) that hide against bark on trunks of large trees. Additionally there may be more floral resources in older forests needed by adults that are not found in younger forests. Similar effects of forest age have been found for beetles in Australian (Grove 2002) and Japanese forests (Maeto et al. 2002), and in Douglas fir forests in the Pacific Northwest (Schowalter 1995). Salamander diversity also increased with forest age in MOFEP sites (Herbeck and Larsen 1999).

These results suggest that current distribution of diversity of both invertebrates and vertebrates in Missouri Ozark forests is a function of previous logging history as it affects forest age at a given location. Thus, the legacy of clear-cutting the state in the 1880s is apparent even after more than 100 years. In setting up the MOFEP experiment, the designers had the wisdom to demarcate a core of uncut forest that would be maintained uncut in perpetuity regardless of the surrounding experimental treatment.

Third, we see little evidence at this time that insect populations on oak trees are declining (or increasing) in Missouri as a consequence of current land use practices (Forkner et al. 2006). We see a very strong effect of local cutting on insect abundance and diversity if we compare a clear-cut slope to a nearby, uncut one. However, at the landscape level after the first round of cutting we saw few effects of harvest, all subtle and relatively weak. This is a tentative conclusion because we have only sampled after a single round of timber extraction, after approximately 10% of the MOFEP forests had been harvested. Future sampling following additional rounds of cutting will be needed to determine the magnitude of the impact of continued harvest, and which management regime will produce the least harm, if any.

Finally, our data address the question of the role of climate change on Missouri forest insects (Marquis et al. 2019a). Reports by MDC forest entomologists during the 1950s–1970s reveal a pattern of peaks and valleys in forest insect abundance across the state from year to year. Our results confirm this pattern but allow us to attribute these changes to changes in local weather. Part of this year-to-year variation is driven in part by late spring frosts, which reduce abundances of insects by killing young, developing leaves, and in part driven by summer droughts that have negative impacts on summer-feeding insects. Because we have many years of sampling, we can say that recovery from these weather events takes three to five years or even more. Predictions by climate scientists suggest that climate patterns will only become more variable, increasing the likelihood of late spring frosts. Summer droughts are also expected to increase in the Midwest states. Both would have negative consequences for Missouri forest insects.

We predict that an increasingly more variable and extreme climate will have negative consequences for multiple species of forest insects in the Missouri Ozarks. These climate change impacts may only be exacerbated as more tree biomass is removed from MOFEP plots. Continued removal of trees may make forests more susceptible to early spring frosts and their attendant negative effects on the insects (Langvall and Löfvenius 2002). Lower tree density should also increase temperatures and decrease water content of foliage in the summer, both of which would have negative effects on the summer-feeding insects (Scriber 1977). Thus tree health might be improved due to lower stocking but insect population decline might be exacerbated.

Return to the issue of insect decline

Many years of continuous data collection are necessary to establish trajectories of insect populations to determine whether they are declining. Establishing the causes of changes can be challenging but experiments like the MOFEP help us determine whether current management practices affect the biodiversity that we seek to preserve. We have found evidence that large-scale deforestation can have significant, long-lasting negative effects on forest insect abundance and diversity. Rapidly changing climate however is likely to have major negative effects on Missouri insects, and may be made worse by the effects of future timber harvest.

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Web resources:

Missouri Ozark Forest Ecosystem Project[1]

Caterpillars on Missouri Oaks, an Illustrated Guide[2]

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2025 Event Calendar

February 11, 2025 • 11am CST

Natural Areas Association Webinar

Presented by Bethany Bradley, Co-Director, Northeast Climate Adaptation Science Center

naturalareas.org/webinars.php

February 19–21, 2025

Missouri Natural Resources Conference

Margaritaville Resort, Osage Beach, MO

mnrc.org

February 24–27, 2025

National Native Seed Conference

Tucson, AZ

appliedeco.org/nnsc25

February 28, 2025 • 4:30pm

Short-Eared Owl Hike

Shawnee Trail Conservation Area,

160 SW 160th Lane, Mindenmines, MO

moprairie.org/events

March 7–9, 2025

89th Conservation Federation of Missouri Conference

Lodge of the Four Seasons, Lake Ozark, MO

confedmo.org

August 21–22, 2025

Missouri Bird Conservation Initiative Conference

Columbia Country Club, Columbia, MO

mobci.net

For the Love of Hickories

by Lauren Pile Knapp, Jacob Fraser, and John Kabrick

Hickories — the ever present, common, but rarely dominant genus of the oak-hickory forest. Although ecologically and economically important, the species in the hickory *(Carya)* genera are often overshadowed in the popular and scientific literature by the oaks. Further, what we know about their biology and ecology and subsequently their management is often lumped with the oaks.

Did you know that Missouri is home to nine species of hickory? Two species are found almost exclusively in the bootheel region, water hickory *(C. aquatica)* and sand hickory *(C. pallida)*.

Water hickory is found in wet bottomlands and swamps and is slow growing compared to other hickories. Conversely, sand hickory is found in the uplands of the bootheel on sandy or gravely soils like those found in the Crowley's Ridge area or on sand ridges in Scott County. Shellbark hickory *(C. lacinosa)* and shagbark hickory *(C. ovata)* are both distinctive for their shaggy platy bark providing important summer shelter for some bats, including the Indiana bat. Shagbark hickory is broadly tolerant of moist and dry sites, but shellbark is more restricted to rich bottomland soils along streams and river floodplains. Also occurring in rich bottomland soils is the pecan *(C. illinoinensis)*, which has been extensively cultivated since the 1700s with over 500 horticultural selections to improve the nuts (taste, size, ease of shelling, and production) and tree hardiness. Bitternut hickory *(C. cordiformis)* also prefers moist sites in low woods or stream sides and is our fastest growing hickory but also the shortest-lived (200 years). Our most common upland Ozark hickories are pignut hickory *(C. glabra)*, black hickory *(C. texana)*, and mockernut hickory *(C. tomentosa)*. Pignut hickory grows throughout the eastern United States whereas black hickory is relegated to primarily the midsouth and south-

Figures by Jacob Fraser

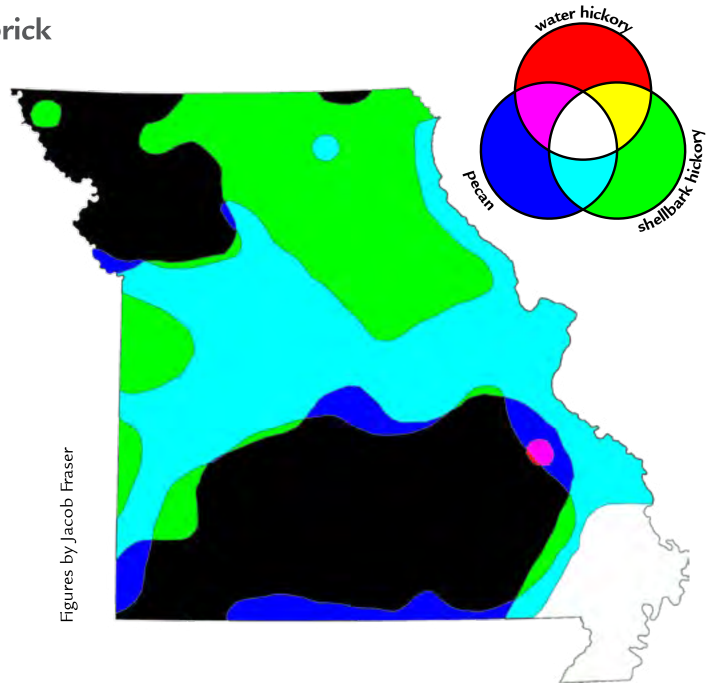

Figure 1. Map of the distribution for three bottomland hickory species in Missouri; water hickory, shellbark hickory, and pecan. Colors indicate the likely range of one or a combination of multiple species. White indicates the common range of all three and black indicates unlikely occurrence of any (Little, 1971).

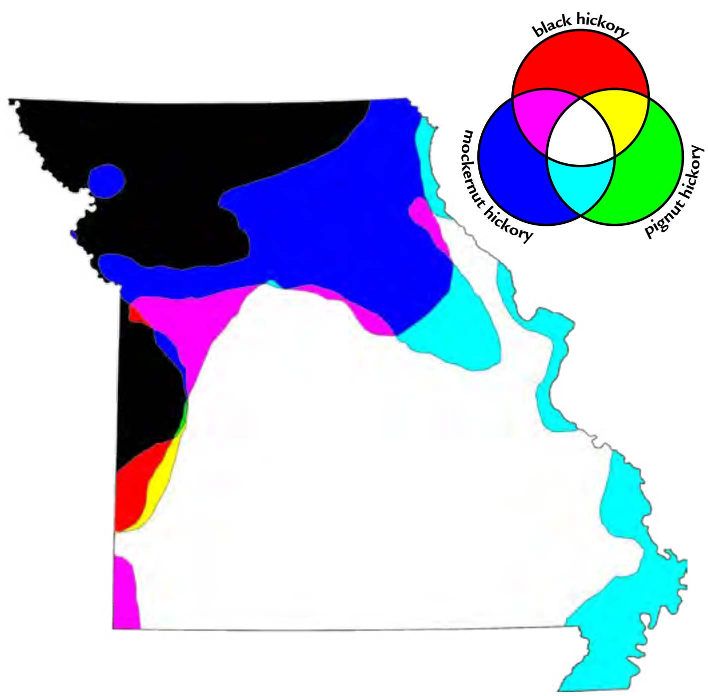

Figure 2. Map of the distribution for three upland hickory species in Missouri; black hickory, pignut hickory, and mockernut hickory. Colors indicate the likely range of one or a combination of multiple species. White indicates the common range of all three and black indicates unlikely occurrence of any (Little, 1971).

ern United States. Both species typically grow on dry sites that historically favored open woodland conditions, and black hickory is particularly tolerant of dry, nutrient-poor, rocky soils. Although somewhat difficult to tell apart, pignut hickory has a nut with pig-like snout which were often fed to pigs and gray bark while black hickory has dark, almost black bark and pear-shaped and somewhat flattened nut. Mockernut hickory is a stately, large tree with hairy (tomentose) leaves and twigs and the hardest wood of all the hickories. It also is adapted to dry sites although it also can be found on lower slopes near streams.

Perhaps because we all have a bit of underdog in us all, we thought this under-appreciated member of the oak-hickory forest type deserved more attention, specifically in upland forests. Most of what we know about the oak-hickory forests of today, is that they are primarily derived from environmental conditions and disturbances that favor their establishment and growth over other species. In upland forests, both oaks and hickories are favored with disturbance, such as fire, and are most competitive on sites that are warmer and drier making them likely candidates to do well in a warming climate.

However, the path that two genera take to reach the forest canopy is markedly different. Oaks tend to respond to forest openings all at once, with most individuals occupying relatively similar heights and sizes, often being dominant or codominant in the forest canopy. Hickories, on the other hand, take a slower approach to the race for the top, and this strategy starts at the earliest stage of the hickory's life, the seedling.

The seedlings of oaks and hickories are well-adapted to waiting out the tough times by investing more in roots than in stems and leaves. Like having a savings account for unexpected life events, investment in roots allows both oaks and hickories to readily regrow if top-killed by fire, browsing, or severe drought. This also allows them to persist in partial shade until there is a canopy opening. When a canopy opening occurs, they capitalize on their earlier investment by using the stored carbohydrates for stem and leaf growth and initiate rapid upward ascent to the canopy. Although oaks are well-known for this adaptive mechanism, hickories invest even more in their roots than oaks, allowing them to persist longer while waiting for a canopy opening. This conservative growth strategy can be seen in midstory hickories that are 140 years old.

As forest stands continue to mature and age, oaks perform best when they occupy the upper canopy of the forest, in dominant or codominant canopy positions. In more suppressed canopy positions, where light from above is limited, their greater shade tolerance allows hickories to fare well, growing more and dying less than the oaks. Although less abundant, through time, a few hickories will find themselves among the oaks in the upper reaches of the canopy.

Maintaining species diversity, including of hickories, is important with increasing stressors from land use change, climate warming, and nonnative invasive pests, pathogens, and plants. Promoting compositional and structural diversity in our forests will become even more critical in the future. To reflect on the words of Aldo Leopold, the father of wildlife ecology and modern conservation, the more we understand and retain 'every cog and wheel' the better it will aid our 'intelligent tinkering' needed for managing resilient forests for the future.

To learn more, visit https://www.fs.usda.gov/treesearch/pubs/62769

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Photo from State Historical Society of Missouri

Figure 1. An intensely logged forest near Grandin, Missouri circa 1907.

Increasing Bird and Native Plant Diversity Through Collaborative Forest Landscape Restoration in Missouri

by Connor Crouch, Cody Norris, Matt Dillon, Tim Perren, Scot Robinson, Kyle Steele, Angie Trombley

In the 1980s, resource managers on the Mark Twain National Forest faced a challenge: they wanted to restore species that were once abundant in the Ozarks, but contemporary forests lacked the open-canopy woodland habitat that many native species need to survive, let alone thrive. The poster child, or more accurately poster bird, for this restoration effort was the Brown-headed Nuthatch. This tiny blue-brown bird with a brown-capped head and a distinctively squeaky call may have been once a common feature of open pine woodlands in the Missouri Ozarks. However, intense logging and subsequent land clearing by Euro-American settlers around the turn of the 20th century resulted in a significant loss of shortleaf pine in the Ozarks. By the early 1900s, the brown-headed nuthatch and the red-cockaded woodpecker, which both depend on open shortleaf pine woodlands for habitat, were extirpated from Missouri.

In response to the logging boom and concerns about erosion and forest sustainability, the Mark Twain National Forest was established in 1939 to promote and protect forests for multiple uses. At the time, suppression of wildfire was a primary directive because foresters believed that fire endangered timber resources and reduced forest health. Although preventing fire for over 50 years allowed intensively logged forests to recover, a lack of fire changed the structure and composition of forests. Instead of the open shortleaf pine-oak woodlands that were common pre-colonization and developed in response to centuries of Indigenous burning, Ozark forests in the mid- to late-20th century lacked structural diversity, consisting of dense, closed-canopy forests dominated by oaks, hickories, and other hardwoods.

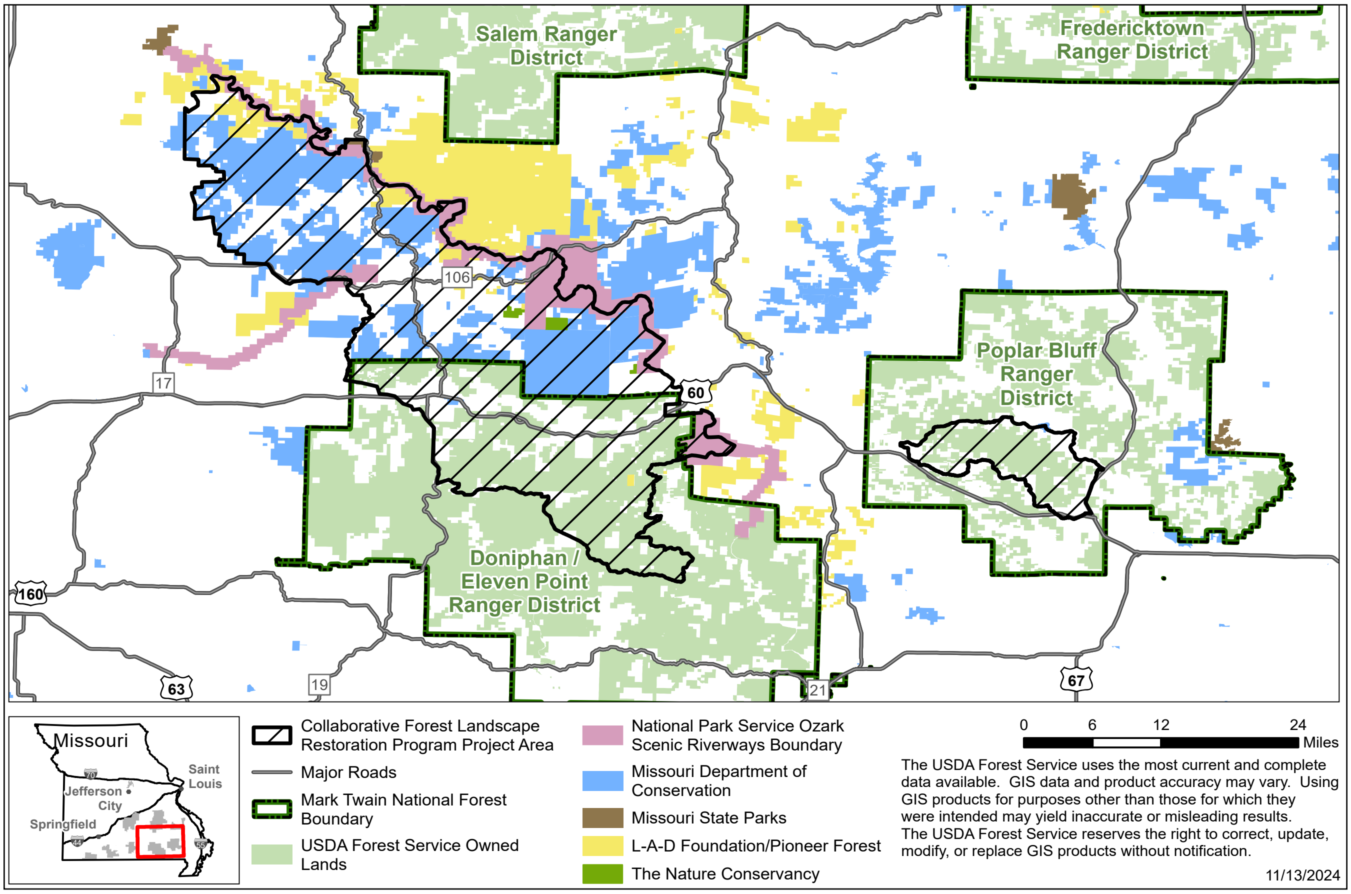
Putting fire back in the forest

As the natural resources community began to recognize the role that fire could play in restoring open pine ecosystems and the species, like the Brown-headed Nuthatch, that depend on them, the Mark Twain National Forest began to implement fire back in the forest. The Forest's first prescribed burns were implemented in the 1980s, and beginning in the 1990s, local projects began using a combination of prescribed burning and mechanical thinning to re-establish shortleaf pine as a dominant tree species in areas of the forest where it was once abundant. Although these projects were small, typically around 100 acres in size, researchers documented encouraging post-treatment results. Wildlife came out of the hollows and bottomlands and up into the fire-restored uplands, and foresters and biologists observed positive responses by native ground flora to the restored open canopy.

In the early 1990s, the Mark Twain National Forest joined with Central Hardwoods Joint Venture, The Nature Conservancy, American Bird Conservancy, and other partners to expand this work. Early successes generated enough

Figure 2. Personnel from the Mark Twain National Forest implementing prescribed fire to restore shortleaf pine-oak woodlands.

Photo by Erin Wolf



ArcGIS map courtesy of the Mark Twain National Forest

Figure 3. Map showing the MoPWR project area (outlined in red), which spans almost 450,000 acres of public and private land in the Missouri Ozarks.

momentum to attempt restoration on a large landscape, with the goal of restoring pre-colonization forests in the area now known as Pineknot. The Pineknot project took longer to implement because it covered 12,419 acres, but it showed even more promising results. The success of these initial restoration projects led to legitimizing prescribed fire as a management tool and incorporating it into the 2005 Mark Twain National Forest Plan, the overarching management document for the Forest. Beginning in 2005, larger, landscape-scale burns were implemented as outlined in the 2005 Forest Plan. This burning is intended to restore the shortleaf pine woodland natural community type and is typically conducted on a three-year burn rotation, meaning areas are burned every three years.

Today, the Forest's larger prescribed burns can range from 2,000 to 5,000 acres each, requiring many personnel and advanced tools for successful and safe implementation. For example, helicopters are used for interior ignition while ground resources ignite the perimeter with UTVs. Typical burn days require around 25 personnel on the ground, including a burn boss, two firing bosses, two type-6 fire engines, one bulldozer, and ten UTVs in addition to smoke monitors and people assigned to highway traffic control. On particularly suitable days for burning, multiple burns may occur on different parts of Forest, making the personnel and coordination involved even more challenging to manage.

Collaborative forest landscape restoration

The next step in scaling up forest restoration in Missouri was to facilitate landscape-scale work across ownership boundaries, which led the development of the Missouri Pine-Oak Woodlands Restoration project (MoPWR). MoPWR, which began in 2012, is part of the USDA Forest Service's Collaborative Forest Landscape Restoration Program, a national effort to implement large-scale, long-term forest restoration. The MoPWR project area, which occupies 444,088 acres, lies within a region of Missouri identified by numerous agencies and entities as having some of the highest priority landscapes for ecological restoration in the Ozark Highlands. The project area includes significant public land ownership (over 150,000 acres) and some of the most undeveloped lands in the region. For the 2,000 years before Euro-American settlement, this area was dominated by mixed shortleaf pine-oak woodland ecosystems. Based on General Land Office surveys from the mid-1800s, shortleaf pine occurred on more than six million acres of the Missouri Ozarks. MoPWR aims to use mechanical thinning, prescribed fire, and invasive species management to restore fire-adapted pine and pine-oak bluestem woodlands that will be more resilient to anticipated climate changes.

A critical piece of MoPWR is the project's collaborative development and implementation. In addition to the Mark Twain National Forest, the Central Hardwoods Joint Venture, Missouri Department of Conservation, L-A-D Foundation, and other groups are working together on this project. For example, MoPWR uses an all-lands approach to facilitate burning across land ownerships, with the goal of making forests healthy across boundaries. The Forest conducts prescribed burns within designated Missouri Natural Areas located in the MoPWR footprint, including Cowards Hollow, Cupola Pond, Haney Pond, and Big Barren Creek. In addition, private inholdings on the Mark Twain National Forest are burned along with public lands for mutual benefit. Private landowners benefit by having trained professional staff implement prescribed fire safely on their land, and the Forest Service benefits by reducing implementation costs and decreasing the amount of dozer line created. Instead of dozer line, private pastures, creeks, and existing roadways are used for fire breaks. Utilizing these existing fire breaks, which are wider than dozer lines, also greatly reduces firefighter exposure and the risk of fire jumping the planned perimeter.

Quantifying restoration success

MoPWR is yielding visible results, so much so that the initial 10-year project was granted a five-year extension. During those first 10 years, the Mark Twain National Forest completed 23,571 acres of commercial timber harvest, 36,053 acres of non-commercial mechanical treatment, and 153,850 acres of prescribed fire. The cumulative treatment footprint of all this work was 138,224 acres, and a total of 59,624 acres are considered structurally restored to woodland conditions because they have received both mechanical overstory treatments and at least two prescribed fires. Prior to these treatments, many areas within the MoPWR footprint were deemed uncharacteristic of historical fuel and vegetation composition, conditions which are now changing in response to restoration treatments. This collaborative work is improving species composition, desired tree makeup and densities, and health of native species' populations.

Staff on the Mark Twain National Forest are using two tools to monitor MoPWR sites and track species' responses. Floristic quality assessments (FQA) have been conducted throughout the project's lifespan and provide a thorough evaluation of the understory plant community. In the Pineknot and Cane Ridge vegetation management areas, 131 permanent vegetation monitoring plots were established through a partnership with

The Nature Conservancy and NatureCITE, and these plots were used for FQA. FQA data was also utilized to test out a second monitoring tool Community Health Index (CHI), which assesses the understory community in addition to other ecosystem components, such as overstory structure and composition and the bird community. CHI is a more rapid assessment designed to supplement FQA in situations where high-intensity understory data collection is not feasible.

These monitoring tools indicate that some restored MoPWR sites are in excellent shape while others still have more work to bring them to the desired community condition. For example, the units that scored in the top 20% of all CHI scores were compared with units that scored the lowest. The top sites had 10 times more native grass and sedge cover, 7 times more forb cover, and 2.5 times more conservative species present than the low scoring sites. The high scoring sites also had 1.5 times lower tree stocking, 3 times less sapling cover, and 1.9 times more seedling cover. Therefore, successfully restored sites tend to have less dense overstory and midstory conditions, more herbs in the understory including indicator and rare species, and more tree regeneration. Notably, Forest staff found that midstory stocking was a better indicator of ground flora score than overstory stocking, which informs future management of these areas. High CHI scoring sites also had more priority bird species present, demonstrating positive impacts of restoration on animals as well as the plant community. Restoration has also been helpful for invasive species reduction and prevention, with most units having less than 1% cover of invasive plants, and for oak regeneration and recruitment, with 62% of units having abundant white oak seedlings and 42% with abundant white oak saplings.

Prescribed fire, in particular, seems to be a boon to restored communities. There was a moderate positive correlation between the number of fires in the previous 20 years and CHI score, indicating more fires produced healthier forests. A moderate positive correlation was also found between the composite ground flora scores and the number of burns in an area. Prescribed

Figure 4. Comparison of a densely stocked, untreated shortleaf pine forest versus an open shortleaf pine woodland. Notice the abundance of understory vegetation in the restored site.

Photos by Scot Robinson

burning removed litter cover that inhibits plant growth and clearly helped proliferate native ground flora. Despite frequent fire, around 92% of CHI units sampled in 2022 have retained their duff layer, which helps protect against excessive soil movement and provides other soil health benefits, indicating that prescribed fire is not hurting the duff layer in most cases.

Just as it is important to know what is working, there are also important lessons learned on the less successful sites, which represent opportunities for adaptive management and continued refinement of restoration treatments. Although more sunlight reaching the forest floor favors desirable forbs and grasses, it also is conducive to development of seedlings and shrubs that compete with herbaceous plants. For example, sumac and blackberry species can become problematic on some sites, and these species should be monitored carefully after restoration. A larger concern is the lack of pine regeneration and recruitment in restored areas, as only 5% of measured units had shortleaf pine seedlings. Work is ongoing to determine which treatments may favor pine regeneration and recruitment and whether prescribed fire regimes may need to be altered to allow pines to recruit.

Where does restoration go from here?

MoPWR is doing important work to return Ozark forests to a healthier, more resilient condition. Increasingly, though, resource managers with the Mark Twain National Forest are beginning to question whether a return to pre-colonization conditions is possible because of the legacy of human impacts on forests and the changing climate. Authors of a recent MoPWR monitoring report (Leahy et al. 2024) concluded, "Based on field experiences and discussions with resource managers and other ecologists, many of us are wondering if ecological restoration, as defined under a historic context, is achievable in the MoPWR landscape." Instead, practitioners will have to use monitoring, such as CHI and FQA, to determine what outcomes are realistic and apply adaptive management to adjust prescriptions accordingly. For example, CHI monitoring indicates that only small patches (typically three acres or less) within units had mature pine-oak canopies, ideal midstory and understory structure, and requisite cover of matrix and conservative ground flora that together meet the reference condition. Further discussions are needed on the next steps in restoration treatments, and questions remain about combating the problems associated with understories dominated by oak and hickory sprouts and overgrowth of sumac and blackberry, all of which inhibit return to reference conditions.

Despite these challenges, one thing is clear: real progress is being made with restoration treatments conducted by the Mark Twain National Forest, Missouri Department of Conservation, and L-A-D Foundation in the MoPWR landscape. Ground cover of native plants and key indicator groups have increased. The remaining overstory shortleaf pines and white oaks have been released to grow with less competition, which should increase resilience to drought due to lower stocking and better adapted species remaining in the stands. In addition to assisting with climate change resilience, treated stands with high CHI scores are also less likely to burn severely during wildfires compared to dense, overstocked stands. The treated stands may burn more readily because they contain more fine fuels but will have lower intensity compared stands that are overstocked and drought-stressed, leaving treated stands less susceptible to overstory mortality.

Even the Brown-headed Nuthatch seems to be responding favorably to landscape-scale restoration. Over the past few years, 197 individual nuthatches have been released within the MoPWR footprint, with the goal of re-establishing their populations in Missouri. This year, one pair of nuthatches was found 30 miles from their original release site, notably in an area that is a restored pine woodland. Forty years after Mark Twain National Forest staff first dreamt of restoring native species like the nuthatch, those dreams are becoming a reality thanks in large part to collaborative forest landscape restoration. Although we cannot go back in time, MoPWR is demonstrating how functional restoration is possible, and Brown-headed Nuthatches are testifying to this success.

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Photo by Noppadol Paothong, Missouri Department of Conservation

Figure 5. Brown-headed nuthatch pair in the pine-oak woodlands in the MoPWR focus area. These cavity nesting birds are expanding their range after the successful reintroduction.

Missouri Natural Areas Newsletter Mailing List

To receive notification when new issues of the *Missouri Natural Areas Newsletter* are posted, e-mail Michael.Leahy@mdc.mo.gov.

This list-serve is *only* used to notify people of the link to the current natural areas newsletter web posting.

Photos by StevePaes

Figure 1. Large buttressed roots of old growth overcup oak help to represent the bottomland forest community at Sand Ponds NA.

Ancient Dune and Swale Topography of Sand Ponds Natural Area Harbors Botanical Treasures

by Steve Paes

The Missouri Department of Conservation's Ozark Region is known for several things including large conservation areas, upland habitats with extensive oak and pine forests and woodlands, dramatic topography with scenic vistas and spring-fed rivers. It is also known for the number of species of conservation concern and high-quality natural communities documented by records in the Missouri Natural Heritage Database.

But the Conservation Area with one of the highest numbers of Heritage records does not meet these criteria. It is one of the smaller Conservation Areas in the Region. It has no dramatic topography or river, not even a stream. It is not even within the Ozarks. The 302-acre Sand Pond Conservation Area, located in southeast Ripley County, is in the Lowlands section of the Mississippi Lowlands Natural Division.

There are five natural communities on the Area. Dry-Mesic Sand Forest, Mesic Sand Forest, Wet-Mesic Bottomland Forest, Wet Bottomland Forest and Marsh. Upland forests occupy 156 acres and there are 140 acres of bottomland forest. The remaining 6 acres are a pipeline right-of-way. The term upland forest is a little misleading though. The sandy "uplands" are only 5–8 feet higher in elevation than the bottomlands. The bottomland "ponds" are surrounded by or adjacent to these sand "ridges." In one or two

Figure 2. Federally listed pondberry shrubs in fall foliage are found in the natural area.

steps one can walk from one to the other with virtually no side slope between them. The ponds are not fed by streams; rainwater filters through the sand ridges to fill them. The sand ridges were cleared and farmed by previous owners and have since been naturally and artificially regenerated after the Missouri Department of Conservation took ownership in 1981. Timber was harvested from the ponds in the early 20th century but they were never cleared for agriculture.

Even with minor changes in elevation there is a high diversity of plant species on the area. With a few feet of change in elevation there is a stark difference in habitat and tree species between the upland and bottomland. The upland habitat species include white, Shumard, northern red, southern red and black oaks (*Quercus alba, shumardii, falcata,* and *velutina,* respectively). Tree species diversity is caused not just by the dichotomy of wet and dry. The bottomland ponds have several different habitats due to the varying amount of time they are flooded. Very small differences in elevations favor some tree species over others. At times the changes in tree species are the only indication there has been a change in elevation and soil moisture. Cherrybark and cow oaks (*Q. pagoda* and *michauxii*) transition to bur and overcup oaks (*Q. macrocarpa* and *lyrata*) and ultimately to water, willow, Nuttall's and pin oaks (*Q. nigra, phellos, nutallii,* and *palustris*) as the elevation gets lower and there are longer periods of flooding. In much of the Ozark region aspect affects diversity. At Sand Pond, where there are no changes in aspect, it is the various periods of inundation that provide diversity.

High species diversity in unique habitats must be a good formula for heritage records. Sand Pond has over 60 records of high-quality natural communities and species of conservation concern. Conservation areas that are 100 times larger will have less than or a comparable number of records. The flagship species on Sand Pond is the federally listed pondberry (*Lindera melissifolia*). The presence of this shrub was one of the main reasons the state purchased the property. In addition, Heritage records document a wide range of other rare taxa including the Western chicken turtle (*Deirochelys reticularia miaria*), vernal crayfish (*Procambarus viaeviridis*) and corkwood (*Leitneria pilosa* ssp. *ozarkana*). Due to habitat conversion in much of the surrounding area, Sand Pond is a major refugia for many species that require these habitats.

The 68-acre Sand Ponds Natural Area was established to recognize the areas unique sand dune-swale topography and its associated rare plants and animals. Most of the Natural Area is on Sand Pond Conservation Area with some on land owned by The Nature Conservancy (TNC).

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The Value of Trees in Enhancing Community Health, Resilience, and Connection

by Eric Hempel

Trees play a vital role in enhancing community health, cohesion, and resilience to climate change impacts. Discussions with community leaders, natural resource experts, and local volunteers highlight how urban trees improve public health, provide ecological services, and strengthen neighborhood bonds. This article explores the benefits of trees in urban spaces, effective strategies for expanding tree cover, and the partnerships that make these projects possible.

Trees and Community Health

Urban trees significantly contribute to public health by providing shade, reducing heat stress, and improving air quality. These benefits are particularly valuable in low-income neighborhoods, which often face greater exposure to extreme temperatures and poor air quality. Dave Dittmer, Natural Resource Manager for Columbia, Missouri, notes that shaded areas make public spaces more inviting, saying, "At a coffee shop with tables outside, people are going to linger longer drinking more coffee, hanging out with friends, if they're in a nice, shaded environment." Shade not only draws people outdoors but also reduces building cooling costs and enhances air quality, fostering healthier, more livable urban areas.

Columbia, Missouri's Office of Sustainability's "Show Me the Heat" project highlights the critical role of trees in public health. By mapping urban heat islands, the project identifies areas that suffer from persistent high

Image: City of Columbia. Data: Missouri Natural Resources Inventory and U.S. Census Bureau

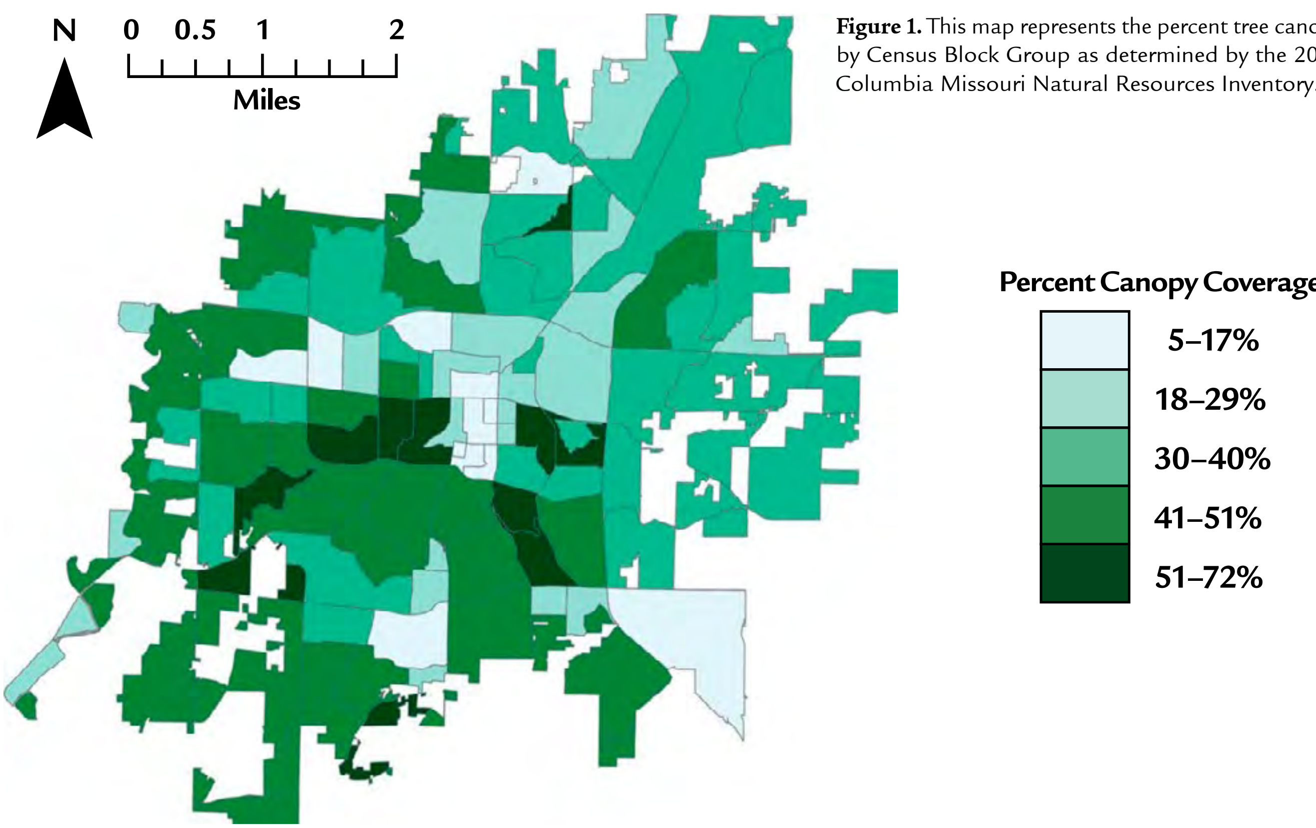

Figure 1. This map represents the percent tree canopy by Census Block Group as determined by the 2022 Columbia Missouri Natural Resources Inventory.

temperatures, especially overnight, due to lack of greenery. The initiative prioritizes tree planting in these "heat zones" to mitigate health disparities, with Corrina McClee, the City's Community Resilience Organizer, emphasizing that "we're working with neighborhoods to co-create solutions, targeting cooling strategies based on what residents need most." This community-centered approach is key to addressing public health and environmental justice.

The Biology and Ecology of Trees: Resilient Species Selection for Urban and Natural Landscapes

Selecting tree species that are resilient to local stressors and future climate conditions is essential for effective urban forestry. Both Dittmer and Columbia's City Arborist, Steve Fritz, emphasize that successful tree selection balances the benefits of native species with the resilience of non-native species where necessary.

"Species selection is critical," says Fritz. "We focus on what species to plant and where to plant them, taking future environmental changes into account." This approach involves choosing species that can thrive in both current and anticipated conditions, such as those found in warmer regions. Dittmer and Fritz highlight the importance of tree diversity, noting that species selection should prepare for challenges like pests or diseases that can devastate homogenous tree canopies. For example, the emerald ash borer infestation illustrated the risks of relying too heavily on a single species. "If a pest targets one type of tree, we're not left with a massive hole in our canopy," Fritz explains.

Urban trees face unique biological challenges, such as limited soil volume, soil compaction, and infrastructure conflicts. Techniques like "silva cells[1]," which provide additional soil volume beneath sidewalks, help trees grow robust root systems even in tight urban spaces. The importance of adapting planting practices to maximize tree health through innovations like fabric containers, which help establish stronger root systems and minimize transplant shock, is also key. "The root bags help with survivability because they ensure that the trees have a stronger, more intact root system when they’re planted. This method has been a game-changer for us." Healthy root systems anchor trees, absorb nutrients, and enable them to endure urban stressors, enhancing tree health and longevity. Both Dittmer and Fritz view trees as essential "green infrastructure," with Dittmer emphasizing, "Trees contribute to a larger network of ecological services that keep our cities livable and resilient."

Fostering Community Engagement and Neighborhood Cohesion

The success of urban forestry initiatives often hinges on active community involvement. Both Dr. Jennifer First of the University of Missouri and Stephen Bybee, Project Director with the Missouri Conservation Corps emphasize community involvement as a cornerstone of sustainable urban forestry. By engaging local residents through listening sessions and educational events, they foster ownership and pride in green spaces. "People just really want community... they want it to be something more than just planting a tree," Dr. First observed.

In Columbia's Garth Nature Area, Bybee's Missouri Conservation Corps leads a restoration project that engages community members in hands-on environmental stewardship. "When community members take part in projects, they develop a connection and feel invested in the space's transformation," Bybee says. This inclu-

1 https://www.deeproot.com/products/silva-cell/

Art by Wildy Self, photo by Eric Hempel

Figure 2. This mural was created at the Show Me the Heat launch party by community members and artist Wildy Self. It it states the goals of the program: Educate, Collaborate, Prepare, Inform. and represents a community vision of a cooler more sustainable place to live.

sive approach brings together diverse groups, creating a space that serves as a community crossroads. Volunteers learn to differentiate between invasive species like bush honeysuckle (*Lonicera maackii*) and native plants such as cherry trees (*Prunus serotina*). By actively engaging with the environment and gaining skills in invasive species management, volunteers develop a deeper appreciation for their local ecosystem, which fosters a lasting interest in environmental stewardship.

Before arriving at the University of Missouri's School of Social work, Dr. First was involved in a community tree planting project in Knoxville, Tennessee. This initiative used listening sessions to shape project goals and incorporates community celebrations like barbecues, turning planting events into social gatherings that foster local pride. The Knoxville project relies on local partnerships. SEED, a community organization with an established presence, has been essential in building trust and engaging residents. "We could not do what we're doing without the organization... in that community, working every day with people and has built that trust," Dr. First emphasizes. SEED's local knowledge allowed the Knoxville team to create goals aligned with community needs, while partnerships with local schools provided an educational dimension to the project.

Dr. First also involved local schools, where students learn about ecology and environmental stewardship. "The schools are really excited about using this as a tool for their students," Dr. First notes, underscoring the project's potential to inspire future environmental advocates. By addressing neighborhood-specific concerns, such as asthma risks from certain tree species, these projects make urban forestry more relevant to residents.

Strategic Partnerships for Effective Urban Tree Management

Urban forestry and environmental restoration require strong partnerships that bring together city departments, local organizations, and volunteers. In Columbia, partnerships with the Missouri Department of Conservation (MDC) and Missouri Conservation Corps (MCC) are instrumental in expanding the city's tree cover. MDC provides funding and training, while MCC mobilizes volunteers to support tasks such as invasive species removal and habitat restoration. These partnerships enable the city to pursue a more ambitious urban forestry agenda.

Cross-departmental coordination within city governments also plays a critical role in urban forestry. Fritz highlights the efficiencies gained when city departments align tree maintenance with road projects. "By aligning our tree work with street resurfacing, we've been able to create a maintenance schedule that works for both departments," Fritz explains. This approach reduces disruptions and ensures urban trees are given the best chance to thrive.

Overcoming Barriers to Urban Forestry

Despite their benefits, urban forestry projects often face significant challenges. In Columbia, Dittmer identifies limited soil volume, infrastructure conflicts, and short tree lifespans as major obstacles for urban trees. "One of the biggest challenges is providing adequate soil volume," Dittmer explains, noting that trees planted in small pits often struggle to thrive. Solutions like structural soils and root production bags help extend tree lifespans, enhancing urban canopy resilience.

Property ownership presents a significant barrier, especially in rental-heavy neighborhoods. Dr. First remarks, "Ownership... who owns the [land] where you're trying to put these trees... that's where barriers come up." Absentee landlords may hesitate to commit to tree planting, making canopy expansion challenging in these areas. By carefully navigating these barriers and demonstrating the benefits of tree cover, programs in Columbia and Knoxville are working to increase community buy-in.

Financial considerations also impact urban forestry initiatives. While some cities enforce tree preservation ordinances with fines for damage, not all municipalities have such policies. Fritz stresses the importance of treating trees as valuable infrastructure, suggesting that financial incentives could help reinforce the role of trees as essential urban assets.

The Road Ahead: Enhancing Resilience and Equity through Urban Forestry

Urban forestry initiatives must balance immediate needs with long-term resilience goals. Expanding tree canopies in vulnerable neighborhoods, addressing environmental justice concerns, and creating equitable access to green spaces are all critical. Projects like "Show Me the Heat" and volunteer-based initiatives at Garth Nature Area illustrate how urban forestry can improve public health, reduce heat vulnerability, and foster community ties.

Achieving these goals requires sustained community engagement, strong partnerships, and a commitment to resilience-focused urban planning. Despite challenges, the collective benefits of urban trees—from climate impact mitigation to community building—underscore their essential role in creating healthier, more resilient urban landscapes. As Dr. First notes, "Success would be building more climate and health-resilient communities... even if it takes years to build that trust."

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Ken McCarty Retires

Long-time committee member Ken McCarty, the state park system's Natural Resource Management Program Director and the Missouri Natural Areas Committee's current co-chair, retired on January 1st. Ken was hired in 1986 as the Missouri Department of Natural Resources' sole Natural Areas Coordinator and served Missouri's Natural Areas Committee (MONAC) in one capacity or another for most of the 38 years of his career. His first official trip to a pending Missouri Natural Area was to see and then present the prior-scheduled Grand Gulf Natural Area nomination to MONAC's altogether intimidating cast of big-name All-Star founding members. Then followed his first major committee assignment to prepare the nomination he presented in November 1987 for what became the Graham Cave Glades Natural Area at Graham Cave State Park. He served as program committee chair for Missouri's hosting of the 2010 Natural Areas Conference and has alternated as Missouri's Natural Areas Committee Chair or Co-chair for the past several rotations.Whether in state parks or on behalf of Missouri Natural Areas, Ken has focused his interests and career around preserving, restoring and managing Missouri's best natural landscapes and remnant native natural communities. His work brought several recognitions, most notably the Natural Areas Association's 2021 Carl N. Becker Stewardship Award along with the Missouri Native Plant Society's 1998 Arthur Christ Memorial Research Award, Missouri Prairie Foundation's 2015 Prairie Professional of the Year, and twice as the Missouri Conservation Federation's Professional Conservationist of the Year. Ken values the opportunities he has been given through his long career that let him work with nature in Missouri's state parks, and he treasures the landscapes that have been restored, revitalized and distinguished as Missouri Natural Areas in his care. But in Ken's words upon retiring, the priceless opportunity and the source of the resonating memories has been living those experiences and sharing those times with Missouri's amazingly long list of accomplished naturalists, natural resource managers and conservation practitioners yesterday and today. In Ken's own words, "It could not be, or have been, better than this."

Photo by Paul Nelson

Figure 1. Ken McCarty from September 4, 2004, 20 years ago at Cardareva Bluff Natural Area. This natural area was designated in 1984. Pictured are Tom Nagel, Karen Kramer, Doug Ladd and Ken McCarty.