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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"

Editor's Note

Missouri's Botanical Diversity

Native plant communities are among the defining facets of a terrestrial natural community, and their integrity serves as one bellwether for designated natural areas. One can judge the native quality of a given terrestrial community based on the plant community and lack of degradation, most often associated with an intact soil profile. Every native plant community in Missouri has somehow witnessed anthropogenic and natural forces throughout history, whether fire, grazing, windstorms, ice storms, and other disturbances. The Age of Extraction following European settlement undoubtedly changed the face of Missouri's plant communities, in many cases completely destroying them, as is the case with so many of our presettlement

Photo by Allison J. Vaughn

A typical vegetation sampling frame along a transect in the Ha Ha Tonka Oak Woodland Natural Area. Among the more stable systems in Missouri, Ha Ha Tonka State Park's woodlands remain highly diverse and managed with a regularly occurring dormant season prescribed fire regime. The heterogeneous mix of forbs, grasses and sedges in the 2,995 acre natural area represents what many ecologists consider a high quality site.

prairie landscapes. Resiliency of native plant communities can only go so far.

While no native plant community is "pristine" in Missouri, we are fortunate to harbor 192 designated natural areas, with some, such as Brickyard Hill Loess Mound Natural Area (featured in this issue), expanding thanks to careful active management and fortuitous land acquisition. As ecologists, landowners, and Missouri citizens charged with protecting our remaining native landscapes for future generations, it is incumbent that careful management techniques are employed not only on natural areas. The threats to native quality are ubiquitous, whether invasive species encroachment, animal overpopulation, changing weather patterns, and limited management resources. Mitigation requires careful, but deliberate, active management.

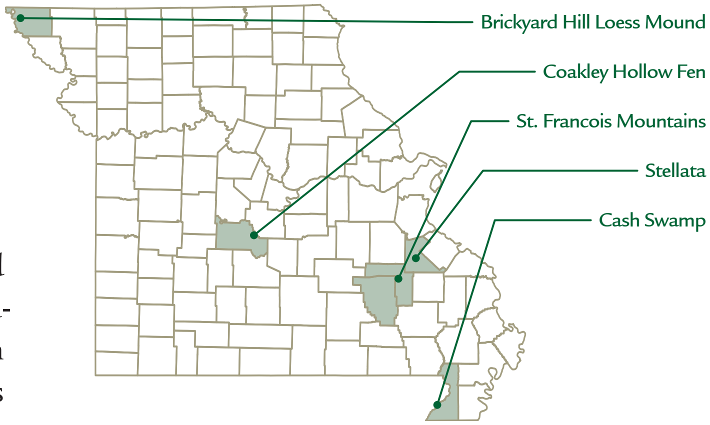
In this issue of the Missouri Natural Areas Newsletter, we'll hear from botanists throughout Missouri who will discuss threats to our native plant communities, the latest science and research in the field of genetics, and larger concepts like the need for stability through management. This edition will also feature articles on some of our rare plant communities, those that exist in Missouri at the edge of range in our situation in America. In Natural Area News, read on about the recent natural area designation at St. Joe State Park, largely recognized for its off-road vehicle trails, but home to high quality woodlands and glades. Several of the articles in this newsletter include open-ended questions or offer room for discussion, creating a path for dialogue and the exchange of ideas to help all of us better protect our native plant and terrestrial natural communities. I hope you enjoy this issue about botany as we enter the cold, dark spells of the winter months ahead.

— Allison J. Vaughn, editor

Allison J. Vaughn is the Natural Areas Coordinator with the Missouri Department of Natural Resources.

Contact: allison.vaughn@dnr.mo.gov

NATURAL AREAS FEATURED IN THIS ISSUE



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NATURAL AREA NEWS

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.

Photo by Justin Thomas

The complex color palette and textures emerging from the backlit leaves of *Tripsacum dactyloides* (Eastern Gamagrass) in early Autumn.

On the Nature of Being

by Justin Thomas

To proactively, and progressively interact with nature, the nature of it all, as managers of landscapes, researchers, and as informed citizens, we must fully open ourselves to its complexity and therein seek understanding. The degree that we grasp complexity and understanding is the degree to which we will succeed in honoring it. One cannot simultaneously protect complexity and ignore it. After all, there is a richly rounded, earthy, and simultaneously ripe, unripe, and overly ripe functionality moving and shaping, poking and prodding, the nature of reality along its inevitable path of destiny. A destiny that is by its nature both directed and random – the influence of each being a matter of relevant temporal and spatial scales.

If when tinkering with systems we are not aware of the ascendent qualities of collective processes, chaos becomes a runaway train. When we acknowledge, understand, and truly honor the directionality and ordered processes of systems, the inherent and deeply evolved patterns of assembly coalesce into a functionally dynamic state we can barely fathom. The reverse of this is also informative, such that when we detect chaos, when we are cognizant of the signs, we can track down the sources of problems and correct them. Yet we must also be acutely conscious that our interpretations are not actual reality but mere constructs based on assumptions and methodologies that themselves are prone to error. As such, we must be a certain way in order to understand and respond to certain things. How we are determines how we respond. This leaves us with the question: how do we need to be?

When we perceive ourselves as separate from living systems we cannot understand them because our perceived separateness is an illusion. We must see our lives, our depth of concern, and our willingness to sacrifice our human wills as embedded features of living systems. Our honest participation requires understanding and our understanding requires honest participation. Yet, too many of us merely entertain an understanding of the processes that support functional dynamism. Others traditionally limit their perspective to one conventional school of thought or another and are lost in translation. Though we mean well, this lack of deep entanglement denigrates the more than human world.

We call it "the outside," that which is other than us, plaguing it with difference and us with indifference — distancing ourselves from the formulae of life that constantly unfold in wonderous and magical ways — not just around us, but within us. We further hide much of this conflict behind our festering sense of callous helplessness — dispatches from the world of wounds. We dodge and deny those flare-ups of raw realty wherein we see just how truly abusive, dismissive, and broken the minds of modern humans are and how that brokenness manifests as the disturbance, devastation, and de-evolution of the sacred — the destabilization of the more than human world that cradles us. We have cast ourselves as the cursed in this self-imposed paradox of false dichotomies. The only fruitful way forward is to consciously transcend how we are for how we need to be.

We fear few things more than the onerous goal of reshaping ourselves. Yet, we also claim the ability to restore, recreate, and reimagine the natural process of natural areas — something we have vastly less control of than our own personal lives. We proceed as though all of nature were brick and mortar — as if nature were merely stone to be chipped and shaved by the barrage of novel epiphanies we share on paper. In reality, the living processes of natural systems contort themselves fluidly as functionality is generated by the spiralingly autocatalytic, the rapturously emergent, and the miraculously ascendant qualities of dynamically stable ecological systems at temporal and spatial scales we have barely begun to consider. It needs little more than patience, compassion, and understanding from us. It is our inability to offer these concessions that clogs the functional gears of recovery and neuters the efficacy of our management. It is our expectations, based on our blind experience, blatant disconnect, and misappropriation of bias, that haunt us.

Just as the thermodynamically-driven evolution of individual lifeforms is generated and maintained by consistently rhythmic selective pressures over relative and multidimensional notes of time, the formation of natural communities is insisted upon and codified by the predictable and inherently creative processes that emerge and intertwine over even deeper time. The less we understand this, the farther into the dark recesses of simplicity and dispossessed embeddedness we cast it and ourselves. Nature's true complexity manifests in each participant lifeform, their combined interactions, and beyond. These deeply creative processes drip with both history and destiny, history and destiny that hinge on the desire and intent for a peacefully knowable tomorrow. After all, evolution is merely the predictive power of living information. Do we want something different? Are we not the same? This elaborately dancing array of complex functionality is so much more than we dare to fathom. Yet some believe that these living processes condensed into a default functionalism through chaos and disturbance — that nature is more accident than intention. Yet, nothing could be more contrary to the evidence.

Photo by Justin Thomas

Damaged ecological systems express chaos and dysfunction in many ways. Here, the common *Liatris squarrossa* var. *hirsuta* (left) is hybridizing (middle) with the state rare *Liatris mucronata* (right) in response to rapidly altered stability. Understanding the ecological complexities of breeding systems and how they behave under stable versus unnatural conditions requires an appreciation that transcends conventional concepts of management.

Because tomorrow's harmony has always been a function of yesterday, we cannot so drastically change the rules of the game now and expect perpetual sustainability. We cannot simultaneously claim to protect the living past's right to tomorrow and deny its curve along the arc of destiny. Doing so generates chaos and discord. Even when truth is a relative term, it depends on consistency. That consistency, that truth, is expressed in the individual and collective behaviors of lifeforms and their roles in ecological processes governed by complexity and stability. To change that, to ignore that, to not be fully cognizant, degrades it. From quantum entanglement to the Big Bang, from the minutely uncertain to the universally certain, there remains a prescient fact that life requires repeatable patterns and the requisite time and space to unfold them. Science's ultimate responsibility is to understand, honor, and communicate this. No natural area will persist without deeper understandings and more intermeshed behaviors than we currently possess.

The inherent ecological embeddedness of lifeforms define communities by the orchestrated adaptations which extend well beyond the lifeforms themselves. These community-based spatial-temporal engendered processes transcend the mere coevolution of lifeforms and manifest as concerted expressions and collective contributions to a stable ecological dynamism. As such, lifeforms are both co-creators and benefactor of process. This emergent, autocatalytic, and dialectic phenomenology of nature is the very soul of ecology. It is time we accepted it as such and communicated our observations of it via this framework. Falling short of this, is missing the target altogether.

One might argue that reality is not patterned complexity, that nature is regularly battered by the ravages of the aleatoric, that nature is cruel and unpredictable, that nature picks winners and losers, that if it could burn it would burn, that harvested forests are healthy forests, that lifeforms are the random benefactors or victims of dumb luck and vicious competition. Nothing could be more mistaken, in light of what is demonstrably real.

By definition, chaotic, aggressive, invasive, and destructive events degrade the stable complexity of deeply functional processes and are antithetical to the vast majority of life. Though unpredictable and temporary, competitive forces do occur, but not at high enough historical frequencies to dissuade stable trajectories at landscape scales. They are relative phenomena, not absolute phenomena. This is one of the greater elements of their grandeur. If they were absolute then the stability upon which complex ecological systems rest, as described above, would not have arisen nor would they currently exist. More simply, ecologically damaging events by definition are rare, scaled-down, and specialized in expression or the intricately assorted lifeforms and communities we know today, whose niches define natural communities, would not have evolved nor would they have persisted. You can't have both degradation and functional community complexity. Though both occur in nature, they are antithetical. Each is the relative absence of the other.

Certainly chaos naturally plays a role in the processes of natural communities, but it is naturally restricted to very small and relatively frequent spatial scales, or exceedingly rare at large temporal and spatial scales — a tip-up mound versus a meteor impact. These are not phenomena that need to be or should be emulated or magnified. The very nature of the unexpected is that is it accidental not intentional. Prescribed chaos is oxymoronic, especially when the goal is to understand processes and where understanding is best achieved by a reduction of the stochastic — and lost in its conflation with order.

The behaviors of ecologically untethered lifeforms — weeds — that emerge from chaos attest to this small-scale and infrequency in nature. For plants, these behaviors include semelparity, profuse seed production, long distance seed dispersal, and long persisting seed banks. These are attributes of lifeforms that express in responses to damaged and destabilized systems because they are infrequent and unpredictable. These are the 'Hail Mary' strategies of the gambler. They are analogous to platelets in the blood in that they have a singular and simple purpose (lack complexity). Their deployment is rare, temporary, and in response to damage. They form the occasional scab needed in an otherwise vastly intact and interwoven anatomy. Such plants represent a mere ten percent of our native flora.

In contrast, 90 percent of our native flora, which historically constituted the vast majority of biomass, requires stable dynamism. These are community contributors. They are interoparous, produce few seeds, disperse seeds locally, are long-lived, and have short-lived seed banks. Such plants and their analogous fauna are the normal state of being. They are the altitude and speed at which the system cruises, in contrast to scab producing events, which are analogous to deviations from the normal as well as outright systems crashes. In short, scabs are important relative to damaged systems, but they are indicators of lost functionality, of systems set adrift on the winds of chaos, not holistic natural community continuity. Their expression is a sign of lost ecological complexity and function, especially when they become dominant landscape characteristics in response to a lack of human understanding. We are terribly far from a deep acceptance or innate understanding of these basic heuristics.

Functional ecological systems are not composed of disparate and isolated lifeforms but of processes consisting of and driven by lifeforms — the lifeforms themselves also being processes. Understanding these processes, at all scales, as best as we can, should be the precursor and prerequisite to ecological management. The success of ecological management must be measured by the manifestations of lifeforms as indicators of the underlying processes at play. This requires an extensive knowledge of not only processes and lifeforms but also the interplay of their stable dynamism. This is how we must see and how we must be if we are to properly engage these systems. Otherwise, we need to clearly define where we are making concessions and define what the ramifications of these concessions are.

Ignoring process is not an option. We cannot simultaneously claim to protect delicate balances, promote process, AND excuse our failings when chaos is gradually overwhelming the descending scales of cooperative ecological complexity and leaving nothing but simple, general, degraded, orderless, and novel remains. A community that loses its complexity, loses its identity. We are no different. We cannot be healthier, more complex, more resilient, more diverse, more inspired and dynamic than the landscapes in which we live.

Justin Thomas is the Science Director of NatureCite
Contact: jthomas@botanytraining.com

A recent research project involving the relationships between soils, vegetation, and hydrology of Karst Fens in the Ozarks is raising many questions about our perceptions of reference condition community types.

Photo by Justin Thomas

Photo by Andrew Braun

Figure 1. Fireweed (*Erechtities hieracifolius*) growing near a dying post oak (*Quercus stellata*) in an otherwise undisturbed woodland.

Too Much of a Good Thing: Nutrient Excesses in Missouri's Natural Communities

by Andrew Braun

Historical accounts (Schoolcraft 1821) and analysis of historic records and data (Beilman and Brenner 1951, Schroeder 1981) suggest that Missouri was once dominated by natural communities with an open character, that is, considerably fewer trees than seen today, as well as more continuous cover of grasses and forbs. Disturbances such as fire, flooding, and grazing are assumed to have maintained this ecological state, and are used strategically today to attain these structural states (Nelson 2010). Logging, mowing, herbicide and other applied disturbances or stresses are also used in natural community management.

Despite many successes, this perspective and the related approaches to natural community management have failed to explain the often contradictory, confusing, or simply negative (indicated by a decrease in conservative flora, and often an increase in weedy flora) responses to these disturbances seen in many ecological restoration and maintenance efforts. One prairie may be nearly shrubless and dominated by a stable mix of conservative herbaceous species, while another prairie a few miles away becomes dominated by sumac and rough dogwood, with increases in hardwood tree species cover. Opinions range from "not enough disturbance" to "the wrong type of disturbance" to "too much disturbance," but clear explanatory ecological mechanisms have proven difficult to come by. Concerns about atmospheric increases in carbon dioxide or industrial and agricultural pollution are certainly well-founded, but it seems that if this were the overriding factor, all of our natural areas would be degraded, which is not the case.

A review of literature and discussions with other ecologists have brought attention to the role of nitrogen availability in terrestrial natural communities. Though much literature exists on ecological nutrient dynamics, it appears poorly recognized in ecological management and monitoring considerations. Many gaps in knowledge exist, and easy answers are nearly always insufficient, but the perspective of nutrient limitation may be a promising, fresh way to examine how Missouri's natural communities work. A review of relevant literature and regionally-appropriate syntheses and hypotheses hopefully prompts further conversations and research. It is hoped that those conversations and research lead to a closer approximation of a true understanding of how our natural communities work and respond to management, so that their ecological integrity and complexity may be maintained in perpetuity.

Nutrient Limitation

Organisms require resources for growth and reproduction, some of which are scarce, and so organisms and their populations do not grow indefinitely. This simple concept is well-known as a foundational fact of ecology. In terrestrial systems, different soils, landscape positions, and climates clearly affect water and light availability. Water and light are critical resources for plants, as are soil nutrients, in particular nitrogen (N), phosphorous, and potassium. In many natural systems, N is the limiting nutrient — primary producers can only construct as much biomass as the combination of actual N availability and their own physiological mechanisms for putting the N to use (nitrogen use efficiency) allows. Vascular plants dominate most terrestrial systems as primary producers. Plants have adapted to differing amounts of N with different strategies in growth, reproduction, defense, and competition.

Instead of discussing nutrient dynamics in the abstract, several examples that could realistically be found in the Missouri Ozarks or tallgrass prairies will be discussed below.

An Ozark Chert Woodland

A group generally adapted to low N situations is the heath family (Ericaceae), often found growing in infertile conditions like sphagnum bogs or, in the case of Missouri's lowbush blueberry (*Vaccinium pallidum*), cherty woodlands with very little nutrient availability. Species adapted to low N soils often grow relatively slowly, and maintain tissues like leaves (where a lot of scarce N is used) for relatively long amounts of time. Species taking up small amounts of N consequently produce tissues with small amounts of N, which returns small amounts of N to the soil upon death of that tissue, thus maintaining a relatively low amplitude of nitrogen cycling — a little up, a little back down. Low N availability is complemented by the relatively dry conditions in these communities, leading to rather low productivity. Other species found in dry, acidic woodlands, like shortleaf pine (*Pinus echinata)*, blackjack oak (*Quercus marilandica)*, and little bluestem (*Schizachyrium scoparium*) (Nelson 2010), are also adapted to low-N situations and can be termed "low-N species" (Perry et al. 2010). Assuming no increases in N, this community may continue on relatively unchanged for a long time. The term used for these sorts of low-productivity, nutrient-limited communities (more often used in aquatic systems, but no less appropriate for terrestrial systems (Rawinski 1992)) is "oligotrophic."

Nearby, a post oak (*Quercus stellata*) dies a natural death, succumbing to disease and stress. Decades or even centuries of accumulated nutrients in the roots are released upon decomposition, leading to a flush of nutrients. Additionally, the tree is no longer dominating the local soil nitrogen supply — a free-for-all ensues in the space once controlled by the oak. The sudden opening of the canopy also increases light availability. Seeds of fireweed (*Erechtites hieracifolius*), mare's tail (*Conyza canadensis*), black raspberry (*Rubus occidentalis*), pokeweed (*Phytolacca americana*), and other "weedy" species, sensing one or more of the shifts in resource availability, germinate and grow (Figure 1).

In contrast to the low-N species, these plants grow fast, incorporating as much as the nitrogen flush into biomass as possible. Events like this were historically small-scale, random, and ephemeral, so time is of the essence, especially because N is easily washed away by precipitation. High N availability leads to fast and tall growth, but as neighboring vegetation is also taking advantage of the nutrient flush, the possibility of becoming overtopped and shaded tends to select for plant species with a strategy of competing for light, not nutrients. Vining plants, able to quickly clamber over their competitors, tend to be abundant in these sorts of situations. Mare's tail can be occasionally found in low-N situations at an inch or two tall with a few flowers, but here, with high resource availability and the trait of indeterminate growth, mare's tail soaks up all it can, growing chest-high and producing hundreds of flowers. Leaves and other tissues for these "high-N" or "nitrophilic" species are relatively "cheap" to make, and can be dropped as soon as they are shaded out and of little use in the struggle for light. When these species die, their N-rich tissues are quickly decomposed and N is eventually returned to a plant-available state, increasing the amplitude of N-cycling around the dead tree (Perry et al. 2010). The local community has become "eutrophic." Many of these high-N species have adapted to the unpredictability of nutrient flushes by casting seeds far and wide by wind or bird dispersal in the hopes that at least some of them soon find themselves in a similarly fertile location. The seedbank of the woodland is loaded with nitrophilic plant seeds, waiting for the next nutrient flush.

If you've taken a walk through a recently-logged Ozark woodland, you've probably noticed these same species present. Blackberries (*Rubus* spp.), in particular, seem to do well in disturbed woodlands. Experiments in Minnesota (Tilman 1987), Quebec (Jobidon 1993), and West Virginia (Walter et al. 2016) have demonstrated a sharp increase in abundance of *Rubus* following N fertilization. Soil disturbance tends to increase N availability by removing or damaging the vascular tissue of resident plants, or even inducing complete mortality of plants that would have otherwise taken up N, and by disrupting the dynamics between living plants, dead plant tissue, soils, and microbes (Davis et al. 2000). More directly, cutting a tree, even with no other soil disturbance, similarly reduces the tree's ability to uptake N. With altered N pathways, an excess develops (Vitousek 1981). During this time, accumulating N may induce germination of *Rubus* and other nitrophilic species. Increased light availability also would favor nitrophilic species. It seems reasonable to conclude that increases of *Rubus* in Ozark woodlands indicate eutrophic conditions.

Many of the conservative plants found in Ozark woodlands are adapted to oligotrophic or mesotrophic conditions, where competition for nutrients is more important than competition for light. Increasing N availability favors weedy plant assemblages that grow fast and tall and may outcompete conservative plants. Loss of conservative plants and a feedback loop of increasing nitrogen may lead to an alternative stable state long after the original disturbance has passed. Conservative species may take a long time to become reestablished, if they are ever able to do so at all.

An Osage Plains Prairie

High-quality, undisturbed tallgrass prairies are dominated by C4 grasses and low-N perennial forbs. Though the total nutrient pool is high in prairie soils (hence their productivity that made them so useful in agriculture), it's likely that nutrients are relatively unavailable in the dense mass of roots of prairie sod, where nutrient competition is strong. This stands in contrast to the chert woodland, which has a lower overall N pool. However, some species overlap is evident, such as little bluestem and big bluestem (*Andropogon gerardii*), legumes like slender lespedeza (*Lespedeza virginiana*) and asters like rough blazing start (*Liatris aspera*) (Nelson 2010). Legumes (family Fabaceae) can be abundant and diverse in either situation because of their ability to facilitate N-fixing bacteria in root nodules when N availability is low (Vitousek et al. 2002). Similar to the chert woodland, and most other intact natural communities, conservation of nutrients through the system promotes a stable structure and composition that may continue relatively unchanged without severe disturbance or nutrient inputs. Though the processes are not fully understood, there are some species in the *Andropogoneae* supertribe (represented in Missouri by bluestems and broomsedges, *Andropogon* spp. and *S. scoparium*) which may be able to alter the nitrogen cycle in soils where they dominate (Lata et al. 2004). At any rate, these plants are low-N species that are adapted to incorporating relatively little N into tissues, which returns relatively little N to the soil during senescence.

A droughty August leads to excessively dry thatch, and a wildfire is able to easily burn through the prairie. Grass and forb stems are singed to the ground. Shortly after the fire has passed, the bacterial community's part in the N cycle resumes, but the damaged plants are unable to uptake any N, a condition worsened by the ongoing drought. Similar to the logged Ozark woodland, excess N builds up in the soil. When rain finally comes, the N becomes available to the prairie plants, but also seeds of nitrophilic plants, triggering an expression of blackberries and other weedy species.

A meta-analysis of 87 studies on fire effects on N dynamics (Wan et al. 2001) found consistent increases in N availability (NO_3, but especially NH_4, which doubled in availability) in response to fire. Knoepp and Swank (1993) suggested that fire could cause N to volatize from soil organic matter, then move downwards in the soil and condense, as well as facilitate conversion of organic N to plant-available N (mineralization) from changes in soil biotic and abiotic factors. In addition to reduced uptake, these processes can increase N availability.

Seeds of sumac (*Rhus glabra* and *R. copallinum*) wait in the soil. This group of sumacs, *Rhus* sect. *Sumac*, includes *R. typhin*a of eastern North America and *R. coriaria* and *R. javanica* of Asia (among others). Germination in *Rhus* sect. *Sumac* is well-documented to be facilitated by heat treatment, which cracks the hard outer coat and allows water to permeate the seed of both Asian species (Washitani and Takenaka 1986, Doussi and Thanos 1994, Ne'eman et al. 1999) and North American species (Li et al. 1999, Cain and Shelton 2003), a trait interpreted by some authors as a direct adaptation or indirect facultative response to fire. Old fields and disturbed roadsides throughout Missouri that have apparently not burned often harbor sumac, so clearly fire is not always necessary for the recruitment of sumac, but it does appear to help.

Photo by Andrew Braun

Figure 2. Winged sumac (*Rhus copallina,* red autumnal leaves) dominates this frequently-burned prairie in southwest Missouri. Shown is about 6 months of basal resprout growth after a March prescribed fire. The red tinge of sumac can be seen in the far background.

Upon germination and establishment, sumac grows quickly, and spreads its leaves from the top of the erect stem, gathering all the sunlight it can in an umbrella-like form. Leaves are not typically produced lower on the stem. Damage to the stem can induce clonal growth, with hundreds of ramets (individual stems) belonging to one genet (genetically distinct individual). Extensive areas of prairie can become dominated by sumac (Figure 2). Sumac is capable of vigorous resprouting. Greenhouse experiments in China, where *R. typhina* is considered invasive, found that species to exhibit traits related to fast growth and nutrient responsiveness (Yuan et al. 2013) and high light acquisition and competition (Zhang et al. 2009, Tan et al. 2018), traits that often provide a competitive advantage in nutrient-enriched soils.

It seems that the architecture and behavior of sumac is that of a disturbance-adapted species. Lower stem leaves would not be useful in areas with high N, as they would quickly be shaded by competing vegetation. Prioritization of fast vertical growth would give sumac the advantage in the competition for light. Clonal growth may further provide access to nutrients and light. If this is true, then sumac dominance on a prairie may indicate increased N availability. Increased N availability in this case, as discussed above, may be a result of damage to the plant community. Dense sumac clones tend to facilitate invasion of hardwood trees species (Aikman 1928, Petranka and McPherson 1979), further accelerating conversion to tree and shrub-dominated community types.

In the dormant season, prairie vegetation is not uptaking N. Any N inputs in the dormant season would likely be washed away in precipitation or otherwise immobilized. A fire at this time may therefore not effect growing-season N availability to plants, and prevent a weedy response.

Additionally, any N in standing litter would be volatized away in the fire, further reducing N availability when decomposers become active again in the spring. A fire in the spring that damages spring ephemerals may disrupt seasonal nutrient dynamics, as this group of species tends to be made up of high-N plants that may significantly influence N movement (Muller and Bormann 1976, Blank et al. 1980, but for a contrasting perspective see Rothstein 2000). Few studies on fire seasonality exist, but one from a Kansas prairie found that in the long-term (10 years), low-intensity, dormant-season (November and February) fire reduced *R. glabra* significantly more than growing-season (April and July) fire (Hajny et al. 2011). It's possible that these nutrient dynamics are responsible for the observed differences in fire seasonality.

Fire is the most time and cost-effective way to manage biomass and nutrient levels in prairies and woodlands. More research related to species-level and nutrient effects in our region should be undertaken to further our understanding of the dynamics between low-N, conservative species, high-N shrubs and weedy species, nutrients, and fire.

An Ozark Dolomite Glade

Ozark dolomite glades with intact topsoil strongly resemble prairies, because they essentially are prairies. They are dominated by C4 grasses and low-N forbs growing in shallow, mollic soils — consequences of prairie processes. Exposed bedrock zones with little or no topsoil are found scattered in glades as a consequence of local geomorphology. These differ from the prairie-like zones of glades by their lack of complex soils and tendency to be dominated by short-statured, short-lived grasses and forbs like annual *Sporobolus* spp., *Rudbeckia missouriensis*, *Leavenworthia uniflora*, and others.

The thin mantle of mollisol (prairie soil) on Ozark glades can easily be disrupted by grazing, leading to erosion of soil and exposure of bare rock. Loss of topsoil removes large amounts of N from the local nutrient pool (Perry et al. 2010), leaving only species adapted to low, primary-succession levels of N availability. Nearly all of the Ozarks has suffered from historic open-range grazing, and it's likely that nearly all glades were at least somewhat impacted by post-European settlement grazing practices.

Records from General Land Office survey notes in the first half of the 19th century suggest that Eastern red cedar (*Juniperus virginiana*) was relatively rare in Missouri at the time. Almost all records are near large to moderate-sized rivers, presumably associated with cliff communities (Nelson 2010). The highly-erodable nature and sparse vegetation of sheer cliffs likely precludes development of complex soils, preventing large accumulations of N. It is presumed that cliffs protected cedar from historic fires, which excluded them from most of the landscape, but at least part of the explanation could be that cedars (and conifers in general) do not compete well with flowering plants in intact soils with relatively high N (Berendese and Scheffer 2009). In arid western North America, where *Juniperus* diversity is high, these species are often found in dry soils with little topsoil development. Long tissue life, long overall plant life (some individuals being >1000 years old), low N concentrations (Wall et al. 2001 in Miller et al. 2005), ability to grow in rather infertile soils, low responsiveness to fertilization (Thomas et al. 2007) and digestibility reducers (phenolics, Dearing et al. 2005) appear to put *Juniperus* in the low-N side of the spectrum. British researchers assigned a circumboreal species, *J. communis*, a value of 3 (on a 0 to 9 scale) as an indicator of soil fertility (N scale of British Ellenberg's Indicator Values, Hill et al. 1999).

Photo by Andrew Braun

Figure 3. An apparently highly-intact patch of dolomite glade in southwest Missouri that has not burned in recent history, but has almost no woody species present, despite being situated in a cedar glade and oak woodland-dominated landscape. Several highly conservative species are present.

Cedars are certainly not a fire tolerant species, so prescribed fire does exclude recruitment. However, another explanation for the encroachment of cedar onto glades and thin-soiled woodlands in the Ozarks could be that post-settlement European grazing practices led to the erosion of thin glade topsoil, creating low-N conditions that few species other than cedar could utilize. Consider agricultural fields that were historically heavily disturbed, leading to a complete loss of topsoil. Upon abandonment, these often eventually become cedar monocultures. Grazing has been discussed as a factor in *Juniperus* encroachment elsewhere (McPherson et al. 1988, Schmidt and Stubbendieck 1993, Briggs et al. 2002). Once cedars could move from the cliff edges to adjacent glades and their expanded bedrock, shallow-soil zones, populations increased and propagule pressure could increase to the point where nearly any small erosive disturbance on a glade could invite recruitment of cedar. In this way, the invasion of cedar is different than the other types of community change discussed above, but still are worth examining through the perspective of nutrient limitation as a case study.

Very few undisturbed glades exist in Missouri, but the rare extant examples, such as the one in Figure 3, appear to have almost no woody recruitment (cedar or otherwise), even in unburned, cedar-dense landscapes. The strong competitive ability of grassland species excludes cedar from intact glade soils. While soil recovery takes place in disturbed glades and cedar recruitment is active, fire can reduce cedar survival, but understanding the mechanisms leading to their appearance in the first place is important for understanding how these communities and their constituent flora work.

Where Next?

In summary, most of our highest-quality plant communities and the conservative species that compose them are defined, in large part, by nutrient limitation. However, historic and current disturbances have not left us with many places that are completely stable in this regard. Perry et al. (2010) provide an excellent review of different tools and strategies for managing nutrients to limit invasive species incursions, but as Davis et al. (2000) point out, there is little reason to differentiate between shifts in dominance to native weedy species or exotic species, as both groups are indicators of shifts in ecosystems processes (in this case, nutrient availability). Perry et al. point out that avoiding the disturbance that increases limiting nutrient availability is the most effective way to limit invasion, but we are past that point in many places. So what do we do from here?

More research is needed to understand exactly how fire, grazing, or other ecological disturbances and stresses can be used to reduce N availability in enriched natural communities, and maintain low N availability in already-stable or semi-stable situations. European researchers have developed an index of indicator values for each plant species in their region, where a given plant species' reaction to N availability (as well as light, acidity, moisture, and salinity) are placed on a zero to nine scale (Ellenberg 1979, 1988, Ellenberg et al. 1991). No such index appears to have been developed for any ecoregion in North America, but could be extremely useful for "reading" the flora of a natural community to estimate its trajectory — are there species that can serve as an "early warning" of increasing N availability, so that action can be taken before extensive destabilization occurs? If not a unidimensional scale, are there plant morphological and physiological syndromes that provide clues for nitrogen availability questions?

There is a tendency for...

Low-N plants to have	High-N plants to have
Low C:N ratios	**High** C:N ratios
Tissues that decompose **slowly**	Tissues that decompose **quickly**
A competitive ability for **nutrients**	A competitive ability for **light**
Slow growth	**Fast** growth
Thick/evergreen leaves	**Thin/deciduous** leaves
Lower herbivory pressure	**Higher** herbivory pressure
Tannins/digestibility reducers	**Alkaloids/toxic substances, spines/thorns/prickles**
Determinate growth (plant reacts little to excess N)	**Indeterminate** growth (plant continues growing as long as N is available)

Perhaps conspicuously absent from mention in this article are discussions of mycorrhizal fungal associations, other nutrient (e.g., phosphorous and carbon) availability, genotypic plasticity, or any myriad of other factors that are undoubtedly critical in community assemblage and function. How do they interact with N availability?

With the "more research needed" part written, it's important to mention that an extensive body of literature exists on this topic — much more than I was able to read in preparation for this article. The on-the-ground conservation community would benefit from diving into this literature and discussing it with others, including those who wrote that literature. They might be very interested to see how their research can be applied in practice. There's a good chance that many of the ideas that develop (including the ones in this article) end up being only part of the answer, or even completely wrong, but the perspective of N limitation does seem like a good place to start answering many of our questions regarding how to restore and maintain Missouri's natural communities.

Andrew Braun is a Natural Resource Ecologist for the Missouri Department of Natural Resources

Contact: andrew.braun@dnr.mo.gov

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Photo by Ron Colatskie

When in flower, the pale yellow inflorescence of Mead's milkweed sticks out like a sore thumb amongst prairie flora associates.

Canary in the Prairie: Saving Mead's Milkweed from Feral Hogs

by Ron Colatskie

In reference to his trip to the Sierra Madre Occidental Mountain Range in northern Mexico, Aldo Leopold recalled, "It was here that I first clearly realized that land is an organism, that all my life I had seen only sick land, whereas here was a biota still in perfect aboriginal health. The term 'unspoiled wilderness' took on a new meaning." In the Missouri Ozarks, finding even a few acres of what Leopold called 'perfect aboriginal health' is exceedingly rare. The cliché' 'everything is relative' is certainly applicable to ecologists as they compare the relative ecological quality of landscapes over a career.

One such 'aboriginal landscape' is tucked away on a steep hillside in the St. Francois Mountains, representing one of the Missouri Natural Area system's highest quality examples of an igneous glade. Situated in a state park about a two hour hike from the nearest parking area, the igneous glade is one of the most rugged and remote sites the Missouri State Park system has to offer. While human activities left their indelible marks on the majority of the Ozark landscape in southeast Missouri, this particular site was seemingly untouched.

When I first set foot on this igneous glade on a humid June day in 2013, I was struck by

Photo by Ron Colatskie

Feral hog damage is profoundly damaging to sensitive glade communities. Rocks are tossed like toys by their destructive rooting behavior, leaving barren pockets devoid of the once rich assemblage of glade flora

the remarkable quality of the flora. Artistically gnarled blackjack and post oaks peppered the hillside amongst a sea of big bluestem and Indian grass which concealed high quality prairie forbs such as white prairie clover, prairie parsley and glade coneflower. Aside from the steep, igneous-boulder-laden hillside, the visitor just has to tilt their head 30 degrees to see a prairie landscape reminiscent of the Osage Plains prairies 200 miles to the west. I was at the glade along with a team of surveyors to conduct stem counts for Mead's milkweed (*Asclepias meadii*), a federally threatened and signature species indicative of high quality prairie communities.

Mead's Milkweed is the proverbial canary in the coal mine for prairie communities due to its extreme sensitivity to ecological damage. The plant was once known to occur in prairies across the Midwest from Illinois to Kansas, with a specimen once even collected in west St. Louis County. By the late 20th century, Mead's milkweed was restricted to a handful of high quality prairie communities throughout its range.

Historic records for Mead's milkweed are exceptionally rare in the Missouri Ozarks. Russel Colton, a naturalist and member of the Engelmann Botanical Club based out of St. Louis, collected a specimen of Mead's milkweed on an igneous glade overlooking the Arcadia Valley in southeast Missouri in 1898. This earned Mead's milkweed a dot on a county presence map in Steyermark's *Flora of Missouri* in southeast Missouri. Mead's milkweed likely persisted on historic prairies and savannas that dotted the Farmington Plain, Belleview Valley and west to the Salem Plateau, hence the plant likely nestled its way into the igneous glade complexes of the St. Francois Mountains, which are essentially igneous prairies.

Ninety three years following Mr. Colton's discovery, ecologists representing a variety of agencies set out on the same glade complex I would visit 31 years later to gauge the success of a recent prescribed fire. Their objective was to observe how the glade flora responded to a prescribed fire, in an era when prescribed fire application was still controversial. They knew this particular igneous glade pocket was unusual in its high quality, so much so that several members of the group discussed the possibility of Mead's milkweed showing its face on this particular visit.

Sure enough, one of the ecologists spotted the alien-like pale-yellow dangling inflorescence of Mead's milkweed, which sticks out like a sore thumb amongst the dark green prairie grasses. So surprised with their find, they gathered around the solitary stem in amazement, questioning the reality of the moment. It was the first observation of Mead's milkweed in southeast Missouri in nearly a century.

In the years following the discovery, managers continued to apply prescribed fire to the igneous glade complexes in the region. Research has indicated Mead's milkweed flowers more readily and thus produces more seed following prescribed fire. Within a mile of the 1991 discovery, several other Mead's milkweed locations were discovered. Each time fire was applied, the number of flowering Mead's milkweed stems observed increased.

In the minds of ecologists, the future of Mead's milkweed conservation in this corner of the Missouri Ozarks was well and good. Just a handful of years down the road, in the late 90's, feral hogs were introduced into the region by unscrupulous individuals looking to offer a new hunting option. The result has been a nightmare for ecologists that have invested their careers in protecting and preserving these same landscapes.

The remoteness and inaccessibility that shielded Mead's milkweed from human activity, allowed feral hogs to thrive in the St. Francois Mountains landscape. The region serves as a core feral hog population in the southeast Missouri Ozarks, likely hosting the highest density of the feral hogs in the state.

On my first visit to the igneous glade in 2013 I had observed minimal feral hog damage in the wooded ridges above and in the bottoms below, but nothing in the glade itself. By my 2015 visit, that had changed; about 5–10% of the glade pocket had experienced some degree of feral hog damage. The feral hog rooting damage, where it did occur, was profoundly devastating. The feral hog bomb exploded in the mid-2010's along with the popularity of the feral hog hunting culture as it found its way into television shows, online forums and social media groups. Illegal releases were likely increasing along with the feral hog population.

As feral hogs search for food, their rooting is not a gentle brush stroke, it's a jackhammer to the flora and soil below. In the bottoms they may root more than a foot deep in search of anything edible including invertebrates, root material, ground-nesting birds, amphibians and small mammals. Biologists have found soil and rocks in feral hog gut contents upon dissection. Igneous boulders the size of microwaves were observed upended by feral hogs.

Efforts to control the feral hogs in the St. Francois Mountains and statewide have been ongoing since the first introductions in the late 90's. Managers came to realize they needed to utilize a variety of tools in their tool kit to eliminate hogs from the landscape including trapping, aerial-gunning via helicopter, and night shoots. A variety of entities including the Animal Plant Health Inspection Service (APHIS), Missouri Department of Conservation, the U.S. Forest Service, Missouri State Parks and adjacent landowners have all chipped in on the effort to rid the region and the state of feral hogs. To illustrate the herculean task before them, over 70% of a hog population must be removed per year to effect a reduction in their population given their exceptional reproductive potential.

By our 2018 survey of the Mead's milkweed population on the glade, we noticed more feral hog rooting with 15–20% of the glade impacted by some form of feral hog damage. Death by a thousand cuts. This survey was particularly tough to stomach as we observed stems of flowering Mead's milkweed knocked over by feral hog rooting, likely a day or two previous. Our GPS units took us to other known sites of Mead's milkweed colonies which were now eviscerated and replaced by weedy species. The thought occurred to us that these likely ancient assemblages of Mead's colonies, which may have persisted for hundreds if not thousands of years, were only to be destroyed by feral hogs just a few days prior to our visit.

Recent hog damage is easy to identify: a deep furrow of contrasting soil and stones stick out with still-moist plant roots upended. A trained ecological eye is needed to spot older feral hog damage. A lush carpet of conservative prairie grasses and forbs are replaced by bright green carpets of prairie tea (*Croton monanthogynus*) and wooly panic grass (*Dichanthelium lanuginosum*), both disturbophiles which thrive in feral hog damage. Reindeer lichen (*Cladonia rangiferina*) fill in the voids on igneous boulders which once hosted razor thin soils and glade flora.

On our last visit this summer, the long hike was replaced by a rough bone-jostling UTV ride on something resembling a road. Damage to the glade had ticked up slightly to 25–30% of the glade, but we're observing less recent feral hog damage and presence than we have in years past.

The reduced hog presence is due in part to a more cohesive effort to combat hogs in the region. A variety of agencies and entities have been working as a united front through the establishment and operation of the Missouri Feral Hog Elimination Partnership. The partnership treats the feral hog population in the state like a wildfire, whereby they snuff out 'spot fire' populations, whittle down on the periphery of the feral hog range and work their way down to the core and ultimately eliminate feral hogs in the state. Speaking to feral hog density in the region, one APHIS aerial gunning flight yielded over 300 hogs in the St. Francois Mountains in one day.

State park staff have also ramped up their efforts, growing their feral hog trapping efforts from an occasional solitary trap in previous years to routinely operating over seven traps across Johnson's Shut-ins and Taum Sauk Mountain State Parks. Over 160 hogs were removed from the park complex from March through November of 2020. The work likely isn't what these naturalists and ecologists signed up for in their career; routinely lifting heavy hog trap panels, hammering t-posts into rocky Ozark soil and wading through mud, blood and feces associated with feral hogs in all the variety of weather conditions Missouri has to offer. However, park staff understand that if hogs are allowed to persist here, it would be sacrilege to all of their and their predecessor's efforts to protect this museum piece of a natural landscape.

Mead's milkweed is just one of thousands of species of flora and fauna at stake in the war against feral hogs. We've come to learn that this effort requires non-stop momentum to accomplish. Taking our foot off of the gas in terms of our feral hog elimination efforts quickly yields the same hog densities in a few short years. It is also imperative that in addition to active removal of hogs on the landscape, we must highlight to the public the disastrous cost of feral hogs on our landscape and the recreational hog hunting culture. Pigs don't fly but they do hitch a ride in trailers, hence the rapid spread beyond a few miles of their range is certainly a result of illegal release to promote more recreational feral hog hunting opportunities.

Following efforts of the Missouri Feral Hog Elimination Partnership and cooperative landowners, the feral hog range is continuing to atrophy. There's light at the end of the tunnel. It is imperative feral hogs are not only managed but eliminated from the state so that Missouri's best and last examples of what Aldo Leopold called 'landscapes of perfect aboriginal health,' exhibited in many of our fine designated Missouri Natural Areas, persist for generations to come. ❧

Ron Colatskie is a Natural Resource Ecologist with the Missouri Department of Natural Resources

Contact: Ronald.colatskie@dnr.mo.gov

Two Mead's milkweed stems (upper center of the photograph) were observed knocked down following a feral hog rooting event, evidenced by jostled rocks and rooted soil.

Photo by Ron Colatskie

Factors Affecting the Viability of Mead's Milkweed, and Steps That Can Be Taken to Ensure Its Persistence

by Christine E. Edwards, Shannon M. Skarha, and Matthew A. Albrecht

Introduction

The genus Asclepias, the milkweeds, with their high diversity of 18 species in Missouri combined with important ecological interactions with insect pollinators (including serving as host plants for monarch butterfly larvae), as well as their presence in nearly all habitat types across the state, are among the most iconic and charismatic groups of plants in Missouri. Despite their ecological importance and popularity among ecologists and gardeners alike, however, some species of milkweeds in Missouri are declining. The most notable among them is Mead's milkweed (*Asclepias meadii)*, a species that has experienced such severe declines that it was listed as federally threatened under the U.S. Endangered Species Act. Mead's milkweed once occurred in six states (MO, KS, IA, IL, WI, IN), but it has been extirpated from Wisconsin and Indiana and only a few populations remain in Illinois and Iowa. Most remaining populations occupy high quality remnant prairies in eastern Kansas and western Missouri, as well as the rhyolite glades in the St. Francois Mountains of the Missouri Ozark Highlands.

Although the initial causes of the declines in Mead's milkweed were habitat loss, habitat degradation and population fragmentation, the species is facing ongoing declines because of low reproductive success. Mead's milkweed produces a single inflorescence, and successful sexual reproduction results in 1 to 2 seed pods per plant (Figure 1, page 25). Reproductive success varies among populations, with a few large populations successfully producing multiple seed pods each year, and the vast majority of populations producing very few or no fruits. Because reproduction is essential to the long-term persistence and sustainability of a species, the low levels of sexual reproduction in most populations of Mead's milkweed are a major cause for concern (USFWS, 2013). However, until recently, the underlying cause of the low reproductive success remained a mystery.

In the scientific literature, the main theory for the low rates of reproductive success observed in many populations of Mead's milkweed was low mate availability (USFWS, 2013). Most species of *Asclepias*, including *Asclepias meadii*, are self-incompatible (Broyles and Wyatt, 1993; Wyatt and Broyles, 1994; Wyatt et al., 1996; Lipow and Wyatt, 2000; Edens-Meier et al., 2017), which is a genetic mechanism that prevents reproduction through self-fertilization and that also limits inbreeding. Because individuals of self-incompatible species can only successfully mate with individuals that have a different mating type, the number of genetically distinct individuals and the relatedness of those individuals affects whether a population can successfully reproduce. Mead's milkweed is also clonal, so neighboring stems are frequently genetically identical and cannot successfully reproduce (Hayworth et al., 2001). Many authors have proposed that populations of Mead's milkweed may have only a small number of genetically distinct, closely related, highly clonal individuals, resulting in a lack of cross-compatible mates that prevents successful reproduction (e.g., Tecic et al., 1998; Hayworth et al., 2001). However, no study had specifically tested this theory.

Research Question: Is Low Genetic Diversity Due to a Lack of Suitable Mates?

The lack of reproduction due to low mate availability in a self-incompatible species is an example of an Allee effect, a phenomenon where having a sufficient number of individuals is necessary for the persistence and growth of populations (Stephens et al., 1999). An Allee effect is detected by finding a positive correlation between fitness (i.e., seed set) and the number or density of individuals of a species (Stephens et al., 1999). An Allee effect can be caused by various ecological or genetic factors (Stephens et al., 1999); the lack of reproduction because of a lack of genetically compatible mates is an example of an Allee effect caused by low genetic and genotypic diversity (Byers and Meagher, 1992; Willi et al., 2005; Wagenius et al., 2007; Luque et al., 2016). In this study, we tested for a genetic Allee effect in Mead's milkweed. The specific goals of the study were to 1) understand the factors (genetic diversity, genotypic richness, and/or other factors such as population size) that are most strongly correlated with reproductive success across populations of Mead's milkweed and 2) to determine whether the lack of reproduction observed in some populations is due to a lack of suitable mates because of self-incompatibility, high rates of clonality and low genetic diversity. Understanding the underlying cause of low reproductive success is important because it can help identify the specific management actions that can be used to address the problem; thus, another goal of the study was to determine how

Photos by Christine E. Edwards

Reproductive stages of *Asclepias meadii*; top: flowering umbel; middle: maturing seed pod (follicle); bottom: mature seedpod with seeds, collected from the St. Francois Mountains.

to manage populations of Mead's milkweed to increase reproductive success.

To answer these questions, we genotyped and tracked the reproductive success of every individual in 12 populations of Mead's milkweed throughout the growing season in 2018. This provided estimates of: 1) demographic parameters such as population size and the number of flowering individuals, 2) reproductive success, including fruit set, seed set, seed viability, and germination rate, and 3) genetic parameters such as the number of genotypes, levels of genetic diversity, and genetic structure. We then analyzed the correlation between reproductive success and both population genetic and demographic variables in Mead's milkweed.

Results and Discussion

In total, our study involved 1160 stems of Mead's milkweed distributed across 12 populations. Although we found a large number of flowering stems (273 or 24%), as expected, we found very low reproductive success, with only 42 (3.6%) stems successfully producing a fruit. As has been observed previously, we found that populations varied widely in reproductive success: one population produced 27 fruits, one produced 10 fruits, one produced two fruits, three populations produced one fruit, and six populations produced zero fruits.

Given the prevailing hypothesis that populations of Mead's milkweed have high clonality and low genetic diversity, the results of the genetic analysis were quite surprising. Although we observed moderate clonality, with the 1160 stems belonging to 311 genetically distinct individuals, even the smallest populations contained multiple unrelated genotypes. Populations overall showed high genetic diversity and low relatedness, with individuals in populations frequently more closely related to individuals in geographically distant populations than to those in the same population. Although populations in the St. Francois Mountains were somewhat genetically distinct from the prairie populations in eastern Missouri and western Kansas, we found no structuring of genetic variation within each of these regions, indicating that populations distributed across wide geographic areas form one large, genetically interconnected metapopulation. Because Mead's milkweed has a very long lifespan, the genetic interconnectedness of populations and high within-population genetic diversity may reflect conditions that occurred prior to modern-day habitat loss and fragmentation. Mead's milkweed was likely once distributed throughout large swaths of uninterrupted grasslands, and its wind-dispersed seeds were likely able to travel across large distances. The individuals that remain may simply be long-lived remnants of these past conditions, with high genetic diversity and a lack of genetic structure resulting from widespread historical gene flow across large geographical areas.

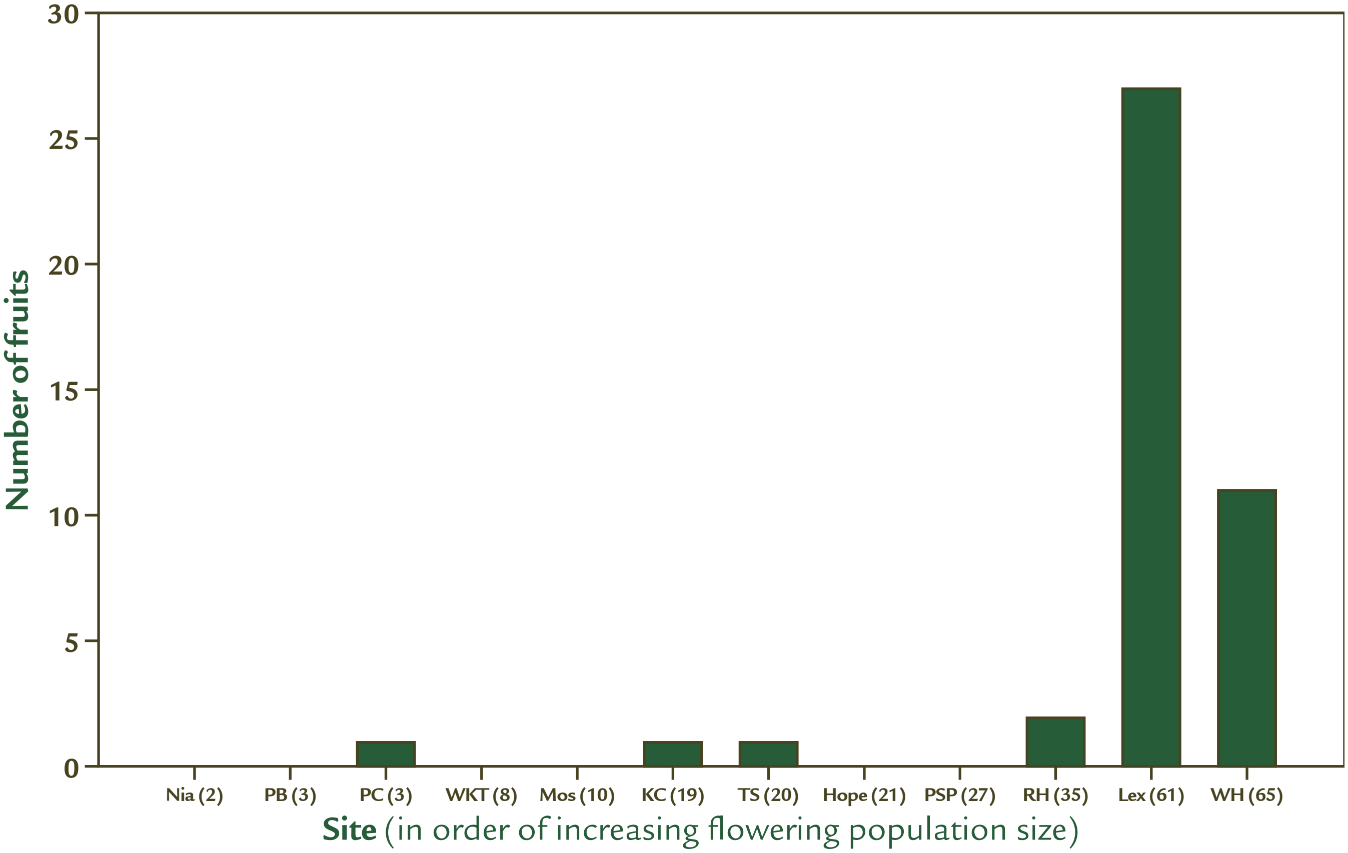
Consistent with the high genetic diversity found across all of the populations, we did not find a correlation between any measure of genetic diversity and reproductive success. These results therefore do not support the hypothesis that low reproductive success in Mead's milkweed is caused by a lack of compatible mates or low genetic diversity within populations. However, we did find that low reproductive success was strongly correlated with another factor: the number of individuals flowering in the population. Interestingly, only the two populations that had at least 50 flowering individuals showed high reproductive success, which is consistent with an Allee effect related to pollination. In other words, a population of Mead's milkweed likely must reach a threshold of around 50 flowering stems to attain high reproductive success. The exact underlying cause of this pollination-related Allee effect is unknown, but it is likely due to either pollinator limitation (i.e., suitable pollinators are attracted only when populations are sufficiently large), or pollen limitation (i.e., the ability of pollinators to successfully transfer pollen between individuals is greater when more individuals in a population are flowering). Future pollination studies are needed to evaluate the relative merits of these two hypotheses.

Implications for Conservation and Management

Given that high fruit set in Mead's milkweed is achieved only in populations that reach a threshold of around 50 stems flowering at once, the goal of management activities for Mead's milkweed should focus on actions that will help achieve this threshold. Many small populations have never been known to contain 50 stems, let alone 50 flowering stems, and the most direct way to attain the sufficient number of individuals will be to augment populations with individuals grown from seed. With the goal of increasing mate availability, the Missouri Department of Conservation (MDC) has been augmenting populations of Mead's milkweed since 2006. Although our genetic data does not support the mate limitation hypothesis, MDC's translocations likely have had a positive effect on reproduction in Mead's milkweed because they increase population size, and we recommend that these efforts continue, particularly in small, isolated populations.

To reach the critical threshold of flowering individuals, another goal of management activities should be to help promote the concurrent flowering of as many stems of Mead's milkweed.

Figure 1. The number of fruits in each site, with sites organized from smallest to greatest flowering population size. The site name and flowering population size (in parentheses) are indicated on the x axis.



Previous studies have found that dormant season fires and increased rainfall in the previous growing season increased fruit production in Mead's milkweed (German and Alexander, 2005). Historically, fires likely burned across broad tracts of contiguous grassland during the same year, resulting in a large burst of concurrent flowering and fruiting across the range of Mead's milkweed. Currently, however, prescribed burns are often conducted in different years in neighboring sites or burn units, such that the flowering response after fire occurs in different sites in different years. To stimulate concurrent flowering of an entire population of Mead's milkweed in the same year, all neighboring sites or burn units within a site containing Mead's milkweed should be burned in the same year. This may require coordination if neighboring sites are managed by different agencies or landowners, but these efforts would likely help increase reproductive success in Mead's milkweed.

Finally, future research is needed to investigate which grassland management practices may help increase the number of flowering stems in populations. Most sites in our study were managed primarily with periodic burns or a burn/hay/fallow rotation. However, the site with the greatest seed set in our study (Lexington Lake, with 27 seed pods) was hayed annually for 30+ years and then burned in the year just prior to our study. Hayed sites have been shown to have greater clonality (Tecic et al., 1998; Hayworth et al., 2001), and one possible explanation for high reproductive success in this population is that the annual haying increased the number of stems per genotype, helping to reach the critical threshold. Another contributing factor could be that the lack of fire enabled the accumulation of energy reserves, so when burning removed competition, many flowering stems emerged concurrently, resulting in a large burst of reproduction. A study that measures the relative effects of different management practices, such as burning at different intervals or haying for several years followed by burning, on the number of flowering stems is needed to determine if any of these strategies may help stimulate concurrent flowering in Mead's milkweed.

Conclusions

In conclusion, this study combined comprehensive sampling, genetic analysis, and demographic monitoring across multiple populations of Mead's milkweed, which provided unparalleled insights into the factors affecting reproductive success. Although the most common theory proposed in the literature for low reproductive success in populations of Mead's milkweed was a lack of genotypic diversity and low mate availability, the results of the genetic analysis did not support this hypothesis. Instead, the results revealed a much more simple underlying cause for low reproductive success in populations: they simply did not have sufficient numbers of individuals flowering at once to achieve reproduction. These results provide a relatively straightforward framework for management that will likely improve the viability of the species. Although additional research is needed to investigate whether haying or variation in fire return intervals may help increase flowering population size, management activities should involve 1) augmentations in small populations to increase population size and 2) coordinating burns so that all neighboring populations are burned during the dormant season of the same year to promote synchronous flowering in the following growing season. Implementing these simple management activities will likely increase the long-term reproductive success in Mead's milkweed, and help improve the long-term sustainability of this emblematic and highly threatened species. ❧

Christine Edwards is the Stephen and Camilla Brauer Associate Scientist of Conservation Genetics in the Center for Conservation and Sustainable Development at the Missouri Botanical Garden

Contact: Christy.edwards@mobot.org

Shannon Skarha was a laboratory technician in the Center for Conservation and Sustainable Development at the Missouri Botanical Garden and is currently a PhD student in the Department of Biology at Duke University.

Contact: shannon.skarha@duke.edu

Matthew Albrecht is a Scientist of Conservation Biology in the Center for Conservation and Sustainable Development at the Missouri Botanical Garden

Contact: Matthew.Albrecht@mobot.org

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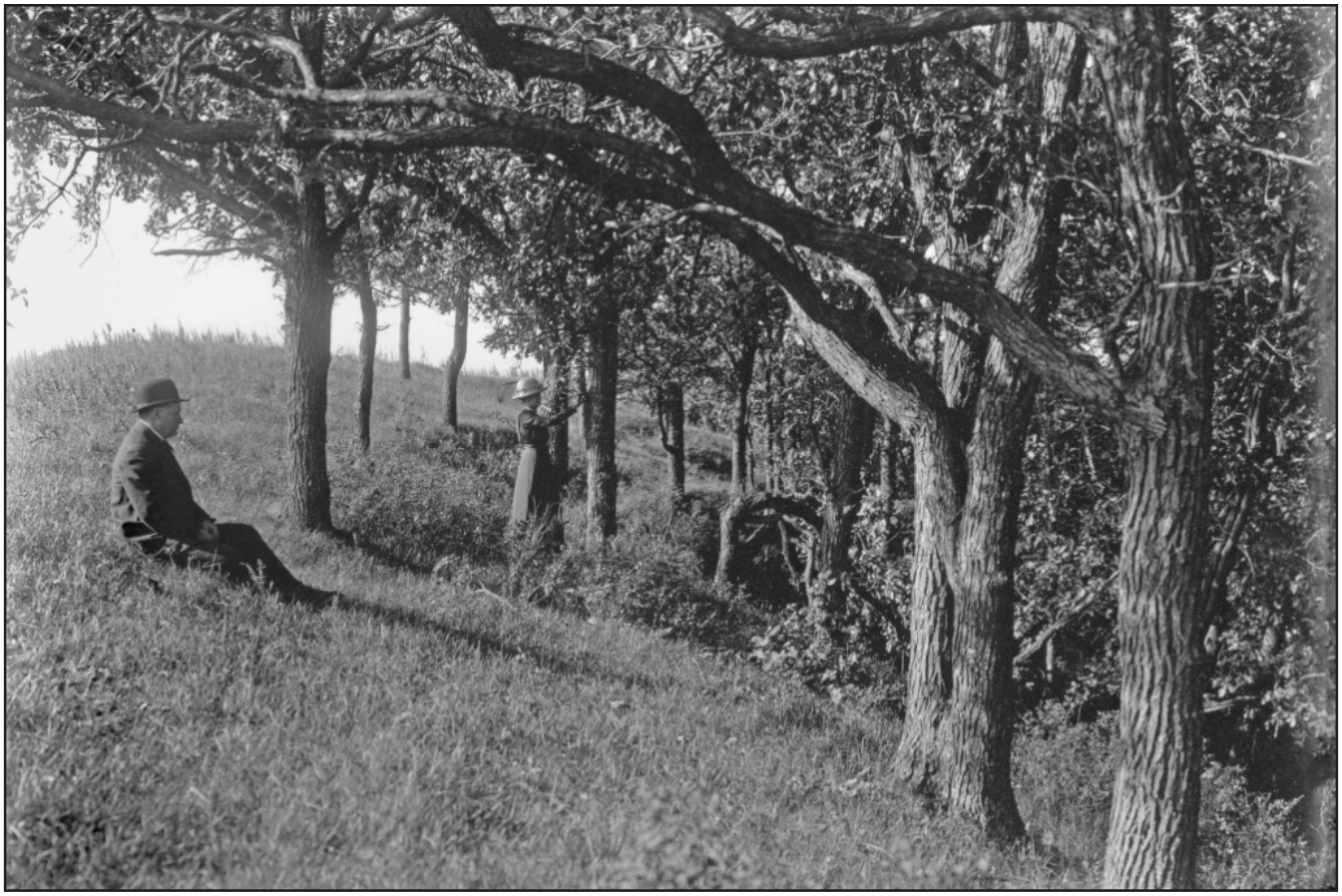

Photo courtesy of the Tabor County Historical Society.

Figure 1. Loess hill woodland found on the east slopes. Circa 1912.

The Diversity of the Loess Hills of Missouri

by Steve Buback

Over 100,000 years ago the northern half of Missouri lay under a sheet of ice. This sheet of ice pushed the ancestral Missouri River from its bed running east from St. Joseph roughly paralleling modern US-36. In the process of moving its drainage river, the ice sheet blocked the river and created a glacial lake in the broad floodplain in Western Missouri and further North. Eventually, this lake broke through the ice and left behind a broad expanse of silt and dust that was picked up by the wind and deposited across the State, providing much of the basis for the soils we see across North Missouri and capping ridgetops in the Ozarks. The heavier particles of this loess, a German term for wind-blown soil, precipitated out first, and were dropped into a series of steep hills from northern Iowa to Van Meter State Park located north of Marshall. The sand and calcium-rich silt particles were the first to fall, and were deposited in a line of North and South hills north of St. Joseph, Mo. These mounds rise 60 to 100 feet above the floodplain, and because of the size of the soil particles they are excessively well-drained. The angular nature of the sand and silt means that these particles can interlock, and the hills can often be very steep. Generally, these soils can be cut into vertical slopes and maintain their integrity. They are also highly erodible when at an angle, and there is often no evidence of soil formation on the tops and sides of these formations, as erosion rates equal or exceed formation rates.

The loess hills were known and occupied by Native Americans prior to European settlement. The tops of many hills and bluffs in the region contain burial mounds and other cultural artifacts. Few settlements are known, and these are usually at the base of the hills. The hills around St. Joseph were especially significant to local tribes, and the Sunbridge Hills Conservation Area was named after a local legend that the area was the starting point for a bridge connecting the heavens and earth. When the Platte Purchase was purchased from the Potawatomi, Ioway and Sac-Fox tribes, far Northwest Missouri was opened (legally) to European settlers. The steep bluffs were unfarmable, but the introduction of cattle, pigs and other livestock left marks that are still visible to this day in the forms of cat steps, that indicate the trails made by cattle (Bush, 1895). The character of these prairies was well-documented in the 1800s through paintings made by George Caitlin and others as steamboat travel on the Missouri River opened up the West.

The earliest description we have of the plant communities comes from William Clark who on July 16th, 1804 described a "range of Ball(d) Hills parallel to the river & at from 3 to 6 miles distant from it and extends far up & Down as I Can See" (Clark, 1804). The river bottoms of Holt and Atchison counties were largely prairie, and it's not hard to imagine fires racing from these bottomland prairies and climbing up the steep hills. When the cultural practice of fire was combined with exceedingly well-drained soil, sheer south and west-facing aspects, and the lowest rainfall totals within the State of Missouri, the resultant communities were unlike anything else found in the state. The hills provide a unique habitat where the glade flora of the Ozarks intermingles with the Great Plains species found in the Flint Hills and western Kansas and Nebraska. This is the same situation reported by the preeminent botanist Benjamin Franklin Bush when he took the train from Kansas City to Watson and wrote his "Notes on the Mound Flora of Atchison County, Missouri" in 1898.

The predominant natural community on these steep, exposed slopes is dry loess hill prairies. There are only 177 acres of this natural community left, as tracked by the Missouri Natural Heritage Database. Historically, this community would have been more widespread, but years of fire exclusion, soil mining, and woody species encroachment has reduced the extent. All of the dry loess hill prairies in St. Joseph, traditionally the Southern terminus, have been encroached by houses, invasive species, and shrubs to the extent that the floral character is gone, and recovery is nearly impossible. The southern extent of the loess hill prairie for all intents and purposes is the band of hills running from McCormack Loess Mounds Natural Area east through Loess Bluffs National Wildlife Refuge.

These loess hill prairies are dominated by a matrix of grasses including little bluestem (*Schizachyrium scoparium*) and sideoats grama (*Bouteloua curtipendula*), with big bluestem (*Andropogon gerardii*) occurring on lower slopes or moving upslope in wetter years. Scattered amongst these grasses are a number of Great Plains species that are at the southeastern extent of their range. These include Nine-anthered dalea (*Dalea enneandra*), Locoweed (*Oxytropis lambertii*), Soapweed (*Yucca glauca*), Scarlet gaura (*Oenothera suffrutescens*) and Downy painted cup (*Castilleja sessilifolia*). Even species such as the weedy Snow-on-the-mountain (*Euphorbia marginata*) are found more commonly on these deep loess hill prairies (and their degraded remnants) than elsewhere in Missouri. Mixed in with these western members of the flora are several species that would be right at home on Ozark glades. Among these are Carolina anemone (*Anemone caroliniana*), Silky aster (*Symphyotrichum sericeum*), Aromatic aster (*Symphyotrichum oblongifolium*), and Plains muhly (*Muhlenbergia cuspidata*). These species are all nearly non-existent in other natural communities of glaciated Missouri, but thrive in the Loess Hills.

Along with the characteristic plants, there are a suite of animals that are unique to the Loess Hills. The Plains Pocket Mouse (*Perognanthus flavus*) was historically found in these hills, although it has not been documented in several decades. Many species of grasshoppers, all associated with bare ground and short grasses in the Great Plains, are found in the loess hills and nowhere else in Missouri. These include the Bigheaded Grasshopper (*Phoetaliotes nebrascensis*) and the Painted Mermiria (*Mermiria picta*). The tiny cicada *Bemaria venosa* seems to be most common in the loess hills, while the dusted skipper (*Atryonopis hianna*) has been recently documented here while it was previously only known from scattered sites on glades in the Ozarks. The recently described *Dalea enneandra* specialist bee *Tetraloniella paenalbata* has been documented on several sites where the local food plant occurs. Finally, the swift tiger beetle (*Cylindera celeripes*) is known from the state only from bare ground on a couple locations in this landscape.

On the protected side of these exposed slopes, historically we would have found rather open communities that resembled the exposed sides. Bush (1895) reported that a shrub community consisting of Hazel (*Corylus americana*), Wild plum (*Prunus* spp.), and Prairie willow (*Salix humilis*) would be found at the base of north and east-facing slopes, and this community would only occasionally reach to the top. Today, due to fire suppression, the protected communities are often heavily wooded, and more closely resemble a rich woods flora with an overstory of Basswood and Northern red oak. Interestingly, some western elements of the flora persist in these communities, such as isolated populations of Wolfberry (*Symphoricarpos occidentalis*) and Sprengel's sedge (*Carex sprengelii*). The Wolfberry populations can be difficult to pick out from its congener Buckbrush (*Symphoricarpos orbiculatus*), but there is a sawfly (*Belennogeneris spissipes*) that apparently will only use Wolfberry and creates distinctive galls on the stemtips.


Photo by Steve Bubeck

Painted Mermeria grasshopper *(Mermeria picta)*. An imperiled grassland specialist found occasionally in grasslands throughout Missouri.

Savannas and woodlands are characteristically associated with these prairies, but the same forces of fire exclusion that have resulted in prairie degradation has also choked out these fire-dependent communities. Stambaugh et al. (2006) performed some of the only fire studies in this system and discovered amazing results. The oldest Bur oaks on these hills approach 350 years old, and showed fire return interval of 5.2 years over the course of that time interval. There was a peak of fire in the European settlement period, and a decline since the 1960s. In the absence of these fires, much of the understory vegetation has changed dramatically, and there are currently no good examples of what these woodlands and savannas should look like. Restoring these communities is one of the biggest challenges ahead. The picture in Figure 1 shows what the some of these woodlands looked like in 1912, some rare visual evidence of what any natural community looked like 100 years ago.

Threats facing the loess hill prairies are similar to those facing prairies throughout Missouri. Rough-leaved dogwood (*Cornus drummondii*) and Smooth sumac (*Rhus glabra*) are increasing in presence on most of the prairies and have already swallowed up many of the smaller prairie openings. Because these prairies occur on steep terrain in fragmented ownership, restoring a historic fire regime is difficult. The construction of I-29 at the base of these slopes, while increasing viewership of the hills, has added to the difficulties of prescribed fire smoke management. Several hill prairies are lost due to previous soil mining, initially for construction of I-29 and continuing for levee repair and construction after major flooding in 2019. The impact of climate change on the loess hill prairies is uncertain, but likely depends on the direction of precipitation shifts. Some projections indicate the 100th meridian, which traditionally delineates the Great Plains from the humid East may be shifting, and in fact Holt and Atchison counties may already represent the transition zone (Seager et al. 2018). This transition from historically wet to dry may be beneficial for many of the Great Plains species which are found on these communities, but the actual results seem unknowable now.

The small nature of these sites makes preserving them more challenging but also more critical. From a conservation standpoint, I tend to think of these prairies as being a chain of islands of habitat. Letting one island in the chain become overgrown could lead to isolating all of the loess hills prairies to the north or south. There are a number of species in the Iowa loess hills that are currently unknown from Missouri, such as Moonwort (*Botrychium campestre*) and the Pawnee skipper (*Hesperia leonardus leonardus*), and without connectivity we could see more species lost from these systems. Since B.F. Bush pioneered his survey in 1895, we have already lost species such as Rocky Mountain bee plant (*Cleome serrulata*) and Wild licorice (*Glycyrrhiza lepidota*) from this landscape, and the more isolated the hills become, the less likely a plant or animal is to recover from extirpation.

The recently expanded Brickyard Hill Loess Mound Natural Area represents a premier example of this landscape type. Located on Brickyard Hill Conservation Area in Atchison County, north of Rock Port on I-29, this area features some of the highest quality loess hill prairie in Missouri. This area represents the only public property where one can find species including Wavy-leaved thistle (*Cirsium undulatum*) and Scarlet gaura, and also features Bur oaks up to 350 years old. Originally designated as a 125-acre natural area in 1975, the Brickyard Hill Loess Mound NA was recently expanded to 443 acres and now includes several loess hill prairies, as well as dry loess woodlands and areas of dry-mesic loess savanna restoration potential. This newly expanded natural area recognizes the importance of connectivity within this landscape and provides a recognition that these prairies do not and cannot exist and survive in isolation. The flora and fauna of this natural area and of the loess hills in general represent a unique contribution to the biodiversity of Missouri. Keeping these ancient assemblages viable will require management and conservation of not just our public properties but private sites, as well, in order to allow plants and animals to migrate and recolonize through this landscape. ❧

Steve Bubeck is a Natural History Biologist with the Missouri Department of Conservation

Contact: steve.buback@mdc.mo.gov

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Star School Hill Prairie Natural Area contains some of the largest and highest-quality loess hill prairies left in Missouri. You can see Iowa and Nebraska in the background.

Photo by Steve Bubeck

Photo by Paul McKenzie

Slimy Pink-Spotted Lichen, *Dibaeis absoluta,* at Hickory Canyons Natural Area.

It's the Small Things that Matter: Cryptogam Conservation and Natural Areas

by Douglas Ladd

People familiar with intact natural systems inherently sense their verdancy: these places are teeming with the richness of life – an amazing diversity of life forms spanning multiple organismal groups. Despite this diversity, we tend to know about, and focus on, only the most visible and charismatic elements of the system. Thus here in Missouri, we have pretty good knowledge about vascular plants and most vertebrate groups, but beyond that we tend to have detailed information only for those organisms that are either economically valuable or capture our interest, or those that can cause physical, economic, or ecological harm.

Cryptogams are small plants that reproduce via spores instead of seeds and associated structures such as flowers. Derived from Greek, cryptogam translates roughly to "hidden reproduction." Cryptogams include one group of vascular plants – ferns, as well as non-vascular plants including mosses, liverworts and the related hornworts, algae, and lichens. In this article we only consider non-vascular cryptogams, since ferns are usually included with flowering plants and are better known, including from a rarity and conservation perspective. Traditionally, some non-photosynthetic organisms formerly included with plants were included within cryptogams, but we now know that these groups are not closely related to plants, and in many cases, such as fungi, are more closely related to animals. Despite these differences, many of the considerations discussed here are similarly applicable to other small, poorly known organisms.

Much remains to be learned about Missouri's cryptogam diversity, and the role, ecology and conservation status of individual species. Intensive field work in recent years has started to reveal the under-appreciated contributions that cryptogams make to biodiversity and system function. Building on disparate evaluations of Missouri cryptogams dating back to the 19th century, Nigh et al. (1992) made some initial estimates of the state's cryptogam diversity totaling 770 non-vascular cryptogams exclusive of algae. Subsequent works have increased and refined this, while explicitly recognizing that significant cryptogam diversity remains undocumented, including numerous as yet undescribed species.

Current estimates of documented non-vascular cryptogam diversity in Missouri include 323 bryophytes (mosses, Darigo 2015), 116 hepatics (liverworts and hornworts, Atwood 2014), and more than 650 lichens (Ladd 1996 and unpublished data), amounting to a documented by known underestimate of some 1,100 taxa. For comparison, a comprehensive list of Missouri's vascular plants includes 2,055 native species (Ladd & Thomas 2015). Thus, about 35% of Missouri's total plant diversity consists of non-vascular cryptogams (the actual proportion is much greater since algae are not included in these estimates). This clearly demonstrates the significance of non-vascular cryptogams as a component of Missouri's biodiversity. It also highlights two critical facts: 1) non-vascular cryptogams are major contributors to ecosystem biodiversity locally; and 2) land managers and conservation planners should be nervous that most decisions are based on responses or presence of vascular plants and select vertebrates, without consideration of cryptogams, despite the fact that the cryptogams often have narrower ecological tolerances and may not have the same responses to management.

Given the lack of even basic information about the abundance, distribution, and ecology of most cryptogams, inferring their ecological role and importance is difficult, but a few general observations can be helpful. Given their near-ubiquity in Missouri's terrestrial systems, it is logical that cryptogams play critical roles in maintaining natural system health, diversity, dynamic stability, resilience and sustainability through time.

Cryptogams are well known for their interrelationships with a variety of animals, ranging from microscopic invertebrates to charismatic and well-known vertebrates. The use of mosses, liverworts, and lichens by nesting birds is well known. These materials provide camouflage, structural support, insulation, and even anti-microbial properties (Glime 2017). Similarly, cryptogams are used in mammal and bee nests, and many smaller animals utilize cover and shelter provided by cryptogams. Fall hikers often note small moving masses of what appear to be lichens on tree trunks in Missouri woodlands. These are larvae of the widely distributed lacewing, *Leucochrysa pavida*, which uses lichen fragments to construct a camouflaging cover packet. Cryptogams are also important food sources for various animals; the critical role of horsehair lichens as food and nest materials for northern flying squirrels in the Pacific Northwest is a well-

Photo by Nels Holmberg

John Atwood of the Missouri Botanical Gardens examines a sandstone canyon for cryptogams at Hickory Canyons Natural Area, Sainte Genevieve County, Missouri.

known example (Hayward & Rosentrenter 1994), but similar interrelationships presumably occur in Missouri habitats.

Cryptogams are also important to moisture relationships and erosion control. Cryptobiotic soil crusts — a complex amalgam of cryptogams and other microorganisms — are critically important for erosion control and soil moisture relationships in many arid environments (Belnap 1994). Extensive cryptobiotic soil crusts in Missouri glades undoubtedly are of similar ecological importance. Healthy soil crusts are also important for the establishment of vascular plants in some systems. The loss of intact soil crust communities associated with novel system impacts caused by cattle grazing is a major concern for the health of many arid rangelands, but the phenomenon has not been examined locally.

An important ecological role for cryptogams, although local data are sparse, is in nutrient relationships, particularly in glade and woodlands systems. While abundant in the atmosphere as an essentially inert gas, nitrogen that is biologically available, or fixed, is a limiting nutrient in many natural communities. Through symbiotic associations with nitrogen-fixing cyanobacteria, many species of lichens, bryophytes, and hepatics provide sources of fixed nitrogen. In wooded uplands on sterile, acidic soils, such as occur in much of the Ozarks, the constant rain of cryptogam-covered dead twigs and branches falling from the canopy may provide a significant source

Photo by Jim Rathert, retired Missouri Department of Conservation

Bona Glade Natural Area, a sandstone glade rich with cryoptogams.

of fixed nitrogen to the system — something crying for further investigation.

Cryptogams lack roots and other water-conducting vessels, and also lack water storage tissues or other moisture-conserving adaptations, and so are at the mercy of the prevailing moisture conditions. Although many have the abilities to become essentially dormant for prolonged periods during intervals of extreme desiccation or cold, most are also sensitive to even slight changes in exposure, ambient humidities, and other habitat conditions. This extreme fidelity to a narrow range of site conditions that may differ from prevailing conditions in most of the area, is a characteristic of many cryptogam associations. Given their diminutive size and site requirements, cryptogams must be considered in the context of microhabitats, which can exist on extremely small scales. Examples include a small, seepy, permanently humid crevice of a large rock outcrop in an otherwise xeric glade or woodland, or a sheltered face at the base of a massive overhanging bluff, where despite frigid winter temperatures in the ambient landscape, the temperature never drops below freezing.

Some cryptogams are incredibly specific in their microhabitat requirements, even to the point of the substrates upon which they grow. For instance one of a group of lichens known as the Script Lichens, *Graphis sophisticascens*, occurs only on bark of larger River Birch trees associated with intact streams. The species was first discovered near Emma, Missouri in the late 1800's, and this remained the only known site in the world for more than a century, although a few additional sites in Missouri and neighboring states have since been discovered, all restricted to the same substrate and habitats (Morse & Ladd 2018).

Role of natural areas

Just as with other organisms, healthy, diverse cryptogam populations are critical to the integrity and ecological health of Missouri natural systems. This is especially important from a natural areas perspective, since by definition these are irreplaceable constellations of interactive biodiversity that exemplify Missouri's natural heritage. The long-term health, diversity, and viability of Missouri natural areas requires maintaining healthy populations of all their components, including cryptogams. The extreme sensitivity of some cryptogams to even slight degradations of microhabitat conditions, including climate and atmospheric pollution, also make them an ideal 'canary in the coal mine' for early detection of potential problems afflicting these systems. As such, increased cryptogam assessment and monitoring protocols can be an effective early detection method for assessing management impacts and responding to global change issues.

Equally important, although less obvious, is the essential role of the Missouri Natural Area system for cryptogam conservation. Given the highly specific, and often poorly understood, microhabitat and ecological requirements of many cryptogams, Natural Areas both provide critical habitat for many populations of conservative cryptogams that might otherwise be extirpated from the state, and can serve as living laboratories from which to gain a better understanding of cryptogams and their supporting habitats and ecosystems. Many other public and private conservation lands in Missouri are managed for multiple outcomes or species-specific goals, incurring resultant risk of exceeding the range of microhabitat condition dynamism to which sensitive cryptogams are attuned. Natural areas by contrast are specifically managed to sustain their component biota and maintain processes within a range of dynamism to which the system and its component organisms are adapted.

The existence of some Missouri cryptogams is dependent on natural areas. For example, a cryptogam with narrow microhabitat requirements is the lichen *Dibaeis absoluta*, sometime endearingly called the Slimy Pink-Spotted Lichen, which is known from scattered occurrences in warmer regions of the world including eastern North America. This species requires lightly shaded, permanently moist, massive rock exposures with constant humidity and minimal freezing conditions. In Missouri it is known from four sites in the southeastern Ozarks, all on massive sandstone formations in areas that are either designated natural areas or have been proposed as natural areas.

Another example of a cryptogram with similar microhabitat fidelity is the Sword Moss, *Bryoxyphium norvegicum*, a northern disjunct species which occurs locally in cool, deep ravines and gorges on moist shaded sandstone, particularly on undersides of ledges overhanging water, including within Pickle Springs and Hickory Canyons Natural Areas. At both of these sites, Sword Moss is associated with a suite of other locally rare cryptogams that are likely relicts from the most recent glacial period. The importance of these populations transcends Missouri: being near the western edges of their ranges, local populations may have global significance from a genetic diversity perspective.

Another geographical disjunction, in this case with tropical biogeographic affinities, is the liverwort *Lejeunea deplanata*. Missouri's only record of this species, at Big Spring Natural Area, is

Photo by Nels Holmberg

Sword Moss, *Bryoxyphium norvegicum*

also the world's northernmost site, again highlighting the importance of natural areas from a biogeographic and genetic diversity standpoint. In each of these examples, the fate of the species in Missouri depends on an effective Natural Areas program.

In the absence of natural area protection, an example of a potentially lost cryptogam is a liverwort associated with wet soils, *Riccia ozarkana*. Described in 1960, this globally rare species is known from three populations in the world – one each in Arkansas, Kansas, and Missouri, and has not been seen since its discovery. The only Missouri site has been severely altered and drained, and the habitat is likely no longer suitable.

From a manager's perspective, maintaining healthy populations of cryptogams requires an altered perspective that envisions management effects as they occur at the scale of the affected organism. This means focusing on sensitive microhabitats, which are often impacted by activities that may seem to have minimal impacts at larger scales. Changes in shading levels, surface runoff rates, sun or wind exposure, or local light or humidity levels at the microscale can have devastating impacts to some cryptogams. In natural areas especially, activities that involve soil compaction, chemical inputs, or altered site conditions or process regimes need to be carefully evaluated at the microscale.

For instance, even on many lands where conservation goals drive management activities, vehicles are often driven freely across the sites, despite our knowledge that compaction issues associated with vehicle use may have significant and enduring impacts at the microscale (witness the totally different vascular vegetation in even infrequently used vehicle tracks). Managers should carefully evaluate access issues and consider the implications for smaller life forms, both plant and animal, that encounter what to them may be immense altered 'landscapes.'

Another management issue impacting cryptogam populations at unknown levels is the widespread use of biocides, on both conservation lands and adjoining private lands. Data on biocide impacts to cryptogams is almost nonexistent, yet some of these chemicals, such as Dicamba, have a known propensity to spread aerially far beyond their area of application, potentially impacting native systems including natural areas. Similarly, some Missouri natural areas are part of larger public lands where biocide use is not prohibited, again raising potential conservation concerns. There is no panacea from a manager's perspective, and difficult compromises are often required, but increased awareness of cryptogam conservation issues should be part of the considerations.

Natural community classifications, especially in natural areas, are too coarse and vague to capture critical microhabitats, so managers should explicitly assess these sites for potential priority microhabitats. Baseline assessments and establishment of simple monitoring should also be implemented for cryptogams of conservation concern; this will serve as a valuable window of site integrity through time. Considerations of both sensitive microhabitats and their component cryptogams should be incorporated in site plans and management actions. This requires adjusting conceptual focus to a different scale than is typically embraced.

Every natural habitat is a mind-bogglingly diverse, interactive complex of species, all influenced by and in turn influencing both each other and the physical environment and process regimes in which they exist. Knowledge gaps and pragmatic considerations mean that managers must make decisions and set goals based on deliberately simplified, comprehensible models and hypotheses. This incurs risks, including system damage and resulting organismal losses, especially at the microhabitat scale, and so we must remain vigilant to potential impacts at the microscale and both have the humility to acknowledge information gaps, and implement mechanisms to accommodate uncertainty and provide feedback that enfranchises as much of the biota as possible.

Tiny, often overlooked, poorly known, and amazingly diverse and awe-inspiring when evaluated at a small scale: cryptogams are essential elements to both the ecological function and resiliency, and aesthetic value of Missouri's natural areas. ❧

Douglas Ladd is a Research Associate at the Missouri Botanical Garden and Senior Lecturer at Washington University.

Contact: dladd@tnc.org

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Photo by Nathan Aaron

A remnant upland prairie along I-44 near Cuba, with downy gentian (*Gentiana puberulenta*) and prairie goldenrod (*Oligoneuron album*) growing profusely.

Finding Positivity and Perspective

by Nathan Aaron

I am a young millennial, born in the mid-90s, raised in Missouri outside of Rolla, and this past year — as tumultuous is it has been — has functioned as an awakening experience. I have felt myself journey through the many continuing phases of trying to understand the natural world. To others I have described it as my "green eye" opening as I suddenly became aware of reality, the inherent truth that is found in nature. It started as simply as a curiosity about plant identification, being drawn into the intricacies of inflorescences, and marveling at the beautiful dance between form and function. The bottom of the rabbit hole that is "plant obsession" took me to the relationships plants have between themselves and the environment, which naturally leads to a kind of depression as I learned just how much destruction has happened in the past few centuries. It is impossible not to wonder about all that has been lost. However, doom and gloom is not my goal. Becoming distraught and grieving over the many deaths of the natural world is certainly a shared experience among the many who care, but I want to take this opportunity to reflect on the natural world concepts that incite positivity.

Recently, I spent several weeks in central Pennsylvania's central Appalachian region. As someone whose roots and biases are firmly planted in Missouri, this was a particularly contextualizing experience. All too often one can resort to despair when considering the state of many of our natural communities here in the Ozarks: glades – soil beaten out to the tune of grazing; wetlands – ponded, channelized, drained; woodlands and prairies – overstocked or overgrazed. What is there to say that hasn't already been said? Having recently become so personally tied to local Missouri ecology, it felt natural to adopt a glass-half-empty mindset. In an interpersonal sense, it's the same as holding a dear friend to a higher standard than you would a recent acquaintance. One cure for this gloomy outlook, I learned, is to get out and absorb some much-needed context.

Most of the thousands of acres of state forest I drove through in central Pennsylvania were ecological graveyards – a sea of Japanese stiltgrass (*Microstegium vimineum*) covers most of the forest floor, occasionally breaking against islands of generalist ferns. The destabilized systems that result from mismanagement of the ever-burgeoning deer herd and lack of active management manifest in the lack of insect and avian

A railroad remnant prairie surviving along a right-of-way just outside of Rolla. Over 100 species of prairie inhabitants are thriving in this one acre strip by the railroad tracks.

Photo by Nathan Aaron

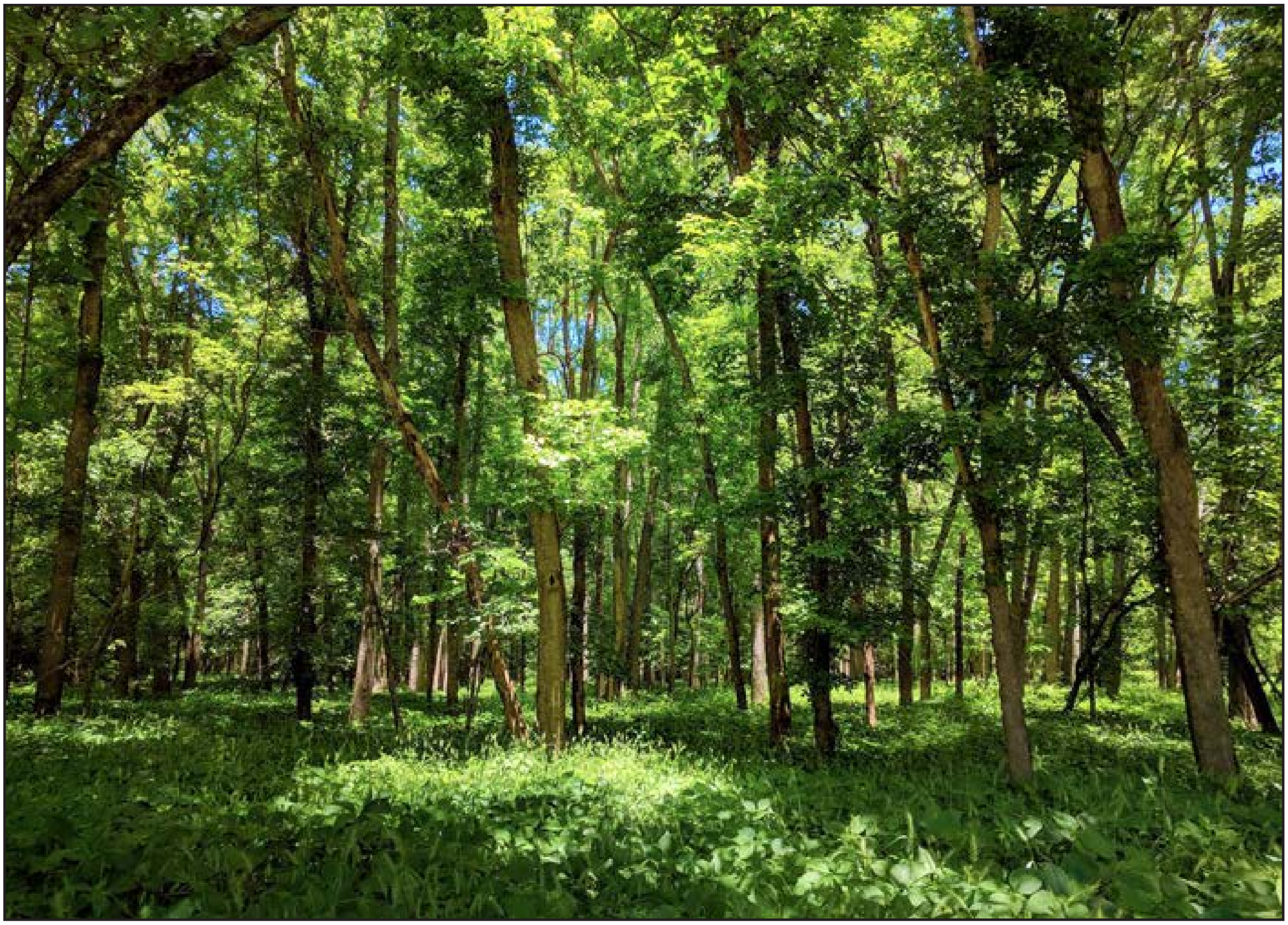

Photo by Nathan Aaron

A 14-acre bottomland forest along a highway north of Rolla. This second-growth forest supports a healthy ground flora, such as Michigan lily (*Lilium michiganense)* and a variety of wild rye (*Elymus)* species.

chatter, a jarring silence. The lack of diversity in the Pennsylvania forests and woodlands was unlike anything I have witnessed in the Missouri Ozarks. My observations in Pennsylvania are vastly limited in scope — undoubtedly there are natural areas that better represent presettlement conditions in the upper ridge and valley region. Regardless, my return to Missouri's natural settings was a welcome one.

The importance of seeking new experiences and observations is a parallax, defined as the effect whereby the position or direction of an object appears to differ when viewed from different positions. Regarding local Missouri ecological systems, the process of shifting perspective has grown increasingly important to me. The visits back east have operated as ways to view the area I know as home in a new frame, shining light on those things I have overlooked, become callous to, or taken for granted. A trip from the airport in St. Louis might take you west down I-44, which, for many miles follows a slight escarpment between the Bourbeuse Plain to the north and the Meramec River Hills to the south. Here it is possible to pass by tiny pockets of remnant prairie, where towering compass plant (*Silphium laciniatum*) in the mid-summer sun watches over these surviving communities. How many times had I passed by these islands of diversity and become depressed at their small size and limited quantity? I must confess a defeatist attitude would often overcome me. Communities surviving at all for this long is a miracle when compared to utter annihilation, regardless of size. In some neighboring states, a tiny railroad remnant prairie may be a natural area, the best remaining example of the landscape type.

The reality that I am young, naïve, and inexperienced, while gaining an understanding of the natural world while living in Missouri has resulted in a sort of privilege, one owing to the fact that at least in the Ozarks, so many of our communities survive. I grew up north of Rolla and can recall vivid memories of spending hours watching Eastern collared lizards sunbathe on local dolomite outcroppings. Nearby, we frequented a bottomland forest with lush, intact ground flora and spring wildflower displays. Growing up, I took these systems for granted, accepted them as the normal condition. As I have transitioned into adulthood and attempted to find an identity in the natural world, I realize that the specific nature of Missouri and the diversity it affords has played an integral part in that process. If I had spent my childhood somewhere else, potentially even in part of the more damaged Appalachians, I may possess a lower standard to what constitutes a surviving ecological community. The natural world that I grew up in, in all its different forms and functions, planted a subconscious seed which sprouted into a thirst for knowledge that can never be sated. I have nothing to owe that to than the rolling woodlands, glades, forests, and prairies of Missouri. And while we should always have an understanding of the level of damage the natural world has sustained, we shouldn't let ourselves forget to celebrate the miraculous beauty that remains.

Nathan Aaron is a Resource Technician with the Missouri Department of Conservation

Contact: nathan.aaron@mdc.mo.gov

Photo by Nathan Aaron

This juvenile Eastern collared lizard (*Crotaphytus collaris*) has made its home along dolomite outcroppings just feet from a county road in northern Phelps County.

NATURAL AREA-RELATED NEWS

Photo by Ron Colatskie

A bee-fly (species ***Bombylius*** sp.) pollinating Prairie Iris (*Nemastylis geminiflora*). Prairie Iris, indicative of high quality glades in the region, persists in the small glade pockets of Stellata Natural Area.

Designation of the Stellata Natural Area

by Allison J. Vaughn

The Missouri Natural Areas Committee unanimously approved the nomination of the 2,077 acre Stellata Natural Area located at St. Joe State Park near Farmington. Dominated by dry chert woodlands, upland flatwoods and dolomite glade natural communities, this area is situated in the St. Francois Knobs and Basins north of the St. Francis River. The natural area takes its name from the epithet of its signature tree species, post oak (*Quercus stellata*). There are also extensive pine woodlands in the natural area, representing the northern-most range of the species. Notable populations of the prairie iris (*Nemastylis geminiflora*), a Missouri Species of Conservation Concern, can be found on the glades.

The Stellata NA makes up 25% of the 8,243 acre state park. While the park is widely known for its extensive off-road vehicle recreational area, much of the undeveloped acreage of St. Joe SP has witnessed extensive thinning and prescribed fire regimes for the past thirty years. The aquatic communities associated with Harris Branch, a headwater stream, are also protected in the area with most of the watershed protected by state park land. The paved bicycle loop between the Harris Branch Trailhead and the Blankshire Trailhead and east provide the best views of the natural area. ❧

Allison J. Vaughn is the Natural Areas Coordinator with the Missouri Department of Natural Resources.

Contact: allison.vaughn@dnr.mo.gov

MoNAC Newsletter Mailing List

To receive notification when new issues of the Missouri Natural Areas Newsletter are posted, e-mail Michael.Leahy@mdc.mo.gov. This list-serve is *only* used to notify people of the link to the current natural areas newsletter web posting.

Cindy Hall Retires from Ozark Caverns

by Allison J. Vaughn

Photo by Allison J. Vaughn

After 35 years as an accomplished Park Naturalist at Lake of the Ozarks State Park, Cindy Hall has retired from Ozark Caverns. Cindy was instrumental in the expansion of the now 1,782 acre Coakley Hollow Fen Natural Area. When travel is possible again, Ken McCarty, MoNAC Chair and Director of the Natural Resource Management Program for Missouri State Parks, will present Hall with an award of a photograph of a Gray Petaltail Dragonfly, a rare insect that inhabits the natural area's eponymous fens.

McCarty writes:

"Cindy was the driver for over three decades of resource management at Lake Ozark and nearby parks. Her career spanned the full history of preserving native Ozark landscapes with prescribed fire, from its experimental and controversial 1980's first steps to routine application at the landscape scale. Cindy was part of the process that made fire normal in state parks. She nurtured the Ozark Caverns Fen through its full recovery, witnessing the first results from the 1980's removal of the overlying gravel parking lot to the living museum that visitors experience today. Cindy rode the helm through several more major ecological restoration projects, for the park's glades, woodlands and flatwoods which ultimately prompted Missouri Natural Area recognition as a best-of-type expression of our Ozark natural heritage. Cindy is also a scientist, specifically intrigued by aquatic macroinvertebrates – through the early and middle parts of her career self-training to become the naturalist who provided substantial detailed discovery and documentation of the aquatic life of Coakley Hollow and Ozark Caverns. Those who worked with Cindy through the years particularly valued her intuitive understanding of prescribed fire, and she long held a major share of the role for implementing the fire program in the central Ozarks area. Cindy was one of a small group of top burn leaders, respected by our fire practitioners as an expert's expert through many years, burns, wildfires and trainings for our staff. Most of all, Cindy was an unyielding advocate for her park's superlative natural resources. We owe much to her efforts, and it is very fitting to recognize Cindy's long contribution to Lake of the Ozarks State Park as one of Missouri's special nature places with this award from our park system on behalf of Missouri Natural Areas." ❧

Allison J. Vaughn is the Natural Areas Coordinator with the Missouri Department of Natural Resources.

Contact: allison.vaughn@dnr.mo.gov

Photo by David Stonner

Cash Swamp Natural Area Expansion

by Mike Leahy

Imagine the primordial swamp of Yoda from the original Star Wars trilogy movie, *The Empire Strikes Back*, and you'll get a sense of what the water tupelo (*Nyssa aquatica*) dominated swamp is like in the recent 637-acre addition to Cash Swamp Natural Area. Located in Dunklin County just across the St. Francis River from Arkansas this nearly 1,000-acre remnant of the old delta region provides an important block of mature swamp for a variety of wetland-adapted flora and fauna. Here species such as the shrimp crayfish (*Faxonius lancifer*) and swamp rabbit (*Sylvilagus acquaticus*) find their home. The area is home to the current state champion swamp cottonwood (*Populus heterophylla*) and Nuttall oak (*Quercus nuttallii*).

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

Contact: Michael.Leahy@mdc.mo.gov

Calendar of Events

January 6, 2021 • 4–5pm • Virtual

Missouri Prairie Foundation's Grow Native! Master Class: Challenges with Native Plants with Scott Woodbury

Registration is free for MPF members and $15 for non-members. For more info and to register visit:

https://moprairie.org/events

January 19, 2021 • 11am • Virtual

Project Budburst

A webinar sponsored by the Natural Areas Association. Follow the citizen science project that has been ongoing since 2007 to track plant phenology in North America, by Emma Oshrin, Ph.D. For more information and to register please visit:

http://www.naturalareas.org/webinars.php

February 1-4, 2021 • Virtual

81st Annual Midwest Fish and Wildlife Conference

http://www.midwestfw.org

February 2-4, 2021 • Virtual

Annual Missouri Natural Resources Conference

https://mnrc.org

March 16, 2021 • 11am • Virtual

Current and Future Carbon Storage Capacity in a S.E. Pennsylvania Forest

A webinar by Jessica Shedlbauer, Ph.D. sponsored by the Natural Areas Association. For more information and to register please visit:

http://www.naturalareas.org/webinars.php

September 20-23, 2021

Natural Areas Conference

Sponsored by the Natural Areas Association. For more info and to register visit naturalareas.org.

Duluth, Minnesota