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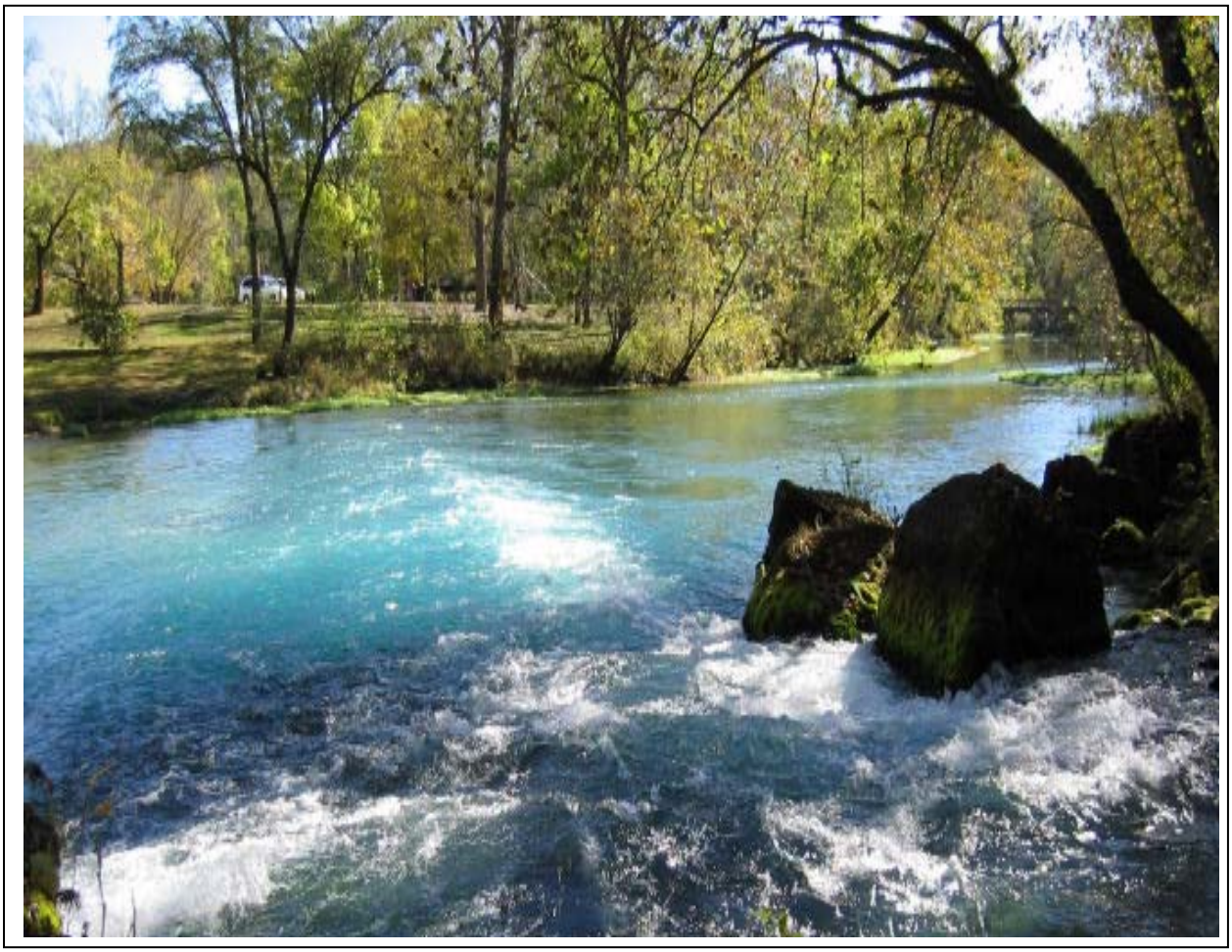
The Fire Ecology of Ozark National Scenic Riverways

Natural Resource Report NPS/HTLN/NRR—2008/031



ON THE COVER
Big Spring, one of the largest single-source springs in North America, on the Current River in Van Buren, Missouri
Photograph by: Angela Smith, Fire Education Specialist, Ozark NSR

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Introduction

Ozark National Scenic Riverways (NSR) is located in a picturesque and predominantly rural area on the Ozark Plateau of southeastern Missouri. The 80,000+ acre park was established as a unit of the National Park Service by Congress in 1964 and consists of 134 miles of the Current and Jacks Fork Rivers. Home to three of the largest single aquifer springs in the United States, Ozark NSR is characterized by steep bluffs, clear running streams, unique karst ecosystems, as well as a rich cultural heritage (Figure 1).

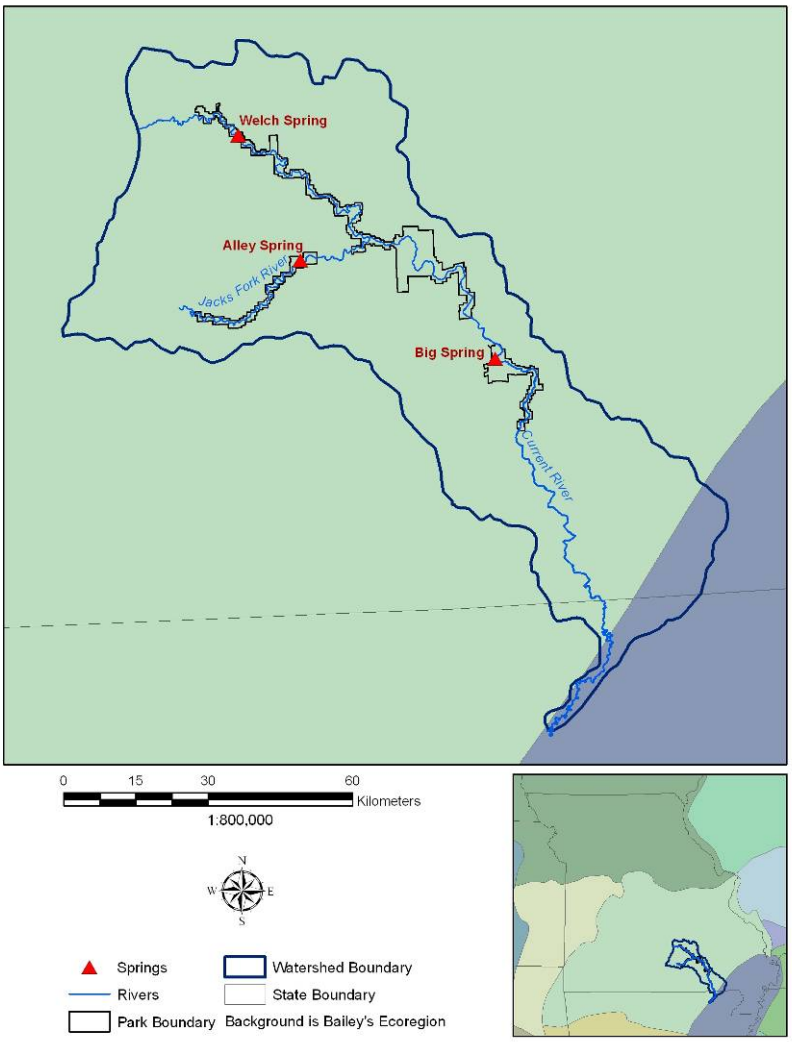

Figure 1. Current River Watershed

Ozark NSR contains a high diversity of natural communities and correspondingly high species diversity largely because it is situated in the Ozark Highlands ecoregion at a tension zone between the deciduous forests to the east and the tallgrass prairie to the west (NPS 2000). The area includes steep valleys, hollows, and narrow ridges. Soils developed over dolomite and sandstone karst bedrock and thus are prevailingly poor and excessively drained. Oak-hickory-

pine forests and woodlands dominate the park with glades on ridges and slopes and riparian forests in the bottomlands (NPS 2000). White, black, and red oaks dominate the overstory with hickories and shortleaf pine, the only native Missouri pine, also playing an important role. The understory consists of maples, dogwoods, gums, and other deciduous forest species. Common animal species include white-tailed deer, wild turkey, coyote, fox, raccoon, squirrel (gray and fox), and a variety of birds, reptiles, amphibians, insects, among others.

The Current River natural vegetation communities face all topographic aspects with 10 - 32° slopes with mean slopes of 18°. The park has a continental climate with relatively humid conditions and mean annual precipitation of 115 cm. Precipitation is bimodal with spring (May, June) and fall (November, December) receiving the greatest rainfall (Guyette and Cutter 1997). January and October are the dryest months on average (Global Warming/Climate Change 2009).

Modern Vegetation Communities

Forest

Missouri's forests are typically dominated by large trees that form a relatively closed canopy and contain a well-developed midstory of shade-tolerant tree and shrub species of varying ages and size classes. Ground flora reaches from one to three feet tall, and consists of shade-loving species and ephemerals. Forest habitats in the Ozarks exist primarily where fire has infrequently visited the landscape, such as moist riparian corridors or steeply dissected hills. At the time of European settlement, forests covered approximately nine million acres of Missouri (Nelson 2005).

Woodlands

Woodlands, the primary Ozark community, range from oak-hickory to oak-hickory-pine depending on aspect, topographic position, and soil. Nelson (2005) distinguishes between "forest" and "woodland" using characteristics such as canopy cover, understory development, and herbaceous richness. The woodland canopy layer is likely to be more open than forest, with sparse mid- and understory layers. Woodlands also contain a thriving herbaceous layer of dense grasses and forbs.

Woodlands were estimated to have covered as much as one-third of Missouri, historically. Estimates of tree density from historic surveys indicate there were 20-60 trees/acre within Ozark NSR – as opposed to 100-200 trees/acre estimated today (unpublished Fire Monitoring Data, Ozark NSR 2002). Regular occurrence of fire is essential to maintaining the open understory characteristic of woodlands, however, fire suppression and intensive grazing are considered the primary causes of woodland degradation (Nelson 2005).

Glades

Glades or barrens are defined as open, unwooded areas on very thin, droughty soils dominated by an herbaceous or graminoid flora and surrounded by forest/woodland vegetation. (Ver Hoef et al. 1993). Prairie species compose a portion of the herbaceous glade species (Nelson 2005). Two primary types of glade habitats found in Ozark NSR are dolomite and igneous (or rhyolite) glades. Dolomite glades are located on moderate to steep slopes with rapidly drained soils. In Ozark NSR, dolomite glades occur almost exclusively on south-facing slopes and at generally lower elevations than the rhyolite glades (Ver Hoef et al. 1993).

Igneous glades, or more specifically rhyolite glades (Figure 2), are found in a relatively local area near the junction of the Jacks Fork and Current Rivers. Found on gentle to moderately steep slopes, the soils are very shallow and typically rapidly drained (Nelson 2005). Igneous glades are rocky outcrops that have an uneven and fractured surface. Exposed rock alternates with vegetation growing in depressions and cracks with accumulated soil. Rhyolite sites are generally less subject to encroachment by trees than dolomite glades because they have shallower soil (Ver Hoef et al. 1993).

Figure 2. Rhyolite glade near Rocky Creek, Ozark National Scenic Riverways (NPS Photo).

A study completed for the park identified woody plant invasion as the most significant threat to glades (Ver Hoef et al. 1993). Regular application of fire is the most effective, widespread, and successful means for managing natural grasslands to reduce or eliminate woody plant species (Guyette and McGinnes 1982). Dolomite glades probably need more frequent fire than do rhyolite glades, partly because the rhyolite glades have lower annual productivity. Furthermore, threats of woody invasion on rhyolite glades are not as great. Ver Hoef's glade study (1993) discussed and dismissed other possible means of controlling woody invasion such as herbicide use, cutting, or mowing. Herbicide may be costly and time-consuming and mowing inaccessible. However, harvesting cedars *was* recommended as a result of observations at the nearby Mark Twain National Forest, where cedar removal did not produce adverse changes in erosion, soil productivity, or water quality on glades.

Savanna

Savannas are open grasslands, dotted with infrequent trees and shrubs (<30% canopy cover). Primarily associated with gently rolling topography, savannas may have covered as much as 13 million acres in Missouri prior to settlement. Generally regarded as the zone where forests and prairies intermingle, savannas require fire to prevent succession into forest (Nelson 2005). However, in Ozark NSR, savannas are not thought to have extended into the steeply-dissected Current River hills. The Ozark NSR Fire Monitoring Plan identified ecological land types of forest, woodland, and glade for the park and did not include the savanna habitat type (NPS 2000.) Thus, savannas are not discussed further in this paper.

Oak Ecology

A brief discussion of oak ecology as it pertains to fire is crucial since oaks are a dominant forest/woodland species in the Ozarks. Oaks have several adaptations which enable them to survive and even thrive in regimes of frequent fire. Mature oaks have thicker bark than most other hardwood species and resist rot even when wounded. They are capable of living for decades after bole injury, and regeneration from root and stump sprouts increases following disturbance (Van Lear and Brose 2002). Despite repeated topkills by fire or predation, oaks are capable of prolific sprouting. Acorns also germinate well below the soil surface where they are protected from the heat of a surface fire. Fires may also kill acorn predators, which may result in increased acorn viability and germination (Johnson et al. 2002). Additionally, fire typically reduces the midstory and overstory, allowing more light to reach the ground. The reduced shading, reduced competition, and prepared seedbed that result from litter removal combine to provide favorable oak regeneration conditions.

Fire History and Pre-European Settlement Conditions

The late Pleistocene vegetation in the Ozarks changed dramatically with climate and glacial shifts. Jack pine was present in the Ozark Highlands about 15,000 years ago. However, this pine woodland was gradually replaced with a boreal spruce forest during the Wisconsin glaciation which lasted until about eleven or twelve thousand years ago (Delcourt and Delcourt 1991). Plant and animal macrofossil and pollen deposits in springs of Benton and Hickory Counties indicate that pines were a dominant component in the Ozark Highlands about 25,000 to 45,000 years before present (BP). By the early Holocene period (12,300 to 9,100 BP), pine, spruce, and ash populations began to give way to deciduous species such as oaks and hickory which in turn created an “oak parkland” dominated by oaks and grasses around 6,500 BP (King 1973). More recently, shortleaf pine moved into the forests about 3,500 years ago (Smith 1984).

Native Americans began moving into the continent around 10,000 — 15,000 years ago. Though some imagine an “ecologically invisible Indian” (MacCleery 1994), Native Americans had tremendous influence on the development of the landscapes that greeted early European settlers. Popular modern images of a "pristine” wilderness untouched by man ignore considerable documentation that portrays a contrary condition. For example, one of Hernando DeSoto’s men described marching through an agriculture field in Florida:

> *…some great fields of corn, beans, and squash and other vegetables which had been sown on both sides of the road and were spread out as far as the eye could see across two leagues of plain.* (MacCleery 1994).

The explorer estimated the size of the fields at 16 mi^2 clearly indicating a substantial impact on the natural ecosystems (MacCleery 1994). Furthermore, routine use of fire by Native Americans was described by many early Euro-American settlers. Roger Williams wrote about Indian land management: “this burning of the Wood to them they count a Benefit, both for destroying of vermin, and keeping downe (*sic*) the Weeds and thickets. (Cronon 1985). Native Americans are known to have burned for many reasons, including hunting, crop management, insect collection, pest management, acorn collection, warfare, travel, and many others (Williams 1993).

By 1580, the Ozark pre-European settlement environment probably consisted of fire-dependent woodlands and glade, with oaks and shortleaf pine as the dominant tree species, depending on the slope, aspect, and soils. Historic accounts by early travelers mention "barrens," which are today commonly interpreted as savannas and/or glades. Father Vivier described the area in 1750, along with his interpretation of the vegetation pattern:

> *…trees are almost as thinly scattered as in our public promenades. This is partly due to the fact that the savages set fire to the prairies toward the end of autumn, when the grass is dry; the fire spreads everywhere and destroys most of the young trees* (Johnson 1993).

Many early visitors to the Ozarks described ecosystems created and maintained through frequent fire. They described open woodlands including the characteristic lush herbaceous vegetation in their reports. Henry Rowe Schoolcraft, visiting the Current River valley in 1818 wrote:

> *Our route lay for the first eight miles across a barren prairie, with little wood and no water; we then entered into lofty forests of pine, and after winding along through valleys and deep defiles of rocks for several miles, found ourselves on the banks of Current's River … To this succeeded a high-land prairie, with little timber, or underbrush, and covered with grass.… a level woodless barren covered with wild grass, and resembling the natural meadows or prairies of the western country in appearance, but lacks their fertility, their wood, and their remarkable equality of surface.* (Schoolcraft 1821*).*

Louis Houck in 1908 described the lush herbaceous layer of Ozark woodlands as:

> *"…open woods and a growth of wild prairie grasses and flowers filling the broad spaces between the trees…All the forests were free from undergrowth and open and park like in appearance."* (Ladd 1991.)

Another historical account describing the Ozark highland in Missouri states:

> "*This eastern and northern region consisted in the main of woodland, the stand being less dense than at present…Also, many forested tracts had a park-like character, young trees and brush being largely wanting…Since settlement of the region, the following changes have taken place in the character of the forest: (1) greater density of stand and more undergrowth, as the result of cutting the large timber and cessation of fires…"* (Ladd 1991).

The fire dependency of Ozark woodlands indicates the extent of Native American landscape manipulation prior to Euro-American settlement. Natural (lightning) ignitions are rare in the Ozarks because of high humidity, moist fuels, and the rarity of "dry lightning" storms. Missouri State Fire Protection records (1970 – 1989) indicated an average of 108 fires per year in the region of the Current River watershed. Of those, less than 1% resulted from lightning (The Nature Conservancy 1997).

Tree ring analysis in the Ozarks region further supports the hypothesis that Native Americans were actively managing their environment. One study of the Current River watershed used

deondrochronological methods to date fire scars, and establish fire history chronologies at 23 sites (Table 1; Guyette and Cutter 1997).

Table 1. Mean fire intervals (yrs) in the upper Current River Watershed (adapted from Guyette and Cutter 1997).

Period	Mean Fire Interval
Native American I (1580-1700)	17.7
Native American II (1701 – 1820)	12.4
European Settlement (1821-1940)	3.7

Variation in mean fire intervals are correlated with human population changes in the Current River watershed (Guyette et al. 2002). The Mississippian culture of Native Americans dominated the area until about 1350, and as an agricultural civilization, they almost certainly used fire to their advantage. Disease, warfare, and migration occurring across much of North America at the end of the Mississippian phase marked the beginning of a long period of depopulation of the watershed. During this time, archaeological evidence of proto-historic aboriginal peoples is sparse (Guyette and Cutter 1997). Considered the de-populated period, 1580-1700 nonetheless supported significant populations of native people to sustain a reduced fire frequency, given the documented rarity of natural ignitions (Guyette and Cutter 1997).

During the 1700s, Native Americans began migrating back into the Current River watershed, pushed west by eastern settlement. A general increase in the percentage of sites burned annually coincides with the arrival of Cherokee, Delaware, and Shawnee. A 5% increase in number of sites burned circa 1720 was attributed to the Osage Tribe's acquisition of the horse (Guyette and Cutter 1997).

The period of 1821-1940 coincided with European-American settlement of the region. Led by "old-stock" white settlers from Tennessee, settlement was completed around 1860 by Scotts-Irish immigrations (Guyette and Cutter 1997). Euro-Americans burned more frequently than Native Americans and for somewhat different reasons. Convinced that ash was a good fertilizer, settlers burned to promote forage for stock, to rid the woods of ticks and snakes, and to clear land.

Fire histories from the early 1800s including vegetation and disturbance regimes of pine-oak woodlands were reconstructed in a study of Government Land Office (GLO) records that combined Public Land Survey information with dendrochronology-based data. A striking pattern of extensive stands of shortleaf pine and oak-dominated woodland in the frequently burned areas southwest of the Current River could be discerned (Figure 3). In contrast, more mesophytic, fire-sensitive species such as red oaks, maples, and eastern redcedar created what the authors call a "fire shadow" north and east of the river (Batek and Rebertus 1999). The "fire shadow" is easily seen on this vegetation map with the approximate axis of the Current River added as a black line.

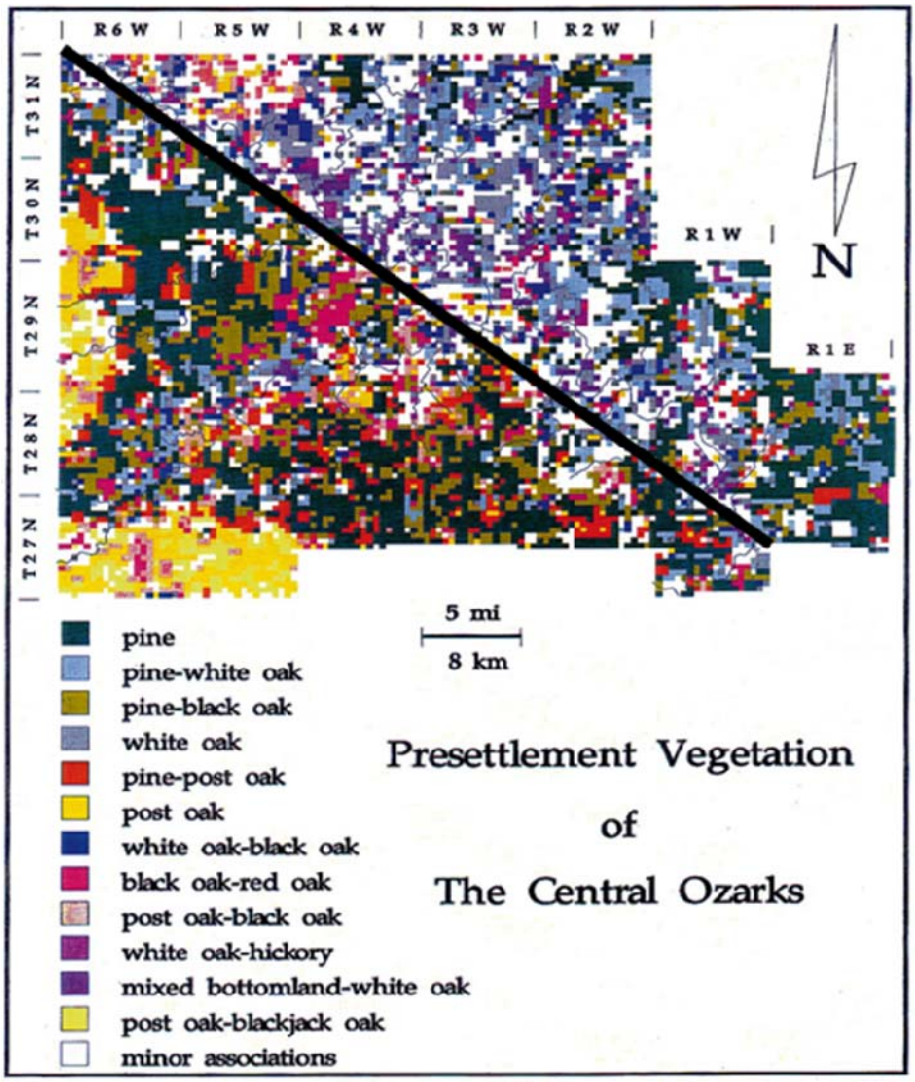

Figure 3. Presettlement vegetation of the Central Ozarks (adapted from Batek and Rebertus 1999).

Archaeological evidence also suggests Native American populations tended to concentrate along the lower reaches of the Current River, where fertile soils are more prevalent (NPS archaeological records 2002). During historical times, the Osage resided in the prairies considerably west of the watershed, but probably traveled to the Current River area to hunt. They may have ignited fires which burned eastward to the Current River under the prevailing southwest winds. The authors concluded that anthropogenic fire regimes played an overriding role in the development of Ozark vegetation in the 1800s (Batek and Rebertus 1999). Interestingly, a quick look at the distribution of archaeological sites in Ozark NSR provides support for this theory. Of 339 sites along the Current River, 210 (62% of sites) are located on the southwest side of the river (NPS archaeological records 2002).

It is likely that in pre-European settlement times, fire behavior was low in intensity because of the frequency with which the areas burned. Low fuel accumulations and the generally moist character of the climate would probably have combined to make severe fires relatively

uncommon. Studies suggest that low-intensity fires were variable, but common in eastern hardwood deciduous forests (17.7 mean fire return interval), with moderate to catastrophic intensity fires occurring much less frequently (Guyette and Cutter 1997; McShea 2002). While only a few days may be necessary for ground fuels to dry and spread fire, catastrophic intensity fires were historically and presently are most likely to occur during periods of extreme drought (Guyette et al. 2006).

Historic Land Use Patterns

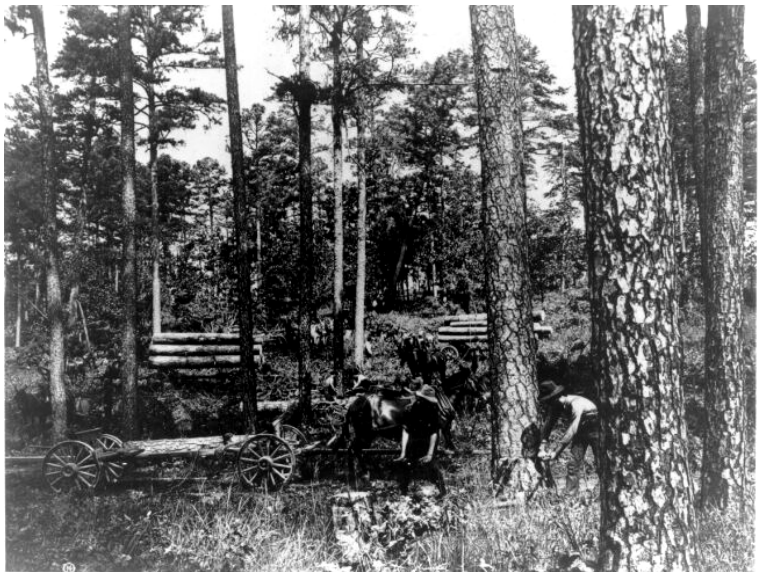

Figure 4. View of timber harvest in old growth shortleaf pine woodland – note woodland conditions (Ozark NSR files).

After the Civil War, railroad development and timber industry expansion had a major influence on Missouri. Between 1880 and 1920, much of the timber was completely clear-cut from the Ozark landscape (Figure 4; Guyette and Cutter 1997). A sawmill at Grandin, Missouri, just south of Ozark NSR, was constructed in 1888. At its peak, the mill consumed 70 acres of woodland per day and was the largest lumbering operation in the United States (Watkins 2003). Between 1888 and 1903, Grandin recorded cutting 648,203,356 board feet of lumber, yielding as much as 4,000 board feet/acre (Presley date unknown).

Table 2. Reynolds County, Missouri Fires in 1929.

Item	Spring	Fall	Total
Number of fires	1,000	250	1,250
Acres burned	100,000	5,000	105,000
Percent of District	20%	1%	21%

Prior to 1925, there was no organized fire protection for Missouri. In May of that year, the state legislature passed an act creating a Division of Forestry, which operated from 1925 to 1931 (Anderson et al. 1942). The 1929 fire report for Reynolds County demonstrated the prolific use

of fire in the area (Table 2). In 1931, however, the state legislature repealed the forestry statues when the governor cut funding for the program. The State Forester resigned saying it was impossible to control fire in the Ozarks (Watkins 2003). There was no further fire protection in Missouri until 1938 when the Missouri Department of Conservation was organized.

Ozark NSR Fire Monitoring Program

In addition to fire suppression and protection efforts, prescribed fire programs were eventually implemented in the park. Fire management and monitoring plans guide the fire program by describing natural resource goals and objectives. In 1994, Ozark National Scenic Riverways completed a Fire Management Plan (FMP) which identifies goals and objectives for fire management in the park. The goals and objectives were developed using local information regarding fire history, woody plant invasion, glade vegetation analysis, and reconstruction of historic vegetation from GLO survey notes.

A Fire Monitoring Plan, developed in March 2000, states that the focus of the prescribed fire program is "maintaining and expanding glades, and improving woodland structure and species assemblages" (National Park Service 2000). Monitoring indicates an inverse relationship between pole size tree density and herbaceous species richness, hence, objectives call for continued reductions of pole size trees through fire treatments. As the Ozark woodlands and glades recover from intense harvesting and long-term fire suppression, openings are filling in with dense stands of pole trees (2.5 cm – 15cm dbh). Increased numbers of trees reduces openings or gaps in the canopy and prevents light from reaching the woodland floor. This loss of light and resources results in loss of herbaceous species (Grabner et al. 1997). The monitoring plan states that the most effective way to maintain species composition and structure of both the overstory and understory is to restore the historical role of fire to the Park's natural communities (NPS 2000).

Table 3. Monitoring objectives for Ozark NSR community types.

Community	Sapling Density Reduction	Species Richness Increase
Dry/mesic woodland	30%	20%
Dry woodland	30%	40%
Glade/woodland transition	40%	40%

The monitoring plan divided specified goals into two major categories for prescribed fire: stimulate both a moderate (30-50%) reduction in sapling (dbh <10 cm) densities and, a moderate (20-60%) increase in ground-level diversity at the quadrant scale. Using studies of vegetation and fire effects conducted in the vicinity of Ozark NSR, the Fire Monitoring Plan further refined goals into six objectives – two for each of three natural community monitoring types: dry/mesic woodland, dry woodland, and open glade or woodland transition. The objectives were to be achieved within two growing seasons after the second burn (Table 3). The Fire Monitoring Plan also established protocols to: assess fire behavior, determine whether resource management objectives were being met with regard to prescribed fire, and determine whether prescribed fire was producing any unintended effects (Figure 5; NPS 2000).

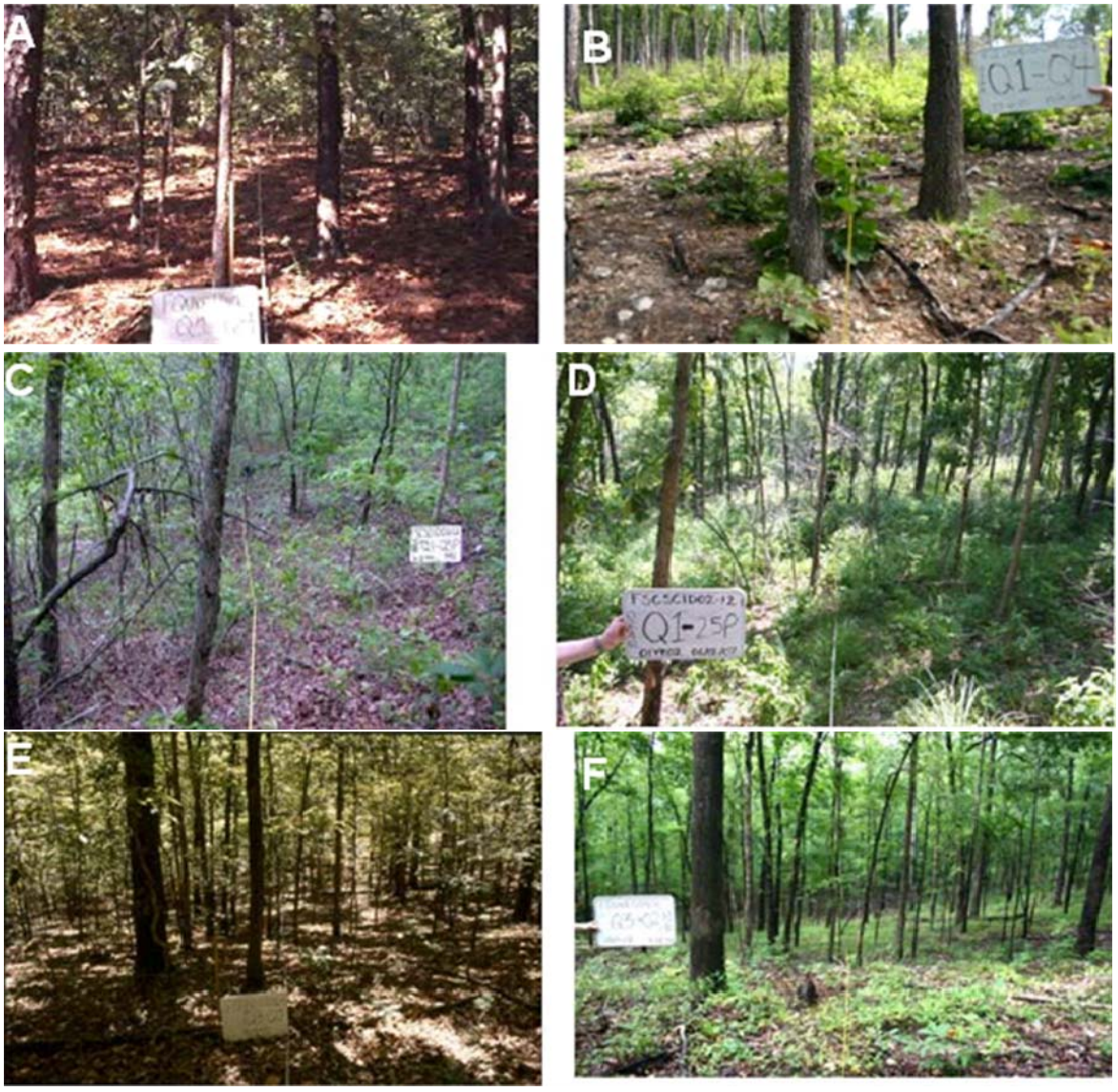

Figure 5. Pre- and post-fire photos of dry woodland and glade/woodland transition community types. **A**. a dry woodland plot pre-fire, and **B**. one growing season after the third prescribed fire over seven years. **C**. A glade/woodland transition plot pre-fire, and **D**. two growing seasons after two prescribed fires over four years. **E.** A dry woodland plot pre-fire, and **F.** two growing seasons after the second prescribed fire over five years. Note the reduction in stem density and increases in sunlight and herbaceous vegetation in each pair of photos (NPS photos).

The resulting Fire Monitoring Program, managed by the Ozark National Scenic Riverways Fire Ecologist, established random plots within Ozark NSR's prescribed burn units; currently there are 53. The plots were intended to monitor trends at the park level and track vegetation within all strata of the fire dependent communities. Measurements are taken before, during, and after prescribed fire at one, two, five, and ten years post burn (Figure 5).

Recent data show positive trends in achieving goals (Ozark NSR Fire Monitoring Data 2008). Sapling densities were significantly reduced and objectives were met. As for the glade/woodland

transition community type, it should be noted that results are significantly greater than "no change" conditions even though the objective was not met (Table 4).

Table 4. Monitoring results for Ozark NSR community types, * indicates significant differences, objectives in parenthesis.

Community	Sapling density reduction (%) ($\alpha = 0.10$)	Species richness increase (%) ($\alpha = 0.20$)
Dry/Mesic Woodland	54* (30)	15 (20)
Dry Woodland	59* (30)	14 (40)
Glade/Woodland transition	34* (40)	29 (40)

Species richness objectives have not been met, but increasing trends are clearly evident. For example, although species richness was not significant at the objective level of 20% for dry mesic woodland, there is a 90% certainty that there was at least a 15% increase from preburn levels. Ozark fire managers believe the species richness results may be linked to the low mortality of canopy trees during prescribed fire treatments. Mature trees were largely unaffected by the prescribed fires implemented thus far preventing light from reaching the herbaceous ground layer. Although sapling density was reduced, total incident light reaching the ground did not increase substantially because overstory mortality did not occur.

Mortality may be related to fire intensity and/or burn seasonality. Timing of the burns may play a role in direct or indirect fire effects on tree mortality in that effects may differ as a result of plant phenology and weather (Leis 2008). Ozark NSR prescribed fires have been implemented in early spring and are often low intensity. Growing-season burns have potential to affect canopy species mortality in that the plant's hydration and carbohydrate reserve status dictate, in part, susceptibility to injury (Richburg et al. 2001). Ozark NSR fire managers are investigating opportunities for late spring and summer burns; however, concerns about affects on endangered species, such as gray and Indiana bats and Swainson's warblers, require careful consideration and further study prior to changing the current practice.

Fire monitors have identified at least two additional concerns in the course of researching the park's communities: reduction in oak saplings in the understory, and the gradual decline of shortleaf pine. In other words, while the existing overstory consists largely of oak (preburn 66-68%) and some pine (3-15%), the midstory contains fewer oak and pine saplings (oaks = 19-23% pine = 0-1%) to replace mature trees. While shade tolerant species such as maple and black gum represent 1-3% of the overstory, these species occupy 7-26% of the midstory (NPS, Dan Swanson, Fire Ecologist, pers. comm, April 2008). The absence of fire during the past 50 years and a corresponding increase in shade may have contributed to the disproportionate species composition. The reduction in ecological woodland disturbance processes which stimulate recruitment of oak and pine saplings into the overstory may have long-term consequences for woodland composition.

Discussion

Historical descriptions and current research of the area now designated as the Ozark NSR indicate a likelihood that glade and woodland community types were much more prevalent historically than they are today (Ladd 1991; Dey and Guyette 2000). It is also probable that fire sustained those natural communities by maintaining their open character and immense species richness in the herbaceous layer (Nelson 2005). As a unit of the National Park Service, Ozark NSR is committed to preserving not only natural resources but also ecological processes, such as fire.

Through the application of prescribed fire, the Ozark NSR Fire Management Program hopes to stem the loss of native species and restore degraded natural communities. Ramifications of the many years of fire suppression continue to be observed even now that prescribed fire is being used. For example, a shift of species composition from oak/hickory/pine dominated forests and woodlands to shade-tolerant species continues to progress. Systematic monitoring is conducted throughout the park to track fire effects relevant to management goals. Trends in sapling density reduction and increases in species richness following prescribed fire treatments have been observed, although at a slower rate than anticipated. Lack of overstory tree mortality may contribute to the slow rate of restoration progress and varying fire seasonality is being explored as a solution. However, concerns about affects on threatened and endangered species warrant careful consideration of fire effects on the whole biotic community.

Finally, the value of scientific monitoring to natural resource management treatments cannot be overstated. Natural resource managers and fire personnel strive to apply understanding of long- and short-term trends in monitoring data in an adaptive management framework. In this way, goals and objectives can be reached in the quest for good stewardship of public lands within Ozark National Scenic Riverways.

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