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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 Waters

In the summer of 2003, I experienced my first canoe trip on a clear, fast moving Missouri Ozark stream. The Niangua River from Bennett Spring to Prosperine, a good twelve mile float, was breathtaking. While most of the land surrounding this part of the Niangua River is privately owned, healthy woodlands with a robust ground cover of native grasses and sedges (the result of an active fire regime) blanketed large areas of the minimally developed watershed which helped to make the waters rich with aquatic invertebrates and smallmouth bass. I became hooked on paddling Ozark rivers after that first experience, one that helped me make a decision to relocate to Missouri from Louisiana.

Since 2003, this stretch of the Niangua River has become home to many more canoe outfitters,

Late July on the Niangua River

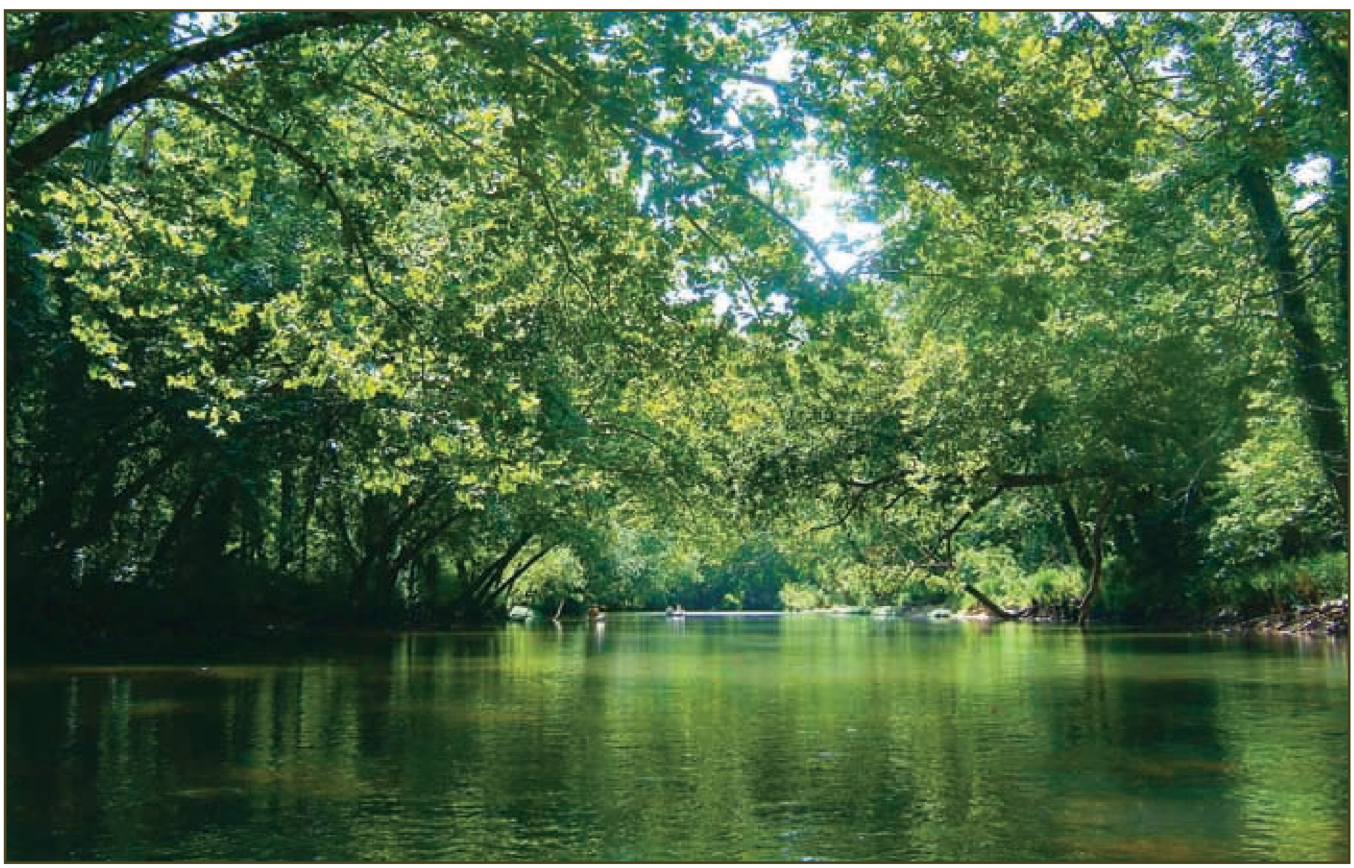

Photo by Allison J. Vaughn

campground and lodging developments, and grazing along the riverbanks. To add to the threats to the river's natural quality, in recent years, flood events occur more frequently which results in heavy nutrient loading and sedimentation. The Niangua River I floated in 2003 is markedly different from the same stretch I floated after the 10-inch rain event that occurred in December 2015. Water quality remains a high priority for citizens of Missouri as evidenced by the thriving Stream Team program and the throngs of water quality volunteers who assist state and federal agencies in monitoring our waterways. This issue of the Missouri Natural Areas Newsletter focuses on Missouri's waters, from the springs of the Ozark National Scenic Riverways to the prairie streams with endangered Topeka shiner populations. We also explore the impacts of climate change and the increase in abundance of these once-historic rain events which now occur more frequently than before.

The Missouri Natural Areas Program protects not only small remnant natural communities, but also watershed-scale landscapes such as the St. Francois Mountains Natural Area which weighs in at 7,028 acres. The recently expanded LaBarque Creek Natural Area now encompasses 2,084 acres of high quality ecosystems spanning ownership between the Missouri Department of Conservation and Missouri Department of Natural Resources. Read on to learn more about the highly diverse LaBarque Creek Natural Area and other themes and topics that pertain to our state's valuable water resources.

— Allison J. Vaughn, editor

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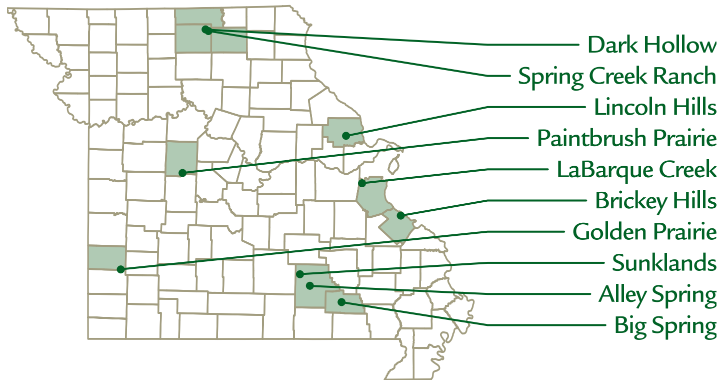
NATURAL AREAS FEATURED IN THIS ISSUE



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

LaBarque Creek's Small, But Mighty Conservation

By Kevin Meneau and Andrea Schuhmann

A one-inch rainfall overwhelms the hilltops of a small urban watershed. Sheets of stormwater scream off numerous impervious surfaces and are collected in nearby pipes to be quickly dumped into normally dry stream channels. The raging torrents exit pipes and rapidly fill increasingly vast canyons gouged out of stream channels which people could once easily step over. Aquatic habitats, and the animals needing it, are devastated across the St. Louis region. The message is as clear as the stormwater is turbid — healthy streams start in small, healthy places. Just a few miles away, the same rainstorm filtered through a mosaic of diverse landscapes within the LaBarque Creek watershed's natural area, slowly producing rivulets which trickle over ancient St. Peter's sandstone waterfalls and gather into an unnamed tributary. These clear and gentle flows augment steady stream base flows to maintain high-quality and diverse aquatic habitats. Small, but mighty conservation lives here.

Photo by Danny Brown

Ghost Falls is just one of many gems tucked away throughout the LaBarque Creek Natural Area. The St. Peters Sandstone formations yield a variety of spectacular geologic features including incised box canyons, shelter caves, sandstone bridges and intermittent waterfalls as observed here.

In 2010, an initial natural area designation of 667 acres was made recognizing upper LaBarque Creek Watershed's sheltered moist canyons, cliffs, bowls, waterfalls, and ravines and the suite of state-listed plants and the natural communities they host. In 2016, an additional 1,417 acres (the balance of Don Robinson State Park and remaining LaBarque Creek Conservation Area) was added. The additional acreage is the source of several Ozark headwater streams that merge to form an outstanding spring branch. This 2nd Order tributary of LaBarque Creek contains an abundance of pool and riffle habitats that form as the stream meanders over sand, gravel, cobble and sandstone bedrock. The surrounding forests and vegetated banks provide critical organic inputs — cycling terrestrial structure, energy, and nutrients into the aquatic environment — in the form of leaves, root wads, and downed trees. These intact, physical and biological elements act in concert to support a remarkable array of fish and aquatic macroinvertebrates here and elsewhere in the watershed.

MDC surveys have identified 54 species of fish that inhabit LaBarque Creek — over three times greater than its downstream Meramec River tributary neighbors. LaBarque Creek's fisheries Index of Biologic Integrity consistently scores above 77, indicating high quality. Many of the fish inhabiting this watershed are long-lived species whose presence not only indicates stream quality but also long-term habitat integrity and stability.

Studies have shown that once 10% or more of a watershed is converted to impervious surface, significant losses in ecological integrity ensue. Unlike the surrounding urban watersheds, less than 5% of the LaBarque Creek Watershed consists of impervious surfaces. Approximately 32% of the entire

LaBarque Creek Watershed is under public ownership (Don Robinson State Park, LaBarque Creek Conservation Area, Young Conservation Area, and Glassberg Conservation Area) to help ensure the long-term protection of this biodiversity hotspot. Collectively, these rich, intact terrestrial communities generate healthy sub-watersheds drained by healthy, small streams. Each healthy tributary may be small, but together the mighty aquatic matrix they form creates a healthy and impressively diverse LaBarque Creek. And within that Creek lies its treasure — tremendous biodiversity.

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The streams of Don Robinson State Park serve as prime examples of headwater streams which course water from the rugged glade and woodland communities to the forest communities in the lower reaches of the LaBarque Creek watershed.

Photo by Kevin Meneau

Planning for Conservation in the Meramec River Basin

By Steven J. Herrington, Ph.D.

"Plans are nothing, but planning is everything." This famous quote by former president Dwight D. Eisenhower speaks to the need for a thorough and measured understanding of all elements that go into a course of action, and that only through that understanding can that course of action be successfully implemented and adapt to changes. The Nature Conservancy in Missouri has applied this principle to conservation planning in order to further long-term protection of aquatic resources in the Meramec River Basin. The Meramec River flows over 200 miles northeast from the Ozarks in east-central Missouri to its confluence with the Mississippi River south of St. Louis. It is among the most biologically significant river basins in mid-continental North America, with diverse and rare aquatic and terrestrial plants, animals, and natural communities. The Meramec and its tributaries also provide important economic and social benefits to the region, including a productive fishery, significant tourism and recreational use and associated economic inputs, and drinking water supplies to St. Louis. Although considered in relatively good health, a number of problems and activities degrade aquatic habitats and fish and wildlife resources throughout the basin. The Meramec River Basin has benefitted from decades of focus by a variety of conservation, planning, and environmental organizations and agencies. These efforts have produced significant conservation benefits; however, these stakeholders determined the need for a comprehensive plan to best align their work for aligning their efforts and further protecting basin resources.

In 2014, The Nature Conservancy completed the Meramec River Conservation Action Plan, a collaboration among 29 conservation stakeholders to develop a unified blueprint for ensuring the sustainability of aquatic resources in the Meramec River Basin. The plan comprehensively identifies and prioritizes target resources for conservation,

Excessive sedimentation from streambank erosion resulting from land conversion is a major problem degrading aquatic resources in the Meramec River Basin.

Photo by The Nature Conservancy

the current health and problems affecting those resources, the source of the problems, and the best actions maximizing the benefit and long-term protection, restoration, and conservation of the Meramec River and its resources. The group determined eight conservation targets to best capture the biodiversity and ecological processes of aquatic resources of the Meramec River Basin. The Lower Meramec River Drainage, Middle Meramec River Drainage, Upper Meramec River Drainage, Bourbeuse River Drainage, Big River Drainage, Huzzah and Courtois Creek Drainages, and LaBarque Creek Drainage were aquatic ecosystem targets, for which actions in those watersheds will ensure the conservation of all associated native biodiversity therein. Freshwater mussels were designated as a separate target given their unique ecological vulnerabilities and special conservation needs.

The current health of the targets, as measured by a combination of biological composition, structure, interactions and processes, environmental regimes, and landscape context, varied from "Poor" to "Very Good," with an overall rank of "Fair" for the Meramec River Basin in total. The Lower Meramec River was ranked "Poor" primarily due to the relatively widespread effects of urbanization on stream function throughout much of the lower river. The Middle and Upper Meramec were ranked "Good," reflecting relatively unimpaired floodplain connectivity and hydrology, though land floodplain conversion from agricultural practices are a concern. The Bourbeuse River was ranked "Fair" because of the high concentration of livestock farming and ranching throughout its tributaries and main stem floodplain, though its hydrology is minimally impaired and it supports a good sport fishery. Despite also having a good sport fishery, a relatively unaltered hydrology, and floodplain connectivity, the Big River was ranked "Fair" due to the presence of several main stem dams and the serious impacts to ecosystem function from heavy metal contamination. The Huzzah and Courtois creeks and LaBarque Creek drainages were the healthiest targets in the basin, being ranked "Very Good" for excellent hydrology, in-stream and floodplain connectivity, riparian corridor condition, and diverse biological communities. Freshwater mussels were ranked "Fair," reflecting recent patterns of biodiversity and population declines throughout the basin.

A variety of problems — or "stresses" — stemming from multiple sources — or "threats" — impair targets in the Meramec River Basin. Twelve stresses were identified as degrading targets in the basin. The first three stresses are interrelated and widespread throughout the basin, with streambank erosion as a potentially significant factor contributing excessive sedimentation in the Meramec River and its tributaries. Although geographically narrow in scope, heavy metal contamination was also highly ranked because of its severe impacts when present and potential to degrade multiple targets, particularly those within or downstream of the Big River. Thirteen threats were identified as sources of the stresses degrading the targets. The six most critical threats were livestock farming & ranching, housing & urban areas, mine tailings & industrial effluents, in-stream gravel mining & reaming, dams & water management, and transportation, utility, & service corridors. Livestock farming & ranching was the most widespread threat across the targets, reflecting the historical and current agricultural footprint within the river and tributary floodplains responsible for multiple stresses degrading targets. Housing & urban areas severely altering stream function in the St. Louis area is thus of particular concern to the lower Meramec River, as well as the Big River, and freshwater mussel targets. Mine tailings & industrial effluents from historical and current heavy metal mining in the Ozarks are the primary source of the contaminated sediments that most strongly affect the Big River. In-stream gravel mining & reaming and dams & water management threats degrade targets in multiple ways, though the extent of their impact in the basin is poorly

Photo by The Nature Conservancy

A new sculpture titled “Where Rivers Flow, Trees Grow” was installed at Edgar M. Queeny Park this fall to raise awareness about the ways native Missouri plants and trees keep our water resources healthy. The 6-foot tall stainless steel sculpture depicts a fish-filled stream that flows up and becomes part of a majestic tree with leafy branches. It was designed and built by 20 St. Louis ArtWorks apprentices in 2015, and commissioned by The Nature Conservancy as part of the “Growing a Healthy Meramec” project with support by the Boeing Company.

understood. Transportation, utility, & service corridors are also widespread and impact targets in multiple ways. A situation analysis helped identify the root causes of the critical threats, as well as conditions and stakeholders that could ameliorate their effects across the Meramec River Basin.

We extracted over 400 goals, objectives, and strategies, as well as research and data needs, from over 40 conservation plans, policies, and publications designed to conserve aquatic resources in the Meramec River Basin. These were synthesized into 87 unified objectives to serve as a template for future conservation planning for this and other river basins. The planning team further refined these to 12 objectives and 14 strategic actions for addressing critical threats in the Meramec River Basin. Strategies were prioritized by ranking several factors relevant to how that action can best achieve objectives for targets, including stresses addressed, duration of outcome, ease of implementation, and costs. Some of the top strategies included: (1) identifying sources of sedimentation throughout the basin in order to better prioritize future actions; (2) assessing land conversion rates to identify areas most likely to be impacted in the future; (3) implementing restoration projects for abating sediment and creating habitat, such as streambank stabilization; and (4) outreach and education for agriculture producers and growing cities for advocating for best management practices, sustainable development, and other water conservation efforts. These strategies represented the first iteration of objective and strategy development across stakeholders in the basin, though future planning efforts are needed to further refine objectives and strategies. In addition to refining strategies, the next steps for implementing the Meramec River Conservation Action Plan included defining research for better understanding target viability and measuring results of conservation actions and developing work plans for implementing the highest-priority strategies.

Since 2014, the Conservancy has worked with partners to help implement several of the strategies developed under the plan. The Conservancy has teamed with the U.S. Fish and Wildlife Service, Missouri Department of Conservation, Ozark Regional Land Trust, and other plan partners to implement on-the-ground restoration, such as reforestation and streambank stabilization using bioengineering, in target areas of the Meramec, including the Huzzah, Courtois, and LaBarque creeks. The partners recently completed an urban outreach project in St. Louis' Queeny Park, where nearly 10,000 trees were planted to improve the watershed for a small tributary to the lower Meramec, and students with St. Louis Art Works created a sculpture symbolizing watershed protection at the park. Among the most important was to better understand sources of sedimentation, the top-ranked problem impacting aquatic resources and highest priority need per the plan. Meramec partners agreed to pursue this need at the basin scale, and in 2015, the U.S. Army Corps of Engineers and the Missouri Department of Natural Resources entered into an agreement to develop a Meramec River Feasibility Study. The goals of the 3-year study are to (1) identify water resources problems impacting river resources such as excessive sedimentation and heavy metal contamination, (2) formulate and evaluate solutions, and (3) prepare recommendations for targeting aquatic restoration projects that will provide the greatest ecological lift. Under this effort, the Conservancy is working with Saint Louis University to complete a basin-scale analysis of nonpoint source pollution and modeling future potential impacts of land conversion and climate change. The Conservancy will also update the Meramec Conservation Action Plan and revise its most effective strategies with this new information. These are among a few of the collaborative actions that partners are taking in the Meramec. Hopefully, this continued planning will help provide some of the "everything" needed to ensure we as conservationists do the things that matter the most for the Meramec River's natural resources and the people who depend on them for generations to come.

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Photo by Missouri Department of Conservation

Adult Eastern Hellbender observed walking on the bottom of the Big Piney River.

The Hellbender

A Journey in Saving a Declining Ozark Highland Salamander

By Jeff Briggler, Ph.D.

Hellbenders are large (~16 to 20 inches long), aquatic salamanders that inhabit cool, highly oxygenated, moderate to swift-flowing rivers in the Ozark Highlands. They have a large, keeled tail, small eyes, a great sense of smell, and a dorso-ventrally flattened body that enables movement in the fast-flowing streams it inhabits. The sides of their body have numerous fleshy folds providing surface area for respiration. Currently, there are two described subspecies of hellbenders (Ozark Hellbender and Eastern Hellbender) found throughout the eastern United States. The Ozark Hellbender is endemic to the southern Ozarks in Missouri and Arkansas. Missouri is the only state with both subspecies of hellbenders. Rivers in the Ozarks that are heavily spring-fed with large, flat rocks and bedrock crevices carved from the limestone and dolomite geology provide hellbenders with food, shelter, and reproduction needs. Hellbenders will typically spend their entire life within a small reach of river living beneath rocks and within bedrock crevices during the day and emerging to forage on crayfish particularly at night. Breeding generally occurs between early September and late October. Males prepare nest chambers primarily beneath large, flat rocks or within bedrock crevices and wait for a female to arrive. Upon arrival of the female, she will deposit eggs within the nest chamber that are fertilized externally, which is an ancient characteristic for salamander species, one similar to fish species. From this point forward the male will guard the eggs and resulting larvae for six to seven months until the hatchling hellbenders venture out of the nesting chamber.

Hellbenders have dramatically declined over the past 40 years in Missouri, with a prominent shift in age structure towards large, mature individuals with young age classes virtually absent. Historic population estimates were over 45,000 animals. Today less than 2,300 are known from the wild in Missouri. In addition, results of a population assessment indicated that all hellbender populations have a high risk of extinction (above 96%) over the next 75 years unless populations are bolstered. Due to the drastic population decline, both subspecies were listed as critically imperiled and state endangered in 2003, and in 2011 the Ozark Hellbender was listed as a federally endangered species.

A multitude of factors have likely influenced hellbender populations (e.g., disease, habitat alteration and degradation, illegal harvest and disturbance, predation, and water quality degradation), and declines are likely due to the cumulative effect of these factors. The Ozark Hellbender Working Group was established to slow the decline of the species and address the multitude of potential threats facing this animal. This group was initially comprised of dedicated researchers and agency personnel with a common interest in the conservation of hellbenders. However, it became clear from the beginning that a coordinated effort was necessary to synthesize the knowledge to date and to provide guidance and support for hellbender research, conservation, and recovery efforts. Today, this collaborative, multi-agency, multi-discipline working group consists of researchers and biologists from several universities, public zoos, fish hatcheries, state and federal agencies, and private citizens from Arkansas and Missouri. Necessary expertise in all disciplines (researchers, managers, herpetologists, veterinarians, pathologists, policy makers, educators, etc.) was crucial to conserve this species. Below are some highlights of the extensive ongoing recovery actions undertaken to address the decline of hellbenders in Missouri.

Outreach & Education

Informing individuals about the plight of hellbenders is important not only to prevent persecution of animals, but also to provide opportunities for people to make conscious decisions to help hellbenders. Considerable efforts have taken place to inform Missouri citizens about hellbenders. The Missouri Department of Conservation has developed and dispersed widely information such as brochures, stickers, exhibits, posters, fact sheets, videos, and TV shows (local, national, and international). Multiple workshops and presentations have occurred over the years to inform individuals of the importance of protecting and enhancing the forested riparian corridor that will improve water quality and habitat for hellbenders and other aquatic life. Now many Missourians are aware of the hellbender and many willingly assist with helping to save this species.

Monitoring

In spring 2009, we implemented an occupancy protocol to assess the long-term population status

Adult male Ozark Hellbender from the Current River defending a nest chamber entrance within a bedrock crevice.

Photo by Missouri Department of Conservation and distribution of hellbenders in Missouri's rivers. Monitoring results showed that hellbender occupancy probabilities by river varied from a low of 8% to a high of 86% and surveyor detection probabilities ranged from 25% to 96%. Long-term monitoring will not only allow biologists to keep a handle on the current population status of wild animals, but also to provide insight into the status of the captive-reared hellbenders released into the wild.

Research

While we have indicated factors contributing to the decline of hellbenders which are likely cumulative, only through continued research of these factors will we be able to begin to understand their impacts on hellbender populations and thus begin to eliminate or address these threats. Over the past twelve years, we have observed an alarming number of abnormalities such as missing appendages, open sores, gashes, eye disorders, tumors and cysts with higher and more severe (life-threatening) abnormalities in Ozark Hellbender populations. It is believed that native bacteria and fungus might be the cause of the open sores that rarely heal due to the weakened immune response of an aging population. Currently, research focuses on the microbiota on hellbender skin and its potential of causing such abnormalities.

Many diseases, especially fungus related, are impacting wildlife worldwide. The amphibian chytrid fungus is known to impact amphibians worldwide and is currently found throughout North America, include hellbenders in Missouri. This fungus has been detected on hellbenders in six rivers and is more prevalent and widespread in Ozark Hellbenders compared to Eastern Hellbenders. Learning more about the frequency, distribution, infection rates, and infection load of such pathogens is important to further determine the impact to hellbenders, as well as other aquatic species. In many cases, animals will have to adapt to many of these pathogens, but recent genetic research is showing promising results related to immune response genes of resistant individuals that can be bred into populations in captive conditions.

Considerable research to assess the general health of wild hellbender populations continues. Scientists compare overall health conditions, hormone levels, and selective heavy metal levels in hellbenders. Information indicates no serious concerns although some accumulation of mercury was observed. This information contains the most comprehensive blood chemistry database for this species and will be of vital importance for future comparisons.

With much effort devoted to propagation and the lack of recruitment observed in the wild, the U.S. Fish & Wildlife Service and Missouri Department of Conservation are examining hellbender sperm profiles (e.g. motility, viability, concentration). Limited data exist on the quality of sperm produced by hellbenders. In 2010, sperm assessments were initiated in several Missouri's rivers to obtain baseline information on sperm health of hellbenders. To date, sperm profiles have been assessed from the majority of rivers in which hellbenders live, and results show that the quality of sperm is good and fertilization of eggs is occurring. These results indicate that the lack of recruitment observed in wild populations is likely due to some other factor.

Investigating hellbender genetics was necessary to inform propagation and re-introduction efforts and to better understand life history traits of the species. Numerous genetic studies over the years show that populations in Missouri are comprised of at least three distinct genetic management units. Such information will aid in making informed decisions regarding the collection of brood stock and eggs from the wild, as well as releases of captive propagated individuals.

Captive Propagation Programs

Captive propagation and head-starting are essential to the long-term recovery of hellbenders in Missouri while addressing reasons for declines in the wild. Without such intervention, both subspecies will likely go extinct in Missouri. The Saint Louis Zoo and MDC Shepherd of the Hills Fish Hatchery have successfully hatched eggs collected from the wild and reared young for future releases. In addition to the successful collection of fertilized eggs from wild populations, in 2011 two clutches of fertilized eggs were discovered in an outdoor raceway that mimics water and weather conditions of a hellbender river at the Saint Louis Zoo, a milestone for the captive breeding program.

This was the world's first captive-breeding of the species. Successful captive-breeding has occurred annually since 2011. To date, we have released over 3,600 captive-reared hellbenders from the Saint Louis Zoo and Shepherd of the Hills Fish Hatchery into the wild. Recent monitoring indicates captive-breeding and subsequent releases in the wild can be successful.

Summary

Hellbenders are the flagship species for the spring-fed rivers in the Ozark Highlands. It is believed that the biomass of hellbenders once exceeded all other individual aquatic species living in these rivers. Addressing threats to hellbenders entails improving water quality and the physical characteristics of the waterways in the Ozark Highlands, which will also improve conditions for many other aquatic species. Many rivers in Missouri with hellbenders are surrounded by public lands with forested riparian corridors that filter rainfall and reduce soil erosion, areas such as the Ozark National Scenic Riverways, Mark Twain National Forest, Sunklands and Current River Conservation Areas. Increased sedimentation and gravel loading tend to change stream conditions by decreasing water volume, increasing stream width, and increasing fine particles and silts that negatively impact the life history needs of hellbenders and other aquatic life. Hellbenders also depend upon the cold water provided from the many springs for increased oxygen exchange. Missouri natural areas such as Sunklands, Horseshoe Bend and Eck Memorail Natural Areas not only play a role in preserving the natural communities along these riverways, but also in protecting many cold-water springs like Big Spring, Blue Spring, Spring's End Forest, and Powder Mill Cave Natural Areas, among others. With further protection and enhancement of river conditions, focused research, continued successful captive propagation, partnerships, and dedication of individuals, the future of the hellbender in the Ozark Highlands is looking optimistic.

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Release of Ozark Hellbenders by Missouri Department of Conservation and Saint Louis Zoo staff on the Eleven Point River.

Photo by Jen Girondo, Missouri Department of Conservation

Photo by Heartland Inventory & Monitoring Network, National Park Service.

The run of Alley Spring supports a diverse community of aquatic vegetation.

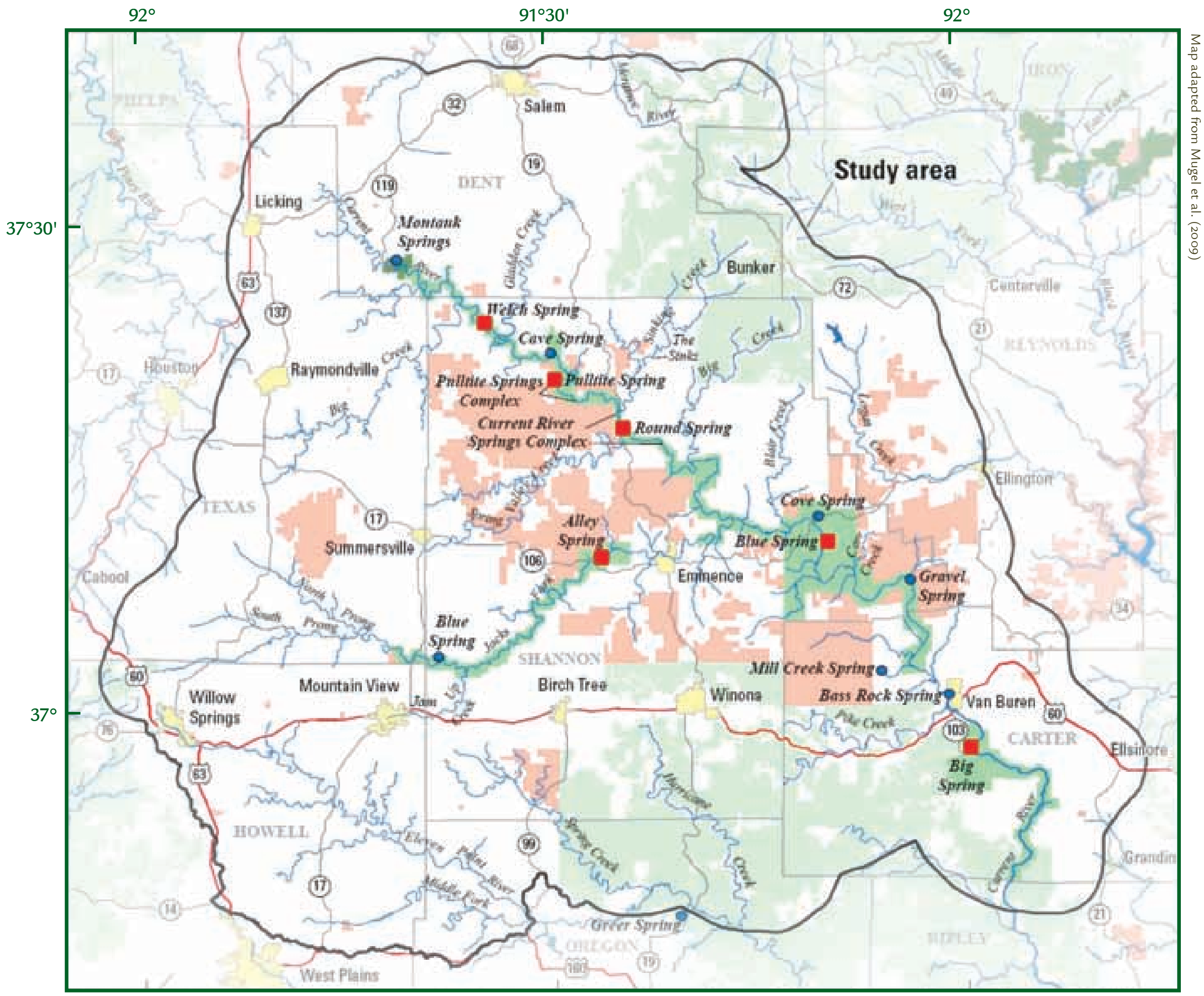
Monitoring Missouri's Large Springs

By Dr. David E. Bowles and Hope R. Dodd

The karst landscape of southern Missouri is well marked with sinkholes, fissures, caves, and springs. Accordingly, the Missouri Ozarks are home to some of the largest springs in North America, in addition to thousands of smaller springs. The crystal clear, thermally consistent, and cold waters (~60°F) issuing from these springs have ethereal qualities that make them features of immense interest and fascination to the public. In addition to their strong cultural heritage, these springs are sources of amazing biological diversity. Ozark National Scenic Riverways (OZAR) was established to conserve and interpret unique scenic and other natural values and objects of historic interest, including more than 425 known springs and 134 miles of the Current and Jack's Fork rivers. Although most of the springs within OZAR are relatively small, seven are defined as 1st and 2nd magnitude (Meinzer 1927; Vinyard et al. 1974). First magnitude springs are those with flows greater than 100 cubic feet per second, and second magnitude springs have flows of 10 to 100 cubic feet per second. At OZAR, these include Alley, Big, Blue (Missouri Department of Conservation ownership), Phillips, Pulltite, Round, and Welch springs. An eighth large spring, Montauk, is located outside of the park boundary at Montauk State Park (Missouri Department of Natural Resources ownership) and serves as the headwaters of the Current River.

The porous and fractured karst landscape that favors the formation of springs also makes groundwater vulnerable to pollution from surface contaminants. Land use, particularly vegetation clearing practices with associated increases in sediment and nutrient loads and other point and nonpoint stressors, pose the largest long-term threat to streams, springs and groundwater in the Ozark Highlands. Resulting impacts to spring integrity from land use changes may include disrupted stream channel geomorphology, increased sediment deposition and bank erosion, increased light penetration and water temperature, increased periphyton biomass resulting from nutrient loading, and decreased leaf litter and woody debris. Recent studies of the possible effects of global climate change suggest that increases in annual average water temperature and changes in discharge may impact spring communities as well (Poff et al. 2002, Cantonati et al. 2006). Invasive species, especially plants, also pose very real threats to the springs (Padget 2001; Bowles and Bowles 2013; Bowles and Dodd 2015) . While a considerable body of scientific literature has assessed threats to groundwater, there is little information on the physical and biological impacts within springs or

Locations (red squares) of the seven springs monitored by the Heartland Inventory and Monitoring Network.



Base from U.S. Geological Survey digital data, 1995, 1:24,000 and 1:100,000
Missouri Spatial Data Information Service, 2007; U.S. Census Bureau, 2000
Universal Transverse Mercator projection, Zone 15

0 5 10 15 20 25 MILES
0 5 10 15 20 25 KILOMETERS

within surface water fed by springs.

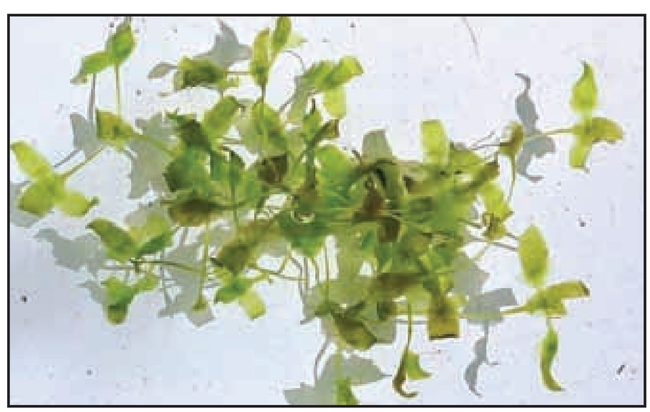
Despite the immense importance of springs to biodiversity and to the water quantity and quality of receiving streams, little inventory and monitoring of physical habitat or biota have been conducted historically for spring systems in North America, including OZAR, although a few one-time vegetation surveys have been completed for some OZAR springs (Drouet 1933; Steyermark 1941; Lipscomb 1969; Redfearn 1972, 1981; Currier 1990a, 1990b; Converse 1994, Yatskievych 1999, 2006, 2013). The absence of baseline biological data and sustained monitoring for these springs makes their management difficult because there is little information by which to assess degradation. Monitoring of aquatic vegetation, fish, and invertebrate communities establish necessary baseline inventories and aid in detection of ecosystem disturbances, such as water quality degradation or introduction of invasive, non-native species. Since 2007, staff of the Heartland Inventory and Monitoring Network have monitored spring communities at OZAR (Bowles et al. 2008; Bowles et al. 2011). Monitoring includes aquatic vegetation, invertebrates, fish, and their respective habitats and water quality. Details on specific sampling methodologies are described in Bowles et al. (2008).

Today, with ten years' worth of data collected by the Heartland Network, a clearer picture of community dynamics within the springs is emerging. A broad assemblage of aquatic vegetation occurs among the springs at OZAR with 69 distinct taxa being known. They include 5 species of algae, and 19 species of mosses and liverworts. The angiosperms are the most diverse group in the springs with 20 species of monocots and 24 species of dicots. The highest richness of aquatic plants among springs based on transect data from all years combined was at Round Spring, where 20 taxa were found. Alley and Blue springs each had 19 taxa, while the other springs had fewer species. Non-native species were poorly represented

Assessing the aquatic vegetation community at Pulltite Spring.

Sampling aquatic invertebrates at Alley Spring.

Sorting fish collected from Alley Spring following an electrofishing survey.



Star duckweed, *Lemna trisulca*.

Photos by Heartland Inventory & Monitoring Network, National Park Service.

among all springs and their percent foliar cover is generally less than 15%. The most commonly occurring non-native plant was watercress (*Nasturtium officinale*). Although most of these non-native species are considered terrestrial or wetland plants, they grow in the spring runs at OZAR where some specimens are completely submersed. Other aspects of plant community diversity and dynamics can be found in Bowles and Dodd (2015).

Perhaps the most unusual angiosperm that occurs in the springs is Star duckweed (*Lemna trisulca*). This species is rare in Missouri and was found in five of seven springs monitored by the Heartland Network (not found in Pulltite and Welch springs). Star duckweed has an S2 state heritage ranking, which indicates its populations are imperiled. The environmentally sensitive red alga, *Batrachospermum* spp., occurs in all of the springs. Monitoring has produced other unusual findings of fully submersed terrestrial or wetland species. For example, *Physostegia virginiana* grows completely submersed at Blue Spring (Bowles and Dodd 2015). The present distribution of *P. virginiana* at Blue Spring is in the same general area as that reported by Steyermark (1941).

The late Julian Steyermark documented aquatic plant occurrence in the springs in his seminal 1941 publication (Steyermark 1941). Since that publication, the plant community structure in several springs has changed markedly. Some species recorded by Steyermark have disappeared and others have been documented for the first time (Bowles and Dodd 2015). The most notable example is of leafy pondweed (*Potamogeton foliosus*), which Steyermark found in most of the springs, but it is now largely absent. Bowles and Dodd (2015) contend that "weedy" species such as *P. foliosus* no longer occur in the springs because those habitats have become more stable as the landscape has recovered from historic disturbances. The present conditions of the watersheds of these springs have changed appreciably since Steyermark began his floristic study in 1928. The historic Ozark forest was the nation's leading producer of lumber from about 1880 until about 1920, which resulted in broad-scale deforestation (Benac and Flader 2004). Such deforestation, coupled with destruction of riparian vegetation by open range livestock, and severe upland erosion likely altered the watersheds of these springs (Jacobson and Primm 1997). Such disturbances may have resulted in increased siltation entering karst recharge features, and reduced recharge times of precipitation into the source aquifer. It is likely that such impacts altered vegetation communities in the springs at the time Steyermark studied them. Regrettably, although forest cover has now largely recovered, we are unable to gauge the extent to which the springs and their biological communities mirror their respective historic conditions. Although some baseline information was available to assess historic changes in the plant community, no such information is available for the invertebrate and fish communities and we are therefore unable to make a judgement on the extent to which they may have been altered.

Photo by Heartland Inventory & Monitoring Network, National Park Service.

The environmentally sensitive red alga, *Batrachospermum* sp.

Aquatic invertebrate assemblages among the springs includes more than 66 genera from over 50 families. Diversity of aquatic invertebrate taxa within the springs is relatively low compared to area streams and they typically have only about one-third as many taxa. What they lack in diversity, however, they make up in numbers as most of these springs have benthic densities several times higher in comparison to streams. The data collected by the Heartland Network shows that intolerant invertebrate taxa, such as the caddisfly genus *Lepidostoma*, are dominant in the springs, which indicates their respective water quality conditions are good. Other common taxa occurring in samples included spring snail (*Amnicola*), water mites ("Hydracarina"), midges (Chironomidae), and amphipods (*Hyalella azteca, Crangonyx, Gammarus*).

Similarly, fish communities exhibit low diversity, typically consist of only four to five species, but include those species intolerant of poor water quality conditions and siltation. The dominant species in most springs were Knobfin sculpin (*Cottus hypselurus*) and Banded sculpin (*Cottus carolinae*), with the exception of Round Spring, which consisted largely of Bleeding shiner (*Luxilus zonatus*). Most of the fish species collected from the springs require clean gravel and cobble substrates and high dissolved oxygen levels. Other fish species collected include Chain pickerel (*Esox niger*) and Hornyhead chub (*Nocomis biguttatus*). Warmwater fishes such as darters (*Etheostoma* spp.) and sunfishes (*Lepomis* spp.) are relatively rare in the springs during the summer, although studies indicate that sunfish species utilize the springs

Banded sculpin (*Cottus carolinae*) are common inhabitants of Missouri's freshwater springs.

Photo by Heartland Inventory & Monitoring Network, National Park Service.

during fall and winter (Peterson and Rabeni 1996; Westhoff et al. 2016).

The data collected during our monitoring reflects the broad natural habitat diversity and physical and chemical stability in these springs. Habitat conditions within a spring depend on their independent watersheds and groundwater sources as well as many other factors. While our findings for the springs at OZAR are generally applicable to springs throughout the region, we have found the springs exhibit a high degree of individuality, and typically an azonal character. It is becoming increasingly clear that physical habitat factors including bank stability, flow, substrate size and diversity, and distribution and diversity of aquatic vegetation may play a primary role in structuring these communities. So far, the springs show that they are stable and exhibit little change within the range of our collected data.

Ozark springs are treasures that must be protected and conserved for present and future generations. The Heartland Network believes its monitoring data will facilitate sound management decisions that will ensure these springs will remain in high quality condition for generations to come.

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Recent increase in extreme rainfall amounts in the Big Barren Creek Watershed, S.E. Missouri

By Robert T. Pavlowsky, Ph.D., Marc R. Owen, M.S., and Rachael A. Bradley

Channel erosion and sediment problems in streams draining forest lands in the Missouri Ozarks have raised concerns by both managers and landowners. More frequent flooding, higher rates of bank erosion and excessive gravel deposition in stream channels can result from a combination of factors including climate change, land management practices, and land use development. The Mark Twain National Forest Soil and Water Program of the U.S. Forest Service Department of Agriculture is cooperating with the Department of Geography, Geology, and Planning and the Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University in Springfield to assess the response of water quality, runoff, and stream morphology to landscape-scale forest restoration activities presently underway. The goal of the project is to determine water, soil, and stream conditions within different management areas to evaluate any negative and positive outcomes in Big Barren Creek Watershed (191 km^2) which drains into the Current River between Van Buren and Doniphan, Missouri.

One objective of this multi-year project is to evaluate rainfall trends to see if increased rainfall may be associated with recent stream disturbances. This report describes the analysis of rainfall records from multiple rainfall monitoring stations to describe variations in annual rainfall and high rainfall days over the past 60 years. High rainfall days are those which are relatively rare in occurrence, but provide extremely high rainfall amounts greater than 3 in. in a single day. The rationale for linking wet periods or high rainfall days to stream conditions is straightforward: more frequent rains are expected to produce more and/or larger floods, which exceed the strength of channel materials, and thus increase bank erosion and bar sediment instability. The results of this study indicate that both total annual rainfall and frequency of high rainfall events have increased in the Big Barren Creek watershed over the past decade. Thus it is probable that climate factors have contributed to the recent flooding and sediment problems in the Big Barren Creek.

Background

Recent studies indicate that more extreme rainfalls may be producing larger floods in the Ozarks (e.g., Foreman 2014). National Climate Assessment

Table 1. Monitoring stations used for this study

Station Name	State	County	Period of Record Start Date	Distance from Big Barren Creek Watershed (km)	Number of Records	Percent Complete
Doniphan	MO	Ripley	4/1/1904	36.4	21,655	98.8
Clearwater Dam	MO	Wayne	11/1/1946	43	21,081	96.2
Mammoth Spring	AR	Fulton	4/26/1904	56.9	21,110	96.3
Summersville	MO	Shannon	4/3/1940	57.3	20,914	95.4
Poplar Bluff	MO	Butler	1/1/1893	61.9	21,306	97.2
West Plains	MO	Howell	7/1/1948	67	21,244	96.9

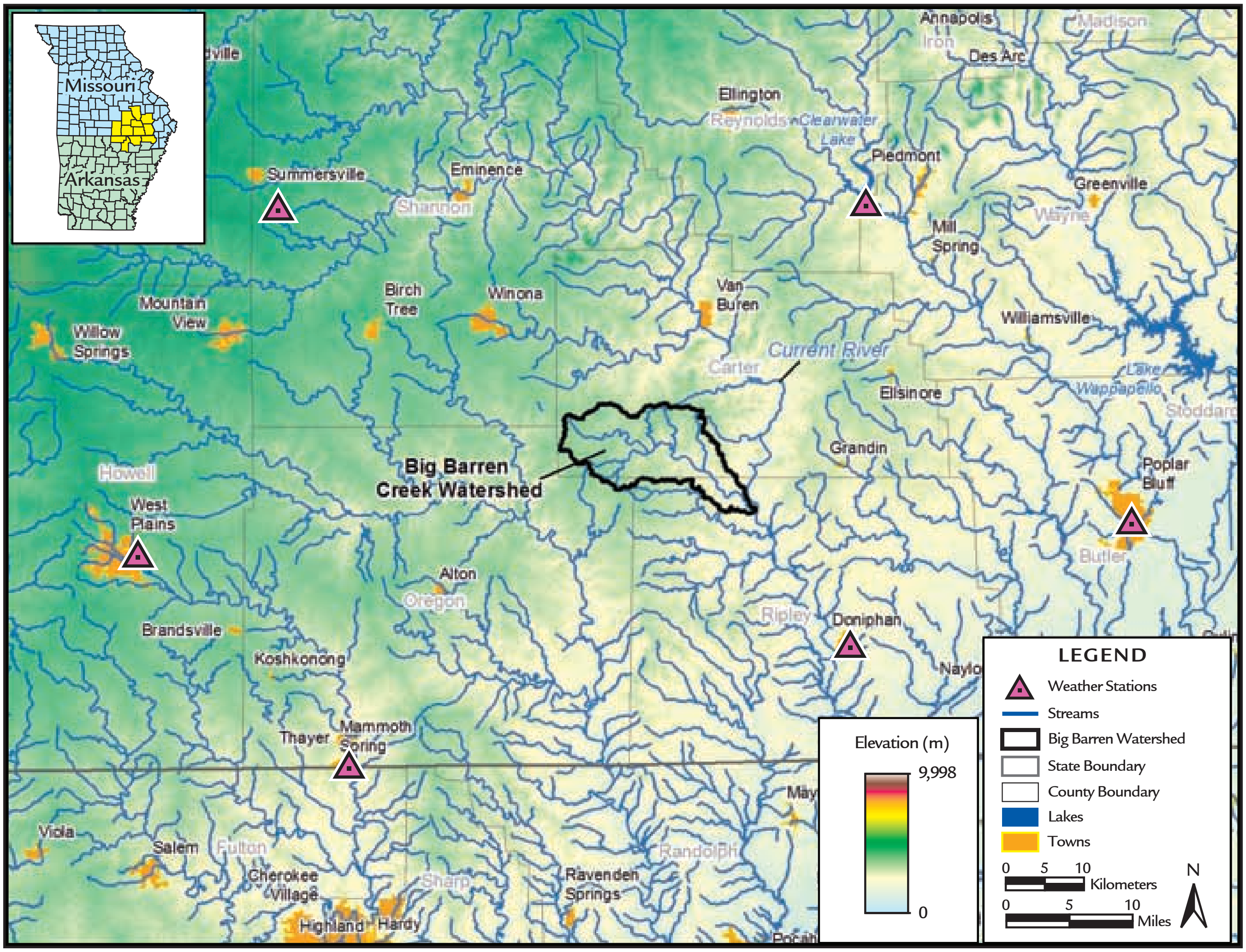


Figure 1. Locations of rainfall monitoring stations near the Big Barren Creek watershed.

2014 predicts warming temperatures, longer dry periods, and higher frequency of intense rainfall events over the next 50 years in southeastern Missouri (Pryor et al. 2014). Historically, high magnitude rainfall events have accounted for a large portion of annual rainfall amounts in the region. Between 1971 and 2000, the top ten wettest days of the year made up 36% to 42% of the total annual rainfall in southeast Missouri (NOAA 2013). However, rainfall trends in the Midwest show that the daily frequency and average rain depths of storm events have not necessarily increased, but that the number of high rainfall days has become more frequent (Villarini et al. 2013). These trends seem to suggest southeast Missouri will experience more extreme dry and wet periods where annual rainfall will be concentrated in higher magnitude events separated by longer dry periods.

The increase in high magnitude events can have implications for flooding and widespread channel instability. Over the past 50 years, out-of-bank flood frequency has generally increased in the Midwest (Mallakpour and Villarini 2015) and the continental United States in general (Xiodong et al. 2013). A temporal analysis of climate-channel morphology relationships over the last 10,000 years indicated a strong link between flood regime and channel morphology in the Midwest. For example, bank-full floods increased in peak discharge by 30% due to increases in mean annual temperature of 1–2 degrees Celsius and mean annual precipitation of 5 to 20% (Knox 2000). From the above review, it is clear that more frequent, high magnitude floods could cause widespread channel instability, excess gravel transport, and higher bank erosion rates as now being observed in southern Missouri.

Historical Rainfall Records

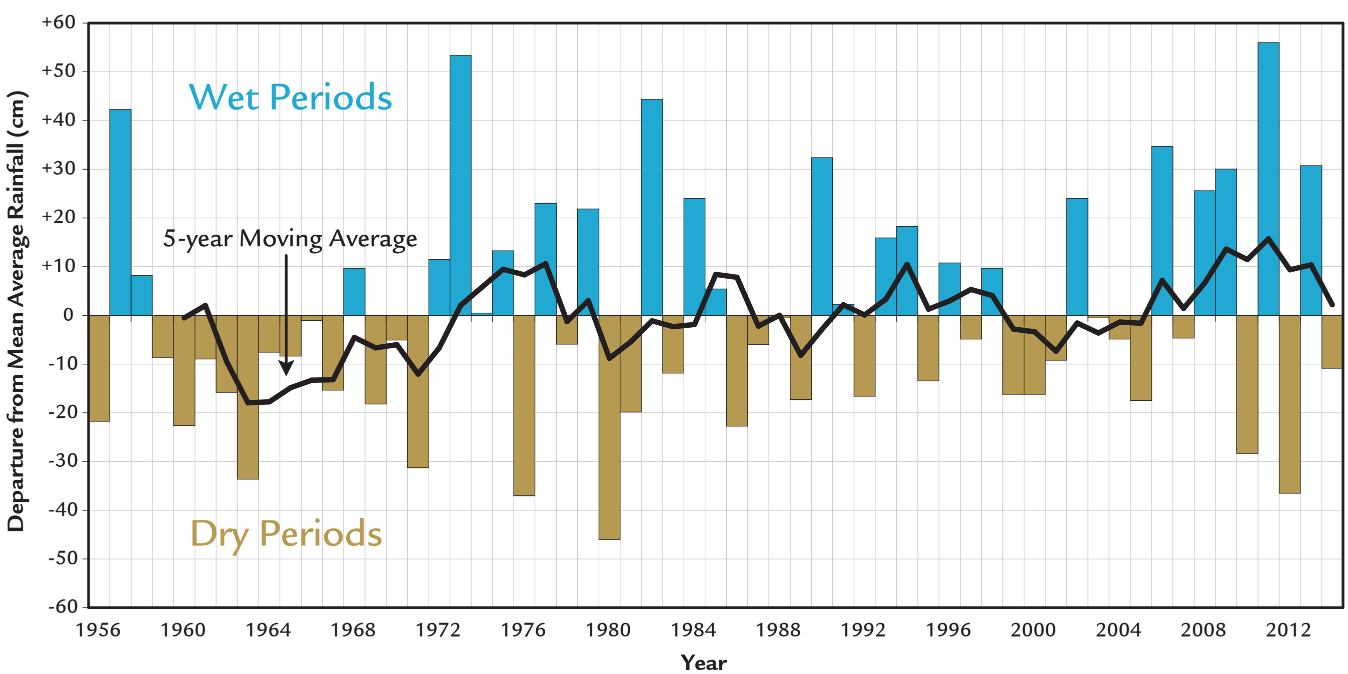
Daily rainfall records used in this study were obtained from the Midwestern Regional Climate Center's (MRCC) cli-MATE (MRCC's Application Tools Environment) database. Since there were no long-term rainfall gauges in Big Barren Creek watershed, rainfall records from surrounding stations were combined to create a rainfall record for the study area. Weather stations selected for analysis were located within 43.5 mi. of the Big Barren Creek watershed, had at least 60 years of rainfall records, and contained daily rainfall records that were at least 95% complete. Six weather stations were used to model the historical rainfall record for Big Barren Creek using the inverse distance weighted method (Table 1, Chen and Liu 2012). The distribution of rain gauges used in this study generally surrounds Big Barren Creek with one gauge located in Arkansas at Mammoth Spring and five gauges located in Missouri at Doniphan, West Plains, Summersville, Clearwater Dam, and Poplar Bluff (Figure 1).

The daily precipitation record for each station was evaluated for a 60 year period from August 1, 1955 to July 31, 2015 creating a maximum record length for each gauge of 21,915 days. The number of daily records for the six stations used for this study ranged from 20,914 (95.4%) at the Summersville station to 21,655 (98.8%) at Doniphan (Table 1). Missing daily values were predicted using correlations to the other stations with complete data sets for those periods. Days with measurements of zero or trace rainfall depths of 0-0.05 in. ranged from 76.8 to 81.3% of the time for the six stations. The distribution of days with rainfall depths greater than 0.05 in. ranged in frequency among the six gauges as follows: (i) 0.05–0.5 in. from 9.9 to 14.8% of the time; (ii) 0.5–1.0 in. from 4.7 to 5.2%; (iii) 1.0–3.0 in. from 3.3 to 3.7%; and (iv) greater than 3.0 in. occurred ≤0.3% of the time.

Rainfall Record Analysis

The mean annual rainfall at Big Barren Creek from 1956–2014 was 47.2 in. (±17.9 in. at the 95% confidence interval) (Figure 2). Over the 60 year study period, annual rainfall trends show relatively pronounced cyclic variations in annual rainfall totals which are expected given the control of regional weather patterns by upper atmospheric oscillations like El Nino and the Pacific Decadal Oscillation (Dai 2013). Annual rainfall totals were compared to

Figure 2. Annual rainfall departure from the long-term average. The average annual rainfall amount over the entire 1956 to 2014 study period was 119.8 cm (47.2 in). Over the same period, the average annual rainfall amount was increasing at a rate of an .22 cm/year.



the mean to look at yearly departure from the long-term average. Overall, rainfall trends cycle from wet to dry to wet periods over periods of 10 years ranging from 5 to 17 years. A relatively long dry period occurred from 1959 to 1971 (13 years) and a wet period from 2005 to 2013 (9 years). Very wet years occurred in 1957, 1973, 1982, 1990, 2006, 2011, and 2013 where rainfall was greater than 25% higher than the long-term average. In contrast, 1963, 1971, 1976, 1980, and 2012 were very dry with annual rainfall totals greater than 25% below the long-term average.

Annual rainfall amounts have tended to increase gradually over the last 60 years with the highest rainfall period occurring during the past decade. Since 1955, average annual rainfall has increased by 5.2 in. (11.7% increase) from 44.6 in. in 1955 to 49.8 in. 2016 or 0.09 in. per year over the last 60 years as indicated by linear regression of total annual rainfall over a calendar year (Figure 2). Since 2005, there has been an extended wet period, even with two dry years in 2010 and 2012, and total annual rainfall increased by 7% over the previous 20 years (1985-2004). These results indicate that over the last 10 years the Big Barren Creek watershed has experienced a relatively wet period compared to the previous 50 years. This pattern is not unique to southeast Missouri. Villarini et al. (2011) show the largest values of extreme rainfall events in the Midwest occur in eastern Kansas, Missouri, and Iowa. Additionally, previous studies of historical rainfall patterns have shown a steady increase in both total annual rainfall and the number of days rainfall has equaled or exceeded 2 in. in the Midwest since the early 1900s (Angel and Huff 1997, Kunkel et. al 1999).

High rainfall events occurred more frequently and with higher magnitude during the last decade compared to the 50 years prior. Daily totals for the highest rain events (≤10% exceedance) have increased over the last decade while the daily totals for more moderate rain events (25% exceedance) have remained fairly constant over the last 60 years

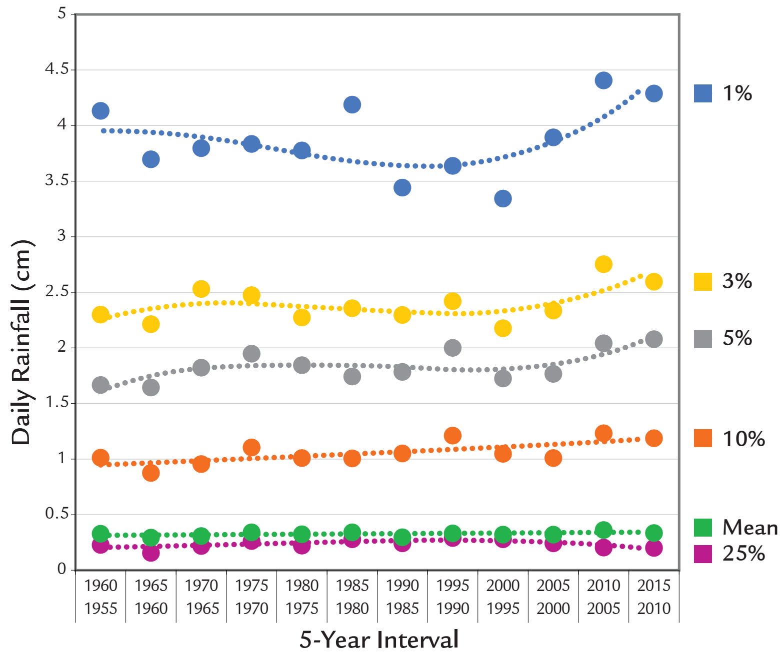


Figure 3A. Daily rainfall records analyzed in 5-year intervals for percent exceedance and mean.

(Figure 3A). The effect of increasing rainfall is most noticeable for the rarest or most extreme events. For example, the 1% exceedance daily rainfall event has increased by 21% over the last decade (2005–2015) compared to the previous 20 years (1985–2005).

This study draws attention to an increase in extreme high rainfall days in Big Barren Creek Watershed and suggests that the upland runoff and stream flows generated could result in more downstream floodplain and channel erosion. There were a total of 16 days with rainfall totals greater than 3 in. over the last 60 years (Figure 3B). However, these events were not evenly distributed over time. Daily rainfall totals only exceeded 3 in. six times from 1955–2005 (0.12 events/year), while exceeding that threshold ten times during the period from 2005 to 2015 (1 event/year) for a 8.3-times increase in frequency over the past decade. Similar trends can be seen in the number of daily totals exceeding 1 in. over the same time period. The number of daily rainfall totals greater than 1 in. varied from 8.2 to 10.6 days per year with an average of 9.5 days per year from 1955–2005 (Figure 3C). However, the frequency of greater than 1 in. events increased to an average of 12 days per year from 2005–2015, over a 20% increase.

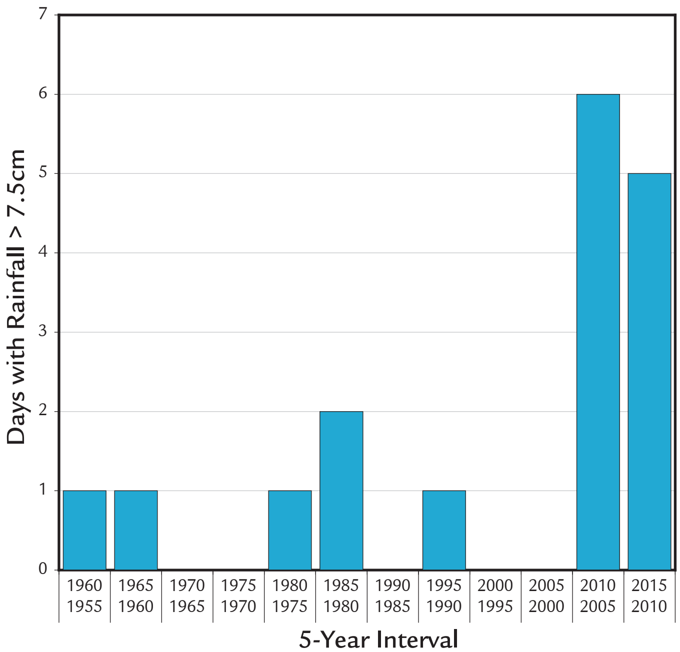


Figure 3B. Daily rainfall records analyzed in 5-year intervals for days greater than **7.5 cm** (~3 in) rainfall

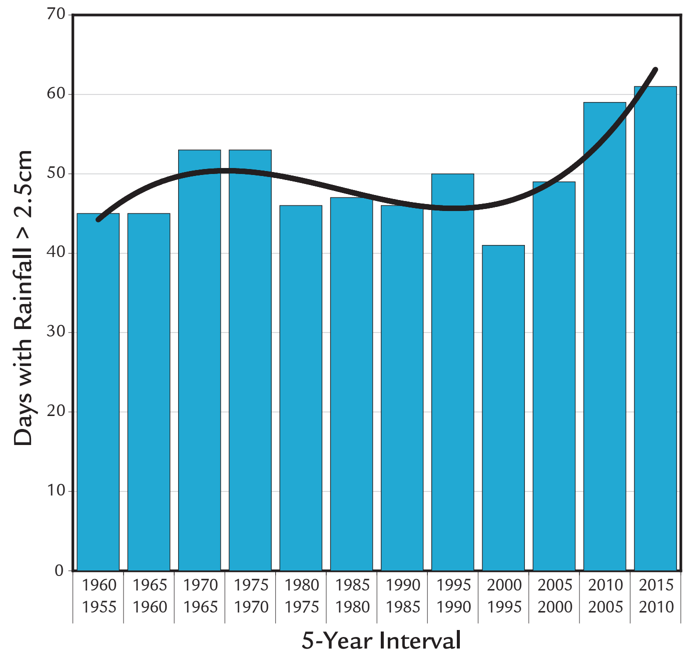


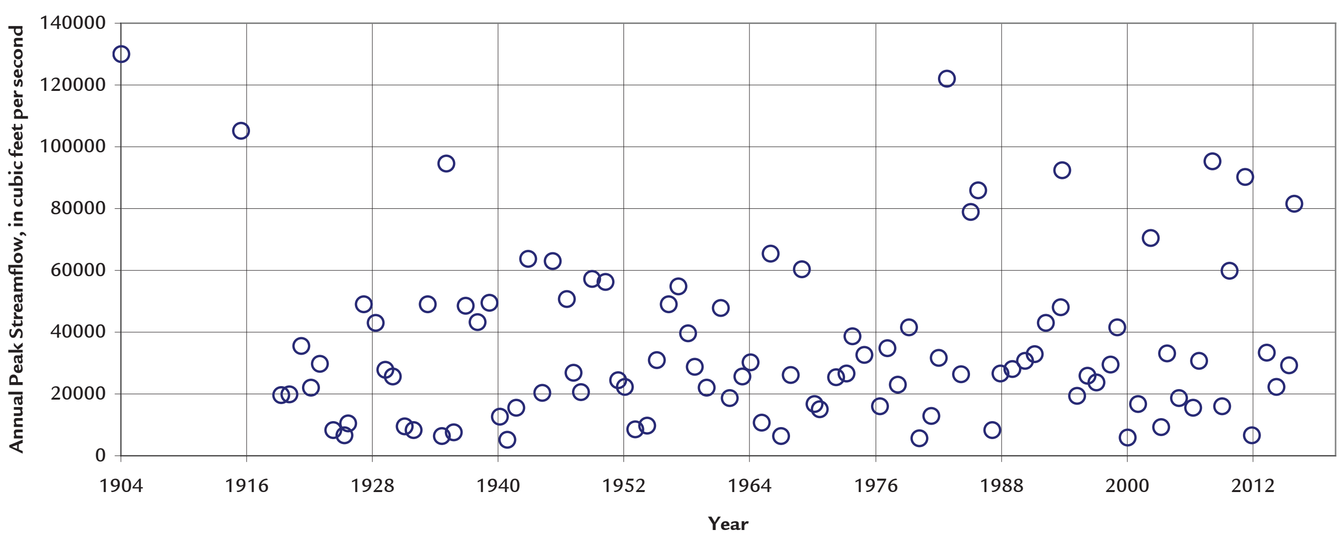
Figure 3C. Daily rainfall records analyzed in 5-year intervals for days greater than **2.5 cm** (~1 in) rainfall

Recent period of larger floods in Ozark Streams

The findings of this study indicate a recent 10 year period of increased high rainfall frequency in southeastern Missouri, and suggest that river flooding may also follow this trend. Indeed, analysis of U.S. Geological Survey (USGS) gauge records also indicates the frequency of larger flood events has increased in recent years in Ozarks watersheds. Foreman (2014) found the 100-year peak flood discharge has increased by greater than 30% over the last 30 years in 11 of 12 Ozark rivers examined with gauging records greater than 90 years and that significant increases in flooding has occurred over the past ten years for several gauges. Moreover, in a recent study by OEWRI of 23 USGS gauging stations across the Ozarks, the 100-year peak flood increased by more than 10% at 70% of the gauges and by more than 50% at 22% of the gauges evaluated (Pavlowsky, 2016).

The annual peak flood record for the Current River at Doniphan, Missouri shows that periods

Figure 4. Peak annual flood series from the U.S. Geological Survey gauge on the Current River at Doniphan, MO.



of relatively large floods occurred before 1936 and after 1982 (Figure 4). Of the largest ten floods on record, seven have occurred since 1982. Larger floods in the earlier period were probably caused by increased runoff rates from watershed surfaces due to land clearing and soil disturbance by early settlement and the timber boom between 1880 and 1920 (Jacobson and Primm, 1994). These land disturbances and resulting floods produced widespread stream channel and sediment disturbances in the Current River basin (Jacobson and Gran, 1999). Improved soil management practices and recovery of disturbed lands probably were responsible for the reduction in maximum annual flood peaks in the period between 1936 and 1982. However, for the larger rivers evaluated, the causes of flooding in the recent period after 1982 are probably the result of climate factors which control rainfall frequency and overall soil moisture conditions and not land use or management changes within the watershed.

High rainfall events with 3 in. per day tend to be associated with the largest floods of record on the Current River at Doniphan. Of the 16 high rainfall days since 1955, seven (44%) resulted in the maximum annual flood for the year and two (13%) others contributed to wet antecedent conditions that contributed to the maximum annual flood. Moreover, four (80%) of the five daily rainfall events exceeding 4 in. resulted in the 2nd, 4th, and 7th ranked highest floods of record, with the fourth producing the maximum annual flood for the year. The relationship among high rainfall, runoff, and flooding can be affected by several factors such as seasonal leaf-on and vegetation conditions, antecedent rainfall and soil moisture, variations in storm duration and tracking, and spatial variability of individual gauge records within a region. However, this study does show a recent trend in increasing rainfall and rainfall events that can produce floods capable of causing channel instability and sediment problems observed along Big Barren Creek. While more intense rainfall events can cause more channel disturbances by producing more frequent and energetic floods, human modifications and management of riparian areas may counter or enhance channel disturbances in the Ozarks.

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Photo by Konrad Schmidt

Male and female Topeka shiners require good water quality and cool temperatures.

Re-introduction of Topeka Shiners into Northern Missouri Using Non-essential Experimental Populations

The Product of an Excellent Partnership

By Dr. Paul M. McKenzie, Jerry Wiechman and Dr. Doug Novinger

The Topeka Shiner (*Notropis topeka*) is a small [up to 2.5" (6.35cm)] (Fig. 1), slim-bodied minnow that is restricted to portions of Kansas, Iowa, Missouri, Minnesota, Nebraska, and South Dakota. The species is characteristic of small, low order (headwater), prairie streams with good water quality and cool temperatures. It is primarily found in streams that exhibit perennial flow although it can persist in areas where there is intermittent flow during the summer months. Due to the loss of habitat and populations across its range, the Topeka shiner was listed as an endangered species by the U.S. Fish and Wildlife Service (Service) in 1998 (U.S. Fish and Wildlife Service 1998) under the Endangered Species Act (Act) of 1973, as amended.

In Missouri, the species has declined precipitously such that only two populations remain including one in the Sugar Creek watershed in northcentral Missouri and the other in Moniteau Creek watershed in central Missouri. To assist in recovery efforts, the Missouri Topeka Shiner State Working Group was established in 1995 and consisted of staff from the Service and the Missouri Department of Conservation (MDC). This group developed an initial "action plan" to regularly monitor the two remaining populations and identify strategies to reduce threats to the species. A key element to the plan was the development of cooperative partnerships among agencies at federal, state, and local levels to work collaboratively with willing private land owners in the implementation of conservation actions that would benefit the species and its stream habitat.

Due to the lack of a federally approved recovery plan for the species, MDC expanded on the initial plan and developed a ten-year strategic plan to outline conservation efforts for the species (Missouri Department of Conservation 2010). A key recommendation of that plan is the establishment of Topeka shiners in five additional watersheds to achieve the goal of seven extant populations.

On January 23, 2013, the Service proposed a rule in the *Federal Register* to facilitate reintroduction efforts through the establishment of a non-essential experimental population (NEP) under Section 10(j) of the Act (U. S. Fish and Wildlife Service 2013a). The proposal identified three watersheds in northern Missouri within the historic range of the species and outlined propagation, stocking, and monitoring procedures.

The NEP designation allows all normal, legal activities on private land to occur without the threat of prosecution under Section 9 of the Act. Thus, incidental take of Topeka shiner in the NEP associated with such activities as agriculture, forestry and wildlife management, land development, recreation and other activities would not be prohibited provided the activity was not in violation of any applicable State fish and wildlife laws or regulations. The Service's proposal was open to public comment and approved July 17, 2013 (U.S. Fish and Wildlife Service 2013b). Outreach efforts included contacts with local governments, agricultural agencies, and the congressional representative as well as news releases to various standard and social media outlets. There was little opposition expressed on the proposed rule, and no dissension after further clarifications were provided. In fact, on Aug. 20, 2013, an editorial in the St. Joseph, Missouri News-Press titled "Fish Tale Good for All" stressed that introducing this species as a NEP would assist in the recovery of the species while removing any regulatory burden on cooperating landowners.

Watershed programs designed to improve stream health, enhance riparian corridors, and restore sensitive prairie communities were outlined in the NEP rule and included in MDC's recovery plan for the Topeka shiner. The plan also included various land owner incentive programs that can contribute to conservation of the Topeka shiner while benefiting private land owners. These same programs have the potential to enhance natural communities beyond the stream corridor throughout northcentral Missouri. Designated Natural Areas that occur in the region which could benefit from these efforts include the Pawnee Prairie Natural Area in Harrison County, the Dark Hollow Natural Area in Sullivan County, and the Spring Creek Ranch Natural Area in Adair and Sullivan counties.

Integral in the NEP partnership was the close cooperation between the MDC and the Nature Conservancy's (TNC) Dunn Ranch in the Little Creek watershed. An MOU established between MDC and TNC helped facilitate initial propagation efforts. Under the agreement, TNC provided ponds to propagate Topeka shiners, removed predator fish, added spawning gravel, and excluded bison from nursery areas with adequate fencing. Additionally, TNC assisted in fish releases, annual monitoring, and implemented stream habitat improvements to improve pool habitat on the ranch.

Additional partnerships were developed to assist in recovery efforts. In 2014, a Memorandum of Agreement was established between the Service's Ecological Services Field Office, MDC and the Service's Neosho National Fish Hatchery to enable the hatchery to complement MDC's Lost Valley Hatchery (LVH) in propagating Topeka shiners necessary for recovery efforts. In 2015, Topeka Shiners produced at the two hatcheries facilitated supplemental stocking to occur in all three NEP watersheds in north Missouri. Prior to the agreement, limited production at LVH required prioritized stocking in only one or two of the streams each year. The additional hatchery increased potential production and provides further protection of invaluable brood stock.

Monitoring of Topeka shiners released in the NEP watersheds 2013–2015 has provided strong evidence that the partnerships have paid off. In Little Creek, survey results revealed that Topeka shiners had survived and expanded their distribution from the release site in 2013 to five headwater sites in 2014 and 10 sites in 2015 (Wiechman 2015). In East Fork Big Muddy Creek, Topeka shiners were found near release sites as well as on adjacent private land upstream and downstream of the 2013 introductions

(Wiechman 2015). In the Spring Creek watershed, one individual was located one mile upstream of the release site and juveniles were captured at other locations indicating that the species was dispersing and reproducing (Thornhill 2015).

The success of NEP introductions to date strongly suggests that such releases will continue to contribute to the ultimate goal of recovering Topeka shiners in Missouri. Due to initial success of introductions in northern Missouri, plans are currently underway to expand the program in central Missouri adjacent to Moniteau Creek populations. The Service will draft an amended proposed 10(j) rule in the *Federal Register* with an opportunity for the public to comment on the proposal. This requirement will facilitate and accommodate introductions in central Missouri. As with the initial rule making, the proposal will include identical exemptions and outline land owner incentive programs to benefit the species, associated headwater stream habitats, and adjacent natural communities. Thanks to an excellent partnership including state and federal agencies, non-government organizations, and private land owners, the Topeka Shiner is a step closer to recovery in Missouri.

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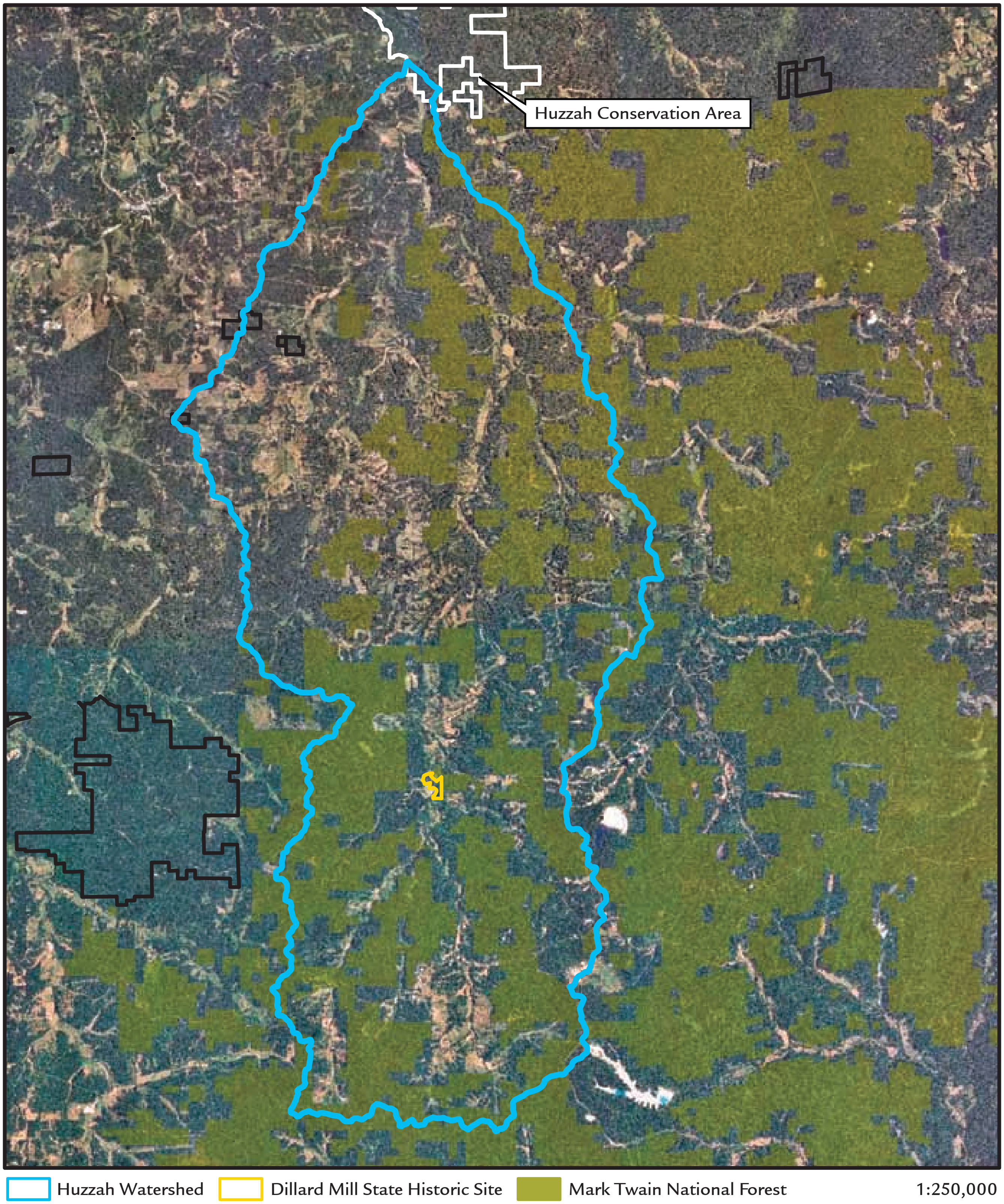
Ponds on Dunn Ranch Prairie are release sites for Topeka shiners.

Photo by Rick Hansen



The Huzzah Creek watershed area

Photo courtesy of Missouri Department of Conservation

Spothanded Crayfish (*Orconectes punctimanus*), a characteristic crayfish of the Huzzah fauna.

Huzzah Creek

An Aquatic Resource Worthy of Conservation

By Mike Leahy and Jennifer Girondo

Huzzah Creek is a tributary of the Meramec River that drains a watershed of 170,000 acres, or roughly an area of 16 square miles by 16 square miles. The lower six miles of the Huzzah, from the Highway 8 bridge to its mouth on the Meramec, has been designated an Outstanding State Resource Waters by the Missouri Department of Natural Resources. The Huzzah is a classic Ozark stream with a sand and gravel bottom bordered by a series of dolomite bluffs. The watershed is an Ozark landscape of woodlands and forests (85%), grasslands (13%) and clear running streams (over 700 miles).

The Huzzah supports a diverse fish and crayfish community with a number of Missouri endemic species. For example, the freckled crayfish (*Cambarus maculatus*), a species of conservation concern, the saddlebacked crayfish (*Orconectes medius*), the woodland crayfish (*Orconectes hylas*) and the Meramec Saddled Darter (*Etheostoma erythrozonum*) are all species found only in Missouri. Conservation of the global range of these species depends on us. Colorful fishes including the bleeding shiner (*Luxilus zonatus*), rainbow darter (*Etheostoma caeruleum*), and orange-throat darter (*Etheostoma spectabile*) ply the waters. Smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*) and goggle-eye (*Ambloplites rupestris*) are abundant and provide for great small river fishing opportunities. Stream condition indices for sites sampled by the Missouri Department of Conservation aquatic biologists here were all in the “fully biologically supporting” category. The riparian forests of the Huzzah are also important habitat for Cerulean warblers (*Setophaga cerulea*), a species of conservation concern. The combination of this native aquatic diversity, coupled with an equally interesting array of native terrestrial communities on the Huzzah Conservation Area, are generating discussions on the possibility of a natural area nomination for a portion of this conservation area.

Conservation of Huzzah Creek depends on the land use activities of the private landowners who own around 2/3 of the watershed. The creek cannot be conserved on the state and federal lands alone. In the following companion article, Rob Pulliam, Fisheries Management Biologist for MDC outlines an exciting effort to continue to build positive working relationships with private landowners and communities in the Huzzah Creek Watershed.

Huzzah Watershed and Landowner Projects Benefitting People, Critters, and Water

By Rob Pulliam

One such effort to work with private landowners on watershed conservation is the Shoal Creek Woodlands for Wildlife (SCWW) Partnership that encompasses portions of the Huzzah and Courtois watersheds. In this locally led private landowner/natural resources staff partnership we are working together to implement Best Management Practices (BMPs) that balance the needs of people and nature. In short, we are working together to improve the quality of life.

Last year, our team met on-site with 28 landowners, wrote 29 project plans, and installed 49 fish, forest, and wildlife BMPs. Six Huzzah Creek landowners installed 23 BMPs that directly benefitted streams as follows:

- Alternative Watering Systems (AWS) – In exchange for landowners removing cattle from wooded corridors along streams, the SCWW Partnership can develop watering sources and distribute water to tanks across the farm for cattle.
  - Two landowners completed AWS that included the following practices:
    - Seven livestock watering tanks
    - Seven livestock watering pads
    - Two trenching and piping projects totaling nearly 8,000'
- Wooded corridors – Planting trees and shrubs along streams
  - Six landowners completed tree and shrub planting projects to create wooded corridors along their Huzzah stream frontage
    - Planted nearly 7 acres of trees and shrubs
    - Planted 1,450 potted trees and shrubs
- Fencing along wooded corridors
  - One landowner installed fence along his newly planted wooded corridor and existing trees.
    - Almost 5,000' of fence installed
    - Approximately 15 acres of wooded corridor was protected from cattle along Huzzah Creek

Finding the win/win solution(s) that balance the needs of landowners and natural resources is possible if you take the time to listen. All the practices described above do just that. From a landowner's perspective, AWS provides a clean and dependable water source for cattle. Clean drinking water for cattle has been shown to improve cattle weaning

Laying out an Alternative Watering System (AWS).

Photo by Rob Pulliam, Missouri Department of Conservation


Photo courtesy of Missouri Department of Conservation

Orangethroat Darter (*Etheostoma spectabile*)

weights by as much as 50 pounds. In addition, the distribution of livestock watering tanks allows cattle producers to subdivide a few big pastures into smaller pastures; doing so improves cattle grass utilization across the pasture system. In addition, cattle manure and urine (free fertilizer for pastures) is better distributed across the farm to grow grass instead of being concentrated near a single water source such as a stream channel to grow algae. Wooded corridors along streams can reduce a landowner's stream bank erosion, field scour, and the amount of sand, gravel, and flood debris deposited in their pastures. Fencing cattle from wooded corridors allows landowners to easily check on the herd in a pasture as compared to a stream channel. Another benefit is animal health. Keeping cattle out of the wooded corridors reduces the chances of cattle getting sick by eating poisonous plants.

From a natural resource perspective, AWS allows cattle producers to rotate their herd more often from pasture to pasture. As more pastures are "rested" from grazing, grasses grow back which can help intercept rain and encourage percolation of water into the soil. Overgrazed pastures can produce erosive run-off and nutrient rich water to receiving streams. Trees and shrubs along streams provide many benefits including reducing stream bank erosion. Other benefits include trapping sediment and fertilizers coming off the land which improves water quality. Adding large woody debris to the stream channels creates habitat for fish and wildlife. Trees keep water temperatures cooler in the summer and warmer in the winter. Trees that provide cooling shade to streams during the summer heat are very important to aquatic life. Cooler water holds more dissolved oxygen than warmer water. Generally speaking, the diversity of aquatic life a stream can support is greater when dissolved oxygen levels are higher.

Worthy goals for the Huzzah Creek Watershed include implementing natural resource management actions that sustains its people, habitats, and species diversity. If we are to reach these goals, management actions must occur on both public and private lands. When working with private landowners, it is imperative that we find solutions that meet their land-use goals and values that balance the needs of nature. These six landowners and their projects prove to be examples that reach this balance.

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Citizen Science Water Quality Monitoring Projects in Missouri

By Randy Sarver

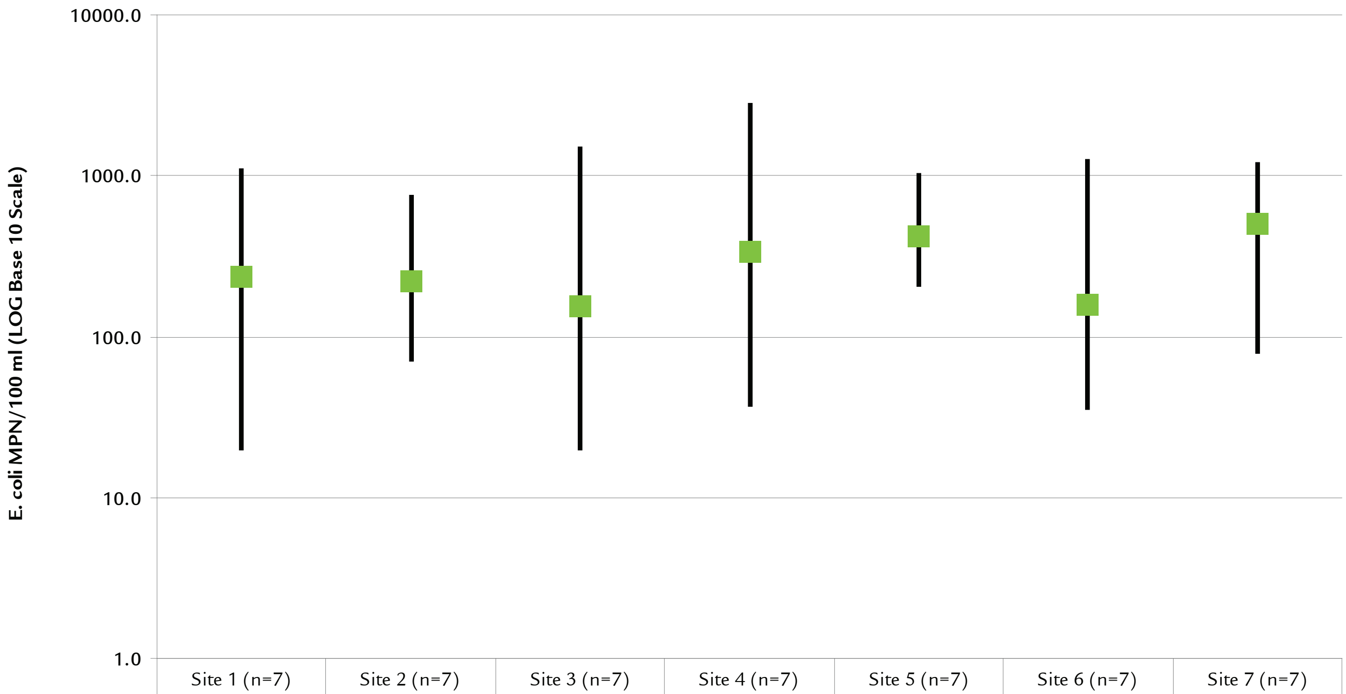
For over twenty-five years, the Missouri Stream Team Program has promoted citizen awareness and involvement in river and stream conservation through a partnership between the Department of Conservation, Missouri Department of Natural Resources, Conservation Federation of Missouri, and citizens of Missouri. The Volunteer Water Quality Monitoring Program has developed into one of the most popular activities of the Stream Team Program.

The goals of the Volunteer Water Quality Monitoring Program include informing and educating citizens about the conditions of our streams, establishing a monitoring network, generating water quality data, enabling citizens to develop new skills, and finally halting degradation of Missouri streams. The volunteer program is flexible, offering progressive levels of training that build on each other. There are currently five levels of training available to volunteers: Introductory, Level 1, Level 2, Level 3, and Cooperative Stream Investigations.

Cooperative Stream Investigation (commonly called CSI) projects for volunteers were added to the Volunteer Water Quality Monitoring Program in March, 2005. The original goal was to facilitate additional collection of *Escherichia coli* (commonly called *E. coli*) bacterial data from state waters; this program has since expanded to include other parameters of interest. Volunteers who have successfully completed Volunteer Water Quality Monitoring Program training through Level 2 are eligible to participate in a CSI project, and additional training is provided to volunteers who make a one year commitment to a project. All CSI data is collected under quality controlled conditions using Missouri Department Natural Resources standard operating procedures and approved/accepted EPA standard methods for analyses of surface water. Therefore, volunteer data collected during CSI projects are high quality, documented, and comparable to agency data. CSI collected data are capable of playing an important role in the

Table 1. Successfully completed Cooperative Stream Investigation projects

Stream	Project Period	Parameters
1. Brush Creek — Franklin County	2005 – 2007	*E. coli*
2. Watkins Creek — St Louis County	2009 – 2012	*E. coli* & chloride
3. Shoal Creek — Barry & Newton Counties	2010 – 2012	*E. coli*
4. Gravois Creek — St. Louis County	2012 – 2013	*E. coli* & chloride
5. Cole and Spencer Creeks — St. Charles County	2012 – 2014	chloride
6. Turkey Creek — Boone County	2013	*E. coli*
7. Mattese Creek — St. Louis County	2013 – 2014	*E. coli* & chloride
8. Truitt Creek — Lawrence County	2014	*E. coli*
9. Fenton Creek — St. Louis County	2014 – 2015	*E. coli* & chloride
10. Williams Creek — Lawrence County	2015	*E. coli*
11. Dry Branch — St. Charles County	2015 – 2016	Total nitrogen, total phosphorus, chloride & total suspended solids
12. Warm Fork Spring River — Oregon County	2016	*E. coli*
13. Dardenne Creek — St. Charles County	2016	*E. coli*



	Site 1 (n=7)	Site 2 (n=7)	Site 3 (n=7)	Site 4 (n=7)	Site 5 (n=7)	Site 6 (n=7)	Site 7 (n=7)
Maximum	1071.5	733.5	1454.5	2737.5	1007.0	1240.5	1179.5
Minimum	20.5	72.0	20.5	37.5	210.0	36.0	80.5
Geomean	236.8	222.2	155.2	338.5	419.4	157.8	504.0

Graph 1. Gravois Creek CSI Project — St. Louis County. *E. Coli* (Log_{10} Scale). April 4, 2013 – October 3, 2013.

MDNR's decision making process relating to Total Maximum Daily Load studies, water quality assessments, and long-term resource use studies.

Since CSI data are treated as equivalent to professionally collected data, it fits one definition of Citizen Science, as defined by McKinley, et al. (2015): "citizen science is indistinguishable from conventional science, apart from the participation of volunteers — both can use a variety of methods and can achieve a variety of goals, including basic research, management, and education. Citizen Science is science (with the addition of volunteers) and should be treated as such in its design, implementation, and evaluation."

Since the initial project in 2005, there have been a total of 13 CSI projects that have been successfully completed (see Table 1). *E. coli* bacteria continue to dominate the focus of most projects. However, chloride and nutrients are also becoming important monitoring parameters.

The most prevalent use of CSI data is assessment of streams for the impaired waters list (Section 303[d] of the Clean Water Act). Until 2016, the data were used as ancillary assessment data to that collected by the Missouri Department of Natural Resources. However, for the 2016 reporting cycle, a revision to Missouri's Water Quality Standards expanded the classified rivers and streams network from approximately 24,400 miles to approximately 115,700 miles. Many of these newly classified streams are categorized as headwater stream size; many are unnamed and unmonitored. With fewer resources to cover more monitoring needs, CSI data have now been used as primary data for 303(d) assessment purposes in smaller streams where no agency data exist.

One example of data use from a CSI project is Gravois Creek in St. Louis County. As the result of the one year CSI project, an unnamed tributary was included on the 2016 303(d) impaired waters list for impairment due to *E. coli*. Not only was the unnamed tributary included on the 303(d) list because of citizen science data, it had the highest geometric mean of any project sampling location and indicated a significant bacterial source (see the geomean for Site 7 in Graph 1).

E. coli data are often summarized as a "geometric mean" (a type of average) of all the test results obtained during a reporting period. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. The geometric mean is really a log-transformation of data to enable meaningful statistical evaluations.

In addition to using CSI data for 303(d) purposes it has also been used to calculate Total Maximum Daily Loads (commonly called TMDLs), to assess TMDLs that have been established for impaired streams, and for modeling purposes for non-point source pollution control projects (Section 319 of the Clean Water Act).

Future use of CSI project data will support development of more rigorous TMDLs for impaired streams, especially streams in need of chloride TMDLs. Additionally, stream nutrient data will be useful in identification of sources of contamination, and, in the long-term, development of nutrient criteria for the Missouri Water Quality Standards.

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Centennial celebration kicks off in state parks and historic sites

Missouri State Parks is gearing up for a celebration of centennial proportions as the park system approaches its 100th birthday. The park system kicked off 18 months of celebrations on April 9, 2016 with the opening of a new exhibition at the Missouri State Museum and the launch of a new statewide passport program.

The park system was officially established on April 9, 1917 with the creation of the state park fund. The first property, the historic Arrow Rock Tavern, was acquired in 1923. The first park tracts were added to the system in 1924 and by the end of 1925, the state park system had grown to eight areas with more than 23,000 acres.

Throughout its history, the park system has continued to grow. Today, thanks in large part to citizen support, the park system includes 88 state parks and historic sites and more than 150,000 acres. In 2015, 19.2 million visitors were recorded at state parks and historic sites. On multiple occasions, Missouri's state park system has been ranked as one of the top four in the country.

To mark the centennial, Missouri State Parks launched the Centennial Passport, a program challenging guests to visit all 88 state parks and historic sites between April 9, 2016 and Oct. 31, 2017. A printed passport is available for purchase at park and historic site gift shops and online. The first 1,000 individuals who complete the printed passport will receive a centennial backpack, made possible thanks to a sponsorship by Bass Pro Shops. A digital passport is also available and can be completed free of charge. For more information, visit mostateparks.com/passport.

Park guests can share their experiences and memories of the park system on Twitter and Facebook using #ShowMeYourStatePark.

For more information on state parks and historic sites, visit mostateparks.com.

Forty Years of Missouri Natural Areas

The Missouri Natural Areas System turns 40 this spring

When people think of Missouri, perhaps they conjure up images of the Arch in St. Louis, Union Station in Kansas City or championship-winning baseball teams. These cultural icons make up part of what makes Missouri unique as a state. But of course a deeper heritage occurs here in the show-me state founded in the very geology, soils, plants, animals and streams that still remain in some semblance to the patterns that have occurred on this spot on earth for thousands of years, long before Missouri statehood in 1821 and the frenetic pace of our current society. In 1977, a group of prescient conservationists working for the Missouri Department of Conservation (MDC) and the Missouri Department of Natural Resources (MoDNR) decided to formally work together in a partnership to identify and preserve biological communities or geological sites as state natural areas to be "permanently protected or managed for the purpose of preserving their natural qualities." This partnership laid the ground work for what today has become the Missouri Natural Areas System of 185 special places totaling 85,767 acres of lands and waters that are key pieces of Missouri's natural heritage. Places like Stegall Mountain, Blue Spring, the Jack's Fork River and Regal Tallgrass Prairie Natural Areas exemplify Missouri's unique natural heritage.

The Missouri natural area program's roots began in 1971 with MDC when then Wildlife Research Superintendent Bill Crawford (also co-founder of the Missouri Prairie Foundation) worked with John Wylie, assistant state forester, assistant director Allen Brohn and other staff to charter a new MDC program, the natural areas system. Famed wildlife artist Charlie Schwartz designed the jack-in-the-pulpit logo for the new program. In June 1977, the Missouri Natural Areas Committee (MoNAC) met for the first

Missouri Prairie Foundation BioBlitz at Golden Prairie Natural Area

Photo by Noppadol Paothong, Missouri Department of Conservation time with MoDNR representatives Fred Lafser, John Karel, Jerry Vineyard and Glen Gessley and MDC representatives Allen Brohn, Bill Crawford, and Bill Pflieger. In 1978, Rick Thom (MDC) and Paul Nelson (MoDNR) began their career-long associations with the natural area program. Today the interagency MoNAC consists of representatives from MDC and MoDNR along with the Mark Twain National Forest, U.S. Fish and Wildlife Service, Ozark National Scenic Riverways and The Nature Conservancy.

Over the past four decades, members of MoNAC have provided the leadership and technical expertise that have made the conservation of natural communities a mainstream goal within natural resource agencies in Missouri today. Back in 1977, the recognition of natural communities and management techniques such as prescribed fire were in their infancy in Missouri. MoNAC members have been instrumental in guiding the development of natural community classification systems, a statewide natural features inventory, the development of the Missouri Natural Heritage Program, and natural community restoration techniques. Some of the first uses of prescribed fire for ecological restoration occurred on prairie, glade and woodland communities of Missouri Natural Areas.

Missouri Natural Areas account for just 0.2% of Missouri's land mass, yet they account for a disproportionate share of the state's natural heritage resources. Today, populations of 433 Missouri species of conservation concern occur on designated Missouri Natural Areas (38% of all species of conservation concern in the Missouri Natural Heritage Database). Populations of 19 federally listed species and 34 state endangered species are found on Missouri Natural Areas (48% of the federally listed species in Missouri and 53% of the Missouri state endangered species, respectively). Eighty-four different types of terrestrial and aquatic natural communities from chert glades to swamps are conserved on Missouri Natural Areas. These natural communities support a myriad of native plant and animal species. Here are a few examples:

- Rogers Creek on Stegall Mountain Natural Area supports 25 native fish species;
- Over 60 native bird species have been documented as likely or definitely nesting within the Lincoln Hills Natural Area;
- LaBarque Creek Natural Area supports over 580 native vascular plant species and 135 bryophyte species; and
- Paintbrush Prairie Natural Area supports 47 species of planthoppers.

Missouri Natural Areas are important reservoirs of native pollinator species such as the blue sage bee (*Tetraloniella cressoniana*) found at Golden Prairie Natural Area. These sites are valuable as reference sites for scientific studies, as templates and sources of propagules for natural community restoration and reconstruction efforts, as outdoor classrooms and as places for unique outdoor recreation opportunities. The concept of natural areas resonates with the public as well; a 2013 opinion survey conducted by the University of Missouri-Columbia for MDC found that 82% of Missouri's general public agreed that MDC should designate 'natural areas' to protect Missouri's best examples of forests, prairies, marshes, and glades.

However, despite the fact that our technical abilities at resource management have increased greatly over these past 40 years, the challenges and threats to natural heritage resources have kept apace too. Back in 1977, we didn't have stilt grass (*Microstegium vimineum*), garlic mustard (*Alliaria petiolata*), silver carp (*Hypophthalmichthys molitrix*) or white-nose syndrome to contend with. There are approximately 3.2 billion more people on the planet now than 40 years ago and we all impact the environment. Increasingly the effects of rapid climate change are becoming apparent. In short, the stresses on our natural systems will continue to force us to adapt our concept of natural areas and how we manage them. Maintaining the relevancy of the Missouri Natural Areas System to the public, especially younger generations and the Pokéman GO crowd, is a challenge. If Missouri Natural Areas are to be around in forty more years (2057!), we must rise to the challenges and be ready to adapt. We owe it to Missourians of today and future generations to conserve those irreplaceable places of our state.

Photo by J. Karel

Western slimy salamander (*Plethodon albagula*)

2016 Missouri Natural Area System Updates

In May 2016, the interagency Missouri Natural Areas Committee (MoNAC) approved two expansions to existing natural areas. The committee has received final approval from the acting director of the Conservation Department and is awaiting final approval from the director of the Department of Natural Resources. Soon these newly expanded natural areas will be posted on the natural areas directory on the Conservation Department website.

Brickey Hills Natural Area — nestled in the steep river hills north of the historic town of Ste. Genevieve at Magnolia Hollow Conservation Area, this newly expanded natural area contains 349 acres of mature forests and woodlands punctuated with limestone outcrops and scattered small springs. The deep valleys here support an abundance of plethonotid salamanders and 35 tree species. A network of area access trails provide for hiking opportunities to see these wooded valleys which are particularly nice to visit in the spring and fall.

LaBarque Creek Natural Area — just 35 air miles from the St. Louis Arch, the newly expanded LaBarque Creek Natural Area contains a rugged remoteness that belies its proximity to the urbanity of St. Louis. This natural area contains portions of LaBarque Creek Conservation Area (Missouri Department of Conservation) and the soon to be opened Don Robinson State Park (Missouri Department of Natural Resources). This natural area contains over 2,000 acres of exemplary sandstone geologic features, forests, woodlands and glades and miles of high-quality headwater streams feeding into LaBarque Creek. Over 15 different natural community types occur here, giving rise to an extremely diverse landscape with more than 580 vascular plant species, 135 bryophyte species, 49 breeding bird species and a dozen species of conservation concern.

National Park Service Centennial

In 2016, the National Park Service (NPS) celebrates 100 years of preserving, protecting and interpreting the nation's most treasured landscapes, historic places, cultural sites, and natural wonders. During this centennial anniversary, 413 national park sites across the nation are celebrating the legacy of the first national park system in the world and embarking on a second century of continued stewardship of our national heritage.

At Ozark National Scenic Riverways, the celebration of the NPS Centennial has taken many forms in order to engage the public in a wide variety of activities that encompass the significance of the first federally-protected river system. Events and activities ranged from recreational activities to stewardship opportunities to cultural and historical programs.

The Centennial kicked off in April with the first of two park stewardship events. For two days in April, park staff, volunteers and partner organizations joined together for the 2016 Riverways Clean-up, scouring the rivers and lands for litter and debris. In September, the second stewardship event engaged college students and volunteers in a day of trail maintenance on National Public Lands Day.

Outdoor recreational workshops and clinics were held throughout the year. These included outdoor photography, birdwatching, fishing, gigging, paddling and night sky viewing. Several guided hikes allow visitors to experience the outdoors, with park rangers leading the exploration of Mill Mountain Natural Area, Prairie Hollow Gorge Natural Area, and several segments of the Ozark Trail.

The rich cultural history of the Ozark Highlands was featured in many of the Centennial programs. The rivers gave life to several historic communities that were important for local residents. Akers, Round Spring and Alley Spring hosted community reunions to remember and reminisce about the not-so-distant past when those areas were thriving centers of the neighborhood. In addition, a number of cultural demonstrations, historical programs and special events illustrated the Ozark lifeways and history of the Ozark region.

Visitors were encouraged to return to experience a variety of programs during the year through the use of a passport program. Stamps could be collected at each centennial program, with the possibility of earning several different centennial souvenirs. The "100 Mile Challenge" program, in partnership with the Ozark Trail Association, provided incentive for visitors to log their miles hiking or padding within Ozark National Scenic Riverways and on the Ozark Trail in order to earn a special commemorative sticker upon logging 100 miles.

Events and programs celebrating the NPS Centennial will continue through the end of 2016 at Ozark National Scenic Riverways. For more information about the schedule of upcoming activities, visit www.nps.gov/ozar.

2017 Calendar Of Events

February 5–8, 2017

77th Midwest Fish and Wildlife Conference

Lincoln, Nebraska

"Private Landscapes, Public Responsibilities"

www.midwestfw.org

March 10–12, 2017

Conservation Federation of Missouri Convention

Capitol Plaza Hotel, Jefferson City, Missouri

www.confedmo.org/annual-convention

June 2–4, 2017

Missouri Native Plant Society Spring Meeting and Field Trips

West Plains, Missouri

monativeplants.org/events

June 10, 2017

Missouri Prairie Foundation's 8th Annual Prairie Bio-Blitz at Stillwell Prairie

Vernon County, Missouri

www.moprairie.org

August 18–19, 2017

Missouri Bird Conservation Initiative Annual Conference

Peachtree Catering and Events, Columbia, Missouri

www.mobci.net

Oct 10–12, 2017

44th Natural Areas Conference

Ft. Collins, Colorado

www.naturalareas.org/conference

The crystal clear blue waters of Ha Ha Tonka Spring in the Ha Ha Tonka Oak Woodland Natural Area.

Photo by Allison J. Vaughn