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"...identifying, designating, managing and restoring the best remaining examples of natural communities and geological sites encompassing the full spectrum of Missouri's natural heritage"

Prescribed Fire in Missouri

Editor's Note

In 1983, on a crisp day in late March, Paul Nelson, then Director of the Natural History Program for Missouri State Parks, lit the first match on a 40-acre woodland tract at Ha Ha Tonka State Park, ushering in the woodland prescribed fire program in Missouri. Foresters and local firemen in the area were opposed to this management action, having spent many years managing wildfires throughout the Niangua Basin. But when the news story aired on local television that evening, the fire event was described as a success with benefits to wildlife and ecosystem health. Due in part to the native integrity of Ha Ha Tonka SP, the demonstration unit soon thereafter served as the nucleus of the Ha Ha Tonka Savanna Natural Area, enticing researchers nationwide to visit the park and study fire effects in a woodland setting. Because the fire program at the park has continued for 31 years with regularly occurring fires of varying seasons, scale, and intensities, Ha Ha Tonka remains one of the best examples of this fire-mediated Ozark landscape, protected as a 2,995-acre natural area.

Research on fire's impacts to flora, bird popula-

Photo by Allison J. Vaughn

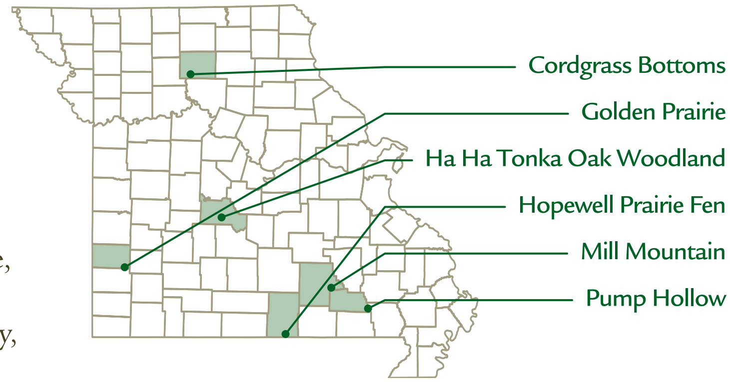
Prescribed fire in the Ha Ha Tonka Oak Woodland Natural Area, March 2009.

tions, small mammals, and insects, much of it conducted at Ha Ha Tonka, supported the concept that fire is vitally important for the sustainability of fire-adapted flora and fauna in Missouri. With the publication of *The Terrestrial Natural Communities of Missouri* (Nelson, 2005, 2010), the Missouri Natural Areas Committee endorsed the implementation of prescribed fire in natural communities throughout the state, and recognized that fire is a primary management tool for the protection of biodiversity. Today, land management agencies and private landowners across the state emulate this natural disturbance process for the health of the ecosystem and for the suites of biota that inhabit our fire-dependent landscapes. While direct mortality of individuals undoubtedly occurs during prescribed fire events, natural community management as defined in *The Terrestrial Natural Communities of Missouri* emphasizes the importance of maintaining and protecting all facets of the community that depend on this irreplaceable, ancient process.

Largely due to anthropogenic forces including fire suppression and resource extraction following European settlement, thousands of acres of our native landscapes are out of context with their historical character. The fine, flashy fuels that early explorers described allowed for low intensity fires across the gradient of prairies, glades, savanna and woodlands; today, much of this character is missing from our natural communities. Restoring a fire regime in fragmented and damaged systems requires skill and care so as not to inflict further damage. 31 years after that first woodland fire at Ha Ha Tonka, we have invited leaders in their respective fields to offer their thoughts on prescribed fire in Missouri. From the impacts of direct mortality in fragmented systems to questions on the heterogeneity of seasonality of prescribed fire, it seems there are still many questions that need to be investigated. The 2015 issue of the Natural Areas Newsletter will look at the impact of fire management upon insects, as part of a larger focus on Missouri's insect biodiversity. Discussions may arise from the articles in this issue of the Natural Areas Newsletter, and readers are encouraged to contact the authors of the articles with comments.

— Allison J. Vaughn

NATURAL AREAS FEATURED IN THIS ISSUE



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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.

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Smoldering Questions and the Opinion Factory

By Justin Thomas

A goofball of a plant known as *Desmodium humifusum* showed up after a series of prescribed fires were conducted in the Ozarks in the late 1990s. The plant had not been documented in Missouri for nearly 50 years, yet it occurred in local abundance after the fires. It was soon touted as a pyrogenic resurrection, and, as happens with such botanical discoveries, there was much talk. Botanists and ecologists, myself included, ascertained that fire must have triggered dormant rootstock or seed into action that prescribed fire was giving this once exiled species a new lease on the land. It became another piece of "feel good" evidence that fire was restorative and the discovery went a long way toward affirming that belief.

It turns out that we were wrong. Not only was it not a resurrected species, D. *humifusum* was not a species at all. It was an aberrant sterile hybrid between two common, rather ordinary, species (Raveille, 2002). Such hybrid events are relatively rare but effects like fire, drought and other forms of environmental stress or disturbance can induce them. This concept is eye-opening for two reasons: on one hand, we are faced with our ignorance about complex breeding systems and how they interact in a dynamic ecological interface — the science of the matter. And on the other hand, because we so readily adopted this false idol, we are faced with our own gullibility and naiveté, our seeming, uncontrollable need to reify the abstractions of our speculation — the psychology and pseudoscience of the matter.

No one wants to believe that what we are so sure of today could be wrong tomorrow, but it is a recurring theme in conservation. We all know the stories: the best of intentions ultimately depleting or otherwise damaging some aspect of the protected target. Don't get me wrong, there are numerous success stories, but there are just enough horror stories mixed in to make us nervous. Multiflora Rose comes to mind, as do Autumn Olive, Bush Honeysuckle and Sericea Lespedeza — introduced species that have negatively impacted our native landscapes with unintended consequences. Even prescribed fire was taboo until quite recently, roughly 25 years ago. We all probably know places where the wrong person with the wrong tool did too much of the wrong thing. And there are divisive and controversial management strategies like patch burn grazing and growing season burning that, depending on whom you ask, are instrument or insult to our dwindling natural world. By adding the human factor into just about any equation, you add human error. However, the severity of that error depends on how many variables are controlled through knowledge, experience, efficiency and tact — you know, *science*.

Image courtesy of www.tropicos.org

Desmodium humifusum is a procumbent trefoil derived from D. ***paniculatum*** and D. *rotundifoium*.

Fortunately, very few people would argue that

Photo by Justin Thomas

A species rich and highly diverse Ozark glade/woodland complex with elaborate structure and high floristic quality that has been encouraged and maintained by prescribed fire for nearly two decades.

properly applied prescribed fire has a downside. Fire, implemented properly, has garnered broad scientific support in terms of bolstering the ecological integrity of natural systems. Prescribed fire is a well-known and trusted tool for increasing and maintaining species richness, diversity and floristic quality in our fire-mediated systems. But outside of dormant season prescribed fire techniques, the published evidence on the benefits of fire becomes hazy to nonexistent. In these less researched situations, the cautious scientists yearn for predictability and mechanism: somebody's opinion regarding someone's interpretation of what someone wrote a hundred years ago about something potentially relevant does not matter here. We need numbers and we need them in reference to contemporary systems. Supposition, anecdote and reminiscence are not enough. The stakes are too high.

My opinions regarding the non-traditional use of prescribed fire are generally perceived as overly concerned, impractical, or downright nerdy. I am aware that my opinions are outside the brazen norm. So, when I was asked to provide my thoughts on the state of prescribed fire in Missouri for this newsletter, I was hesitant. Not because I'm afraid to voice my opinions, or that I don't have something to say, but because my opinions don't matter. Outside of the function of formulating testable questions, opinions are too volatile to matter. Until the questions derived from opinion are tested repeatedly, until we can predict outcomes with some semblance of accuracy, opinions are misleading, and they are counterproductive to a viable science program. So, instead of espousing my opinion on prescribed fire, which I'm probably not even qualified to do, I'd rather propose some testable questions regarding the dynamic mechanistic properties of natural systems as they relate to fire in today's altered and damaged landscapes:

1. Does the initial floristic integrity of a site determine how well it responds to fire?

Ha Ha Tonka State Park is one of the shiniest jewels in the crown of conservation. The species richness, diversity and quality (floristic integrity) at this state park is so phenomenal that it has become the pinnacle of what can be achieved through a prescribed fire program in the Ozarks. But, Ha Ha Tonka SP was in pretty decent shape before the contemporary burn program. There are exceedingly few places in Missouri that have the restorative potential that Ha Ha Tonka SP did and still does. We have many thousands of acres of sterile forest in the Ozark Highlands that either lack restorative potential or that will require decades of commitment to respond with a semblance of biological integrity, if they can at all. Some of these places do not seem to be responding floristically well even after decades of prescribed fire, presumably due to the low colonization potential, past land abuse, both, neither, or something altogether different that we don't understand yet. Whenever such sites do not respond with the expected structure and composition, many managers seek more aggressive techniques like thinning younger trees, prescribing hotter burns and/or utilizing growing season burns. In fact, the combination of thinning and burning in immediate succession is standard protocol in management these days. The results of which rarely resemble any stage of the ecological trajectory that sites with a higher restoration potential have almost immediately, such as Ha Ha Tonka SP. Furthermore, sites that have high floristic integrity presumably have higher resilience and can more rapidly adapt (Hillebrand et al. 2008; Thomas 2013; Tilman and Pacala 1993) to aberrant or extreme fire behaviors. Sites with low floristic integrity do not. This difference, which is the difference between an intact fire-mediated system and a system that lacks recovery potential, is profound. We need to understand this dynamic to ensure that we are not pushing already damaged systems into positions for which they cannot muster sound ecological responses. Research along this line would be very easy to conduct and could provide user-friendly response variables to guide the research needs of the following questions, as well.

Photo by Allison J. Vaughn

Goldenrods and asters bloom well into late September on Lodge Glade in the Ha Ha Tonka Oak Wooodland Natural Area.

2. Does fire intensity positively correlate with the expression of Winged Sumac and blackberries?

There appears to be a definite relationship here. In my experience, extremely hot fires in woodlands and forests very often result in increased densities of Winged Sumac and blackberries all knitted together like a shredded wheat patty, with a frosting of catbrier and grape vines on top. It seems that the more practitioners increase fire intensity, the more aberrant, unpredictable and disparate the results become. Results which typically resemble early successional communities with dense shade and low quality herbaceous development; a situation that can persist for at least 15 to 20 years. Follow-up burning in these areas seems to restart the clock and further push successional progress into a negative feedback loop. This is especially noticeable in prairies where Winged Sumac increases its rhizomatous growth with each burn. In forested systems, I have heard it argued that we 'just need to wait a few decades' for these types of conflagrations to work their magic and that these areas will eventually reach their target open woodland/savanna conditions. This platitude comes with no evidence. Given the lack of adequate colonization dynamics in many places throughout Missouri, botanical recovery is unlikely. I worry that fires that are hot enough to induce even a moderate density of Winged Sumac and blackberries from the seed bank are often at the expense of, or in direct competition with, more conservative species. Again, the results of this type of management would be very easy to quantify from a botanical perspective.

3. Does seasonal heterogeneity in a prescribed fire program result in increased community quality and function?

The only historical evidence of fire in the Midwest that likely would have occurred with enough frequency to influence the ecology of the region is that of anthropogenic ignition; said ignition was solely an autumnal phenomenon. Today, autumnal fires are less frequent than spring fires, and there is an increasing interest in and use of growing season fire. To be clear, I would define the "growing season" as the entire span of non-dormancy, beginning with cellular elongation, meristematic division and seed germination and ending with above ground cellular stasis or death (typically mid-February to late October). While attempts to justify summer burns are based on an assumed emulation of lightning fires, an idea that seems historically plausible (Petersen and Drewa 2006), we have no reason to believe it is contemporarily relevant. If historic lightning-induced summer fires occurred with enough frequency to matter, which they very well may not have, they occurred with fire behaviors about which we can only surmise, and in an intact landscape with fine fuels and strong recolonization potential. Today, we are managing highly damaged systems in an extremely fragmented landscape with uncharacteristic fuels and pathetic colonization potential due to over a century of fire suppression. This clarification provides enough difference to warrant extreme caution when entertaining the possibility of growing season fire as a management tool. Here, too, we lack the requisite knowledge of this highly unpredictable force. Such techniques could be easily tested on small tracts of land under a closely monitored experimental design.

We know that growing season fires can result in herbaceous plant mortality (Howe 1994; Towne and Craine 2014). Published research on the subject, though sparse, demonstrates that C3 grasses and forbs are negatively impacted by the practice, especially fires conducted in late spring following green-up. In other words, these late season fires may only benefit C4 grasses. Given that C4 grasses are not a common component in most modern Ozark systems, there does not seem to be an upside here. Besides, most prairies and glades are heavily dominated by C4 grass and are forb-poor.

While hiking through a site that experienced a July wildfire a year prior, I once stumbled onto 76 stems of *Liatris mucronata* (Narrow-Leaf Blazing Star: a species of conservation concern with a C-value of 10) that had been allocating significant resources into flowering stems when they were burned. Four of the plants were bolting, but the charred stems and rotten bulbs of 72 plants were lifeless. That translates into 95% percent mortality

Photo by Justin Thomas

Liatris mucronata in the White River Hills.

on a species adapted to grassland systems growing in grassland fuels. Yikes!

The other method of adding seasonal heterogeneity in the fire cycle involves spring/late spring fires. I've been told on several occasions by several reputable sources that spring fires are conducted more often than fall fires to avoid the logistical difficulties inherent in burning during the fall deer hunting season, to take advantage of more moderate weather and to increase the gross annual acreage. Following European settlement across much of the Ozarks, especially in the Niangua Basin, landowners regularly burned their woodlands in the spring to provide forage for cattle (namely C4 grasses). While there does not appear to be an obvious difference in the effects between fall, winter and early spring (pre-green up) burning, late spring fire effects remain dramatically understudied. What is particularly concerning is that in recent years practitioners have implemented late spring fires later and later into the growing season. Though there isn't a single published account of its effects, sites in the Missouri Ozarks are often burned with a fully developed and flowering spring flora. Soon after sap begins to run in early February, tillers and rhizomes of herbaceous plants begin to elongate into thawing duff and litter, awaiting the end of frost. It seems that burning at this point in time must result in some level of mortality. How much? Is it negligible? We do not know.

In summary of this question, given that the historic application of prescribed fire was exclusively autumnal; that late spring fires are conducted for convenience rather than effect as land managers no longer cite forage production as a primary driver; that even though lightning fires may have existed historically, they are no longer relevant in our damaged and fragmented landscapes; that significant evidence suggests that spring growing season fires can negatively impact C3 grasses and forbs; and that there are important unanswered questions regarding its effect on an actively growing spring flora, perhaps we should stop claiming that a seasonal heterogeneity in prescribed fire application is a good thing for vegetation. At least until we can demonstrate it with data.

Danville Glades Natural Area in Montgomery County during a regional dry spell in 2013. Note the dead trees that prescribed fire had not burned out of the glade. An examination of their vascular cambiums revealed that they were dead, not dormant, above ground.

4. What role does climate have relative to prescribed fire?

It is probably safe to say that the open woodland, savanna and prairie structures ascribed in our mythos of a presettlement Missouri were primarily climate derived and secondarily anthropogenically maintained. Missouri's position along the transition zone between grassland and deciduous forest biomes has existed for several thousand years. During the historically drier spells grasslands prevailed, and during wetter spells, forest encroached to the degree that prescribed fires set by the first Americans would allow it. So, in a sense, woody encroachment in our once grass-dominated systems is as much a matter of available moisture as it is fire suppression, if not more. The dry spells that killed trees in 2012 and 2013 barely hold a candle to the documented historic droughts that lasted for decades (Stambaugh et al. 2011). As more and more sites become altered by the processes of "mesification" through time, the less relevant our concepts of historical vegetation types will become. Even today, it is possible that there are sites where the application of prescribed fire may actually result in a decrease in floristic integrity and abundance. If land managers are responsible for maintaining biodiversity in perpetuity, we need to know more about this relationship — especially given the concerns over the speed and extent of global climate change, the lack of adequate colonization dynamics in a fragmented landscape, and the rapid colonization potential of invasive species.

Of course this list of questions could go on *ad infinitum*. And I didn't even include discussion regarding the effects on plant population genetics. Neil DeGrasse Tyson often comments that good scientists love the questions more than the answers, and that this love of questioning propels science, and thereby society, forward. The myriad reticulations of questions that arise from the topic of prescribed fire range from its effect on landscape scale processes to the very genetic structure and evolutionary trajectory of the species contained within. We are moments away from understanding the way these two traditionally separate topics are united, the point where ecology and evolution interface. But we cannot achieve this level of knowledge unless we sharpen our skills, ask harder questions, communicate better and fall in love with the idea that the questions can simultaneously inform, enlighten, and ultimately, humble us all.

Justin Thomas is Director of the Institute of Botanical Training and has 17 years of experience as a field botanist, ecologist and educator in Missouri and the greater Midwest. He holds degrees from the University of Missouri and Miami University.

Contact: jthomas@botanytraining.com

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Effects of Fire on Macrofungal Communities in Missouri (or What Little We Know)

By Christopher Crabtree

Fire within our natural communities and landscapes has profound changes on floral and faunal assemblages and many of these changes are readily observable. But what is the effect of fire upon a major organismal group that people rarely pay attention to and rarely see—fungi? How do individual species and overall fungal diversity fare following a wild or prescribed fire and restoration efforts, both immediately and in future years? What fungi, if any, are fire-tolerant or fire-dependent in temperate North America? Answers to these questions and many more do not exist for the forests, woodlands, savannas, prairies and glades of Missouri. Most fungi-fire research in North America has been limited to coniferous forests of the Pacific Northwest and Alaska. Across the globe, boreal forests of Europe and various landscape types of Australia have been studied, but these give little insight to effects in Missouri's natural communities. In addition to the location and habitat differences between these distinct biomes, many of the fire studies investigated high-intensity wildfires, whose impacts are much greater than the prescribed burns and wildfires in our region. However, these findings from across the globe offer useful information, and with the addition of personal observations as a mycologist, an understanding of what is occurring or what may occur with this interaction begins to evolve.

Before looking at the larger questions at hand, we need to narrow the scope of fungi to be discussed. When most people think of fungi, morels, puffballs or moldy food in our refrigerator comes to mind. But the diversity of fungi, large and small, greatly outnumbers the vascular flora of most any natural community; we just rarely (if ever) get to see them. Those that are readily observed are the minority of representative fungi of a particular habitat, not the majority. The mushrooms, toadstools, polypores, puffballs, morels and other non-lichenized fleshy fungi that we see are collectively known as macrofungi. Macrofungi comprise an array of ecological niches and life

Photo by Christopher Crabtree

Marasmius rotula "Pinwheel Marasmius". This small macrofungus is common in most natural communities where small branches or other woody debris is present. Numerous species of Marasmius are found throughout Missouri and are quick to inhabit remnant litter and debris after a fire. Some species of Marasmius can be found on charred tufts of prairie grasses.

histories, including mycorrhizal associates, saprobes, parasites and even those that at times have the ability to switch from one lifestyle to another. Although many liberties are being taken and generalizations made for such an expansive kingdom and complex topic, fungi that either live off of nonliving and decaying material (saprobic/saprotrophic) or form mutualistic associations with plants at the root tips (mycorrhizal) are the main fungal groups to be discussed within this article.

The Kingdom Fungi currently possesses around 100,000 described species, but is estimated to contain anywhere from 720,000 to 5.1 million species worldwide (Blackwell 2011, Schmit & Mueller 2007). Just how diverse are fungi in Missouri's natural systems? Nobody knows! In 1937, W.E. Maneval published *A List of Missouri Fungi with Special Reference to Plant Pathogens and Wood-Destroying Fungi* and a follow-up supplemental list in 1948 (Maneval 1937, 1948). In these publications, Maneval lists upwards of 1,300 fungal species in Missouri. These detailed works exclude all lichenized fungi, mycorrhizal fungi, soil fungi and fungi of leaf litter, which garner a substantial portion of our overall fungal diversity. The Missouri Mycological Society has currently documented around 700 to 800 macrofungal species within the state, most of which were not included in Maneval's publications. The total fungal diversity of the state may never be adequately described, as the diversity of any specific group of fungi is far from complete. With this understanding, we proceed with what we currently know, accepting that our discussion of fungal diversity is lacking and tentative at best across the Missouri landscape.

Although little is known about the diversity of fungi in our natural systems, it is known that some fungi have very broad habitat requirements and can be expected in most of our natural communities. Conversely, other fungi have very narrow requirements and will be found in selected natural communities or specific microhabitats. In the same way that plants are adapted and suited to specific moisture regimes, light/shade intensities and substrate pH, fungi adapt to local conditions. As fire changes the face of a landscape that will in turn affect large-scale fungal distributions, it also changes subtle physical and chemical components of the soil and nutrient sources that fungi depend upon. Defining the specific criteria that limit a fungus' presence after a fire becomes a multifaceted investigation that easily gets lost in the smoke: some fungi have adapted to fire-dependent natural communities and in many ways. Some thrive following a fire, producing an explosion of mycelium or sporocarp (fruiting body) production that was stimulated by the heat, change in soil alkalinity or absence of competition created by fire. Some fungi require fire for spore germination or sclerotia (compact mycelia in a dormant stage) development. Others have adapted to utilize heavily charred or burned woody debris. These fungi take advantage of the newly altered habitat, but may quickly fade from the landscape as the time between fire events lengthens. The fungal communities will change over time as soil chemistry stabilizes, nutrient supplies increase or change, with the immigration of other organisms (plant, animal, bacteria, other fungi), and as competition for resources increases.

On the larger scale of fire in landscape reshaping and restoration, there is expected to be a shift in macrofungal communities if the disturbance is such that the overall structure and composition of the community is altered. A closed woodland system with its site specific biotic (plant and microbial species present) and abiotic characteristics (humidity, soil moisture, soil warming/solar exposure, evaporation rates, etc.) will support or display a much different suite of species than a very open woodland system that has very different conditions associated with tree species present, canopy closure, soil exposure and a multitude of other characteristics.

The following ecological fungal groups are being used to help detail how fire affects various types of fungi:

Ectomycorrhizal Fungi (ECM):

The genera *Amanita, Russula, Lactarius, Boletus* and *Cortinarius* are a few of the more conspicuous ECM fungi in Missouri's woodlands and forests. These genera contain species that are host generalists as well as host specific. Their presence and sporocarp production in any landscape is dependent upon host tree species, soil characteristics, moisture, and abiotic conditions of the location. Many of the more common species of these genera can be found spanning the spectrum of our various woodland communities. Low intensity fires

Photo by Christopher Crabtree

Amanita rubescens "The Blusher" is an ectomycorrhizal fungus and is one of Missouri's more common Amanita species that can be found in woodlands managed with fire.

that consume leaf litter, reduce small diameter woody stem numbers, and stimulate herbaceous plant growth do not have significant impacts on most ECM fungi. However, a soil-sterilizing fire that drastically consumes or alters the organic material and upper soil horizons and causes mortality of all tree size classes will impact ECM fungi. The host of ECM fungi must remain present and alive, and much of the ECM's mass is in the upper soil strata. ECM fungi associated with fire-intolerant tree species cannot persist in areas where burning is frequent enough to eliminate the required host.

Published reports of the impacts of fire on mycorrhizal communities vary greatly with some research showing little impact and others stating that ECM communities are greatly affected. The details of the magnitude and intensity of the fire are rarely discussed and remain a crucial component to the results of the studies. Research in Alaskan forests have shown that ECM fungi take longer than some other fungal groups to repopulate following large fire events (Treseder, Mack and Cross 2004). A low intensity fire in oak forests in Spain resulted in a lower relative abundance of particular fungal groups and a decrease in mycorrhizal tips, but had no significant change in species richness and composition when compared to adjacent, unburned units (de Roman & de Miguel 2005). A recent study in Oregon specifically studied prescribed burns of various seasons and distinguished burn impacts from the general soil and moisture differences of the units. The study found that mycorrhizal communities are able to withstand hot prescribed burns and ECM fruiting is driven by the soil carbon-to-nitrogen ratios rather than the burn seasonality. The study also find that burn season can reduce fungal productivity and change fruiting patterns (Trappe & Cromack Jr. 2009). Prescribed fires in Missouri's forests and

Photo by Christopher Crabtree

Sarcoscypha dudleyi "Scarlet Cup" grows on small diameter branches of oaks and other hardwoods on the forest floor. This species prefers low, relatively moist areas where fire is infrequent.

woodlands, which are typically low intensity fires, probably have little impact on ECM fungi. One notable fire impact, or result, that everyone who enjoys morels will like is that some Western morel species are only abundant in the years immediately following fires.

Endomycorrhizal Fungi

Very few endomycorrhizal species produce fruiting bodies that would be observed in the field, but this group is included because it is extremely important and is associated with greater plant diversity than ECM fungi. Nearly all monocots, in addition to a large percentage of dicots, are associated with endomycorrhizal fungi and allow many to thrive in rather poor soil conditions. Research has shown that most endomycorrhizal fungi are not greatly affected by prescribed fires or mild to moderate wildfires (Treseder, Mack and Cross 2004).

Leaf-litter Saprotrophic Fungi:

Burn cycles that regularly reduce leaf litter or herbaceous plant material will in turn drastically reduce the diversity of litter-inhabiting fungi. An array of relatively small macrofungi can be found inhabiting and degrading the compacted plant litter of not only the shaded forest floor, but also in open woodlands, savanna, and prairie communities. An inspection of compressed leaf litter will reveal the thickened mycelial strands (rhizomorphs) of numerous species. The ephemeral genus *Marasmius*, which can be found in droves immediately following a rain event, is one of the most common leaf-litter fungi in our Missouri landscapes. Their presence is best expressed in areas where heavy to moderate shade allows moisture to be retained in litter for longer periods. Thick prairie vegetation can have the same effect as a dense forest canopy and support interesting assemblages of litter-inhabiting fungi. Some species of saprotrophic fungi can be found in the months following a fire on the unburned or charred remnants of leaves and plant matter; these species are either rapid colonizers of any plant debris or are able to survive by means of spores and/or mycelia in the soils or unburned substrates. Many leaf-litter dependent saprotrophic fungi of forests and dense woodlands require thicker litter deposits that retain more moisture and/or have been initially degraded by bacteria and other fungi.

Lignicolous Fungi (Wood-Rotters)

A dead tree is able to support a great number of fungal species throughout the lengthy degradation process. Species that are present at the initial stage (when the tree first falls to the ground) will differ drastically from those present when the tree is barely recognizable from decomposition, with various fungi using specific microhabitats, associated nutrients, and competing with each other. The progression is a fascinating one! Abiotic conditions may play more of a role in determining which fungal species will be present than the tree species itself. A tree under heavy shade, in a humid microclimate, and in contact with the ground will degrade faster and display more macrofungi than one perched in an open setting. However, regardless of location in the landscape, one can reasonably expect to find a suite of the most common polypores: *Stereum* spp. (false turkeytails), *Trametes* spp. (turkeytails and kin), *Trichaptum biforme* (violet-toothed polypore) and a few others on deciduous trees. After the bark has long since fallen off the dead tree (or been consumed by fire or other natural processes), under the right conditions and in the right habitat, some very wonderful macrofungi will emerge. In shaded lowlands, a variety of *Pholiota* species, *Mycena* species and *Galerina marginata* can be found, in addition to a plethora of others. Smaller branches and twigs support their own assortment of species that is very distinct from those inhabiting logs, stumps and dead-standing trees. In many cases, canopy cover and the associated microclimatic conditions dictate the fungal groups present. Adding support to abiotic conditions as drivers of lignicolous fungi, research has shown that fungal diversity greatly increases with distance from edge habitat.

Natural communities managed routinely with fire have less large and small woody debris, giving less opportunity for fungal species richness. These areas are also more open than their unburned counterparts, allowing for greater solar exposure and faster surface drying. Logs heated by fire or partially or even fully charred rarely have macrofungi present and persist longer in the landscape, even if in areas more conducive to fungal growth. These fuels become similar to logs lying in the sun, persisting for what seems like an eternity. The heating and charring caused by fire changes the exterior composition enough that many lignicolous fungi either cannot invade or utilize the altered substrate, or did not survive the heating. There are, however, lignicolous fungi that do quite well using charred substrates, *Pycnoporus sanguineus* being one (Sharp 2011).

Phoenicoid Fungi, Anthracophilous, Pyrophilous & Carbonicolous

The names say it all. These fungi are adapted to soils or substrates that have burned. These fungi include wood-rotters, mycorrhizal fungi and parasites, but regardless of their life history, they do their best work after fires. A few are found in such inhospitable places as ash and debris piles of campfires. With the exception of a few small cup fungi, they do not seem to be commonplace in Missouri's natural communities. Further investigations in Missouri may reveal numerous species within this highly specialized group of fungi.

In summary, in fire-adapted and fire-maintained natural communities, fungi that are not well suited to this routine disturbance will thrive only in locations where fire is absent, very infrequent or at a low intensity that does not alter their necessary microhabitat. A diverse landscape, as was present prior to European settlement and that resource managers work to maintain, provides suitable habitats for an array of species. Management and restoration efforts of our natural communities will ultimately favor some macrofungi over others, just as it does for all other organisms. Fire simply forces fungi into their best-suited habitat and maintains a heterogenous landscape, with hillsides, pockets and dark recesses suitable for specific fungal species. There are vast gaps in our knowledge and understanding of fire and its effects on fungi, and on fungi in general. But when it comes time to look for your favorite edible fungus, keep in mind three things: 1) just because trees or logs are present does not mean you will find the fungus you want, 2) simply because a fungus fruiting body is not observed does not mean it does not exist below, and 3) mushrooms will always grow where they want and when they want!

Christopher Crabtree is a Natural Resource Steward for the Missouri Department of Natural Resources. He is currently chair of the Ecology Committee for the Mycological Society of America. He has collected fungi in various parts of the United States and Central America, but spends most of his time observing and collecting fungi in central and northern Missouri.

Contact: christopher.crabtree@dnr.mo.gov

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Smokin' Prairies

Plant-derived smoke effects germination success of tallgrass prairie seeds

By Marcello Pennacchio, Lara V. Jefferson and Kayri Havens

A little over 20 years ago, a team of researchers working at South Africa's National Botanical Institute and the Botany Department of the University of Stellenbosch discovered that seeds of a local plant species, known as false heath (*Audouinia capitata*), germinated in significantly greater quantities after they were exposed to plant-derived smoke. This team, comprised of Hannes de Lange and Dr. C. Boucher, concluded that smoke had somehow broken dormancy in this species, which naturally occurs in the fire-prone shrublands of the Cape Floristic Region of South Africa. Since then, researchers working in other fire-prone areas around the world have discovered scores of other plants whose seeds also sprout in greater numbers when treated with smoke. These areas include the Southwest Botanical Province of Western Australia, the chaparrals of the Californian Floristic area and, in more recent times, tallgrass prairies of the Midwestern United States. In all, 1,355 species from 120 families have been tested worldwide, all of which have been listed in a book we published early in 2014, Ecology of Plant-derived Smoke. This global compendium also provides details about the plants screened and the methods used in the various studies.

While researchers may have only recently discovered that plant-derived smoke can promote germination, it is likely it was already used for this purpose many centuries before. The French Récollet missionary, Gabriel Sagard, for example, reported that the Huron Tribes of New France, an area of North America that extended from Newfoundland all the way to the Gulf of Mexico, used smoke to promote seed germination in the New World from as early as 1624. According to his journals, they suspended special germination boxes

Photo by Joan O'Shaughnessy

lined with multiple layers of soil and pumpkin seed above fires where the smoke formed, significantly improving the number of sprouters.

However, exactly how plant-derived smoke promotes seed germination is not yet well understood. Researchers in Western Australia and South Africa recently discovered an active substance in smoke which they showed promoted germination in lettuce seeds in concentrations as low as 10^{-9} mol/L. The substance they discovered was a butenolide compound that was subsequently named karrikinolide. This word was derived from the Australian Aboriginal Nyungar word for smoke, *karrick*. Karrikinolide is produced when cellulose, a naturally occurring plant fiber, is burned. Exactly how this and other related smoke compounds affect seed germination is currently the subject of further research.

As part of our own research at the Chicago Botanic Garden, we discovered that the seed of several Midwestern tallgrass prairie species also respond in one way or another to smoke. Until recently, it was thought that a period of cold treatment, called cold stratification, was all that was required to promote germination in many of the species. As part of our study, we tested the effects of smoke on 37 common prairie species, using aerosol smoke produced by burning commercially available straw. The smoke was pumped into a chamber, where the seeds were stored. Water, in which smoke has been bubbled through, can also be used (see Ecology of Plant-derived Smoke for methods and ways to generate smoke and smoke water).

Approximately one-third of the species we tested reacted positively to smoke, while others were either inhibited, or exhibited no effect at all (Table 1). This is consistent with results for other species around the world. We screened six species of *Echinacea*, with germination being significantly promoted in all but one of them, Topeka purple coneflower (*Echinacea atrorubens*). In contrast, a one minute exposure to aerosol smoke was sufficient to significantly increase germination of Tennessee coneflower (*E. tennesseensis*) seed from approximately 50% to over 90%. This finding was significant at the time because this species was federally listed as endangered in the United States (it has since been delisted, having sufficiently recovered from its previous state). It is for applications such as these that the use of smoke, and its natural products, may prove useful in the future.

Surprisingly though, some of the species we tested required significantly longer periods of exposure to aerosol smoke to mediate a response. The hairy mountain mint (*Pycnanthemum pilosum*), a species considered very rare in the Chicago region and elsewhere, required at least 32 minutes of treatment before there was a response. This highlights the need to perform dose-response trials when testing the effects of plant-derived smoke on seed germination. Doubling exposure times is recommended, i.e. 1, 2, 4, 8, 16, 32 and 64 minutes of exposure in order to achieve an accurate picture. Alternatively, seed can be treated for 1, 10 and 60 minutes. Exposure times greater than 60 minutes usually decreased germination, or inhibited it altogether in most of

Table 1. Effects of smoke on the seed germination of tallgrass prairie plant species of the Midwest.

Promotes Germination

Astragalus canadensis
Bouteloua curtipendula
Ceanothus americanus
Echinacea angustifolia
Echinacea pallida
Echinacea paradoxa
Echinacea purpurea
Echinacea tennesseensis
Lespedeza capitata
Oligoneuron rigidum var. *rigidum*
Parthenium integrifolium
Pycnathemum pilosum

No Effect

Amorpha canescens
Andropogon gerardi
Arnoglossum atriplicifolium
Asclepias tuberosa
Baptisia australis
Boltonia decurrens
Chasmanthium latifolium
Dalea purpurea
Echinacea atrorubens
Elymus hystrix
Helianthus grosseserratus
Iliamna remota
Liatris aspera
Rudbeckia hirta
Schizachyrium scoparium var. *scoparium*
Silphium laciniatum
Sorghastrum nutans
Sporobolus heterolepsis
Symphyotrichum laeve
Tradescantia ohiensis

Inhibits Germination

Epilobium gladulosum
Monarda fistulosa
Silene regia

the species we tested. Other important factors that need to be considered when conducting studies of this type are listed in our book.

One species whose germination was significantly inhibited by short exposures to smoke was wild bergamot (*Monarda fistulosa*). This is a species with a wide distribution throughout the United States. Its germination decreased by approximately 30% after only 1 minute of smoke treatment. Inhibitory effects such as these can usually be counteracted if the affected seed are immediately rinsed with water. Two to 5 minutes is usually enough time to wash out the inhibitory agents, but not diminish the effects of the promotory agents.

That smoke can inhibit seed germination comes as no surprise, given the number of potentially harmful compounds and oxidatively abrasive chemicals that exist in smoke. Many plants release volatile chemicals, such as camphor, alpha-pinene, alpha-phelandrene, eugenol, polycyclic aromatic hydrocarbons and gases like carbon monoxide when burned, many of which are potentially also harmful to humans. Therefore, protective measures should be taken to avoid inhaling smoke during work of this type.

Our results also revealed that two of the tallgrass species we tested, blue wild indigo (*Baptisia australis*) and Indian grass (*Sorghastrum nutans*), did not respond to any smoke treatments at all. While it was not immediately apparent why they did not react, it is tempting to suggest that they simply may not have evolved with the necessary receptors or mechanisms to respond. Several research teams are currently looking into the mechanisms of action of plant-derived smoke, with some researchers focusing their attention on the effects of smoke products on the common test-plant species, mouse ear cress (*Arabidopsis thaliana*). We were the first to show that the seed of this species responds to smoke.

Studies such as these are sure to increase our understanding of seed dormancy and germination. It is also hoped that other uses for plant-derived smoke will emerge. Recent studies have showed that in addition to helping break seed dormancy, smoke and its products could potentially be used in the fight against invasive plant species. By making all the seeds of an invasive species germinate at once, the seedlings can be treated with a single dose of herbicide, saving time and money for land managers. Smoke could also be used in environments that require fire-related cues, but cannot be burned due to their locations. These include remnant prairies in urban environments and roadsides. Smoke water and the active constituent of smoke, karrikinolide, can be used in cases such as these. Other research has determined that treating the seed of certain plant species with plant-derived smoke, such as tomato seeds, significantly increases the yield of tomatoes.

Conclusions

It is not at all surprising that smoke has been used to promote and even inhibit germination. Plants produce hundreds of natural products, many of which are liberated and carried aloft with other smoke particles when plants are burned. We are only now starting to discover how these products are generated and, more importantly, how to apply them. That the seed of many species respond to smoke is also not surprising. Various ecosystems are prone to fire, especially in Mediterranean climatic regions, resulting in plants that have adapted to its effects and products. Our studies have shown, however, that other ecosystem types, including temperate Midwestern tallgrass prairies, may also produce smoke-responsive plant species.

Marcello Pennacchio is an ethnobotanist, conservation scientist and a freelance author. He has written two reference books on smoke and a children's book about Australia.

Lara Jefferson joined the Chicago Botanic Garden's Plant Science and Conservation department as a postdoctoral researcher under the supervision of Dr. Kayri Havens. While managing a Conservation and Land Management Intern Program at the Garden, Lara and Marcello Pennacchio conducted research on the effects of smoke on the germination of prairie species, resulting in two books. She currently works in Western Australia providing technical and strategic advisory services for mining clients, including resolving environmental issues.

Kayri Havens is currently the Garden's Director of Plant Science and Conservation and Senior Scientist. Her research interests include the effects of climate change on plant species, seed germination, restoration genetics, the biology of plant rarity and invasiveness.

Contact: marcellopennacchio@gmail.com

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The Role of Savanna & Woodland Restoration and Prescribed Fire in Bird Conservation in Missouri

By Frank R. Thompson III, Jennifer Reidy, Melissa Roach, D. Todd Jones-Farrand and Sarah W. Kendrick

Midwestern savannas and woodlands are transitional communities between the closed canopy deciduous forests that dominate the eastern Unites States and the prairies and grasslands that dominate the central Unites States. In this paper, savannas generally have 10–30% tree cover and abundant grass and forb cover while woodlands are typically 30–80% tree canopy cover, have a sparse understory, and ground cover dominated by grasses and forbs. These transitional communities were once widespread and common throughout the Midwest, but after European settlement, most were either converted to other land uses or fire suppression resulted in their succession to closed canopy forests. Savannas and woodlands require fire to maintain their open canopy, suppress invasion of woody vegetation, and sustain the herbaceous and shrubby ground cover.

There is great interest in restoring savannas and woodlands across Missouri because these landscape types have been greatly reduced in extent — from being abundant to rare — and because of their floristic and wildlife diversity. Savannas and woodlands support a diverse array of wildlife in part because they are transitional habitat types. Wildlife found in savanna and woodland include species that overlap from forest or grassland habitats, are savanna or woodland specialists, or generalist species that occur across most of the habitat gradient. Restoration of savannas and woodlands usually consist of some combination of tree thinning and prescribed fire on sites that were once savanna or woodland but have succeeded to closed canopy forest due to the absence of fire.

The Central Hardwoods Joint Venture identified 16 forest-woodland and 13 grassland-shrubland bird species as regional conservation priorities because of concern for their status and the importance of this region to these species (Table 1). The extensive loss of savanna and woodland has contributed to the concern for some of these bird species; however, the restoration of savanna and woodland can have both positive and negative effects for species on this list. For example, three pine savanna-woodland specialists have been completely extirpated, or nearly so, from Missouri. Both brown-headed nuthatches and the federally endangered red-cockaded woodpecker are no longer found in the state, while Bachman's sparrows have decreased dramatically and can only be found in very localized patches. We would expect these species to benefit from savanna and woodland restoration that

Table 1. Bird species of regional concern that inhabit forest-woodland and grassland-shrubland communities in Missouri.

Central Hardwoods Joint Venture
partnerships for conservation

Forest-woodland

Red-cockaded woodpecker*
Brown-headed nuthatch*
Cerulean warbler
Swainson's warbler
Bachman's sparrow
American woodcock
Red-headed woodpecker*
Wood thrush*
Worm-eating warbler*
Kentucky warbler*
Ruffed grouse
Yellow-billed cuckoo*
Whip-poor-will *
Northern flicker
Eastern wood-pewee*
Blue-gray gnatcatcher*

Grass-shrubland

Blue-winged warbler*
Prairie warbler*
Painted bunting
Bell's vireo
Bewick's wren
Northern bobwhite*
Eastern kingbird*
White-eyed vireo*
Brown thrasher *
Yellow-breasted chat*
Eastern towhee*
Field sparrow*
Orchard oriole*

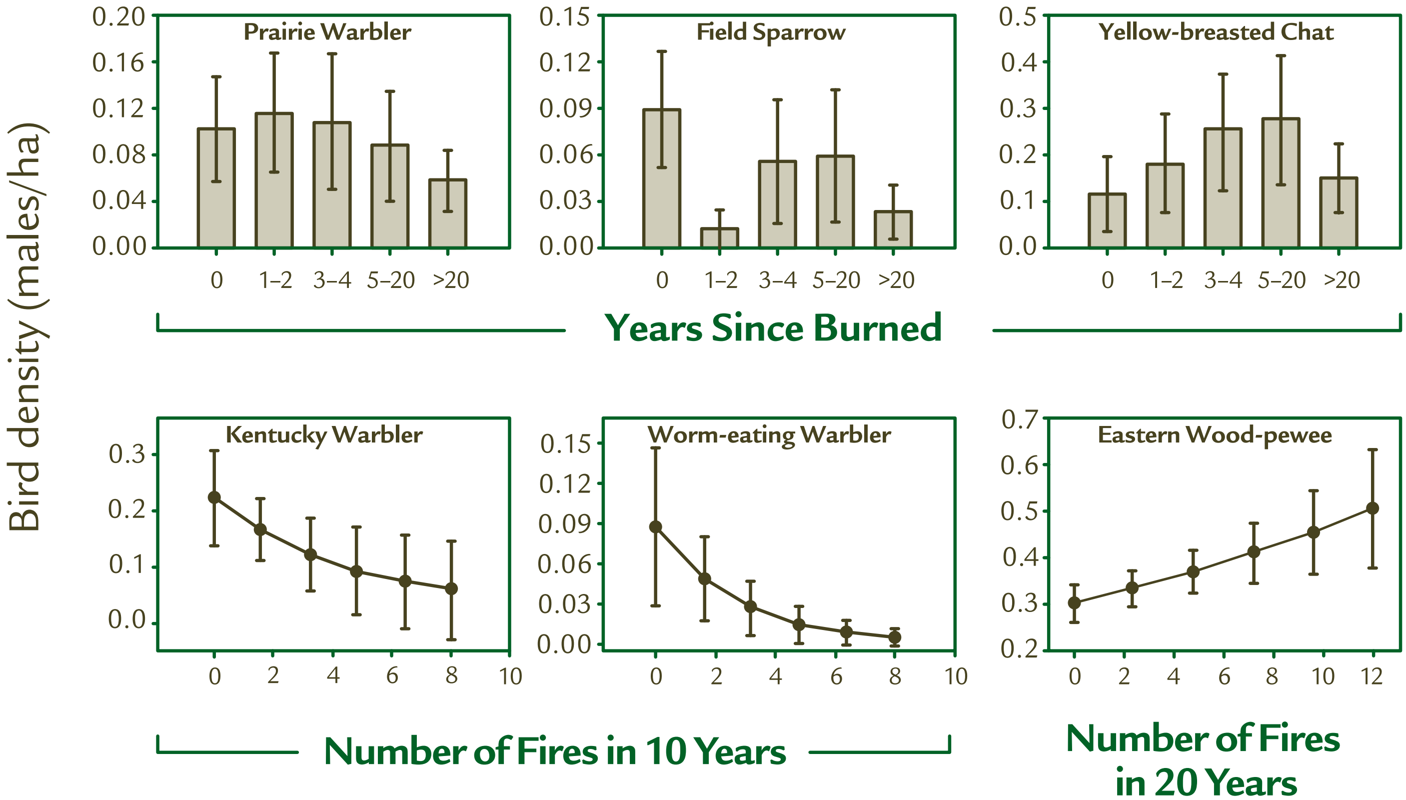
*Species that the authors surveyed to determine the effects of prescribed fire and restoration management in the Missouri Ozark Highlands.

featured pine. Also, from what we know about other forest-woodland birds such as red-headed woodpecker, yellow-billed cuckoo, Eastern whip-poor-will, and Eastern wood-pewee, we would expect these species to benefit from prescribed fire. In general, we expect the group of grassland-shrubland and woodland birds to benefit from prescribed fire and thinning. Woodlands, however, would likely have too much tree cover for some of these shrubland-dependent species, while frequent fire in grassland-shrubland landscapes could prevent the development of woody shrubs or saplings that are required by other woodland-dependent birds. There is also some uncertainty about whether certain early successional species such as prairie warbler and yellow-breasted chat, normally found in regenerating forest following disturbances such as large-scale blow downs, stand-replacing fires, and clearcut timber harvest, will also respond positively to savanna and woodland restoration.

Between 2009 and 2011, we conducted research on the effects of oak savanna and woodland restoration by conducting bird point-counts at 565 points in managed sites and 362 points in non-managed sites across the Missouri Ozark Highlands. Points were located on lands owned by the Missouri Department of Conservation, Missouri Department of Natural Resources, The Nature Conservancy, and the U.S. Forest Service. In 2013, we initiated research on the effects of pine savanna and woodland restoration as part of the Mark Twain National Forest Cooperative Forest Landscape Restoration Project and will continue to survey birds at 253 points in the project area through 2015, while we conduct a parallel study surveying 102 points on the Ouachita National Forest in Arkansas and Oklahoma. We are focusing on many of the same priority species listed in Table 1. Here we review some of the general patterns from our oak savanna and woodland study. Detailed results are available in several publications listed below.

Photo by Allison J. Vaughn

Western Star Flatwoods Natural Area, one of the reseach sites in this study.



Forest and woodland species

Yellow-billed cuckoos, Eastern wood-pewees, and blue-gray gnatcatchers were abundant across managed savanna and woodland throughout the survey, and responded positively to regularly occurring prescribed fire. For example, Eastern wood-pewees increased in abundance by 67% as the number of fires in the last 20 years increased from 0 to 20. We found few red-headed woodpeckers regardless of management activity and surmise that most restored sites were either still too overstocked with trees, too small-scale, or too isolated to entice these charismatic woodpeckers. Wood thrush, Acadian flycatchers, worm-eating warblers and Kentucky warblers are often associated with forests with dense understories of shrubs or small trees, which they use for nesting or foraging. This suitable landscape type could be suppressed by regularly occurring fire. Worm-eating and Kentucky warblers both, in fact, had lower abundance at sites with more frequent or more recent fires. Abundance of worm-eating and Kentucky warblers declined to near 0 as the number of fires increased from 0 to 8 in the last 10 years. Wood thrush, a forest priority species, were uncommon across managed and non-managed sites, probably because they prefer more mesic sites than our sample design allowed.

Grassland-shrubland species

Field sparrows, Eastern towhee, yellow-breasted chats, and prairie warblers all responded positively to fire, but varied in the degree of the response. Field sparrows were most abundant the year after a site was burned, whereas yellow-breasted chats and prairie warblers were both most abundant several years post-burn. These patterns are consistent with nest site selection by these species as yellow-breasted chats and prairie warblers generally prefer sites with more shrub cover and understory than field sparrows. Eastern kingbirds, Northern bobwhite quail, and orchard orioles were rarely detected at our survey stations. Similar to our explanation of red-headed woodpeckers, the managed sites were likely not open enough or prevalent enough in the landscapes to attract many of these birds.

Pine-bluestem Woodland restoration study

To date, we have competed preliminary assessments of our bird surveys from the Mark Twain National Forest Cooperative Forest Landscape Restoration Project. The pine woodland landscapes within these sites have an even greater amount of recent management (e.g., prescribed fire and thinning) than the oak savanna and woodland sites we studied between 2009-2011; this, too, is reflected in bird abundances. Following the pine warbler, yellow-breasted chat and Eastern wood-pewee were the most abundant birds across this pine landscape, further demonstrating these species' positive response to restoration efforts which include prescribed fire. Equally interesting is that typical forest species such as Acadian flycatcher, ovenbird, and worm-eating warbler were also common in the landscape within the project area.

The diversity and abundance of priority birds found across these communities is one argument for active restoration and use of prescribed fire in these wooded landscapes. Another compelling reason is that keeping the entire gradient of grassland-shrubland-savanna-woodland-forest natural communities in these landscapes across the Ozark Highlands is a good strategy for making these landscapes resilient and able to adapt to future changes such as climate change and urban expansion.

Frank R. Thompson III, USDA Forest Service, Northern Research Station

Jennifer Reidy, Department of Fisheries and Wildlife, University of Missouri-Columbia

Melissa Roach, Department of Fisheries and Wildlife, University of Missouri-Columbia

D. Todd Jones-Farrand, Science Coordinator, Central Hardwoods Joint Venture

Sarah W. Kendrick, Missouri Department of Conservation

Contact: frthompson@fs.fed.us

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Photo by Allison J. Vaughn

Located in the River Cave burn unit at Ha Ha Tonka State Park, fall wildflowers and warm season grasses abound after a March prescribed fire.

Eastern Wood-Pewee Response to Savanna-Woodland Restoration in the Missouri Ozark Highlands

By Sarah Kendrick

Several years ago, I assisted Jennifer Reidy working under the direction of Dr. Frank Thompson conducting breeding bird point counts to track bird response to savanna-woodland restoration projects in the Missouri Ozark Highlands. The variety of management regimes and bird communities represented within a single transect was remarkable. The management units chosen for our study sites varied by fire regime and thinning/timber harvest programs; some areas had been thinned and burned, others were thinned and not burned, and some were burned and not thinned. Standing in woodlands with fairly high canopy cover and no recent fire, I typically detected red-eyed vireos, Eastern wood-pewees, and, on occasion, an ovenbird or an indigo bunting. Conversely, when I surveyed points in intensely managed savanna or open woodland units that had been treated with fire more recently and rigorously, I found myself writing furiously to record the numerous individuals I detected: prairie warblers, blue-winged warblers, Eastern towhees, Eastern wood-pewees, indigo buntings, scarlet and summer tanagers, and yellow-breasted chats. The marked difference in bird diversity between areas treated with regularly occurring fire and areas with less treatment with fire was as dramatic as night and day. In fact, from 100 meters away, I could hear before I could see when I was approaching an open woodland unit with a long fire history; the raucous, laughing calls of chats seeped into the surrounding closed woodlands from these open areas.

One may have noticed during a hike that few bird species occur in both closed canopy forest/closed woodland and savanna/open woodland settings. However, Eastern wood-pewees (hereafter, pewee) and a few others can be found in both settings. Pewees require fairly tall canopy trees for nesting, and appear to use many areas of varying openness that possess a tall tree canopy, from savanna and open woodland to closed woodland and forest. Unlike the other focal priority bird species we documented in the multi-year study, I detected pewees across the gradient of landscape types. In 2009, the pilot year of the Thompson-Reidy study, I noted that pewees are apparently abundant across these varying landscape types of differing management regimes.

The Eastern wood-pewee is a medium-sized flycatcher of the family *Tyrannidae*, whose breeding range covers the eastern half of the United States, barely north into eastern Canada and west to the Rocky Mountains; at the Rockies and west to the Pacific, the Eastern wood-pewee is replaced by its cousin, the Western wood-pewee. Upon researching this fairly abundant bird in Missouri (whose "peeeee-ah-weeeeee" song is nearly impossible to miss in any Eastern deciduous forest), I found that little research on their breeding demography existed, presumably because of an inability to gather a large sample of nest contents. Pewees nest high in the canopy, usually up to and exceeding 60 feet.

Because pewees are found in savanna, woodland, and forest alike, we realized that we could investigate this bird's response to restoration in an interesting way. We studied breeding demography

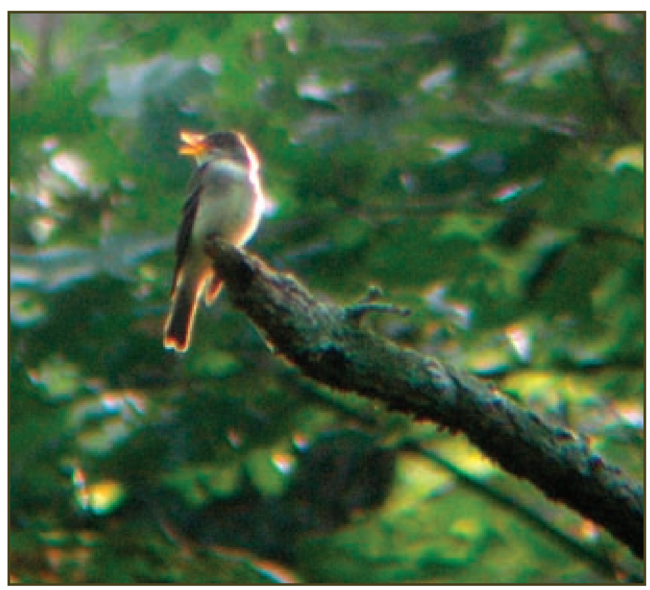

Photo by Sarah Kendrick

A photo of an Eastern wood-pewee at sunrise, taken with a video scoping pole.

(nest survival, rates of brood parasitism by brown-headed cowbirds, clutch size, number of young fledged, and feeding rates) and abundance (using point counts) of this fairly common flycatcher across a gradient of savanna-woodland restoration in the Missouri Ozarks. As a measurement of canopy detection, we used percent tree stocking, a measure of tree density. To overcome the difficulty in accessing high pewee nests, we attached a home security camera to the top of an 18 m telescoping pole with a live-feed monitor that we watched from the ground. After hefting up sections of the teetering pole to the right height, we balanced the camera over the nest to view and record its contents — all the while cringing and apologizing to the parents who were fiercely defending their nest by attacking and clacking their bills at the alien object invading their nests. The adults quickly returned to the nest and quieted down after we removed the camera and left the area. [Note: if we detected blue jays, American crows, raptors, or parasitizing brown-headed cowbirds in the area, we did not use the telescoping pole in an effort to avoid drawing the attention of potential nest predators.]

Between 2009 and 2011, we discovered and monitored 310 pewee nests on 13 study sites across the Missouri Ozarks, and confirmed the contents of 167 nests using the video pole (Kendrick et al. 2013 and 2014). We modeled the effects of nest stage (incubation and nestling stages), nest height, percent tree stocking, and percent forest canopy cover in a 10 km radius on nest survival. Only nest stage and percent forest cover in a 10 km radius predicted whether or not a nest was successful (fledged young). Period nest survival was 72% in the incubation stage and 32% in the nestling stage for the nests we monitored. Surprisingly, pewee nest survival *increased* with decreasing forest canopy cover in a 10 km radius, contrary to research that has shown increases in predation and parasitism rates with increasing forest fragmentation on the nest survival of forest birds (Donovan et al. 1995, Robinson et al. 1995, Thompson et al. 2000). Brood parasitism was very low, with only four nests (0.01%) parasitized. Other exciting new findings included 15 observed instances of double brooding (two broods fledged in the same summer), five

Photo by Sarah Kendrick

Operating the video monitoring pole

Photo by Sarah Kendrick

Monitoring a nest.

Photo by Jennifer Reidy

A pewee fledgling.

of which reused the same nest for a second brood after fledging a first successful nest!

To measure the birds' abundance across these management units, we conducted point counts across 19 sites at 921 points; abundance estimates increased 83% across our observed range of tree stocking (0–180%). Percent tree stocking is a measure of the percent of an area covered by tree canopies and is estimated from the tree diameters in a certain radius. Percent stocking can exceed 100% because tree canopies can overlap. We felt this was an appropriate measure of tree cover in a site, because it more precisely measures the extent to which a site is occupied by trees than a canopy cover percentage. Also, percent tree stocking is directly affected by restoration activities, namely thinning and prescribed fire, whereas, in some cases, canopy cover may not be.

Effects of management and fragmentation on pewees in the Missouri Ozarks can seem a bit confusing, given that their nest survival improved with increased fragmentation in the landscape, but their densities increased with tree stocking (greater densities in non-managed forested sites). Pewees appear to be less susceptible to brood parasitism on our study sites, which is an important note on the fragmentation effect found in the literature. Also, pewees may be less susceptible to the guild of predators that have been shown to increase with forest fragmentation in the landscape (Cox et al. 2012). Pewee density increases in areas of greatest stocking (usually non-managed forested sites) supports our general knowledge of the pewee as a forest interior bird, but this species is by no means exclusive to this community. Although nest survival across savanna, woodland, or forest communities did not dramatically differ, all three communities were heavily used by pewees on our sites.

Fewer expansive patches of open savanna-woodland exist across the Ozarks in comparison to closed canopy forest; it is difficult to discern or predict widespread changes to nest survival and densities of other woodland-forest species that may have been obligate to these landscapes, or historically used these areas exclusively. In terms of managing natural woodland systems for fire-mediated herbaceous and stocking responses as well as increased bird diversity, restoration of savannas and woodlands appears to be a great landscape-scale strategy. The pewee study was not only a great adventure for me, but also a rare opportunity to see the diverse range of natural community response to a growing management regime of restoration fire and thinning across the Ozarks.

Sarah Kendrick is Wildlife Programs Supervisor, Missouri Department of Conservation

Contact: Sarah.Kendrick@mdc.mo.gov

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Photo by Sarah Kendrick

Prescribed Fire and Cedar Removal Enhance an Ozark Fen Complex

By Dan Drees

All of the 180-acre Mill Mountain Natural Area in Shannon County is within the 1,231-acre Mill Mt./Buzzard Mountain prescribed fire unit. However, the area immediately surrounding the Mill Mt. Shut-ins (where Rocky Creek cascades through massive boulders of igneous rock) is naturally protected from fire by the abundance of rock. Consequently, the stoic old-man's beard lichen (*Usnea angulata*) hangs like Spanish moss from old-growth Eastern red cedar trees that gracefully grow from a scrabble of boulders and cobbles.

The constant spring-fed waters of Rocky Creek give these shut-ins an energetic voice, even during prolonged drought. During flood events, the shut-ins roar with the voice of a great opera tenor. It is obvious why the Mill Mt. Natural Area was designated for its natural quality, and why the Ozark Trail parallels this portion of Rocky Creek. Less obvious is the moist-soil fen complex that borders a portion of the Ozark Trail just south of the present natural area. In the Missouri Ozark Highlands, Riddell's goldenrod (*Solidago riddellii*) is a rare but characteristic fen plant that is dependent on significant sunlight and wet/damp organic soil. Unfortunately, when firefighters appropriately and successfully subdued historic wildfires in the Ozarks, an unintended consequence of this success was the unprecedented expansion of fire-intolerant Eastern red cedar tree seedlings.

In the absence of the historic fire regime, the Riddell's goldenrod population at the Mill Mt. fen was shaded by an invasion of cedars that quickly grew too large and dense to be managed with fire alone. Luckily, some Riddell's goldenrod still survived in the few remaining fen openings.

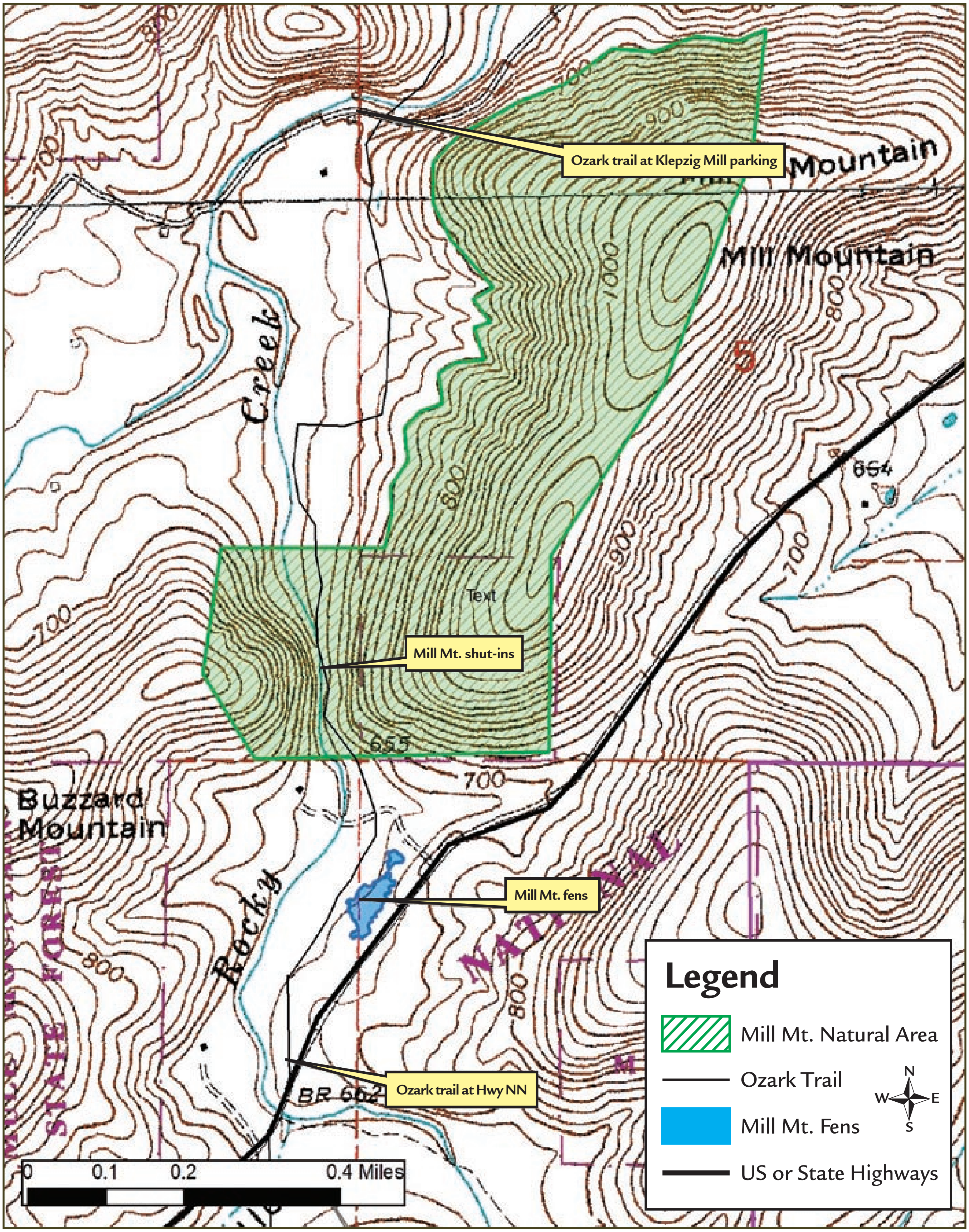
The scattered populations of Riddell's goldenrod indicated that there was still a good opportunity to recover a rich fen community of plants and animals, especially fen dependent insects. Beginning in January 2012, Ozark National Scenic Riverways (ONSR) staff cut 9 acres of cedars on and near the fen complex. Cedar slash was dragged away from the fens and burned in piles in the surrounding pine woodland.

Photo by Dan Drees

Riddell's goldenrod (*Solidago riddellii*) at Ozark National Scenic Riverways

On April 13, 2013, ONSR staff burned the fen complex. The response of the native grasses and wildflowers was tremendous; data obtained from 2 Riddell's goldenrod monitoring plots (each 10 meters × 25 meters) indicated a population increase of 1,026% over pre-management numbers (from 115 in 2011 to 1,125 in 2013, and 1,295 individuals in 2014).

To see the Riddell's goldenrod in peak bloom (and the many butterflies attracted to their nectar), hike the Ozark Trail along these fens in late September. If you hike this area again in mid-



Map by Dan Drees

Mill Mountain Natural Area and adjoining points of interest.

October, you will see a profusion of New England asters that saturate the fens in deep, lavender-colored beauty. Goldenrods, asters, and other fire-tolerant forbs are very important nectar sources for migrating monarch butterflies.

The Mill Mt./Buzzard Mt. Prescribed Fire Unit includes property owned by ONSR and the Missouri Department of Conservation. The prescribed fire event was also attended by Wildland Fire staff from Buffalo National River, The Nature Conservancy, AmeriCorps-St. Louis, and the Winona Rural Fire Department. It is a true measure of success when staff from six entities join together to accomplish a common goal.

Originally, ONSR developed two prescribed fire units of 710 acres in the Mill Mt. and Buzzard Mt. region. Cooperation with MDC allowed for the consolidation of these two units into one large unit, and added additional acreage for a 1,231 acre prescribed fire unit. This expansion greatly increased operational safety and efficiency by expanding the perimeter of the unit to an existing road system; it also dramatically impacted the financial efficiency of the project compared to previous years, reducing the average cost per acre for treatment from $30 to $12. Most importantly, however, the expanded burn unit now benefits the fen complex.

Fifteen rare plant species have been documented from a nearby fen complex owned by The Nature Conservancy. This concentration of rare plants represents the highest concentration in Missouri. All 15 species benefit from the regularly occurring fire management provided by The Nature Conservancy.

The National Park Service's Ozark National Scenic Riverways preserves a nationally significant portion of the natural and cultural resources of the Current River Watershed. The Mill Mt. burn was prescribed to reduce the threat of wildfire occurrence that may potentially threaten historic or privately owned structures adjacent to the burn unit.

Additional objectives of this prescribed fire included restoration of declining glade, woodland, and fen habitat, once common in the area. The burn plan included a goal to increase the average number of grass and wildflower species in the glade habitat by at least 40% from pretreatment conditions. Vegetation monitoring data collected from a plot on each mountain in the burn unit indicate that glades averaged a 51% increase in native grass and wildflower species following treatment.

Increasing the diversity and abundance of native grasses and wildflowers typically serves as a desirable measure of success because these native herbaceous plants are often suppressed when woody plant encroachment occurs. In the Missouri Ozarks, restoring the diversity and abundance of herbaceous plants typically increases wildlife diversity and abundance.

Prairie warblers, Northern bobwhite quail, and wild turkeys are among the bird species that show notable population increases associated with glade and woodland restoration. Many bird species benefit from glade and woodland restoration because the herbaceous plant diversity and density promotes greater insect diversity and abundance. Recently, Eastern collared lizards from nearby Stegall Mountain have established a breeding population on Mill Mt. following restoration activities likely due to similar floral diversity and canopy openness.

Herbaceous plants also serve as the primary forage for white-tailed deer and the newly reintroduced herd of elk in the region. Historically, it has been suggested that elk were the keystone grazing herbivores in Ozark glade and woodland natural communities. Today, elk once again wander over Mill Mt. and other nearby public lands due to a reintroduction effort.

We manage glades, woodlands, and fens to benefit many species that are currently declining, while also restoring fuel levels to their historic condition. The success of the Mill Mt. collaborative restoration effort is measurable in numerous ways, but ultimately it may be the discovery of a fire-dependent species inhabiting the area that has not yet been documented. Hopefully, the tremendous increase in Riddell's goldenrods is mirrored by similar increases in rare pollinators that are yet to be documented.

Dan Drees is Fire Ecologist for the National Park Service, Ozark Highlands Park Group

Contact: daniel_drees@nps.gov

Prescribed Fire Effects on Herpetofauna in Missouri

By Jeff Briggler

Fire has played an important role in creating and maintaining habitat for plants and animals in Missouri. There is a large body of knowledge concerning the use of prescribed fire for wildlife management, especially plant communities and more mobile animal species, but the response to fire by low mobility species such as amphibians and reptiles has not been as comprehensively surveyed. However, the reptile response to fire has been receiving increased attention in the past decade. In fire suppressed landscapes, resulting plant communities may not be suitable for many amphibian and reptile species that depend upon fire-mediated habitat to meet life history needs. For example, fire suppression on Missouri's glades regularly results in Eastern red cedar encroachment and significant declines in Eastern collared lizard populations. Similarly, fire has been implicated in causing direct mortality leading to declines in other species of herpetofauna such as Massasauga rattlesnakes, box turtles, and spotted salamanders.

The use of fire as a management tool to maintain natural communities can have an immediate or short-term effect as well as a lasting, long-term effect on herpetofaunal communities. Immediate impacts often result in direct mortality, injury that influences fitness, or an unnatural dispersal to new areas that may or may not be optimal habitat to escape the fire. Short-term effects include reduction of the litter layer and natural cover, increased soil temperature, and changes in the timing and duration of moisture in a habitat. For the short-term, a burned area exposes herpetofauna to predators such as hawks and owls, and can result in a loss or reduction of the prey base. Changes in the moisture level may have a positive or negative impact to certain species, depending on whether the evapotranspiration is reduced or increased as surface vegetation is removed by fire. On the short-term basis following fire, increased solar radiation exposure will occur, resulting in an increasing soil temperature that can intensify desic-

Photo by Jeff Briggler

Ornate box turtle emerging from overwintering site in early spring. Once emerged and active on the surface, little protection is provided from fire due to its behavior to close up in its shell for protection.

cation in amphibians or result in early emergence of many reptiles from hibernation. Long-term effects of fire typically improve and/or restore habitat for herpetofauna, but burn parameters including seasonality, intensity, frequency, and acres treated, combined with landscape features like topography, natural community types, and fuel loading will significantly influence the long-term diversity and abundance of herpetofauna.

Herpetofauna are considered more susceptible than other species to the effects of fire due to their limited mobility and ectothermic nature. The following considerations regarding fire implementation will help to optimize herpetofaunal populations in Missouri's fire-mediated systems:

Seasonal and Temporal

Winter burns, generally between November 1 and March 31, occur when most herpetofauna are inactive; winter burns are optimal to reduce direct mortalities and injuries. In Missouri, these dates will vary depending on location, habitat, and latitude, as well as fluctuations in precipitation and temperature conditions. Even within these "safe dates" from a herpetofaunal perspective, soil temperature will greatly influence surface activities of these animals. Warm winter days can induce breaks in hibernation. For example, the state endangered Massasauga rattlesnake has been documented on the surface in February after several unusually mild winter days. In addition to "safe dates," soil temperature inversions (i.e., when soil surface temperatures exceed deeper soil temperatures) are more reliable to predict the timing of surface emergence of many reptiles. Once soil temperatures reach 45°F, several snake species will begin emerging from hibernation and are very vulnerable to fire due to reduced motility. A snake survey following a prescribed burn after the "safe dates" in northwest Missouri accounted for a total of 46 individuals of 12 reptile species with 35 mortalities, including 17 Graham's crayfish snakes.

Unfortunately, "safe date" recommendations for reptiles may not be safe for some amphibian species. Several salamander and frog species will make annual migrations to breeding wetlands in February and March. In most cases, these animals are afforded some protection from mortality

Photo by Michael Cravens

Massasauga Rattlesnake

Massasauga rattlesnakes (*Sistrurus catenatus*) are no longer common throughout much of their historic range. They were listed as state endangered in Missouri in 1974. Massasauga rattlesnakes inhabit a variety of prairie types, generally in or near large river floodplains. They have been able to exploit this habitat due to their ability to overwinter in crayfish burrows, which occur in high densities in bottomland prairies with poorly drained soils. In the spring, the snakes are found near hibernacula in bottomland prairies. After emerging, Massasaugas tend to migrate to uplands including prairies, old fields and open woodlands. Massasaugas usually occupy these areas until around mid-September when they begin their migration back to the lowland prairies for hibernation.

While habitat loss of bottomland prairie has been the primary factor behind Massasauga rattlesnake declines, the most significant current threats involve stochastic environmental events (primarily flooding), habitat degradation, and land management practices adversely impacting the animals. One major threat to their population is conducting prescribed burns immediately after the rattlesnakes emerge in mid-March due to large numbers of snakes using communal hibernacula. Massasaugas and other snake species are extremely vulnerable to mortality due to their inability to escape fire when they are cold and exposed on the surface in early spring. Prescribed burns for this species should only occur in the winter months when snakes are below the surface in burrows. However, mortality can still occur with the species even with the preferred "safe dates" due to early, rising spring temperatures. One such burn conducted within the "safe dates" on a public land site in northwest Missouri resulted in the mortality of 23 individual snakes of 6 species, including 3 endangered Massasaugas. Managers extinguished the fire after several acres had burned. Extra consideration should be taken into account for spring burns in close proximity of known snake hibernacula.

by fire due to their habit of seeking shelter (e.g., rocks, logs) during daylight hours and requiring wet conditions to migrate. However, there have been a few documented cases of wood frog and spotted salamander mortalities during winter burns in Missouri.

Frequency of Fire

Several herpetofauna species, especially long-lived species with low reproductive rates such as turtles and rattlesnakes, are susceptible to even slight mortality declines. Annual burning to achieve a quicker plant response can have impacts on many reptile species. Even an annual mortality rate of 1% in box turtle populations will begin a steady decline of the species due to low reproductive rates. A survey of a prescribed fire unit following a burn in late October 1999 on a private prairie in southwest Missouri documented 72 individuals of 8 species of amphibians and reptiles with 29 mortalities. Twenty-two three-toed box turtles were among the mortalities. Such cumulative effects of annual burns may push some populations beyond recovery, especially if recolonization from neighboring sites is not possible.

Intensity

The intensity and speed of a prescribed fire can have various effects on the herpetofaunal community. Most amphibians and reptiles are unable to outrun fire; therefore, slower fires may allow some of the more motile species to get ahead of the fire, especially if they are not trapped in a ring-head fire. However, fires that move quickly across the landscape are more likely to leave cover unburned, such as logs and clumps of dense litter. This potentially allows some animals to seek cover. Unfortunately, slow-moving species such as three-toed box turtles are vulnerable to fire when they are active on the surface, since the primary safety mechanism is to close themselves into their shells. Fires that do not burn all existing vegetation are preferred to allow some shelter nearby as the surrounding vegetation regrows following a fire event. Because fire speed and intensity impact some species and their associated habitats, knowing which species exist on the landscape — especially species of conservation concern — is important in determining management goals.

Scale

The size of the burn unit matters, especially in fragmented landscapes. It is generally recommended by herpetologists that no more than 1/3 of a designated area is burned per year, even if the area is only 200 acres. Many public lands, especially grasslands, are surrounded by suboptimal habitat that limits the opportunity for recolonization by amphibians and reptiles. While it may prove easier to burn entire tracts at one time, it will have long-

Photo by Jeff Briggler

Massasauga Rattlesnake emerging in a burned landscape.

term impacts to the herpetofaunal species if the given unit is small in size and a disjunct island of optimal habitat.

Natural Community Type

The type of natural community can influence fire's effects on herpetofauna. In Missouri's Ozarks, many forested tracts have a greater abundance of natural cover such as downed logs, rocks, stumps, trees to climb. These natural features allow animals to readily seek shelter from fires. In addition, these forested landscapes are often more intact and less fragmented in nature, which allows for potential recolonization. Grasslands, however, have limited cover potential unless crayfish or mammal burrows are nearby. Too often these grasslands are small-scale relicts with limited recolonization potential for most herpetofauna. The potential effects to populations can be influenced by the burning conditions within these various natural community types.

Topography and Wetlands

Historically, naturally occurring fires moved across the landscape as dictated by topography, slope, aspect, fuel moisture and availability. It is generally accepted that most reptiles like open, dry habitats, while amphibians tend to inhabit cool, moist environments with thick leaf litter. In a natural fire regime, southern exposures generally burn more often and hotter than north and east facing slopes. Restoring a fire regime to mimic naturally occurring fires on the landscape should be a goal for the health of the community. Too often, modern fireline placement follows roads and streams rather than topographical features that dictated fire behavior historically. Wetland shorelines and sinkholes, for example, did not burn as frequently or with the same intensity as a grass covered, south-facing slope. When fire is used as a management tool to restore natural communities, the landscape should dictate where fire moves and how much of the area burns. Many wetland environments and cooler, moist forests and streambanks did not burn as regularly or with the same intensity as a typical dry, rocky woodland, and it is not ecologically sound to force fire into these environments. The heterogeneity of a fire-mediated landscape, which allows for certain unburned areas within a unit, can provide cover and protection to many species of herpetofauna and other organisms.

There is a complex balance in using fire as a management tool for natural community management and maintaining herpetofaunal diversity. Favorable results of the plant community, for example, may not directly benefit the herpetofaunal community. Intensively managing a grassland to improve plant diversity may cause more harm to the existing, functional herpetofaunal community, especially if burning during the active season. There are unanswered questions pertaining to fire's impacts on herpetofauna and other organisms. *The Habitat Management Guidelines for Amphibians and Reptiles of the Midwestern United States* by Kingsbury and Gibson (2012) and the Midwest Partners in Amphibian and Reptile Conservation (2009) offer recommendations for prescribed fire, as well as professional ongoing field research. Prescribed fire practitioners should ask 1) do we know the diversity and distribution of the herpetofauna on the site, especially species of conservation concern, and 2) will fire be beneficial, detrimental, or have a neutral effect on the herpetofauna. These questions are not always easy to address, and even after many years of prescribed fire in Missouri, there is still much we don't know about fire's impacts to amphibians and reptiles. Using fire responsibly and taking into consideration the natural complexity of the entire natural community will help guide management, but equal consideration for these less mobile animal species, especially the herpetofauna, should be a part of the discussion. Considering some of the recommendations above will be of benefit to the herpetofauna and to the rest of the community.

Jeff Briggler is the State Herpetologist with the Missouri Department of Conservation

Contact: Jeff.Briggler@mdc.mo.gov

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Photo by Eugene Vale

Missouri Department of Natural Resources staff conducting prescribed fire at Trail of Tears State Park, Jackson, MO.

Ecologically Appropriate Fire in the Missouri Landscape: A 35 Year Reflection

By Doug Ladd

When I started working in Missouri in 1980, there was growing acceptance of the concept of fire as a beneficial management tool for prairie. Beyond this, there was almost no consideration of the role of fire in other native systems, especially timbered systems, other than as a negative process with destructive consequences to both human society and ecosystems.

This prevailing dogma existed despite several insightful but long overlooked or disparaged studies documenting fire as a regular process fundamental to the development and perpetuation of Missouri's post-glacial systems[1]. Scorched by the damaging impacts of intense slash-enhanced fires in the post-logging era, and lulled by the comforting creed of Smokey Bear, Missouri resource managers cleaved to a convention largely dictated by the unquestioning mantra of early twentieth century forestry and the comforting shibboleth of the "Eastern Deciduous Forest."

Some inconvenient truths remained difficult to reconcile. Early accounts of Missouri display a compelling consistency in their depiction of open woodlands with minimal understory and well-developed ground layer vegetation with a prominent graminoid component and a visually striking diversity of forbs. These accounts are all the more convincing because of their thematic commonality, despite originating from authors with a diversity of nationalities, intents, and educational backgrounds. Associated with these accounts is a robust collection of narratives mentioning Native American fire, often expressly linking aboriginal fire practices and vegetation character. Since these observations did not fit the paradigm *de jour*, they were dismissed as "unscientific" or simply ignored. Even now, this historical and cultural context is often missing from fire research.

Today, thanks to diverse, mutually reinforcing

1. Bielmann, A.P. and L. G. Brenner. 1951. "The Recent intrusion of forests in the Ozarks", *Annals of the Missouri Botanical Garden* 38: 261-282; Pyne, S.J. 1982. *Fire in America*, Princeton University Press; Stewart, O.C. 2002. *Forgotten Fires*, University of Oklahoma Press.

analysis by historians, biologists, and anthropologists, the scientific community is largely in consensus on the broad issue: the Missouri landscape, like most of the Midwest and eastern North America south of the transition zone, has been shaped by a regime of pervasive, frequent, generally low intensity fires since the closing of the last glacial period. This fire regime was overwhelmingly from aboriginal ignitions, and these ignitions were deliberate, enduring cultural practices derived from a sophisticated comprehension of the landscape, its biota, and their response to management.

I think our collective discomfort with the concept of beneficial woodland fire stems from a combination of factors, including preconceptions. We have all vicariously experienced one of the most destructive fires in history — Walt Disney's celluloid conflagration that nearly killed Bambi's father. Given fire's potentially powerful destructive impacts to us and our infrastructure, we appropriately have an aversion to uncontrolled fire, even as we embrace controlled fire with our fireplaces, chimineas, and celebratory bonfires. Another factor influencing perception of fire is the potential for landscape fire, even when ecologically appropriate, to have deleterious consequences for specific management outcomes such as damaging valuable hardwood timber. Unfortunately, as a species we appear to be culturally attuned to seeking comfort in simplicity and absolutes, under which the reality that some fire is bad leads to demonizing all fire.

Given the rich and varied documentation of pervasive and deliberate aboriginal fire as a major factor influencing the North American landscape for thousands of years, it is surprising, and frankly disheartening[2], that there continues to be debate in Missouri about fire as an ecological process fundamental to the health of our natural systems and their component biodiversity. This debate encompasses not only the degree to which society should ensure ecologically appropriate fire across some portion of the landscape, but even as to whether fire was ever really a major part of the pre-European settlement landscape. This latter argument is subconsciously reinforced by the stubborn persistence of the Ozark forest myth.

We contrive semantic dances around the issue here in Missouri, but the stark reality is that forest, in the traditional sense of a system characterized by a dense canopy and understory and shade-tolerant ground layer with minimal fire influence, was a rare element of the pre-European settlement landscape. True forests in this sense were probably largely restricted to the Missouri River bottoms (where hydrology and a highly dynamic channel precluded frequent fire regimes) and some highly dissected valley systems in the Ozarks. Just as elsewhere in the Midwest, we need to explicitly acknowledge that the majority of Missouri timberlands, including most of the Ozarks, was some variant of a more open woodland system, and that this system was as dependent on the aboriginal fire regime as it was on local rainfall patterns. One approach would be to expand our concept of "forest" to include a broad array of timbered habitats, including those influenced by a long-standing regime of frequent, low-intensity fires.

There has been significant progress in fire management, including major on-the-ground accomplishments and effective application of fire to restore ecological health by state, federal, and private agencies and organizations. A series of data sets are emerging from fire management and restoration activities, some covering several decades. As with the convergence of the early accounts of the Missouri landscape, a clear consilience emerges from these data: restoration of ecologically appropriate fire to Missouri habitats with remnant biotic integrity increases native plant diversity and herbaceous ground cover. These increases are typically accompanied by decreases in ground layer woody vegetation (seedlings and sprouts), and often by increased relative frequency and cover among graminoid taxa. Both aggregate cover and per-unit-area diversity increase, often by large degrees.

Data for the effects of fire on conservative floristic elements and aggregate floristic quality are more variable and seem to depend on the degree of remnant integrity of the site, which is a direct reflection of past management history. Overall,

2. It also puzzles me that there is a dangerous assumption that the default condition in our landscape is the unburned state. In light of all available evidence, the ecologically appropriate default assumption should be that fire was a part of the system, and justifications and studies should be applied before deviating from a process known to be essential to the ecological health of the system. All the more disturbing are the lack of any data correlating fire-free management with retention of native diversity or aggregate conservatism.

Photo by Allison J. Vaughn

Land management agencies implement prescribed fire in Ozark woodlands.

however, the prevailing trend at the landscape scale across all terrestrial habitat types (including woodlands, prairies, glades, fens) is that mean conservatism of a site's vegetation is difficult to increase. This directly reinforces the concept of conservative taxa as those which, once removed from a system, are least able to become reestablished. What is heartening is that those conservative taxa present in a system under fire management tend to increase in abundance and relative dominance, thereby increasing mean conservatism and floristic quality at the plot level. These data are buttressed by accounts of dramatic increases in populations of various plants of conservation concern with the advent of a fire regime, such as the flourishing of previously unknown snakemouth orchids (*Pogonia ophioglossoides*) under a frequent fire regime at Shut-In Mountain Fens in Shannon County.

An encouraging generality that has emerged from analysis of vegetation response to restoration of ecologically appropriate fire regimes is that these increases in plant diversity and cover occur without significant depression of mean floristic conservatism; that is, the increases are not the result of recruitment of a suite of opportunistic taxa indicative of system destabilization. Another general trend associated with ecologically appropriate fire regimes in Missouri landscapes is a reduction in the abundance, cover, and diversity of nonnative taxa. While a few introduced weeds (notably *Lespedeza cuneata*) are fire-adapted, the majority of our allochthonous flora is not.

Our local biota are the distillation of thousands of generations of selection for the process regimes, site conditions, and biotic and abiotic interactions that prevailed in the post-glacial period. Aboriginal fire was a consistent factor in this regard, and our modern pre-European settlement natural systems reflect an adaptation to — and need for — fire to sustain them. Data consistently reveal that removal of fire results in an inexorable loss of vegetative diversity, cover, and aggregate floristic quality. It stands to reason that these losses reverberate across other biotic groups, reducing system resiliency and integrity, and increasing vulnerability to invasive species establishment.

While less data exist regarding fire regime effects on non-vascular biota, it is well known that fire-induced increases in ground layer diversity and abundance create what land managers refer to as "more groceries on the ground." This increased diversity and abundance of forage, fruits, seeds, rhizomes, etc. provides resources for a diverse suite of other organisms, which in turn provide resources for their predators and dependent species. Appropriate fire management in Midwestern woodland systems also provides critical structural attributes for wildlife, including a guild of woodland and savanna birds that, not surprisingly, are among the most endangered of our avian diversity.

Fire management is subject to the whims and trends of the day, and careful attention must be paid to ensuring that these practices, however well-intentioned, are not ultimately deleterious to system integrity. For instance, little data exist to indicate that growing season fires were a significant part of the presettlement landscape, yet there is growing use of these as a management tool. While application of occasional growing season fires has direct management benefits (such as increased control of invasive woody vegetation in degraded sites), there is little antecedent for this process in the genetic memory of the biota. This should give us pause, and at the very least trigger a robust assessment process to ensure that there are no irreversible impacts to pollinators and other biota. While the general pattern of frequent fire in shaping and maintaining the landscape and its incredible organismal diversity is clear, even if not fully acknowledged, many unknowns and uncertainties remain. Among these are information regarding patterns of heterogeneity of fire behavior and coverage, feedback loops with browsers and grazers, the extent and duration of fire-free intervals, and other information.

All too often it seems that there is a trend to diversify management treatments — fire timing, frequency, or other factors — simply from an assumption that a diversity of treatments is good because ecosystems are "dynamic." This shallow thinking poses grave risks to system integrity, and courts irreversible degradation. In reality, our contemporary biological systems are the distillation of thousands of generations of selection for a discrete range of site conditions and process regimes — the direct legacy of the post-glacial environment, including its aboriginal influences. Maintaining or emulating this constrained dynamism must be the operative concept for managers, or the result will be inevitable loss of conservative biotic elements and cascading loss of system resiliency and function. The sacred responsibility of managing our Missouri landscape to sustain its full array of diversity and function must include consideration of pre-European settlement composition, structure, and function — not from some misplaced fantasy of recreating a static utopian artifact, but in order to ensure that we are not exceeding the amplitudes of the constrained dynamism to which the system is attuned.

Existing knowledge gaps are exacerbated by the realities of the contemporary environment. The fact that a certain pattern of fire prevailed in presettlement times does not guarantee that it will have the same effects in today's fragmented landscape, subject to influences of allochthonous biota, altered hydrology, and changing climate patterns. We need a robust and ongoing culture of documentation and investigation, learning and adapting as we progress, enfranchising careful application of fire to nurture the healthy, diverse landscape upon which we as a society are ultimately dependent.

We need to change default conceptions across a broad segment of society. An unburned, fire-starved, overstocked woodland should not invoke notions of a sylvan paradise but instead be seen for what it is: a stressed, degraded, biotically depauperized system. This system no longer has the resiliency to sustain the wondrous diversity and function inherent in our post-glacial systems — one that no longer effectively infiltrates rain and recharges groundwater, reduces flood impacts, nurtures healthy, carbon-rich soils, supports diverse wildlife populations across broad organismal spectra, or provides the myriad other functions and services upon which local watersheds and human communities depend.

We have inherited the responsibility and consequences of managing the land from the Native Americans displaced by our ancestors. Our cultural practices will determine, for better or worse, the extent to which future generations will have healthy, diverse, resilient ecological systems to sustain their quality of life. Our legacy should be to ensure that at a landscape level we retain sufficient integrity, diversity, and functionality to make this possible.

Doug Ladd is Director of Conservation Science, The Nature Conservancy, Missouri Chapter

Contact: dladd@tnc.org

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Missouri's Comprehensive Natural Glades Map Accessible to Everyone

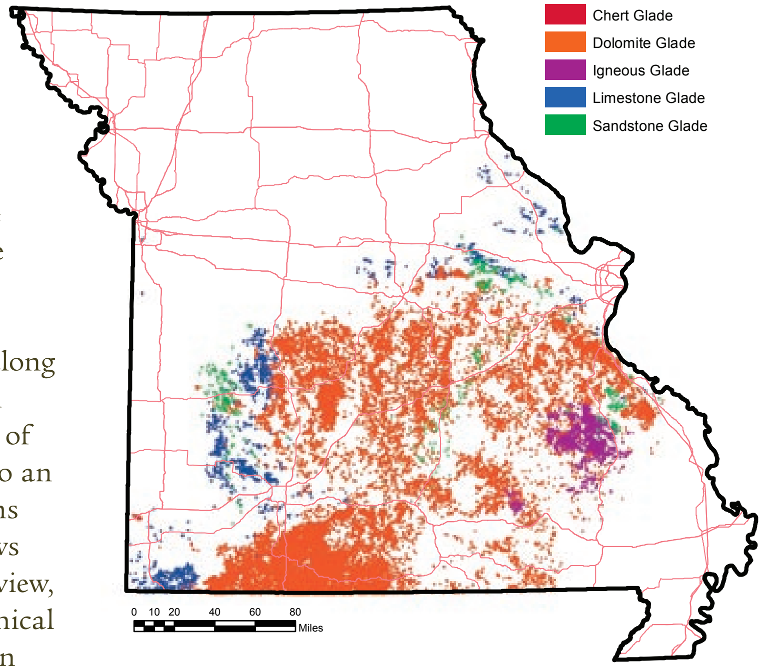
By Allison J. Vaughn

Now GIS and internet users can access the virtual locations of Missouri's restorable glades. GIS/ ArcMap users can download the "Missouri Natural Glade" shapefile[1] from the Missouri Spatial Data Information Service[2], along with the metadata that provides the technical information behind the development and use of the shapefile. Internet users can open a link to an interactive map tool that displays the locations of over 88,000 Missouri glades. The tool allows users to zoom to whatever scale they wish to view, change the map background layers (topographical maps, satellite, terrain, etc), and save their own custom versions of the map. One can also use tools in the mapping program to identify glade type (igneous, dolomite, limestone, sandstone, and chert). The Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (GCPO LCC) developed the interactive map.

The *Preliminary Report on the Identification, Distribution, and Classification of Missouri Glades* (Nelson and Ladd 1983) enumerated the first effort to map Missouri's glades using aerial photographs available in the early 1980s. The conclusions drawn in the 1983 report were based on the mapping of glades on 50 7.5-minute topographic maps across portions of the Missouri Ozark Highlands. These hand-drawn maps developed in 1983 provided a generalized glimpse of glade occurrences and crude patterns; furthermore, the hand-drawn maps presumed rock type and associated floristic elements. The 1983 report surmised: "Undoubtedly, as surveying continues and our knowledge of glade occurrence becomes more sophisticated, additional glades will be discovered…"

Thirty years later, ArcGIS spatial mapping capability provided that necessary sophistication. The impetus for systematically employing ArcGIS to comprehensively map Missouri glades became apparent with the completion of the *Central Hardwoods Joint Venture Glade Conservation Assessment*

1. <http://gcpolcc.databasin.org/maps/4a84fba3e73e43f3988d1eea3e090f14>
2. <http://msdis.missouri.edu>



(Nelson, et al. 2013). Today's "virtual natural glade map" is the result of mapping glades using high-resolution spatial satellite image projections and field verification. The process of mapping more than 88,000 glades proved a daunting task, which required five years to complete.

In 2008, Paul Nelson (then the Mark Twain National Forest Ecologist) initiated glade mapping on Mark Twain National Forest (MTNF) in response to the approval of the ecosystem-based 2005 MTNF Forest Management Plan. Nelson expanded mapping across the Ozarks following completion of the *Central Hardwoods Joint Venture Glade Conservation Assessment* (Nelson, et al. 2013). Eight states participated in publishing the 200 page glade assessment report which is available for download[3]. The glade conservation assessment is a collaborative effort among 8 states to document the current status and distribution of 24 distinct glade ecosystems and their associated species of conservation concern within the Central Hardwoods Bird Conservation Region. This assessment is a necessary first step in identifying glade complexes that have the greatest potential to satisfy the conservation needs of the broader suite of species that depend on glades for their survival. Respective state conservation agencies, The Nature Conservancy, Natural Heritage Programs, universities, and other entities amassed a list of 207 plant

3. <http://www.chjv.org/projects.html>

species for which glade habitat is obligate, optimal or suitable for sustaining them. The assessment documents what is known and unknown about the 207 species of conservation concern associated with shallow bedrock glade natural communities. It provides the background information needed to develop a plan of action to conserve glade ecosystems and their extant species of conservation concern.

Upon his retirement, Nelson contracted with the American Bird Conservancy to complete mapping of Missouri's remaining glades with efforts joined by the Missouri Department of Natural Resources and funding from the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (GCPO LCC) and the Missouri Department of Conservation.

The sophistication of ArcGIS mapping software, coupled with aerial spatial images, made it feasible to map glades on a virtual GIS scale. Each of the 609 7.5-minute quadrangle maps was divided into linear grids to systematically map all glades. GIS spatial layers and information used to map glades included spatially explicit topographic, infrared, leaf-off, soils, geologic and bedrock outcrop maps. Arriving at an accurate map requires repeated rounds of image interpretation and field validation resulting in greater mapping precision.

A concise map of Missouri's extant natural glades has major conservation implications. The glade mapping project revealed that the majority of Missouri's glade acreage still exists, although in variously disturbed condition and quality. Mapping methodology and field verification assumes that the mapped glades are to some degree restorable (other than glades destroyed by highways, housing developments, reservoirs and quarries). This means that it can be reasonably assumed that if a landowner cuts and burns cedars and keeps livestock off these thin-soiled native grasslands that landowners can recover some semblance of biological integrity.

An equally important application of the mapping data is the analysis of Missouri's glade distribution/patterns, rock substrate type and floristic affinities. Revision of the 1983 glade report utilizing the new map data is currently underway.

Paul Nelson is now mapping Arkansas glades under contract with the American Bird Conservancy and hopes to complete mapping of the entire Ozark Highlands Ecological Section in 2015. Many organizations have provided support to map Missouri and Arkansas glades including the GCOP LCC, US Fish and Wildlife Service, US Forest Service, Missouri Department of Natural Resources, Missouri Department of Conservation, Arkansas Game and Fish Commission, Arkansas Natural Heritage Commission and the American Bird Conservancy.

Allison J. Vaughn is a Natural Resource Steward with the Missouri Department of Natural Resources.

Contact: allison.vaughn@dnr.mo.gov

References:

Nelson, P. W., J. A. Fitzgerald, K. Larson, R. McCoy, A. Scholz, J. Taft, T. Whitsell, B. Yahn. 2013. *Central Hardwoods Joint Venture Glade Conservation Assessment for the Interior Highlands and Interior Low Plateaus of the Central Hardwoods Region.* Central Hardwoods Joint Venture.

Nelson P.W. and D. Ladd. 1983. "Preliminary report on the identification, distribution, and classification of Missouri glades." Pp. 59-76 in C.L. Kucera (ed.). *Proceedings of the seventh North American Prairie Conference*. Southwest Missouri State University, Springfield, Missouri.

Photo by Susan Farrington

Blazing Star at Hopewell Prairie Fen Natural Area.

2014 Missouri Natural Area System Updates

By Mike Leahy

In January 2014 the inter-agency Missouri Natural Areas Committee (MoNAC) approved three new natural area nominations and the delisting of one natural area. The committee seeks final approval by the directors of the Department of Conservation and the Department of Natural Resources. Below I outline these exciting new nominations for Pump Hollow, Hopewell Prairie Fen and Golden Prairie Natural Areas and the unfortunate decline of Cordgrass Bottoms Natural Area that led to its proposed removal from the Missouri Natural Areas System.

New Natural Areas

Pump Hollow Natural Area is a 940-acre site in Carter County on the Mark Twain National Forest. This natural area features acidic seeps (a rare wetland natural community type), a high-quality Ozark headwater stream and its surrounding watershed of restorable pine-oak woodlands. The area supports 10 plant species of conservation concern, most of them associated with the rare seeps. A number of the plant species associated with the acidic seeps are much more common in the southeast U.S., including netted chain fern (*Woodwardia areolata*) and screwstem (*Bartonia paniculata*). The headwater stream's riparian zone contains stands of common alder (*Alnus serrulata*) and Ozark witch hazel (*Hamamelis vernalis*) with other areas supporting luxuriant stands of mosses, royal fern (*Osmunda regalis*) and dwarf crested iris (*Iris cristata*). The area supports at least 258 native plant species and fish and invertebrate species associated with good quality headwater streams. Future management of the area will include spot treatments of invasive, exotic species and thinning and prescribed burning to restore the pine-oak woodlands in the uplands.

Hopewell Prairie Fen Natural Area is a 181-acre site in Howell County on the White Ranch

Conservation Area (Missouri Department of Conservation). This natural area features prairie fens, an imperiled wetland natural community type. Only twenty prairie fens are currently known in Missouri. The prairie fens provide habitat for four plant species of conservation concern. The fens and groundwater fed creeks provide habitat for sixteen dragonfly and damselfly species, including the gray petaltail (*Tachopterix thoreyi*), a species characteristic of high-quality fens. Surrounding the fens are open dry chert woodlands with thick stands of native grasses and forbs. The area as a whole has a significant component of prairie plant species. Bird species characteristic of woodlands in various successional stages noted during the breeding season on the area include prairie warbler, eastern bluebird, yellow-breasted chat, summer tanager and the yellow-billed cuckoo. Management of the area consists of spot treatments of invasive, exotic species and prescribed burning. A short interpretive hiking trail and fen overlook is planned for the future.

Golden Prairie Natural Area is a 320-acre site in Barton County that is nearly all original tallgrass prairie. This site supports prairie mole crickets (*Gryllotalpa major*), regal fritillary butterflies (*Speyeria idalia*), and Arkansas darters (*Etheostoma cragini*) — all species of conservation concern. The area provides habitat for declining grassland birds such as the Henslow's sparrow. Golden Prairie is a mosaic of upland dry-mesic sandstone/shale and hardpan prairie along with prairie swale wetlands and headwater streams. Fifty-four bird species have been observed on the site along with 360 native plant species. The site is owned and managed by the Missouri Prairie Foundation and was designated a National Natural Landmark in 1975 by the National Park Service. The presence of Arkansas darters in a headwater stream is unusual for an upland prairie but is attributable to the presence of a spring that feeds the stream here. Management consists primarily of spot treatments of invasive, exotic species and prescribed burning.

Photo courtesy of Missouri Prairie Founation

Golden Prairie Natural Area.

Natural Area Delisting

Cordgrass Bottoms Natural Area is a 76-acre site in Linn County located in Pershing State Park (Missouri Department of Natural Resources). The area was designated as a Missouri Natural Area in 1979 for its wet bottomland prairie community which was dominated by cordgrass and other distinctive prairie associates. Unfortunately, since 1979 the wet bottomland prairie has been irrevocably destroyed by excessive flooding and sedimentation from Locust Creek, the primary stream in the area which has been channelized for many miles upstream of the park. Cordgrass Bottoms formerly supported a vibrant wet bottomland prairie but is now a sediment-laden silver maple and willow thicket. In the past 30 years, numerous feet of fine, silty sediment has accrued due to unnatural flood events caused by ditching and land clearing upstream. No traces of the signature flora of the wet bottomland prairie exist here today. Because the natural community for which this natural area was designated has been irreparably damaged, MoNAC agreed that it was in the best interest of the Natural Areas Program to remove this site from the system following a visit to the site in May, 2013. Delisting a natural area from the system must be vetted at two separate MoNAC meetings as a precaution against hasty natural area delistings. Following the site visit in 2013, the delisting of Cordgrass Bottoms occurred at the May 2014 meeting. The recent expansion of Pershing State Park and wetland restoration efforts on this land (the Zell Tract) will hopefully abate some of the threats to the remaining wet bottomland prairie on the park.

Mike Leahy is Natural Areas Coordinator with the Missouri Department of Conservation

Contact: Mike.Leahy@mdc.mo.gov

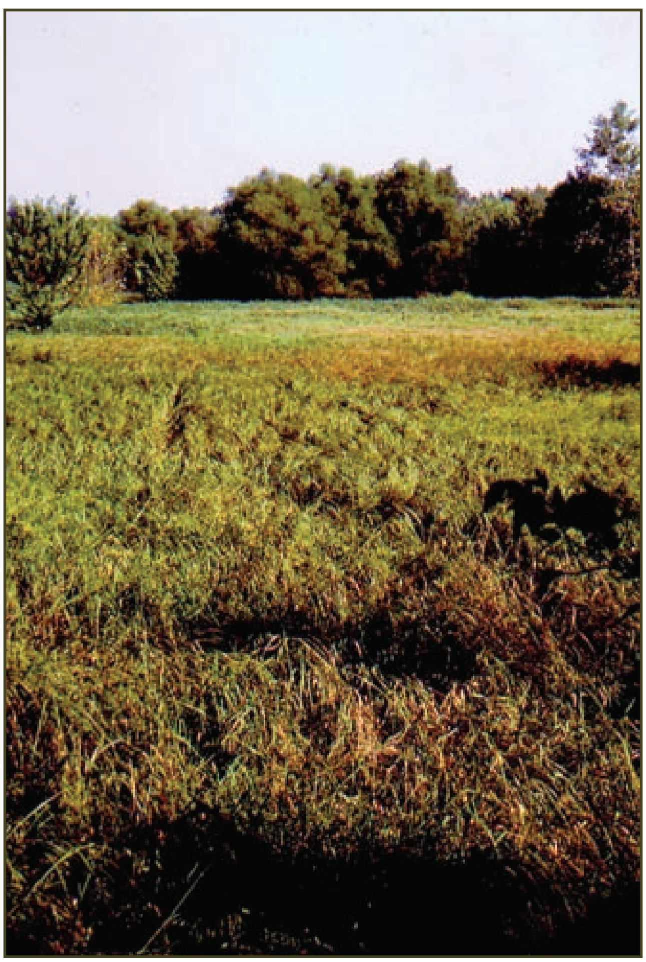


Photo courtesy of Missouri Department of Natural Resources

Cordgrass Bottoms Natural Area at time of designation, 1978.

Photo by Tom Woodward

Cordgrass Bottoms Natural Area today.

Calendar Of Events

December 20, 2014 • 8:00–10:30 am

Birding at the Audubon Center at Riverlands

West Alton, MO

Free and open to the public.
Details: <http://riverlands.audubon.org/events/birding-trip-riverlands-dec-20-8-1030a>

January 13, 2015 • 1:00 pm

Oak Woodlands and Forests Fire Consortium sponsored Webinar

Join online: <https://forestry.adobeconnect.com/_a1140350139/r8rvswg0fmi>

Managing vegetation composition and structure in fields using prescribed fire and combinations of fire and other treatments by John Gruchy, Private Lands Habitat Program Coordinator, Mississippi Department of Wildlife, Fisheries, and Parks.

February 4–6, 2015

Missouri Natural Resources Conference, Osage Beach, MO

"Values of Conservation: Fostering Natural Resources Appreciation through Research, Management, and Outreach" . Registration information: <http://www.mnrc.org>

February 8–11, 2015

75th Midwest Fish and Wildlife Conference

Indianapolis, IN

Registration and details: <http://www.midwestfw.org>

February 13–16, 2015

Great Backyard Bird Count

Worldwide

For more details on this citizen science event, visit <http://gbbc.birdcount.org>

March 26, 2015

3rd Annual Missouri Botanical Symposium

Rolla, MO

Registration information: <http://www.missouribotanicalsymposium.org>

November 3–5, 2015

Natural Areas Conference

Little Rock, AR

Registration and detail: <http://www.naturalareas.org/conference>