The Missouri Comprehensive Conservation Strategy

Responsibly Addressing the Challenges and Opportunities of Modern Conservation Through an Integrated Strategic Approach

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Foreword

Missouri supports an abundant natural heritage, ranking 21st in the nation in terms of its numbers of native animal and plant species. More than 180 native fish species, including the endemic Niangua darter, ply the state's diverse streams and other aquatic habitats. More than I 00 species of native amphibians and reptiles occupy a myriad of habitats from mountaintop glades to lowland swamps. Missouri supports nationally significant river and stream systems, some of the largest forested tracts left in the Midwest, a high density of cave and karst features, and some of the largest remnants of the eastern tallgrass prairie. The opportunity to conserve rich fish and wildlife diversity in Missouri is great. Considered together, these resources provide significant economic advantages, including forest products and outdoor recreation. This Missouri Comprehensive Conservation Strategy combines, for the first time in the nation, a State Wildlife Action Plan, a State Forest Action Plan, Priority Watersheds, private lands, community conservation, public use, and other conservation partner priorities into a single document.

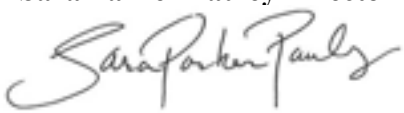
Missouri's vision for landscape conservation involves creating healthy habitats and working lands within the Conservation Opportunity Areas, which include Priority Geographies as identified within this document. These areas prov-ide the best opportunity to improve the state's fish, forest, and wildlife, so as to provide Missouri citizens with clean air and water and the health benefits of outdoor connection, ecosystem services, and economic profits from outdoor recreation, forest products, and related resources. Successful progress includes extensive partnership development, landowner engagement, public and private habitat enhancements, species reintroductions, development of a Landscape Health Index, and continual realignment of resources to provide additional support.

While identified as a priority, Missouri still needs to bettei· define our strategic approach for public use and community conservation. In this work we will outline the criteria that define our priorities and determine where we need to provide for many different public use oppo1tunities, to address community conservation needs, and to ensure that nature, conservation, and an inherent need for interaction with the outdoors remain relevant to our public. The result will be opportunity areas for both public use and community conservation to identify where effort should be focused.

Partnerships are key to the success of this strategy. The CCS belongs to the citizens of the State of Missouri and reflects the priorities and input of many partners. Accomplishing this innovative vision requires teamwork on many levels: locally with landowners and businesses, statewide with private and governmental agencies and industries, regionally with neighboring states and organizations, and nationally with federal agencies and associations. All are important, and I challenge each partner to find ways to contribute in the role that fits them best at whatever scale and level they are comfortable.

Missouri citizens have a proud history of dedication to the appreciation, conservation, and restoration of our rich natural heritage. In 1937, citizen-led efforts created the Missouri Depaitment of Conservation, uniquely designed as an apolitical, science-based conservation agency with exclusive authority over fish, forest, and wildlife. In 1976, citizens renewed their commitment to conservation by passing an amendment for a one-eighth of 1 percent sales tax to provide consistent funding for fish, forest, and wildlife conservation. Missouri citizens also participate in many conservation organizations that actively serve various niches in habitat management, outreach, hunter/angler recruitment, science, and many other endeavors. Today, more than 90 percent of Missourians remain interested in their fish, forest, and wildlife resources. Together, through focused efforts and science-based decisions, we can build on our proud heritage to provide a future for both our rich fish, forest, and wildlife resources and our citizens. After all, the health of both is inextricably intertwined.

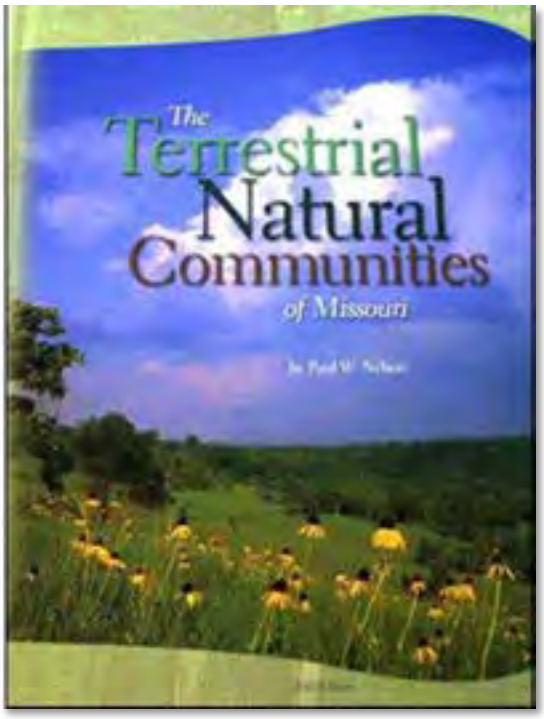
~ Sara Parker Pauley Director

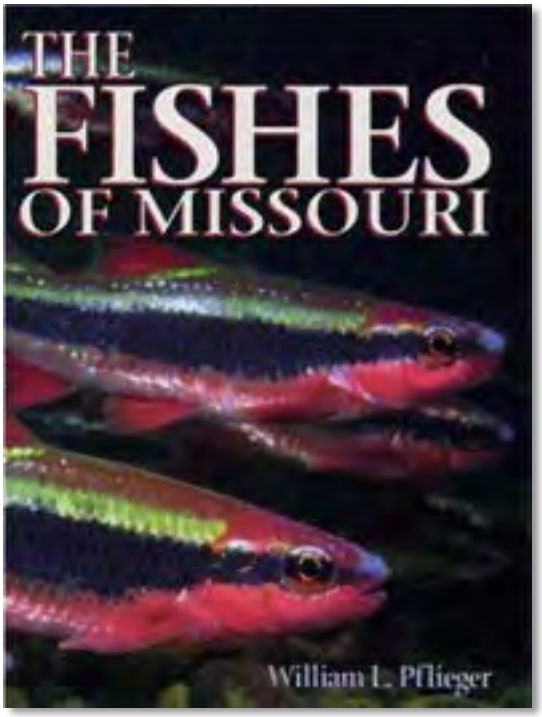


Primary References

The basic terrestrial natural community classifications and the natural community descriptions within the Missouri CCS are generalizations, primarily adopted from those descriptions published within *The Terrestrial Natural Communities of Missouri*, authored by Paul W. Nelson, copyrighted by the Missouri Natural Areas Committee (2010). This valuable reference tool was compiled with resources, knowledge, and expertise from the Missouri Department of Conservation, Missouri Department of Natural Resources, U.S. Department of Agriculture – Forest Service, U.S. Fish and Wildlife Service, National Park Service, The Nature Conservancy, Missouri Resource Assessment Partnership, and many other important contributors.

The aquatic natural community classifications and descriptions within the Missouri CCS are primarily adopted from *The Fishes of Missouri*, authored by William L. Pflieger (1997).





Acknowledgments

Like previous versions, the Missouri Comprehensive Conservation Strategy (CCS) is the result of teamwork and input from conservation partners to establish the priorities, goals, and strategies that will guide collaboration and investment to maintain and restore Missouri's natural diversity and build connections with our public to show the vital role that nature plays in our daily lives. This version takes a major step forward by fully combining the State Wildlife Action Plan (SWAP) and State Forest Action Plan (SFAP) into a single document, the first successful venture of this nature in the nation.

The idea of combining the SWAP, SFAP, priority watershed, private land, public use, and community conservation priorities into a single framework in one document began as the previous version of the SWAP was being developed. Dennis Figg was coordinating the steering committee while Missouri Department of Conservation (MDC) director Bob Ziehmer and deputy director Tom Draper developed the vision to combine all resource priorities into a single plan, so it would indeed be "Comprehensive" and represent the highest conservation priorities of the state. The SWAP and SFAP would also be used to satisfy the requirements of both the U.S. Fish and Wildlife Service (USFWS) for receiving State Wildlife Grants and the U.S. Department of Agriculture – Forest Service (USFS) for receiving Cooperative Forestry Assistance Act Grants. Submitting a single document to both federal agencies meant that timing and planning could coincide, further simplifying the process.

The 2015 version of the CCS incorporated the geospatial interests of the SWAP, SFAP, priority watersheds, and private land efforts, including the priorities of our conservation partners. However, it did not fully integrate the SFAP into the text portion. Although MDC's administration has changed, and Dennis retired before the 2015 version was completed, the original vision has been sustained and is accomplished in this version of the CCS (2020).

MDC serves as the steward for the development and maintenance of the CCS on behalf of conservation partners and citizens who have contributed input throughout the process. Partners generously shared their emphasis areas with MDC, so these could be incorporated into the analyses delineating the Conservation Opportunity Areas (COAs). They participated in multiple meetings and roundtable discussions and provided input on draft versions, helping further shape the CCS into its final form. They partner daily with local, regional, and statewide teams to put conservation on the ground or to support policy vital to continued success. Without the collaboration among partners none of this would be possible.

Phillip Hanberry (Missouri Resource Assessment Partnership, housed at the University of Missouri–Columbia) conducted geographic information system (GIS) analyses that helped both to review and update the delineations of the COAs and to develop tiered priorities to guide implementation. Phillip also provided extensive mapping expertise.

The CCS Steering Committee, consisting of Ange Corson (Science), Kevin Borisenko (Regional Resource Management, Central), Gus Raeker (Regional Resource Management), and Norman Murray (Statewide Resource Management), provided vision, guidance, and review throughout the process. Branch Chiefs Bill White (Community and Private Land Conservation), Brian Canaday (Statewide Resource Management), and Jason Sumners (Science), retired Division Chief Lisa Allen (Forestry), Statewide Resource Management Section Chiefs Justine Gartner (Forestry) and Joel Porath (Wildlife), along with John Tuttle (Assistant Deputy Director, Resource Management) and Mike Hubbard (Deputy Director, Resource Management), all provided

administrative guidance throughout the process and support for staff involvement to develop and implement the CCS.

Nate Muenks served as primary plan coordinator, overseeing every aspect of the development to see the CCS through to fruition. Gus Raeker served as coordinator for the SFAP portion, working with various partners and staff members to draft sections that relate specifically to requirements for that portion of the document. To meet USFS requirements, George Kipp performed many of the forest analyses. Gus and Nate authored or edited much of the document and coordinated with others who wrote specific sections.

Kelly Rezac provided significant assistance in coordination with the Wildlife Diversity Team, which is comprised of representative taxa specialists, natural history biologists, and division representatives. The team developed Missouri's list of Species of Greatest Conservation Need (SGCN), conducted an analysis of the COAs to determine whether the COA portfolio was missing significant SGCN populations, and wrote/reviewed many portions of the CCS. Mike Leahy, as the natural community ecologist, provided significant expertise, editing, and written sections to the CCS.

The CCS team has benefited from the contributions of many staff members who have worked on writing sections of the document since 2015, contributing to case studies, gathering information, helping with logistics, and coordinating with others to keep the CCS moving forward. These include Donnamarie Duffin, Miranda Brandt, Danielle Fox, Mike Jungen, Katherine Ward, and Ross McNearney.

Several sections are new in this version of the CCS. Frank Nelson and Tom Treiman teamed up to lead a group of staff to develop a chapter describing the value of ecological processes and the economic importance of these ecological services. Erin Shank and Russell Hinnah took the lead in writing the community conservation chapter to summarize the rapidly evolving vision for engaging communities of people in the care of nature where they live.

MDC's Strategy 1.1.1 team (tasked to deliver Strategy 1.1.1 of MDC's *Design for the Future* FY19-23 Strategic Plan) has worked hard to provide practical guidance to staff and partners on how to turn the CCS into actions on the ground. Implementing the CCS in PGs and other focal landscapes is one of MDC's top four priorities, and local teams of staff are working with partners and landowners to make the goals reality. The team has led the ongoing development of the Landscape Health Index via a partnership with the University of Missouri (Dr. Thomas Bonnot and Dr. Richard Stanton, Jr.) and USFWS (Kelley Myers and Dr. Todd Jones-Farrand), a priority tiered approach, and other tools to clarify what implementation and success look like.

All told, the CCS embodies partnership and teamwork, in both its making and its implementation. The vision is large and requires vital tools to define it and bring it to reality through on-the-ground projects. It will be the professionals, landowners, and teams at all levels who dedicate themselves and the resources provided by our conservation-minded citizens and partners who continue to make the vision contained in this CCS a success.

Acronyms

The following is a list of acronyms used throughout this work.

ACR – Audubon Conservation Ranching Program
ADD – Attention Deficit Disorder
ADHD – Attention Deficit Hyperactivity Disorder
AFWA – Association of Fish and Wildlife Agencies
ANSI – American National Standards Institute
AON – Assessment of Need
AOPs – Aquatic Organism Passage Barriers
ASD – Autism Spectrum Disorder
ATVs – All-Terrain Vehicles
BMPs – Best Management Practices
CCG – Community Conservation Grant
CCS – Comprehensive Conservation Strategy
CDC – Centers for Disease Control and Prevention
CFI – Continuous Forest Inventory
CFLRP – Collaborative Forest Landscape Restoration Program
CFM – Conservation Federation of Missouri
CHI – Community Health Index
CITES – Convention on International Trade in Endangered Species
COA – Conservation Opportunity Area
CRP – U.S. Department of Agriculture – Conservation Reserve Program
CS – Consumer Surplus
CWCS – Comprehensive Wildlife Conservation Strategy
CWD – Chronic Wasting Disease
CWPP – Community Wildfire Protection Plan
DU – Ducks Unlimited
EAB – Emerald Ash Borer
ECBD – Emotional, Cognitive, And Behavioral Disabilities
ECS – Ecological Classification System
EQIP – U.S. Department of Agriculture – Environmental Quality Incentives Program
ESA – Endangered Species Act of 1973
FSA – U.S. Department of Agriculture – Farm Service Agency
FEPP – Federal Excess Personal Property
FFP – The Firefighter Property Program
FIA – Forest Inventory and Analysis
FIADB – Forest Inventory and Analysis Database
FLA – Forest Legacy Area
FLP – Forest Legacy Program
GAP – Gap Analysis Program
GHG – Greenhouse Gas
HUC 16s – Sixteen-Digit Hydrologic Unit Codes

IPM – Integrated Pest Management
IUCN – International Union for Conservation of Nature
LCS – Land Conservation Strategy
LHI – Landscape Health Index
LTA – Land Type Association
MBBR – Monarch Butterfly Biosphere Reserve
MDC – Missouri Department of Conservation
MDNR – Missouri Department of Natural Resources
MFPA – Missouri Forest Products Association
MIAD – Missouri Integrated Aquatic Database
MIFPC – Missouri Invasive Forest Pest Council
MNRC – Missouri Natural Resources Conference
MOA – Missouri Office of Administration
MoBCI – Missouri Bird Conservation Initiative
MOFEP – The Missouri Ozark Forest Ecosystem Project
MOFRAC – Missouri Forest Resources Advisory Council
MoIP – Missouri Invasive Plant Task Force
MORFS – MDC Missouri River Field Station
MPF – Missouri Prairie Foundation
MRBO – Missouri River Bird Observatory
MSA – Missouri Soybean Association
MTNF – Mark Twain National Forest
NA – Natural Area
NAWCA – North American Wetlands Conservation Act
NAWMP – North American Waterfowl Management Plan
NCED – National Conservation Easement Database
NDVI – Normalized Difference Vegetation Index
NGO – Nongovernmental Organization
NHD – National Hydrography Dataset
NIACS – Northern Institute of Applied Climate Science
NLCD – National Land Cover Database
NOAA – National Oceanic and Atmospheric Administration
NPS – National Park Service
NRC – National Research Council
NRCS – U.S. Department of Agriculture – Natural Resources Conservation Service
NSST – NAWMP Science Support Team
NWOS – National Woodland Owner Survey
NWTF – The National Wild Turkey Federation
ONRW – Outstanding National Resource Waters
ONSR – Ozark National Scenic Riverways
OSRW – Outstanding State Resource Waters
PFL – Priority Forest Landscape
PFQF – Pheasants Forever and Quail Forever
PG – Priority Geography
PPR – Prairie Pothole Region
PW – Priority Watershed

QRL – Quail Restoration Landscape
QUWF – Quail and Upland Wildlife Federation
RCPP – U.S. Department of Agriculture – Regional Conservation Partnership Program
RCT – Regional Coordination Team
RWOM – Rapid White Oak Mortality
SCW – Shoal Creek Woodlands PG
SCWW – Shoal Creek Woodlands for Wildlife Partnership
SECAS – Southeastern Conservation Adaptation Strategy
SFAP – State Forest Action Plan
SFI – Sustainable Forestry Initiative
SFSCC – State Forest Stewardship Coordinating Committee
SGCN – Species of Greatest Conservation Need
SOC – Soil Organic Carbon
SOCC – Species of Conservation Concern
SRISP – Scenic Rivers Invasive Species Partnership
SWAP – State Wildlife Action Plan
SWCDs – Soil and Water Conservation Districts
T&E – Threatened and Endangered
TCM – Travel Cost Method
TNC – The Nature Conservancy
TRIM – Tree Resource, Improvement, and Maintenance
USACE – U.S. Army Corps of Engineers
USDA – U.S. Department of Agriculture
USFS – U.S. Department of Agriculture – Forest Service
USFWS – U.S. Fish and Wildlife Service
USGCRP – U.S. Global Change Research Program
UTC – Urban Tree Canopy
UTV – Utility Task Vehicle
WNS – White-Nose Syndrome
WRE – U.S. Department of Agriculture – Wetland Reserve Easement Program
WRP – U.S. Department of Agriculture – Wetland Reserve Program
WTU – Whitetails Unlimited
WUI – Wildland Urban Interface

Missouri's Comprehensive Conservation Strategy at a Glance

CCS Subcomponents

To help explain the composition and structure of Missouri's Comprehensive Conservation Strategy (CCS), below is a general roadmap and a synopsis of its subcomponents.

Section One: CCS Overview

Section One provides an introduction. It describes CCS, why Missouri embraced and is embarking on this effort, what guiding principles are setting the framework, what timeframe it covers, and who is involved.

Section Two: Prioritizing Where to Work

Section Two depicts how Missouri prioritizes conservation investments geographically. With finite resources, it is critical to ensure that conservation funds, personnel, volunteers, and other resources are first directed toward the places where they can have the greatest benefit in conserving natural resources and ensuring that Missouri citizens have maximum gain from investments. Given the complexity of conservation and the diversity of goals conservation organizations work toward, it is necessary to have multiple types of priority areas.

The section describes and presents several of these individual priority designations, including priority forest landscapes (PFLs), priority watersheds (PWs), land conservation priorities, Forest Legacy priority areas, community conservation priority areas, public- use priority areas, multi-state and international priorities, partner priority areas for conserving wildlife, and other focal landscapes. The section also shows and presents Missouri's approach of rolling many of these priority areas up into composite conservation opportunity areas (COAs) and priority geographies (PGs). These are areas that rise to the top as being important for many different disciplines and conservation goals. They are landscapes that pose exceptional opportunity for maintaining and enhancing conservation values through multi-disciplinary and multi-partner coordinated efforts.

Section Three: Missouri Natural Systems Assessment: Conditions, Trends, Threats, Challenges, and Opportunities

If there is one constant regarding Missouri's natural communities and the ways in which people and wildlife benefit from them, it is change. The health and stability of natural communities and the ecosystem services derived from them are shaped by a variety of forces. **Section Three** takes an in-depth look at these influences and related implications with individual sections focusing on:

- Species and natural systems health and conservation
- Pollution prevention, control, and mitigation
- Private lands
- Missouri's public lands managed for the greatest public good
- Climate change
- Improving and maintaining high-quality soil and water resources
- The role of fire – historic, wild, and prescribed
- Missouri's growth, harvest, and consumption of forest products
- Recreation, human health, and relevance of nature
- Logistical framework for improvement and sustainability

Each of these themes includes an overview paragraph; a set of desired future conditions of pertinence to the issue (which will guide

strategies later in **Section Seven**); and then a comprehensive summary of key conditions, trends, threats, challenges, and opportunities related to Missouri's natural communities and the benefits that must be taken into account when employing strategies and actions to achieve desired future conditions.

Section Four: Missouri Species of Greatest Conservation Need and Natural Community Conservation

The primary aim in **Section Four** is to provide an introduction of Missouri's native flora and fauna and to describe the selection process and criteria for designating Species of Greatest Conservation Need (SGCNs). This section provides an overview of Missouri's ecological regions and a detailed description of the state's seven primary natural community types: Grassland/Prairie/Savanna, Forest/Woodland, Glades, Cave/Karst, Wetland, Rivers/Streams, and Cliff/Talus. Each natural community type has its own dedicated chapter including:

- An overview of the specific natural community and each of its subtypes
- Map(s) displaying specific locations for the COAs per each natural community
- Decision criteria used to determine the COAs
- Listing of SGCNs associated with each natural community
- Threats and challenges specific to each natural community and associated species
- Habitat management actions and opportunities to restore and maintain a healthy natural community
- A detailed description of each natural community subtype with an accompanying case study featuring specific examples of conservation actions being applied

Section Five: Community Conservation

Conservation within communities and among community networks provides many health benefits and services, including reduced stormwater runoff, flooding mitigation, enhanced outdoor recreation, heating and cooling cost reduction, and reduction of heat island effects. In addition, studies show that incorporating nature into communities reduces crime, calms traffic, reduces effects of attention deficit disorder (ADD), and much more.

Section Five describes the state of community conservation across Missouri – with topics including community forestry, watershed planning, wildlife management, open space and parks management, and more. The section provides case study examples of what is currently being implemented and helps articulate what conservation actions and investments are needed in moving forward.

Section Six: Natural Resource Economics and Ecological Services

While healthy natural communities and diverse wildlife may serve as a primary backbone for conservation, it is important to recognize that conservation benefits people in many other ways as well. **Section Six** delves into many of these economic and ecosystem services provided by natural resources – including things like outdoor recreation (hunting, fishing, hiking, floating, birdwatching, etc.) and tourism, forest products, clean drinking water, carbon sequestration, soil protection, aesthetics, and more. This section will quantify and qualify the importance of these outcomes and explain the importance of sustained efforts toward their conservation.

Section Seven: Actions for a Regenerative Conservation Future

Section Seven provides the "call to action." It provides a listing of four goals, sixteen strategies, and several example action items to be employed to maximize effectiveness in conserving natural resources and ensure that these resources provide maximum value to Missouri citizens.

Section Eight: Evaluation of the CCS

Section Eight describes the primary processes to be used to monitor and evaluate the success of conservation efforts through implementation of the CCS.

Section One: CCS Overview

Introduction

What Is CCS?

The Missouri Comprehensive Conservation Strategy (CCS) is the integration of Missouri's State Forest Action Plan (SFAP), State Wildlife Action Plan (SWAP), watershed priorities, public and private land conservation opportunities, community conservation strategy, and other conservation challenges and opportunities into a unified framework. This framework ensures a cohesive interdisciplinary conservation strategy that increases the health of Missouri's land and water. It contributes significantly to regenerative practices that improve the state's natural resources.

Missouri's CCS focuses on key conservation challenges and opportunities. The framework embraces landscape-scale conservation, working to maintain, enhance, restore, and re-create healthy natural systems, while not overlooking the value of site-level conservation. This approach will increase the resiliency of these systems to potential threats, increase connectivity among habitat systems, and provide benefits to a broad suite of species, including but not limited to those of greatest conservation need. These robust landscapes also will support more reliable production of various sustainable, renewable resources (e.g., forest products, grazing forage, seed, etc.) and other benefits (e.g., outdoor recreation, health benefits, ecosystem services, species recovery) that benefit Missouri's economy and quality of life. This integrated approach proactively encourages an increase in connection between citizens and nature and ensures the responsible use of limited federal- and state-entrusted, partner, and citizen resources.

The Missouri Department of Conservation (MDC) serves as the steward in the development of the CCS; however, partners have been engaged throughout the process and they, as well as Missouri citizens, are key to informing, properly aligning, and effectively implementing the strategy. For all intents and purposes, the CCS is Missouri's conservation strategy.

Missouri is the first state to consolidate all these different planning needs into a common framework. Some planning needs are required for states to receive federal dollars toward state conservation efforts. Others are required simply because they ensure the most effective use of limited resources. Aligning several conservation plans, each with distinct goals and requirements, allows Missouri partners to synergize toward effective and efficient conservation of Missouri's natural resources, benefiting Missouri citizens now and into the future.

Guiding Principles

MDC –Design for the Future

MDC has a mission to protect and manage the fish, forest, and wildlife resources of the state and to facilitate and provide opportunity for all citizens to use, enjoy, and learn about these resources. This mission was developed from MDC's vision of a future with healthy fish, forests, and wildlife, where all people appreciate nature. From these themes, a five-year strategic plan (2019–2023) was developed to outline MDC's *Design for the Future*, which is included in **Table 1.1**.

Strategy 1.1.1 prioritizes the development and implementation of the CCS, which is essential to delivering MDC – Goal 1, *MDC Takes Care of Nature*. However, the CCS is incorporated throughout MDC's strategic plan. For example, aiding in the delivery of MDC – Goal 2, *MDC Connects People with Nature*, the CCS framework includes a component of MDC's community conservation strategy, providing

public access to nature. To effectively implement the CCS, conservation actions are coordinated among partners and stakeholders, including private landowners, nongovernmental organizations (NGOs), federal agencies, and military installations. Working collaboratively across Missouri, coordinated and consistent conservation actions provide the greatest impact on the health of Missouri's natural communities and strengthen the connection of Missourians to their fish, forest, and wildlife resources.

The CCS also provides the framework for attaining MDC – Goal 3, *MDC Maintains Public Trust*. A crucial component of the CCS is enhancing partnerships so as to identify shared priorities and investments. This includes sharing the cost of conservation actions and expanding the size of the areas improved through collaboration with private landowners, federal agencies, NGOs, military installations, cities, and counties, collectively. The CCS focuses efforts to focus conservation actions toward landscapes and conservation challenges and opportunities yielding the greatest return on the investment of limited resources. This approach ensures that Missourians' investments will derive the greatest conservation benefits.

Table 1.1 – MDC Design for the Future with Goals, Outcomes, and Strategies

Updated 9.26.18

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Missouri Conservation: Design for the Future

FY19 -23 Strategic Plan

GOALS	OUTCOMES	STRATEGIES
MDC TAKES CARE OF NATURE	Missouri has healthy land, water and forests	Implement our Comprehensive Conservation Strategy (CCS) to prioritize and tier our approach to water and land management in Missouri
		Maintain and improve the ecological functions of Missouri's watersheds and wetland systems
		Prevent, where possible, and control the impacts of priority invasive species and diseases
	Missouri has sustainable fish and wildlife	Manage, through sound science, harvestable fish and wildlife species at biologically and socially acceptable levels
		Recover and maintain species of conservation concern (SOCC) to sustainable levels
		Increase voluntary compliance with the Wildlife Code of Missouri through a community policing approach to resource law enforcement
MDC CONNECTS PEOPLE WITH NATURE	Missourians have places to go to enjoy nature	Use our Land Conservation Strategy (LCS) to focus future acquisitions, disposals, and resource protection
		Implement a Community Conservation strategy
		Expand opportunities for outdoor recreation activities on MDC and partner lands and facilities
		Implement a tiered approach to area maintenance and infrastructure development
	Missourians value nature	Develop a statewide relevancy campaign to showcase the importance of nature in our economic vitality and quality of life, and increase support for conservation
		Deliver efficient and effective nature-based educational programs to diverse audiences
		Cultivate partnerships with organizations that build MDC's capacity to deliver conservation
MDC MAINTAINS PUBLIC TRUST	Missourians are confident their investments are used wisely	Anticipate the needs of customers and deliver high-quality products and services
		Promote a culture of continuous improvement
	Missouri is a recognized leader in conservation	Recruit, develop and retain a diverse and skilled workforce
		Support a positive work environment where all people are valued and respected

U.S. Fish and Wildlife Service – State Wildlife Action Plan

The SWAP and associated State Wildlife Grant were initiated by the U.S. Fish and Wildlife Service (USFWS) to support states in the achievement of conservation goals in two critical ways: (1) by providing financial support and (2) through the development of the plans themselves. Congress identified eight required elements (**Table 1.2**) to be addressed in each SWAP. The eight required elements can be found distributed throughout the CCS and readers can be directed to particular elements through the Roadmap located in **Appendix A**.

Table 1.2 – SWAP Requirements

1. Species SGCN	Information on the distribution and abundance of species of wildlife, including low and declining populations as the state fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the state's wildlife.
2. Habitat	Description of the locations and relative condition of key habitats and community types essential to conservation of SGCNs.
3. Threats	Problems that may adversely affect SGCNs or their habitats.
4. Actions	Descriptions of conservation actions determined to be necessary to conserve SGCNs and their habitats and priorities for implementing such actions.
5. Monitoring	Proposed plans for monitoring SGCNs and their habitats, for monitoring the effectiveness of the conservation actions, and for adapting these conservation actions to respond appropriately to new information or changing conditions.
6. Review and Revision	Procedures to review and revise the plan at intervals not to exceed ten years.
7. Partner Involvement	Plans for coordinating the development, implementation, review and revision of the plan with federal, state, and local agencies that manage significant land and water areas within the state or for administering programs that significantly affect the conservation of identified species and habitats.
8. Public Involvement	Plans for public participation in the development, revision, and implementation of the plan.

U.S. Department of Agriculture – Forest Service – State Forest Action Plan

As a condition of receiving federal Cooperative Forestry Assistance Act funds, states are required to develop SFAPs. Missouri developed its first SFAP in 2010, and it is now due for a ten-year comprehensive revision. SFAPs are expected to provide an analysis of forest conditions and trends, identify issues and priorities, and outline strategies to ensure healthy trees and forests into the future. They also must demonstrate how states will utilize federal resources toward advancing the three priorities of the U.S. Department of Agriculture – Forest Service (USFS) National State and Private Forestry Program:

- Conserving and managing working forest landscapes for multiple values and uses
- Protecting forests from threats
- Enhancing public benefits from trees and forests

Required elements of SFAPs are listed below in **Table 1.3** and readers can be directed to particular elements through the Roadmap located in **Appendix A**.

Table 1.3 – SFAP Requirements

Statewide Forest and Woodland Resource Assessment: • Conditions and trends of forest and woodland resources in the state • Threats to forest and woodland lands and resources in the state consistent with national priorities • Areas or regions of the state that are a priority • Multi-state areas that are a regional priority
Statewide Forest and Woodland Resource Strategy: • Long-term strategies to address threats to forest and woodland resources in the state • Description of resources necessary for state forester to address statewide strategy • Strategy must address national priorities
Stakeholder Group Coordination (at minimum): • State Forest Stewardship Coordinating Committee • State Wildlife Agency (most states have separate forestry and wildlife agencies) • State Natural Resources Conservation Service Technical Committee • Lead agency for FLP (if not state forestry agency) • Applicable federal land management agencies • Military installations
Other Plans to Incorporate: • Community Wildfire Protection Plans • SWAP
FLP Assessment of Need must be integrated into SFAP, included as an attachment to SFAP, or through a combination of both approaches.

Citizen and Partner Engagement

A key principle behind the CCS is that no single citizen or conservation organization can adequately conserve Missouri's natural resources on its own. Success requires engagement and partnership with a diversity of people and organizations. Partnerships have long been recognized as important collaborations to advance common objectives. Increasingly, the conservation community is recognizing the need for improved partnership, finding common ground and pooling resources toward shared interests. The diversity among partners involved is being recognized as an asset, enriching diversity in thought and approach and drawing strength from variation in beliefs and resources.

These partnership concepts are strongly supported in the development and implementation of the CCS. The CCS allows partners to develop shared vision and tools to effectively and efficiently focus finite resources toward collective priorities and landscapes offering the greatest potential to improve Missouri's diverse natural resources. This approach ensures efficiency by encouraging ecosystem functions that support Missouri's natural resources and ecosystem services in balance with the varying interests among people.

Partner engagement can take many different forms – from landowners implementing habitat practices on their properties to volunteer groups participating in honeysuckle pulls, to deer hunters participating in chronic wasting disease (CWD) sampling, to organizations contributing grant moneys to landscape initiatives, to teachers incorporating conservation messages in their lessons, and much more.

Several other examples of diverse partnerships and interdisciplinary collaboration have been incorporated throughout this document, such as the Shoal Creek Woodlands for Wildlife Landowner Committee (SCWW) discussed in **Section Five**. Similar approaches are currently being encouraged to initiate implementation of the CCS in communities and across Missouri's key conservation landscapes described in **Section Two**. Anyone interested is encouraged to learn more about CCS and determine how best to engage.

In addition to engagement in the implementation of CCS, citizens and partners have also engaged in its development. Some of the many ways in which citizens and partners have been involved in the development of CCS are listed below in **Table 1.4**. One engagement example becoming increasingly popular is the Missouri Conservation Partners Roundtable, hosted annually by MDC. This event is an incredible networking opportunity representing a great diversity of organizations and disciplines, which encourages broad engagement, the sharing of a spectrum of perspectives, and building understanding and appreciation for shared and conflictual interpretations in the planning and implementation of Missouri conservation.

Collectively, there are no limits to what can be achieved in the conservation of Missouri's natural resources and the ability of citizens to reap the benefits they offer.

Table 1.4 – Partner and Stakeholder Engagement in CCS Development

MDC – Annual Partner Roundtable Discussion (Direct CCS Communication and Feedback Sessions in 2018 and 2019)
Missouri Forest Resources Advisory Council (State Forest Stewardship Coordinating Committee) – presentation, discussion, and review
State Natural Resources Conservation Service Technical Committee – presentation, discussion, and review
Mark Twain National Forest – Direct meeting, presentation, discussion, and review
Invitation to meet with USFWS National Wildlife Refuge staff, National Park Service – Ozark National Scenic Riverways staff, U.S. Army Corps of Engineers (USACE), and Fort Leonard Wood staff
Invitation provided to partner wildlife organizations to submit wildlife conservation priority landscape data for inclusion in our delineation of Missouri COAs
Internal coordination between MDC branches via the CCS Steering Committee and through administrative reviews
Partner/Stakeholder Initial and Draft Document Review Opportunities in March 2020 and April 2020 (**Appendix B**)

Timeframe and Revision

The 2020 CCS serves as the comprehensive revision of both the 2010 SFAP and the 2015 SWAP. By including both the SFAP and the SWAP into an all-encompassing conservation strategy (i.e., CCS), Missouri becomes the first state to completely integrate both federal programs into one document. Since both federal documents require a ten-year revision, the USFS and USFWS will receive the revised CCS every ten years. Note, this 2020 CCS submittal does alter Missouri's current timeline for SWAP revision, which would have required a comprehensive revision in 2025.

The CCS will be reviewed on a five-year rotation starting in 2025. Each review and subsequent revision will include any changes or shifts in Missouri's conservation priorities. Any modifications in Missouri's conservation priorities outside the five- and ten-year rotations will be communicated to both the USFS and USFWS in accordance to the revision guidelines for these documents. The first comprehensive revision of the CCS is scheduled to be submitted to the USFS and USFWS in 2030.

Section Two: Prioritizing Where to Work

Geographic Prioritization – Evaluation, Narrowing the Focus, and Developing and Implementing a Tiered Approach

Section Two takes a deep dive into the past and present spatial/geographic conservation priorities that have been delineated for the state of Missouri. This key section:

- Describes and highlights the significance of many of Missouri's landscape evaluations (both MDC and partner)
- Describes the utilization of these powerful resources to discover commonalities and narrow the geographic focus of conservation priority
- Describes the need for and the development of Missouri's COAs and PGs
- Compares the spatial coverage of Missouri's COA network with that of the collective landscape evaluations
- Describes MDC efforts in response to partner feedback to create tiered prioritization approaches to conservation management
- Discusses important conservation collaborations in areas of multi-state and international geographic significance through detailed case studies

Delineating areas of geographic conservation significance is an important foundation to guide on-the-ground collaboration. These resources allow partners, including Missouri's private citizens, to visualize where conservation efforts are being focused and where their resources are being put into action.

A Closer Look at Missouri's Landscape Prioritizations

Collectively, Missouri conservation partners have long-identified key landscapes of priority across the state based on varying respective interests. While some assessments have been based on the specific priorities of a single partner, several have involved a collaborative evaluation of overlapping interests. Some assessments have been specific to the state of Missouri, while others have been part of a regional or national evaluation effort.

The following summaries provide a closer look at the significance of many of Missouri's important landscape evaluations

The Nature Conservancy Portfolio Sites (maps.tnc.org/gis_data.html)

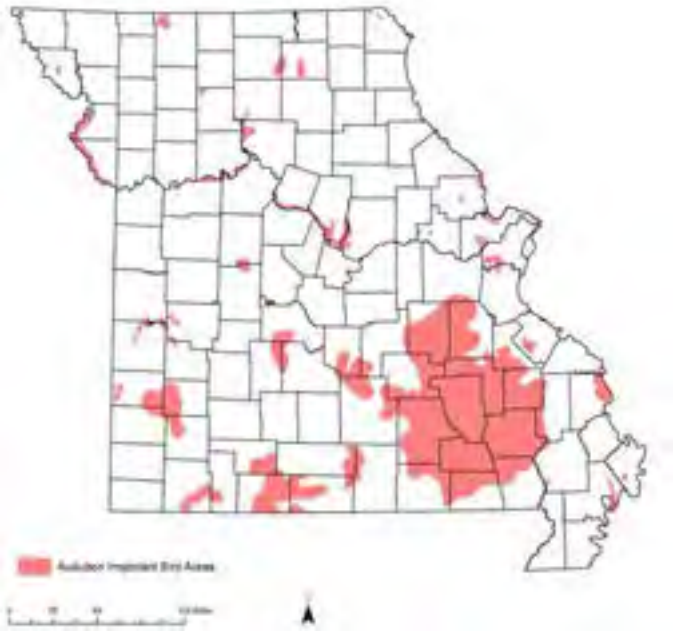
This dataset from The Nature Conservancy (TNC) provides a vision for conservation success for ecological systems, natural communities, and species representative of an ecoregion by showing the boundaries of areas that TNC has prioritized for conservation. Many portfolio areas were derived from Ecoregional Assessments, but other priorities derived using other planning methodologies are included in this global dataset. Information on species and habitats within the U.S. portfolio is available via a new interactive web map viewer or a GIS data download.

Figure 2.1 – The Nature Conservancy Portfolio

Audubon Important Bird Areas
(audubon.org/important-bird-areas)

As the U.S. partner for BirdLife International, Audubon spearheads an ambitious effort to identify, monitor, and protect the most important places for birds. Audubon also collaborates with 19 international partners to extend a web of protection throughout the Western Hemisphere. To date, Audubon has identified 2,758 IBAs covering 417 million acres of public and private lands in the United States. Among them are high-priority Global Important Bird Areas (IBAs), places like New York City's Jamaica Bay, areas within Alaska's Arctic Slope, and coastal bird sanctuaries in Texas. Birds depend on a diverse range of habitats, and the threats that confront them are equally varied.

Figure 2.2 – Audubon Important Bird Areas



Missouri Grassland Coalition Focus Areas
(mdc.mo.gov/conmag/2004/12/grassroots-works-grasslands)

Dwindling prairie habitat, and the demise of the species that depend on it, sparked the formation of the Grasslands Coalition. Led by the Missouri Prairie Foundation (MPF), the Coalition formed in 1998, within a month after the greater prairie chicken had been placed on Missouri's state endangered species list.

The Coalition has two goals: (1) to help the public understand the importance of grasslands, and (2) to improve grassland habitat in areas that could make a significant and lasting difference to a growing number of species like the prairie chicken.

To decide how and where to direct resources, coalition members inventoried 15 areas that, at the time, still supported prairie chickens. Based on the amount and quality of existing grasslands and the level of landowner interest, nine of the areas were chosen as focus areas.

Figure 2.3 – Missouri Grassland Coalition Focus

North American Waterfowl Management Plan Focal Landscapes (**fws.gov/migratorybirds/pdf/management/NAWMP/2012NAWMP.pdf**)

These landscapes are most significant to North American waterfowl and waterbirds. They are derived from refinement of the 2004 North American Waterfowl Management Plan (NAWMP) update. These areas were prepared by the NAWMP Science Support Team (NSST) based on information provided by Joint Ventures and NSST members.

Entities proposing new areas or boundary adjustments were asked to provide rationale for why an area should be deemed continentally significant. Such information included the period(s) of the annual cycle during which an area was of importance, the percentage of a species population supported by a given area during that annual cycle period, and/or the percentage of total North American waterfowl occurring in a given area during some period of the annual cycle.

Objective decision criteria for assessing "significance" to continental waterfowl populations were difficult to establish. For example, comparing the relative importance of smaller areas with high waterfowl densities to larger areas with abundant waterfowl at low densities was problematic. These comparisons became increasingly difficult when made during different periods of the annual cycle. Moreover, the quantity and reliability of population survey data varied among regions and proposals. In addition, some areas were identified as critical to a single species of high concern whereas others were deemed important because they were used by numerous species. Certain arid locations provide high value to waterfowl, but those values are inconsistent among years because of a highly variable environment (e.g., playa wetlands). Finally, the NSST recognized that additional areas of North America attract large numbers of waterfowl or species of concern but were not currently considered of great significance at the continental scale.

In the future, some of these areas may be included (and others removed) as new information is used for map development.

Figure 2.4 – Continentally Significant Migratory Waterbird Habitats

National Wild Turkey Federation Focal Landscapes (nwtf.org/about/big-six)

The National Wild Turkey Federation (NWTF) has taken a more strategic approach to conservation delivery with the introduction of the "Big Six." NWTF conservation experts identified regions across the country with similar ecosystems and conservation issues. Six areas of concern were established to help identify the most urgent needs and to better monitor conservation objectives. These are listed below.

This application allows the NWTF and its partners to better focus limited funding and staff on the top priority conservation needs within each region. The improved system no longer focuses on individual areas but will impact the recovery of species and habitats across large landscapes.

The areas of distinction within the Big Six include 738 million acres of identified focal landscapes. The NWTF's limited funds will have a greater impact in meeting the conservation needs within each region. This process will also ensure wild turkey populations, health, and stability for future generations.

Conservation challenges and opportunities within the Big Six include:

- Improving habitat diversity
- Improving forest health
- Improving pine management
- Improving water quality
- Increasing winter wildlife survival
- Maintaining healthy hardwood forests
- Restoring oak woodlands and savannas
- Restoring prairies
- Stopping habitat loss

Figure 2.5 – NWTF Focal Landscapes

Mark Twain National Forest Management Areas 1.1 and 1.2

(fs.usda.gov/Internet/FSE_DOCUMENTS/fsm8_045305.pdf)

The Mark Twain National Forest (MTNF) has identified management areas of emphasis to proactively promote the restoration and conservation of terrestrial natural communities. While Management Areas 1.1 and 1.2 are specifically identified for focused effort, the implementation of the following goals can be applied across other areas of the MTNF as opportunities are identified.

The identified goals include:

Goal 1.1 –Terrestrial Natural Communities

Maintain, enhance, or restore site-appropriate natural communities, including the full range of vegetation composition and structural conditions.

Goal 1.2 –Nonnative Invasive Species

Maintain desired ecosystems throughout the forest with few occurrences of nonnative invasive species. Prevent new invasions and control or reduce existing occurrences of nonnative invasive species.

Goal 1.3 – Soils, Watersheds, and Water Quality

Minimize erosion and compaction.

Restore and maintain soil productivity and nutrient retention capacity.

Protect the water quality and integrity of the watershed on USFS lands.

Maintain healthy, regenerative, and diverse natural communities.

Prevent wetland degradation and loss and restore and enhance wetlands when possible.

Establish and maintain riparian management and watercourse protection zones to:

- Maintain, restore, and enhance the inherent ecological processes and functions of the associated aquatic, riparian, and upland components within the riparian corridor
- Maintain streams in normal function within natural ranges of flow, sediment movement, temperature, and other variables
- Restore or maintain impaired waters as classified by the section 303(d) of the Federal Clean Water Act
- Protect and improve state and national outstanding resource waters

Goal 1.4 – Wildlife and Aquatic Habitat

Provide the range of natural habitats necessary to support populations of existing native plant and animal species.

Restore and manage natural communities as the primary means of providing quality terrestrial, karst, and aquatic wildlife and rare plant habitat.

Support recovery of federal- and state-listed species, protection and management of habitat for regionally listed species, and protection and management of habitat for other identified species of concern.

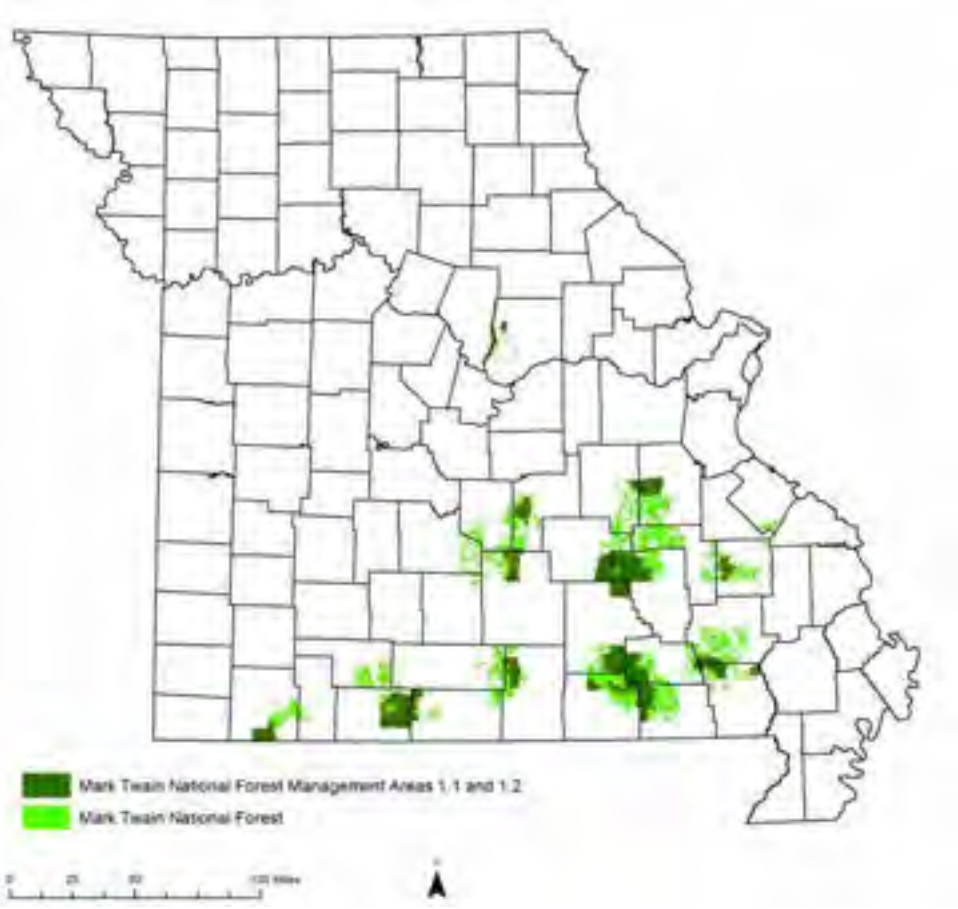
Provide specialized habitats that are a healthy functioning part of the larger landscape and require no special protection or additional management considerations.

Provide specialized MTNF – Forest Plan 1.4 habitat components (such as standing dead trees, cavity and den trees, downed woody material, temporary pools, ephemeral springs and seeps) across the landscape in amounts and types commensurate with the natural communities in which they occur.

Encourage habitat that responds to demand for both consumptive and nonconsumptive fish and wildlife use.

Maintain native and desired nonnative fish populations through habitat protection and enhancement and stocking programs.

Figure 2.6 – MTNF Management Areas 1.1 and 1.2



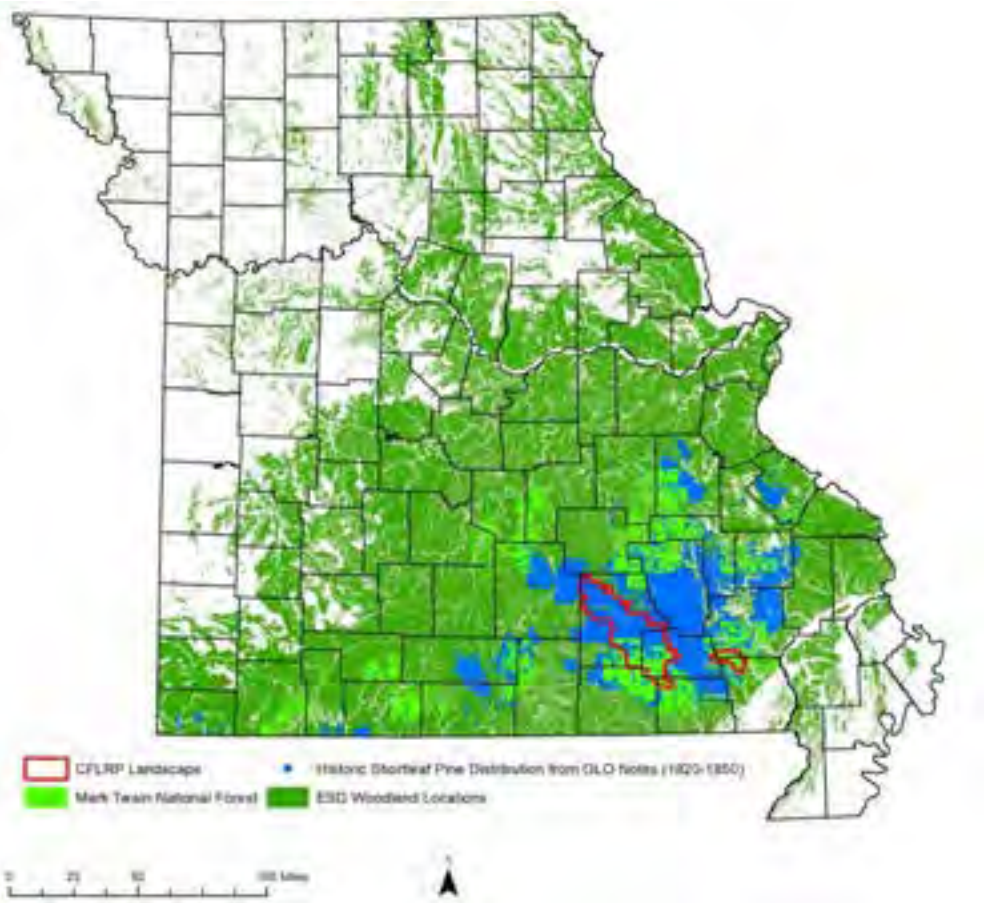
USFS Collaborative Forest Landscape Restoration Program

(fs.fed.us/restoration/documents/cflrp/2011Proposals/Region9/MarkTwain/revMoPWRCFLRPproposal20110217.pdf)

Six million acres of old growth shortleaf pine woodland once covered the southern Missouri Ozarks. Historical intensive logging, open range grazing, and changes in the fire regime reduced this coverage to fragments, leaving much of the landscape out of character and dominated by small-diameter, often diseased red and black oak. Seven major landholding entities partnered to restore approximately 116,000 acres of this globally imperiled shortleaf pine and oak bluestem woodland by marketing small-diameter biomass and restoring the historic fire regime.

Based on past restoration work in shortleaf pine/bluestem demonstration units and the MTNF Pineknot Project, ten years of thinning and frequent prescribed burns are being implemented to create a landscape dominated by the largest and oldest shortleaf pine with a grass/forb groundcover. Restoration at this scale is helping to protect important target bird species addressed in the Missouri Bird Conservation Plan as well as many other taxonomic groups, to promote natural vegetation characteristics, and to stimulate the local economy.

Figure 2.7 – Collaborative Forest Landscape Restoration Program – Pine-Oak Woodlands Restoration



Missouri's PFLs

PFLs are large landscapes (>10,000 acres) offering Missouri's best opportunities for sustaining forest resources and the benefits and services derived from them. They are places that offer the greatest conservation benefit and are also under significant but mitigable threat. PFLs are important places for focusing limited resources (dollars, staff, volunteers, grants, etc.) toward strategic planning, collaborating, and implementing conservation.

The development of PFLs is required for states to continue receiving federal funding from the USFS. Missouri's PFLs were designed to meet the needs and requirements of all USFS funding – including Forest Legacy and Forest Stewardship Programs, each with unique requirements for priority landscapes.

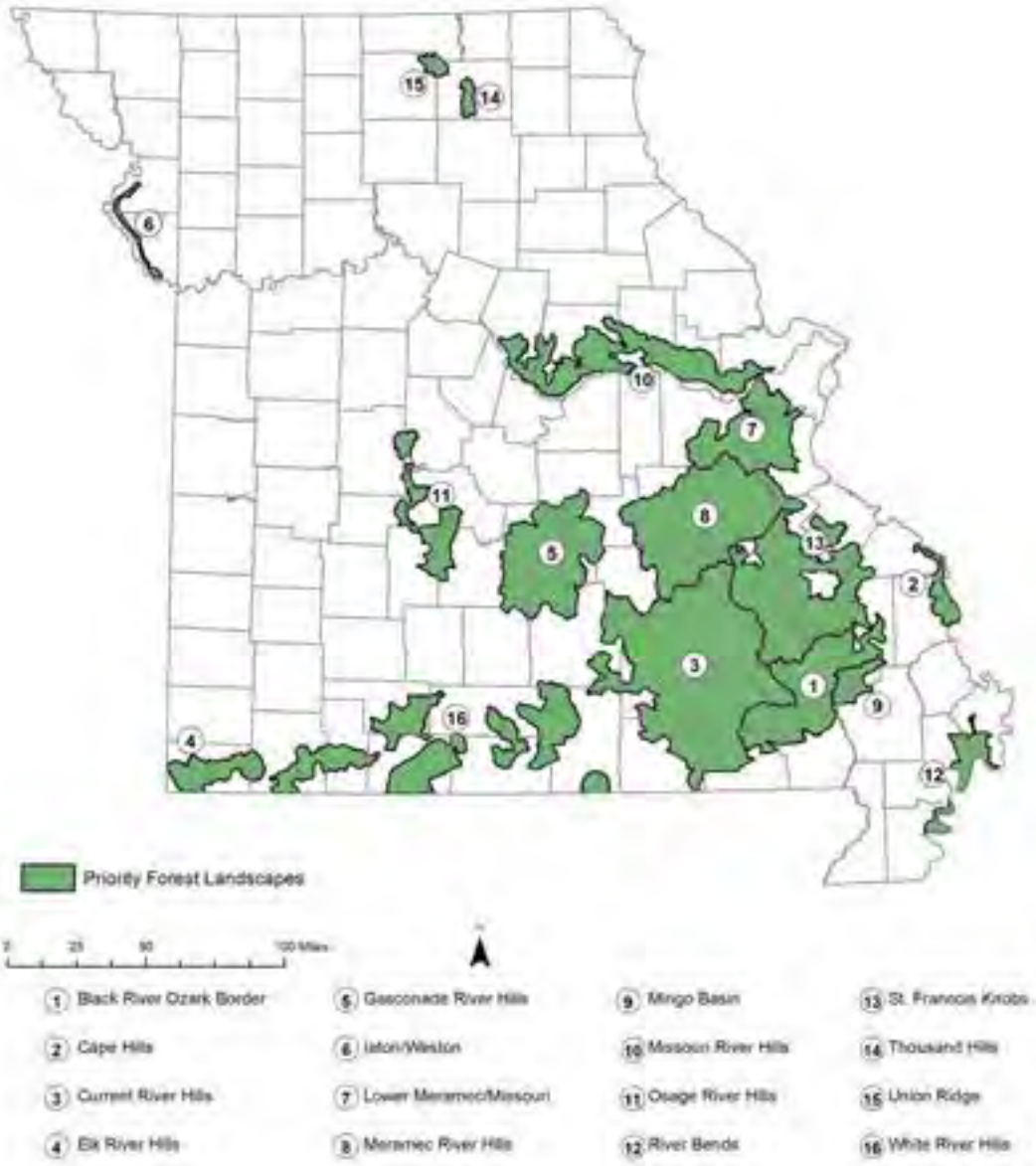
Missouri's PFLs were primarily developed by tracing the outline of the highest-scoring places in the state as depicted by a Forest Opportunity Model developed specifically for this purpose. This model was developed based on eight attributes of forest importance and threat:

- Biodiversity
- Forest productivity/carbon sequestration
- Soil and water conservation
- Recreation and social values
- Forest patch size
- Current harvest pressure
- Insect and disease vulnerability
- Land use change risk

In many cases, PFL boundaries also consist of distinct transitions between forest and nonforest cover. One additional PFL was identified outside of the model based on criteria that the landscape is an existing PG for forest restoration and wildlife conservation with active partnerships in place. Further information on the Forest Opportunity Model (including maps of all contributing data) and PFLs can be found in **Appendix C**.

The following map shows the resulting PFLs. On this map, approximately 42.8 percent of Missouri's existing forestland is recognized as PFLs.

Figure 2.8 – Missouri Priority Forest Landscapes



Missouri's Forest Legacy Program and Forest Legacy Areas

The USFS Forest Legacy Program (FLP) is a valuable resource available to states for protecting important working forestlands that are threatened from conversion to nonforest uses and for sustaining or improving the diverse benefits and ecosystem services eligible forestlands provide (USFS 2017). The FLP accomplishes this purpose by providing competitive funding to states for fee title acquisition of forestlands to be placed in public ownership or under conservation easements held by public agencies. MDC administers FLP for Missouri, but other state and local government agencies such as the Missouri Department of Natural Resources (MDNR) county governments, and municipal governments are eligible to hold land and easements acquired through FLP as well.

Missouri's goals for utilization of the FLP include:

- Ensuring the future health of important watersheds and streams that produce clean, affordable drinking water; mitigate flooding; and provide important aquatic habitat and recreation
- Protecting habitats important to improving populations of sensitive wildlife species
- Maintaining outstanding opportunities for outdoor recreation
- Maintaining the productivity of Missouri's forestland and sustainable production of forest products
- Protecting karst features (caves, springs, fens), other unusual natural features, and cultural sites
- Protecting the scenic values of forestlands important to Missouri citizens where they live and play; and important to maintaining the integrity of Missouri's tourism economy

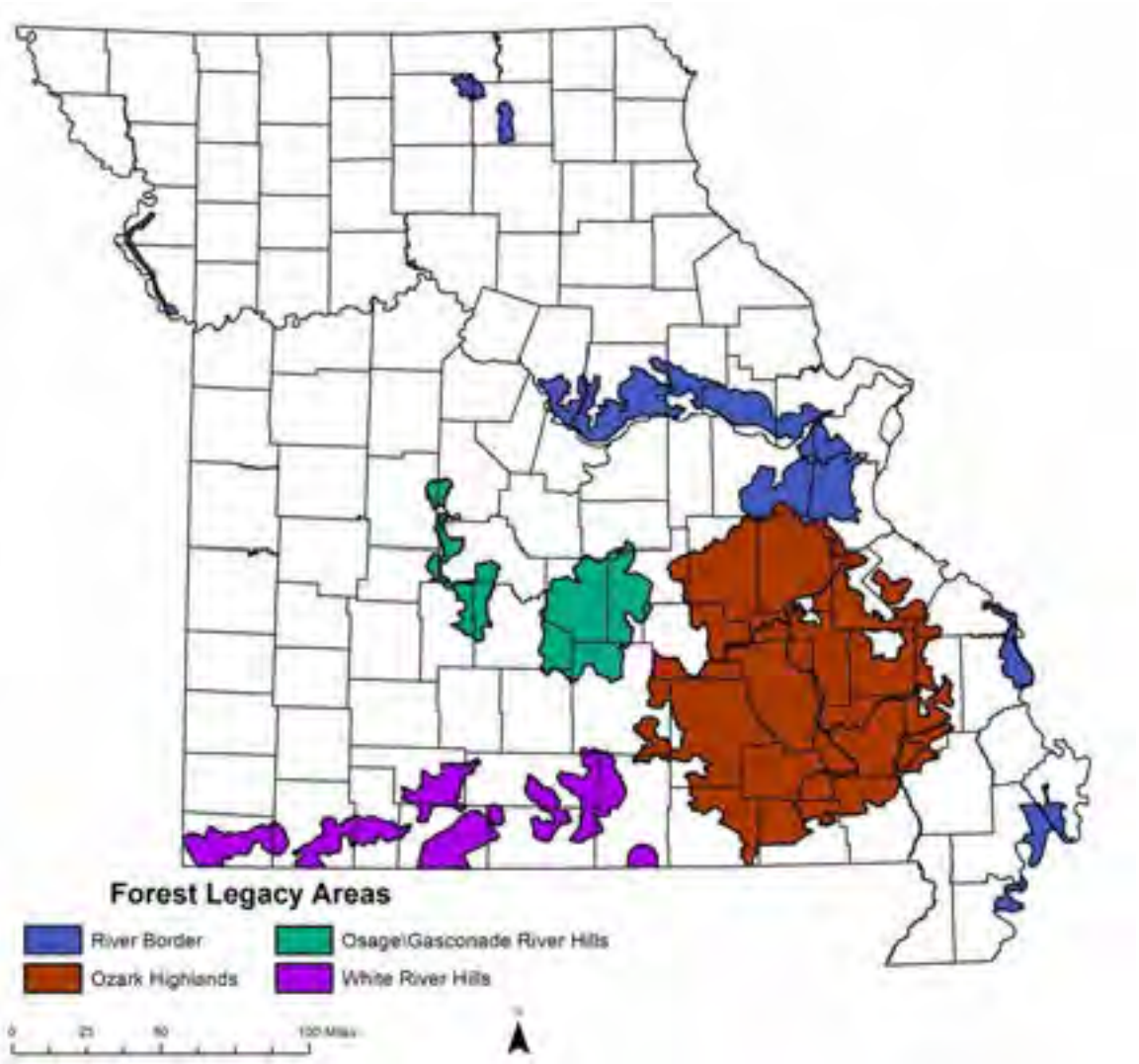
Appendix D provides much greater detail on Missouri's FLP and how Missouri's CCS meets the USFS requirements for states to develop a Forest Legacy Assessment of Need to participate in the program. However, one of these requirements that is especially applicable to this section is that states are required to delineate Forest Legacy Areas (FLAs).

FLAs are significant geographic landscapes eligible to be considered for Forest Legacy projects. Only tracts within FLAs can be submitted to the USFS for competitive funding for fee title public land acquisition or conservation easements. Missouri's method for determining FLAs is one and the same as the method used for determining PFLs and is based on eight attributes of forest importance and threat, as described in **Appendix C**.

These attributes align well with seven of the public values identified in the FLP Guidelines, of which all FLAs must contain at least one. One PFL (River Bends) was delineated because of its high habitat and wildlife restoration potential outside of the Forest Opportunity Model.

PFLs serve as the building blocks for four distinct FLAs – River Border, Ozark Highlands, White River Hills, and Gasconade/Osage River Hills. These FLAs are found in the map below but are also described in much greater detail in **Appendix D**.

Figure 2.9 – Missouri Forest Legacy Areas



Missouri's Comprehensive Wildlife Conservation Strategy

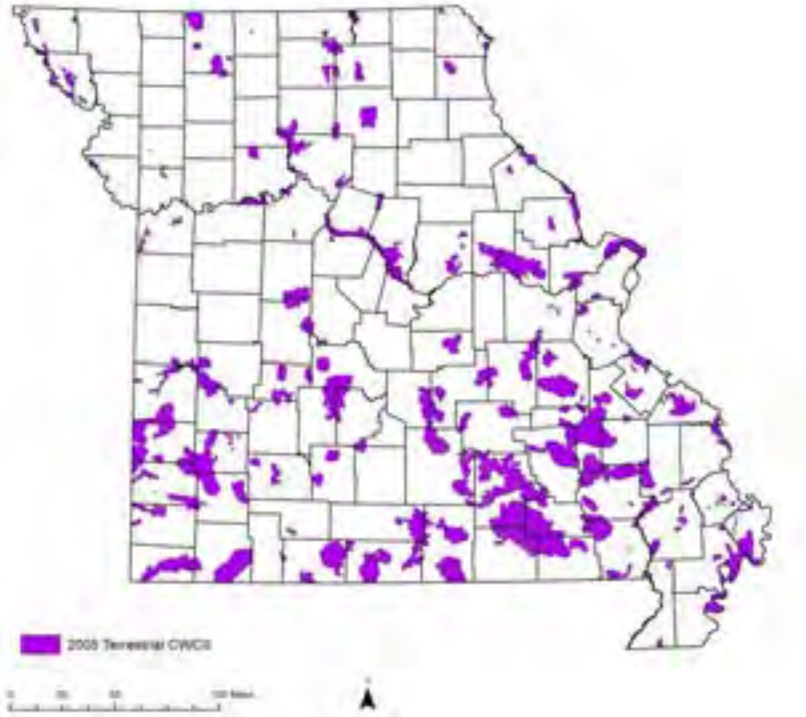
Missouri developed the Comprehensive Wildlife Conservation Strategy (CWCS) in 2005 (Missouri's first SWAP), the goal was to use all the information acquired in the prior 30 years to identify a set of COAs to support and conserve viable populations of all wildlife and the habitats on which they depend. MDC recognized that for the CWCS to be effective in advancing the conservation of Missouri's full diversity of fish, wildlife, and plant resources, the approach must be habitat-based rather than species-based.

To build the CWCS, MDC used an ecological framework to guide terrestrial and aquatic assessments. Target species, habitats, natural communities, and landscapes were identified for each ecological unit. At the time, MDC staff from all divisions set geographic priorities based on these rigorous assessments. Spatial data layers were developed and used to identify concentrations of conservation targets. Conservation partners then shared their priorities with MDC. All this information was combined to identify a framework of conservation opportunity representing the diversity of Missouri.

The CWCS was designed to be adaptive and to morph through time. Information and experience from the development and implementation of the CWCS were used in the development of both the Missouri SFAP and the Missouri PWs.

Partner input was a key component in the identification of Missouri's first COAs in the 2005 CWCS. The current 2020 COAs are a refinement of the original COAs, taking into consideration new information and assessments, new conservation partner priorities, and changes on the landscape since 2005.

Figure 2.10 – 2005 Terrestrial Comprehensive Wildlife Conservation Strategy



Missouri's Aquatic CWCS (Aquatic GAP)

The National Gap Analysis Program (GAP) was initiated in 1988 to provide a coarse-filter assessment strategy for identifying and prioritizing biodiversity conservation needs. In 1997, in cooperation with the Missouri Resource Assessment Partnership and financial assistance by the U.S. Geological Survey (USGS) National Water Quality Assessment Program, the U.S. Department of Defense–Legacy Program, and MDC, GAP initiated a statewide pilot project for the state of Missouri.

The principal goal of the project was to identify riverine ecosystems and species not adequately represented (i.e., gaps) in the matrix of conservation lands in Missouri, as well as to provide spatially explicit data that could be used by natural resource professionals, legislators, and the public to make more informed decisions for prioritizing opportunities to fill these conservation gaps and to devise strategic approaches for developing effective long-term biodiversity conservation plans.

Several geospatial and tabular datasets were developed to meet the information/data needs for identifying conservation gaps and subsequently prioritizing opportunities to fill these gaps:

- Maps of a hierarchical classification of riverine ecosystems
- Predicted species distribution maps
- Ownership and stewardship maps
- Maps of human stressors

These data were then used to conduct a gap analysis of both biotic and abiotic conservation targets and to develop a statewide freshwater biodiversity conservation plan.

Figure 2.11 – 2005 Aquatic Comprehensive Wildlife Conservation Strategy

Missouri's Outstanding National and State Water Resources

Missouri has three designated Outstanding National Water Resources (ONRW) (**Table 2.1**) and forty-three designated Outstanding State Water Resources (OSWR) (**Table 2.2**). Missouri's Water Quality Standards define ONRWs as:

"*Waters which have outstanding national recreational and ecological significance. These waters shall receive special protection against any degradation in quality. Congressionally designated rivers, including those in the Ozark National Scenic Riverways and the Wild and Scenic Rivers System, are so designated*."

Missouri's OSRWs are high-quality waters with a significant aesthetic, recreational, or scientific value, which are specifically designated as such by the Clean Water Commission.

Lowering of water quality (which may be allowed for important economic and social development for other waters of the state) is not permitted in ONRWs or OSWRs.

Table 2.1 – Missouri's ONRWs
10CSR20-7 MDNR Division 20 – Clean Water Commission

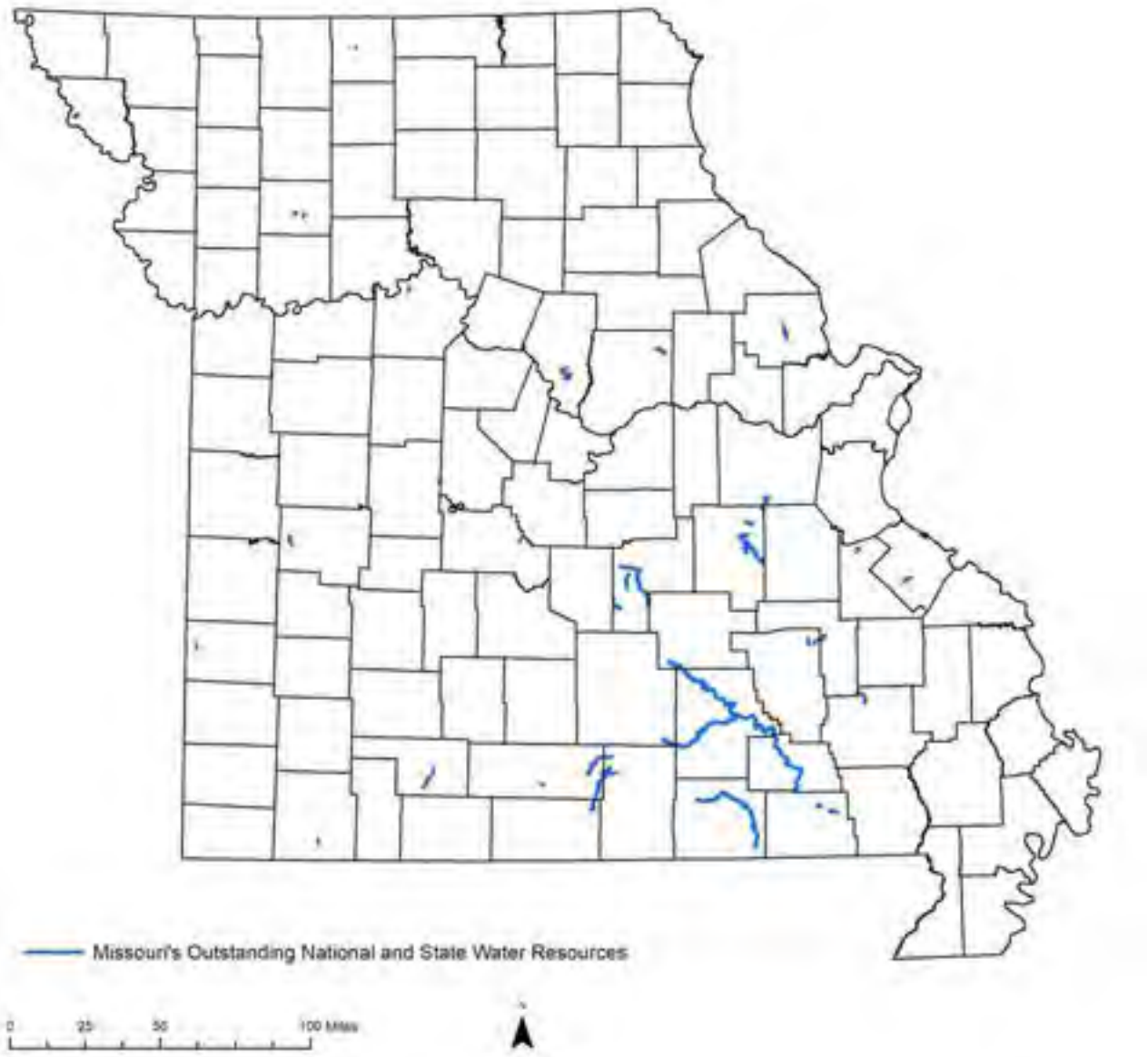
Water Body	Location	County(ies)
Current River	Headwaters to N. Ripley Co. Line Sec. 22,32N,07W to Sec. 15,25N,01E	Dent to Ripley
Jacks Fork River	Headwaters to Mouth Sec. 29,28N,07W to Sec. 9/15,29N,03W	Texas to Shannon
Eleven Point River	Headwaters to Hwy. 142 Sec. 32,25N,05W to Sec. 21,22N,02W	Oregon

Table 2.2 – Missouri's OSRWs
10CSR20-7 MDNR Division 20 – Clean Water Commission

Water Body	Miles/Acres		Location	County(ies)
Baker Branch	4	mi.	Taberville Prairie	St. Clair
Bass Creek	1	mi.	Three Creek Conservation Area	Boone
Big Buffalo Creek	1.5	mi.	Big Buffalo Creek Conservation Area	Benton-Morgan
Big Creek	5.3	mi.	Sam A. Baker State Park	Wayne
Big Sugar Creek	7	mi.	Cuivre River State Park	Lincoln
Big Lake Marsh	150	ac.	Big Lake State Park	Holt
Blue Springs Creek	4	mi.	Blue Spring Creek Conservation Area	Crawford
Bonne Femme Creek	2	mi.	Three Creeks Conservation Area	Boone
Brush Creek	0.7	mi.	Bonanza Conservation Area	Caldwell
Bryant Creek	1.5	mi.	Bryant Creek Natural Area in Rippee Conservation Area	Ozark/Douglas
Bull Creek	8	mi.	Mark Twain National Forest Sec. 24,25N,21W to Sec. 22,26N,20W	Christian
Cathedral Cave Branch	5	mi.	Onondaga Cave State Park	Crawford
Chariton River	9.8	mi.	Rebels Cove Conservation Area	Putnam-Schuyler
Chloe Lowry Marsh	40	ac.	Chloe Lowry Marsh Conservation Area	Mercer
Coakley Hollow	1.5	mi.	Lake of the Ozarks State Park	Camden
Coonville Creek	2	mi.	St. Francois State Park	St. Francois
Courtois Creek	12	mi.	Mouth to Hwy. 8	Crawford

Crabapple Creek	1.0	mi.	Bonanza Conservation Area	Caldwell
Devils Ice Box Cave Branch	1.5	mi.	Rock Bridge State Park	Boone
East Fork Black River	3	mi.	Johnson's Shut-Ins State Park	Reynolds
First Nicholson Creek (East Drywood Creek)	2	mi.	Prairie State Park	Barton
Gan's Creek	3	mi.	Rock Bridge State Park	Boone
Huzzah Creek	6	mi.	Mouth to Hwy. 8	Crawford
Indian Creek	17.5	mi.	Mark Twain National Forest	Douglas-Howell
Ketchum Hollow	1.5	mi.	Roaring River State Park	Barry
Little Piney Creek	25	mi.	Mouth to 21,35N,08W	Phelps
Little Black River	3	mi.	Mud Puppy Natural History Area S22,T24N,R3E to S25,T24N,R3E	Ripley
Log Creek	0.4	mi.	Bonanza Conservation Area	Caldwell
Meramec River	8	mi.	Adjacent to Meramac State Park	Crawford/Franklin
Meramec River	3	mi.	Adjacent to Onondaga and Huzzah State Forest	Crawford
Mill Creek	5	mi.	Mark Twain National Forest	Phelps
N. Fork White River	5.5	mi	Mark Twain National Forest	Ozark
Noblett Creek	5	mi.	Above Noblett Lake, Mark Twain National Forest	Douglas-Howell
Onondaga Cave Branch	0.6	mi.	Onondaga Cave State Park	Crawford
Pickle Creek	3	mi.	Hawn State Park	Ste. Genevieve
S. Prong L. Black River	2	mi.	In Little Black Conservation Area	Ripley
Shoal Creek	0.5	mi.	Bonanza Conservation Area	Caldwell
Spring Creek	17	mi.	Mark Twain National Forest	Douglas
Spring Creek	6.5	mi.	Mark Twain National Forest	Phelps
Taum Sauk Creek	5.5	mi.	Johnson's Shut-Ins State Park Addition S23,T33N,R2E to S5,T33N,R3E	Reynolds-Iron
Turkey Creek	4.6	mi.	In Three Creeks Conservation Area	Boone
Van Meter Marsh	80	ac.	Van Meter State Park	Saline
Whetstone Creek	5.1	mi.	Whetsone Creek Conservation Area	Callaway

Figure 2.12 – Missouri's Outstanding National and State Water Resources



Missouri's Priority Watersheds

All Missouri's watersheds are important, but they cannot all be addressed simultaneously; therefore, a prioritization process is necessary. Concentrating first on Missouri's highest Priority Watersheds (PWs) allows more time and resources for citizen engagement and ownership of watershed health. With leadership and support from the local public, the collaborative role of conservation partners is to serve as a catalyst, provide education and technical expertise (science), and assist with administration including identifying additional partners and resources.

Missouri's watershed prioritization is based on two guiding objectives: (1) conserving aquatic health and biodiversity and (2) providing quality areas and opportunities for outdoor recreation. Some significant aquatic areas have already been identified in the 2005 Conservation Wildlife Conservation Strategy and Aquatic GAP process that identified 158 aquatic COAs based on a representation of the diversity of watersheds, aquatic systems, and species of Missouri. However, there are other watersheds that meet the biodiversity and recreational prioritization objectives that are not aquatic COAs; so, a broader approach is neccessary that includes these watersheds in the prioritization process. Once candidate watersheds are identified, there are other mandatory aspects that are considered in the process:

- Is there enough existing local interest/participation in a designated target watershed or can interest be generated (local buy-in)?
- Can the most significant watershed issues/opportunities be reasonably addressed (feasibility)?
- Can multiple priorities be met in overlapping areas?

By prioritizing watersheds, a proactive approach can be taken in establishing cooperation among stakeholders by offering watershed-specific education, assistance, and resources. Every watershed project is likely to be somewhat unique, which requires flexibility and innovation. This approach not only allows local citizens to be responsible for their stream resources, it also provides more partnering opportunities in the way of financial resources to assist in achieving desired outcomes. It is important to remember that this is a dynamic process that must continually be re-evaluated for relevance within a watershed with regards to the interests of all the watershed stakeholders.

Figure 2.13 – Missouri Priority Watersheds

Missouri's Quail Restoration Landscapes

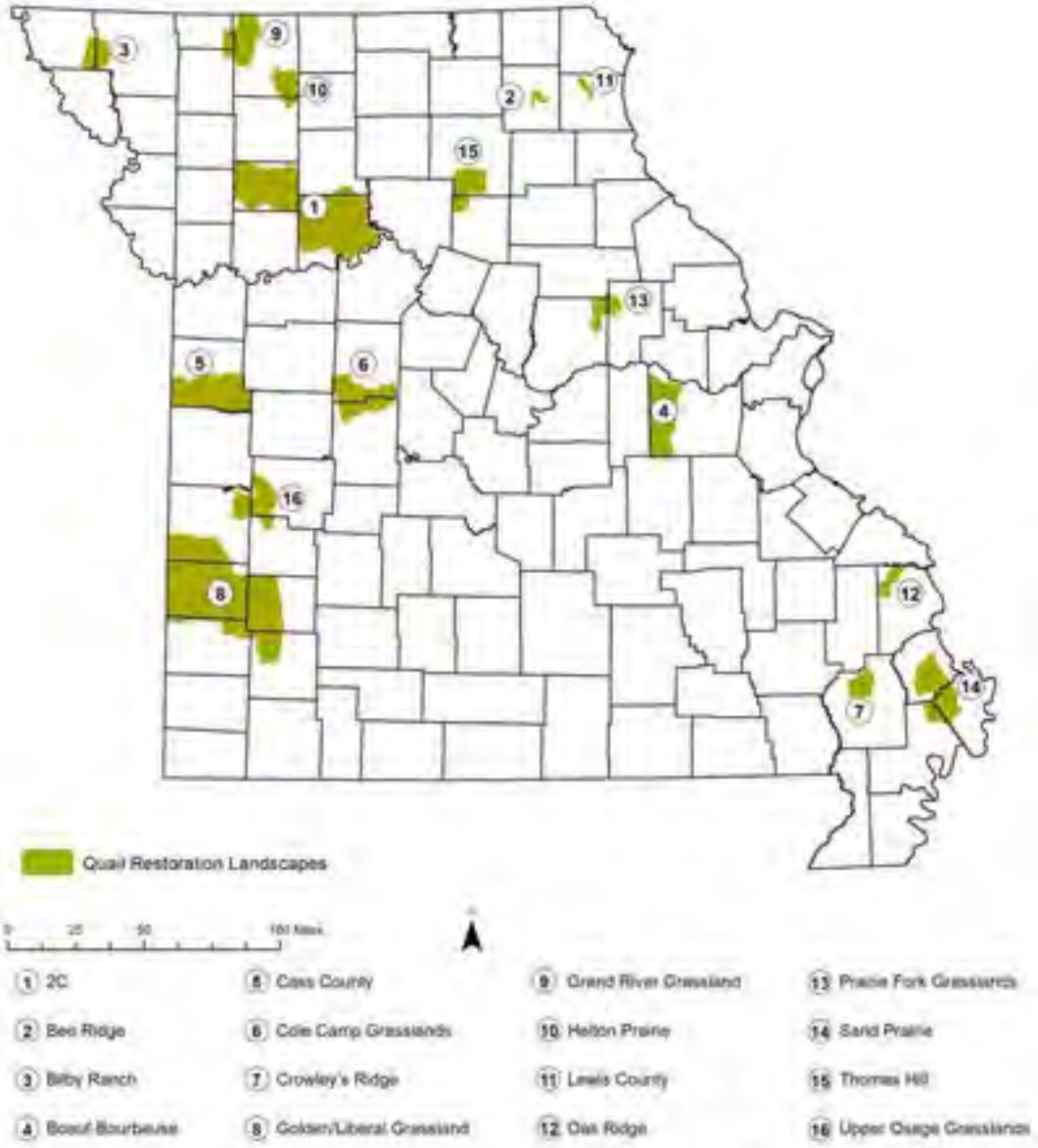
The establishment of Missouri's Quail Restoration Landscapes (QRLs) is an effort to improve quail populations on a landscape scale by focusing management efforts within geographies with the greatest likelihood of maintaining populations over time. The QRLs were selected based on multiple factors such as current habitat and land cover conditions, existing quail populations, and potential benefit to other grassland, savanna, and woodland wildlife. These landscapes are not the only places conservation partners promote and encourage quail conservation in the state; they have just been identified as the best places to address multiple conservation resource concerns with limited financial resources.

Maximizing usable year-round habitat to improve quail production and overwinter survival will be the barometer guiding management recommendations within QRLs. Emphasis is placed on natural community management for both public and private lands (i.e., native grassland, savanna, and woodland restoration, native cover establishment for grazing, soil health, and conservation plantings). In addition to providing habitat for quail, this management approach creates habitat benefiting many other species such as grassland songbirds and pollinators.

Priority management practices for public lands include prescribed burning; savanna, woodland, and prairie restoration; edge feathering; shrub cover enhancement; and reducing cover of invasive species and exotic cool-season grasses such as tall fescue. Within a subset of QRLs, grazing occurs on some conservation areas to help maintain suitable vegetative conditions.

Practices on private lands benefiting quail may include similar practices to public land management, as well as establishing native vegetation for forage production, soil conservation, and pollinator habitat and establishing buffers for crop fields and waterways, as well as managing existing idle lands such as U.S. Department of Agriculture's (USDA) Conservation Reserve Program (CRP) acres.

Figure 2.14 – Missouri Quail Restoration Landscapes

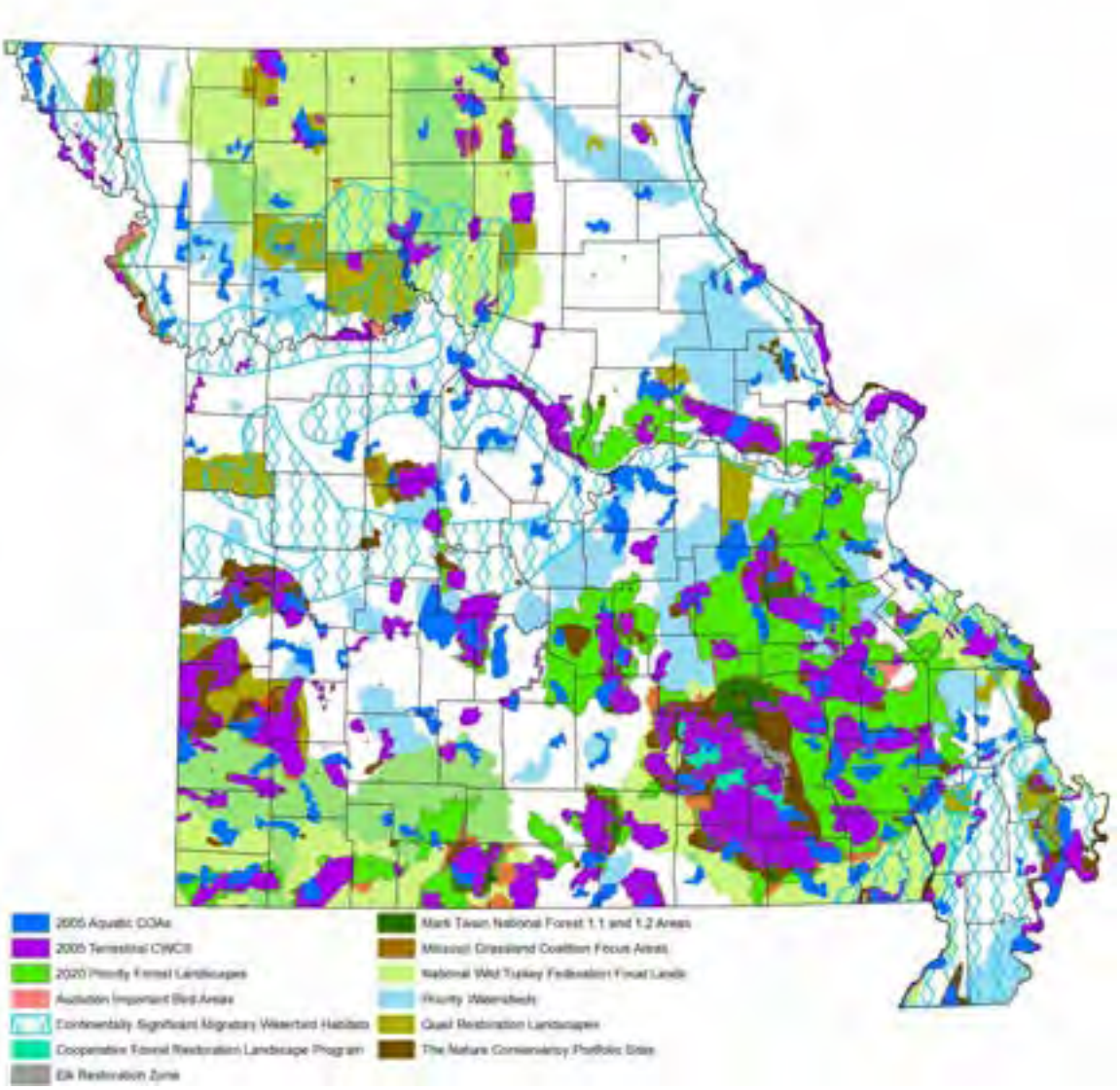


Overlaying Missouri's Landscape Prioritizations

As demonstrated, Missouri has undergone a significant amount of landscape prioritization for varying reasons and by varying partners. An important exercise during the development of Missouri's CCS was to develop a deeper understanding of each of these priorities, including spatially. This exercise included an overlay of the geospatial data from the existing landscape evaluations to identify their collective geographic coverage.

The following map (**Figure 2.15**) is a result of this exercise, which illustrates that, collectively, the identified priorities cover approximately 75 percent (33,269,826 acres) of Missouri's landscape.

Figure 2.15 – An Overlay of Missouri's Landscape Prioritizations



The Need for Combined Prioritization (i.e., Prioritizing the Priorities)

As demonstrated in the preceding list of landscape priorities and the degree of their collective geographic coverage within the state, Missouri's landscape offers ample opportunities for natural resource conservation. All these opportunities offer a degree of conservation value; however, the existing opportunities greatly outweigh the level of resource availability and support to address them simultaneously. And while opportunity may exist statewide, not every acre of Missouri holds equal conservation value and potential for success.

Understanding these realities comes with the recognition that "if everything is a priority, nothing is a priority" and "we can't do everything everywhere." Resulting from this understanding is the necessity to develop a combined prioritization strategy for resource allocation toward those conservation actions and landscapes that result in regenerative resource management and offer the greatest return on investment. The result is the necessity to develop and maintain Missouri's COAs network – a powerful tool in identifying the best landscapes to focus limited resources first.

However, despite the development and existence of the COAs, it is important to maintain a level of focus on the landscape assessments, which are crucial to long-range conservation planning. These datasets directly inform the 2020 Missouri COA network. If these assessments are modified through time, the COA network may also change accordingly.

The Identification of Missouri's Conservation Opportunity Areas

The CCS framework establishes the need for Missouri to develop tools to effectively and efficiently focus finite resources toward landscapes offering the greatest potential to improve Missouri's diverse natural communities. Investing in a landscape- and natural community-based approach to conservation ensures efficiency by providing the landscapes and ecological functions that support species rather than trying to provide the needs of each species individually, which is unrealistic.

Working with conservation partners and a multitude of data, MDC challenged staff to research, analyze, and identify the geographic areas of significant conservation potential throughout the state, which were aptly named Conservation Opportunity Areas (COAs). Missouri's first COAs were identified in 2005 during the development of the state's first SWAP (Comprehensive Wildlife Conservation Strategy). The COA network was revisited and streamlined during the SWAP revision, which served as the initial developments of the CCS, in 2015, and were revisited in 2020. The 2020 COAs represent the greatest opportunity for regenerative conservation of the state's native flora and fauna and the natural communities they are a part of, including forests and woodlands; savannas, prairies, and grasslands; glades; caves and karst; wetlands; rivers and streams; and cliff and talus.

The COA network encompasses the core natural community–based conservation landscapes in Missouri and makes up about 13 percent of Missouri's land area. Development of the COAs was informed by varying data sources, including the geospatial priorities identified by Missouri's SWAP (past COA boundaries from 2005 and 2015); SFAP (PFLs – 2010 and present); PWs; CWCS/Aquatic GAP; known conservation partner priorities including TNC Portfolio Sites, Audubon IBAs, Missouri Grassland Coalition Focus Areas, NAWMP Landscapes, NWTF Focal Landscapes, and MTNF Management Areas 1.1 and 1.2 and Collaborative Forest Landscape Restoration Program (CFLRP) Landscapes; other landscape priorities; and a whole host of other data including Ecological Site Descriptions (ESDs), Land Type Associations (LTAs), current and historic land cover, habitat and species models, and Natural Heritage Database species and community data. See **Appendix E** for a list and description of layers used to create the COAs.

During the initial COA development in 2015, COAs were identified independently for each of Missouri's primary habitat systems (later combined into a single geographic information system (GIS) layer) using both GIS prioritization and professional knowledge. Sixteen-digit hydrologic unit codes (HUC 16s) were used as planning units for all habitat systems, because HUC 16s are small enough to approximate land condition but still large enough to be ecologically meaningful. For each habitat system, we attempted to identify the historic extent of the system (e.g., historic, unplowed prairie). Within the historic extent, current condition was assessed using land cover identified by the 2011 National Land Cover Database (NLCD) has since been updated in 2016 (Dewitz 2019). Areas that were identified as opportunities from previous assessments (e.g., CWCS) or that had good current condition were further prioritized based on the presence of conservation partner lands and species of conservation concern (SOCC)s related to the habitat system.

After the initial GIS prioritization in 2015, habitat system experts reviewed the locations to determine if the identified areas were appropriate and were capturing the entire opportunity for a habitat system. Teams revised the criteria used for selecting areas and identified areas that should or shouldn't be included. Teams used local knowledge of areas related to habitat condition, landowner engagement, and the statewide significance of an opportunity for selections. Partners were then invited to review and provide feedback on both the selection criteria and the draft COA maps.

The Missouri COA network is a combination of all team and partner inputs and represents the greatest opportunities for regenerative conservation of fish, forest, and wildlife resources for all habitat systems within Missouri. The final selection criteria and COA maps for each habitat system are provided in the habitat system chapters.

The identified COAs are strictly habitat- and species-based at this time and do not incorporate other important conservation considerations such as public use and recreation or community conservation. The figure includes both opportunities unique to only one habitat system and areas that have overlapping opportunity for more than one habitat system (e.g., forest/woodland and glade areas).

The CCS prioritizes proactive conservation through deliberate and focused effort within COAs. What does this mean? It means that the COA network represents core landscapes that have great potential to serve as strongholds for Missouri's native communities and respective species assemblages. Therefore, within these discrete landscapes, conservation partners, including private landowners, are encouraged to proactively seek out opportunity and invest time and resources to improve the ecological function of the overall landscape on both public and private lands.

Regarding private lands in the COAs, each landowner is a steward of their property with their own needs and unique possibilities of management. One of the objectives driving efforts within the COAs is finding commonsense solutions to meet landowners' goals while balancing the needs of nature. The key is working with willing local private landowners, through voluntary participation, to customize a conservation program that fits the needs of landowners and nature, while ensuring thoughtful protection of the landowner's interests and bottom line. To the point, Missouri's citizens manage the clear majority of Missouri's landscape, and the state's private landowners hold the key to the success of conservation in this state.

Based on success, new data, and expert feedback, the 2020 COA network includes some modification from that of 2015, but these changes are relatively minor. In the future, as goals are reached, success is observed within the currently identified COAs, and/or additional supportive data are obtained, COA boundaries may be expanded or otherwise modified to account for newfound or potentially lost opportunities. The COA boundaries today are the geographic core (anchor points) of a long-range strategy to improve the ecological function of Missouri's overall landscape – they are expected to morph through time.

It is important to note that regardless of identified opportunity areas and/or priorities, conservation partners will continue to provide services to citizens statewide and constantly continue to explore valuable opportunities to conserve Missouri's natural communities and the species they support.

An interactive map of Missouri COAs and the PGs is available (**short.mdc.mo.gov/ZBs**). (Note: This map includes watersheds for reference for each of the stream reach COAs. The watersheds for reference are not COAs but, rather, watershed boundaries for the stream reach COAs to be used as a guidance tool for needed watershed analysis when planning conservation management to benefit the stream reach COAs.)

Important Missouri COA Network Notes/Caveats

- The COAs do not capture every high-quality natural community in the state, nor was that the intent. The intent was to identify landscapes of greatest conservation opportunity for the regenerative conservation of Missouri's natural communities and flora and fauna.

- **About 80 percent** (76,246 acres of the 95,001 total acres) of Missouri Natural Area acres fall within the COA network.

- The COA network is not meant to give the impression that work outside the COAs does not have conservation value. However, for natural community and species conservation, the identification of a COA network is a powerful tool in identifying the best landscapes on which to focus limited resources first.

- Portions of each of Missouri's landscape assessments and prioritizations are captured within the COA network. There are other Missouri conservation priorities that are represented, but also not completely captured, in the COA network, including areas of high public use, community conservation, and more.

Figure 2.16 – 2020 Missouri COAs

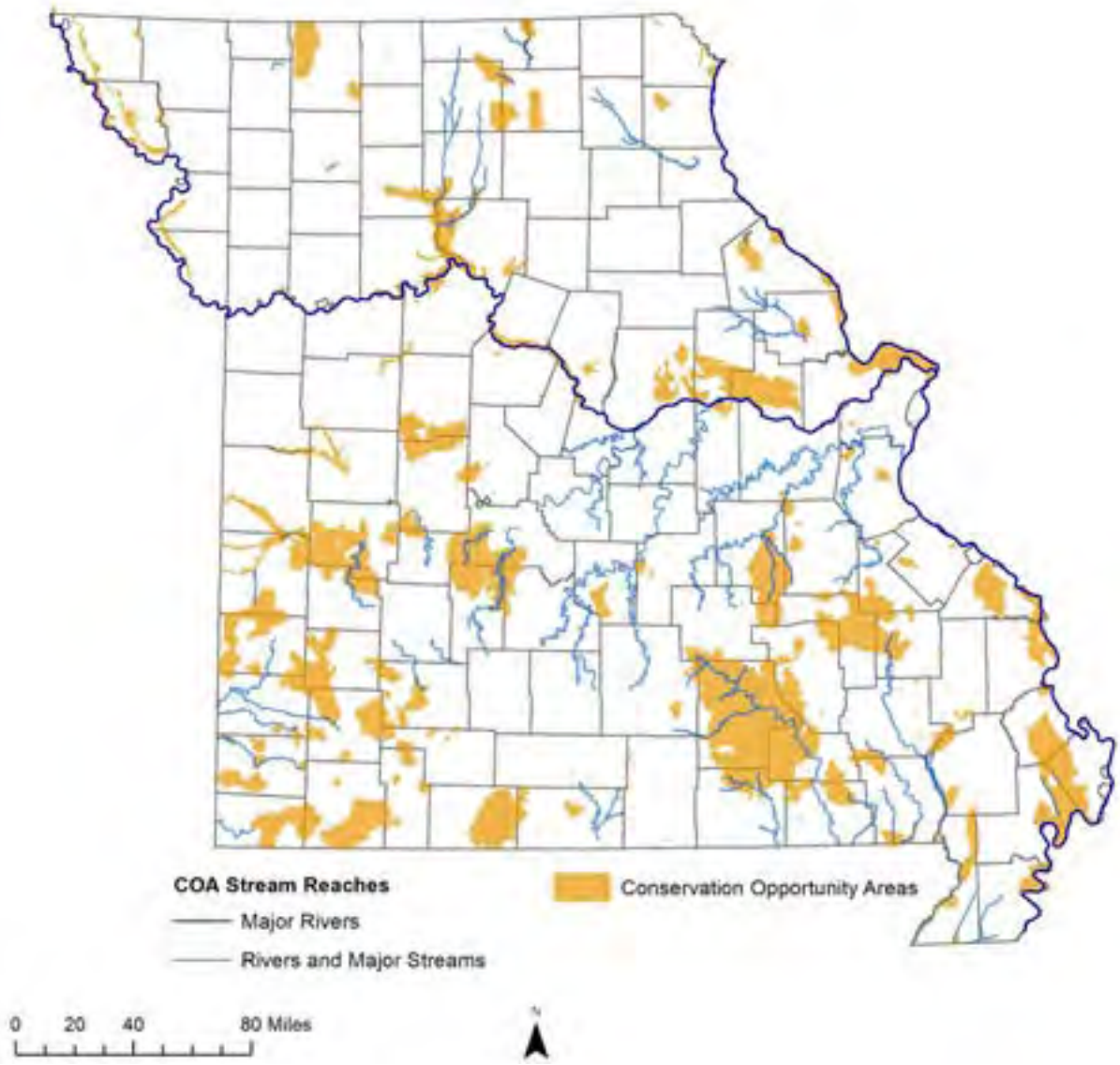


Figure 2.17 – 2020 Missouri COAs Illustrated by Primary Natural Community(s) of Emphasis

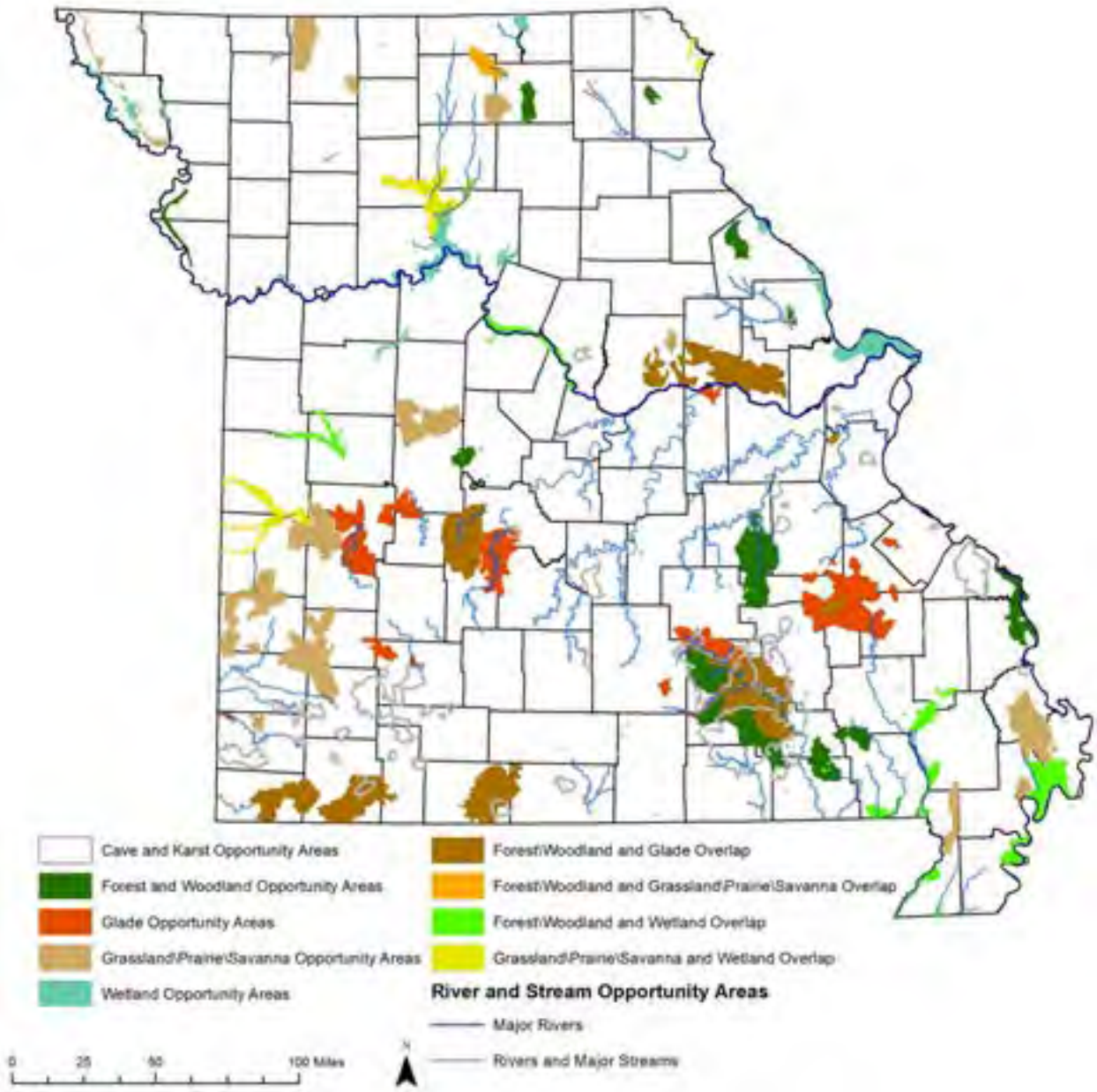
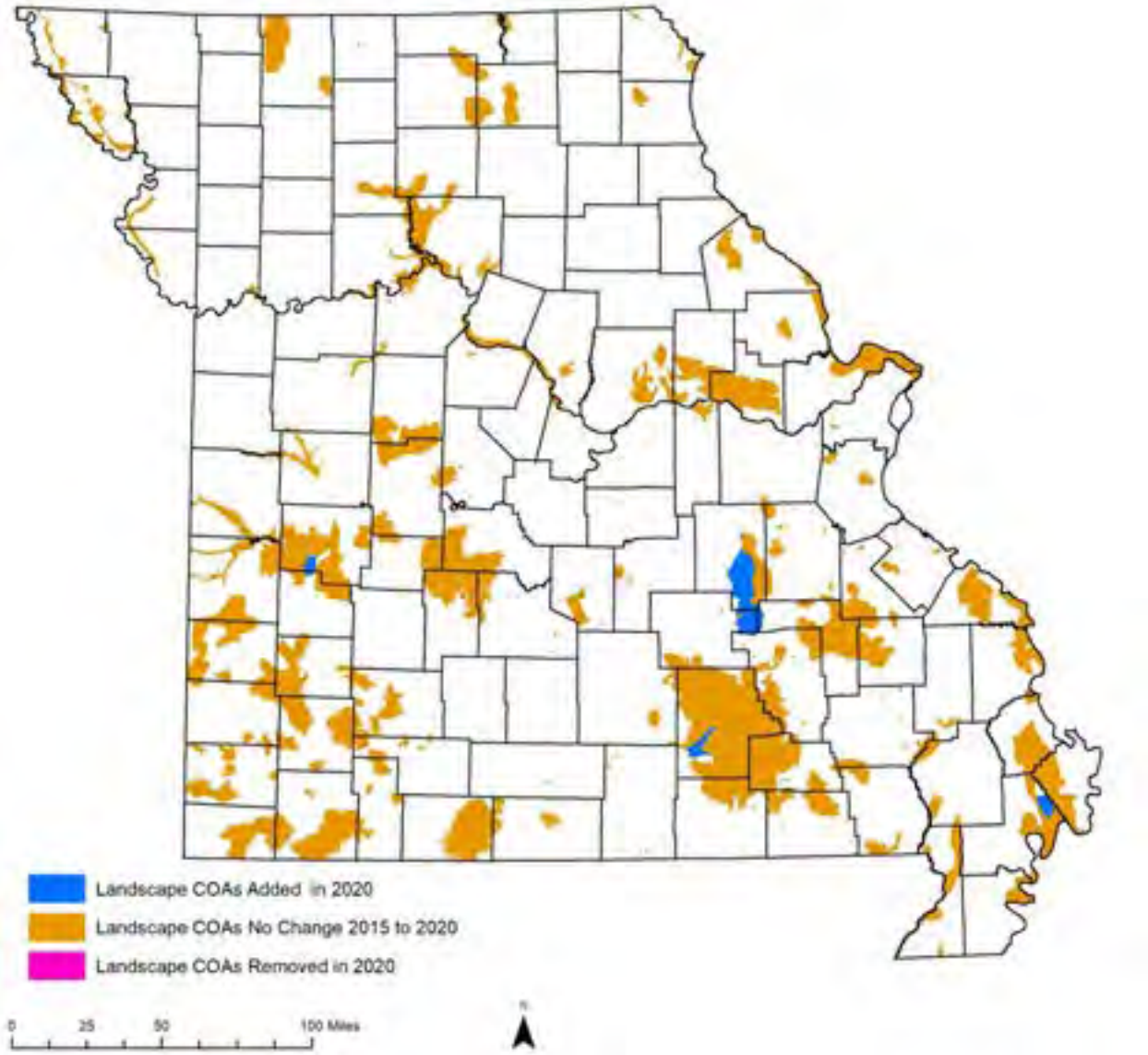
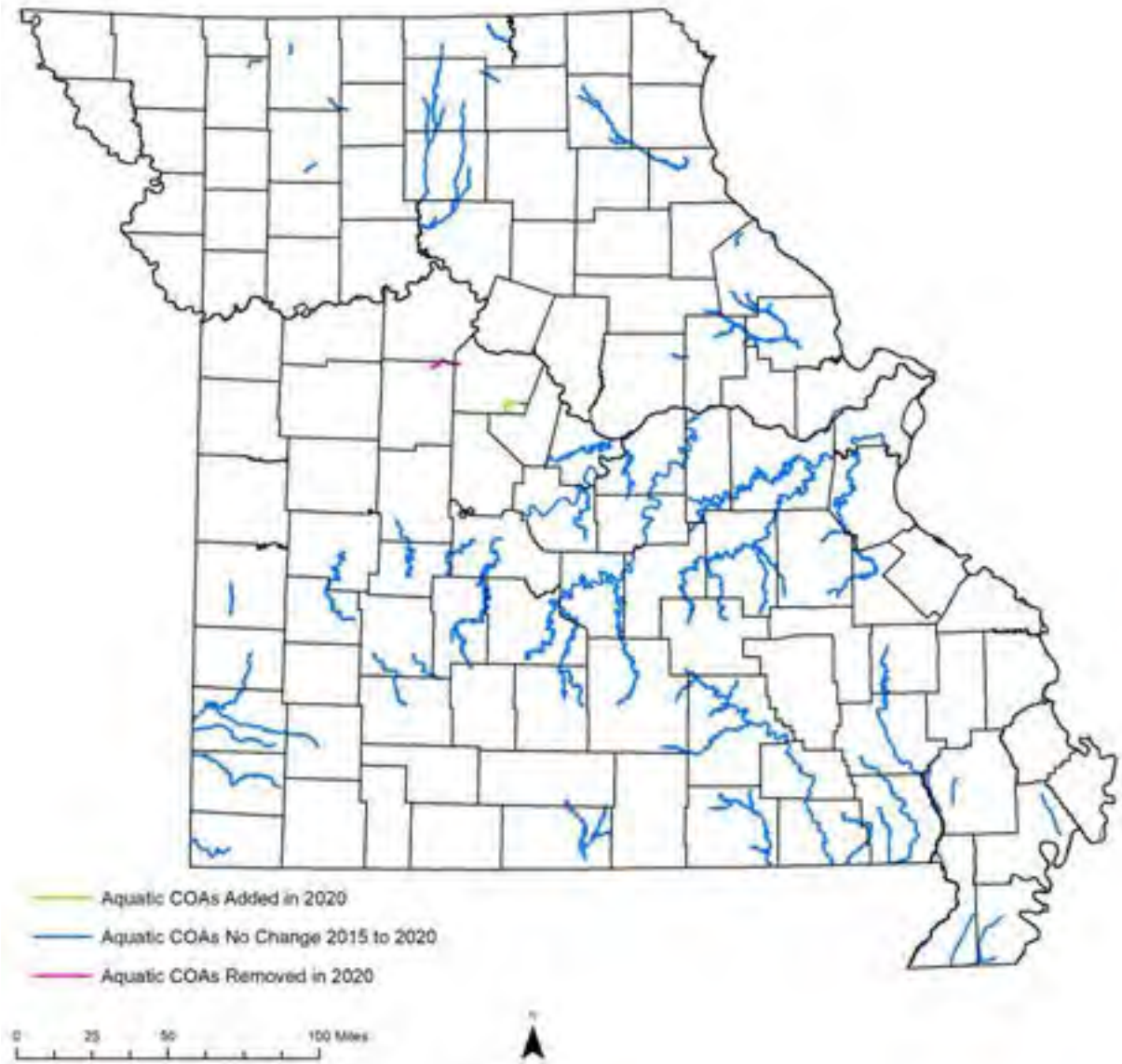


Figure 2.18 – Missouri Landscape COA Expansions/Removals Since the 2015 Revision



Note: Some of the COA modifications are very minor adjustments and are not visible at this map scale.

Figure 2.19 – Missouri Aquatic COA Additions or Removals Since the 2015 Revision



Note: Some of the COA modifications are very minor adjustments and are not visible at this map scale. Additionally, a watershed approach must be employed, after a watershed evaluation, to meet the objectives of the aquatic COA streams.

Quality Assurance Assessment of the 2020 COA Network

Development of the Missouri COA network was informed by a multitude of resources and input, including the landscape assessments described in this section. After the development of the revised COAs in 2015, and again with the minor revisions to the 2020 COAs, MDC conducted a quality assurance (coverage) exercise to ensure that the COA network positively correlates with Missouri conservation partner interests and priorities.

In this exercise, MDC created a heat map from overlaying all priority areas previously described, basically stacking the priorities across the state to:

- Visualize the degree of overlap of the various priorities
- Identify "hot spots" of geographic prioritization

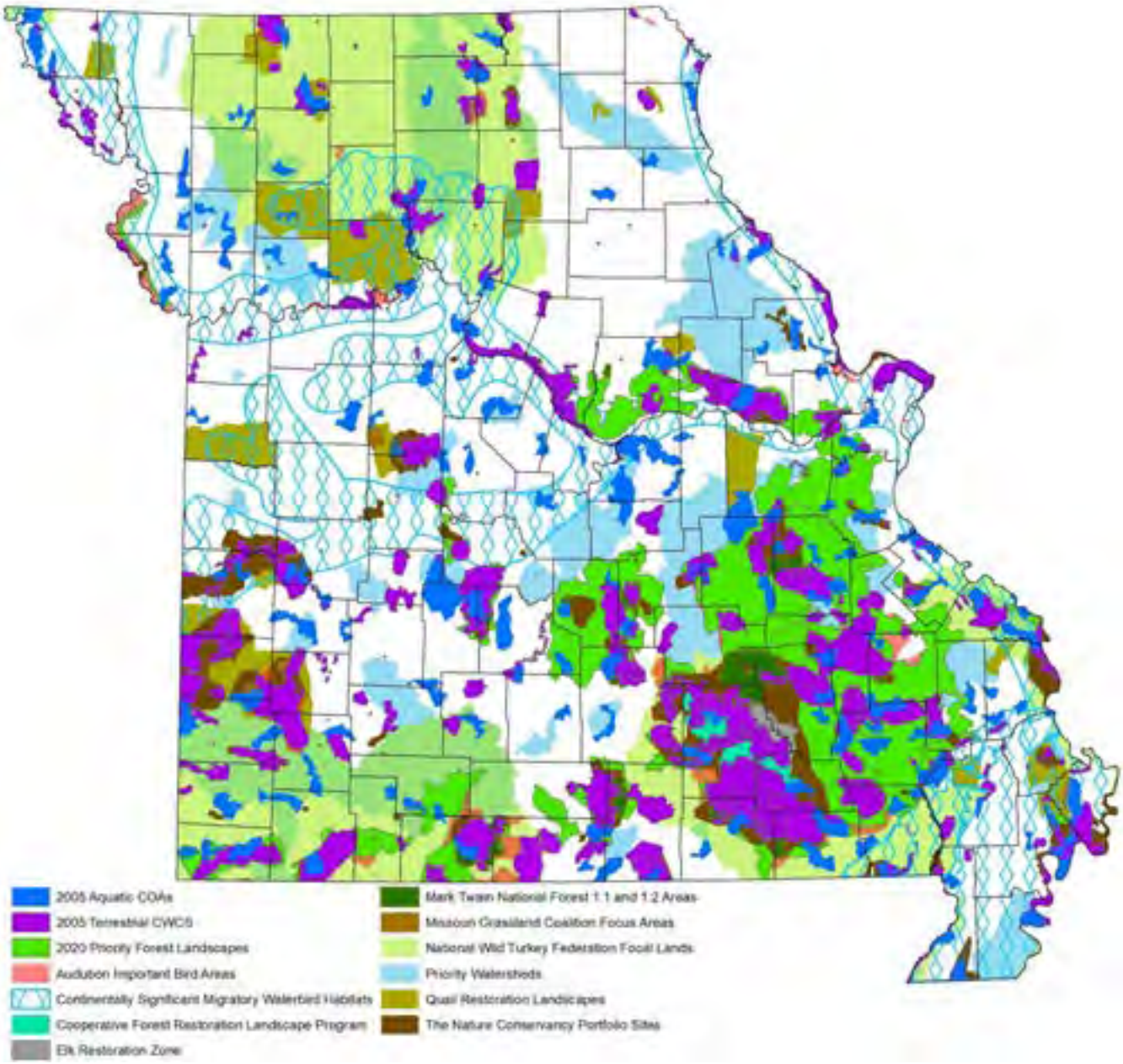
The more overlapping priorities a landscape is represented in, the higher the score, or "heat" associated with that landscape, which depicts high conservation interest among Missouri conservation partners.

The result of this quality assurance exercise illustrates that there are landscapes across Missouri that represent a high level of conservation interest among assessments and partners. These areas of highest conservation interest are well represented in the 2020 COA network, supporting the COAs as important landscapes to focus collaborative work toward regenerative natural community and species habitat management in concert with overlapping public interests and profitable private working lands.

The following three-map series illustrates:

- The extent of various Missouri landscape assessments overlaid on a single map (**Figure 2.20**)
- The heat map, depicting the degree of conservation prioritization interest in landscapes across Missouri (**Figure 2.21**)
- The extent to which the 2020 COA network represents the highest priority landscapes on the heat map (**Figure 2.22**)

Figure 2.20 – Missouri Combined Landscape



Priorities, Overlay

Figure 2.21 – Missouri Combined Landscape Priorities, Overlay Heat Map

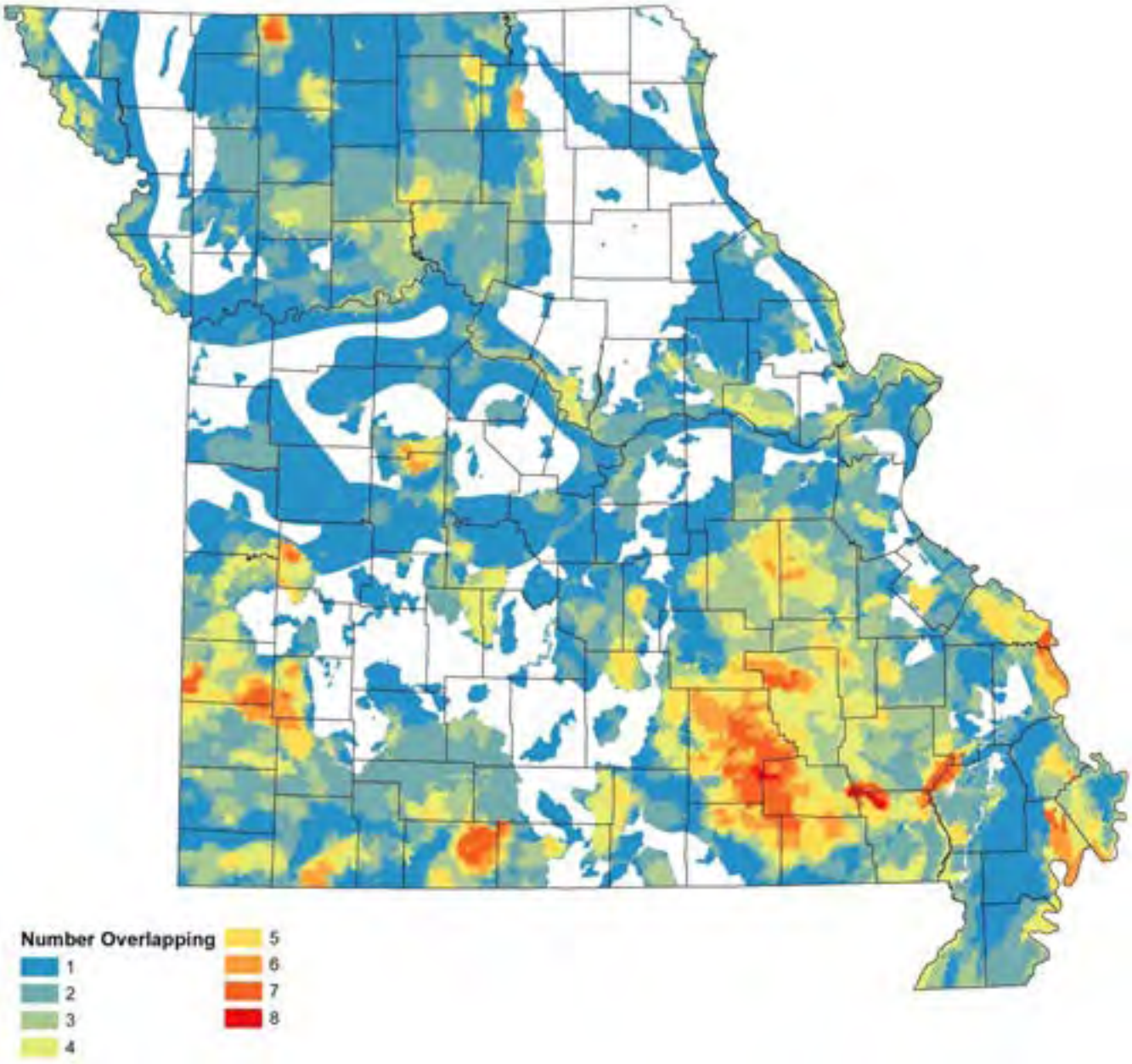
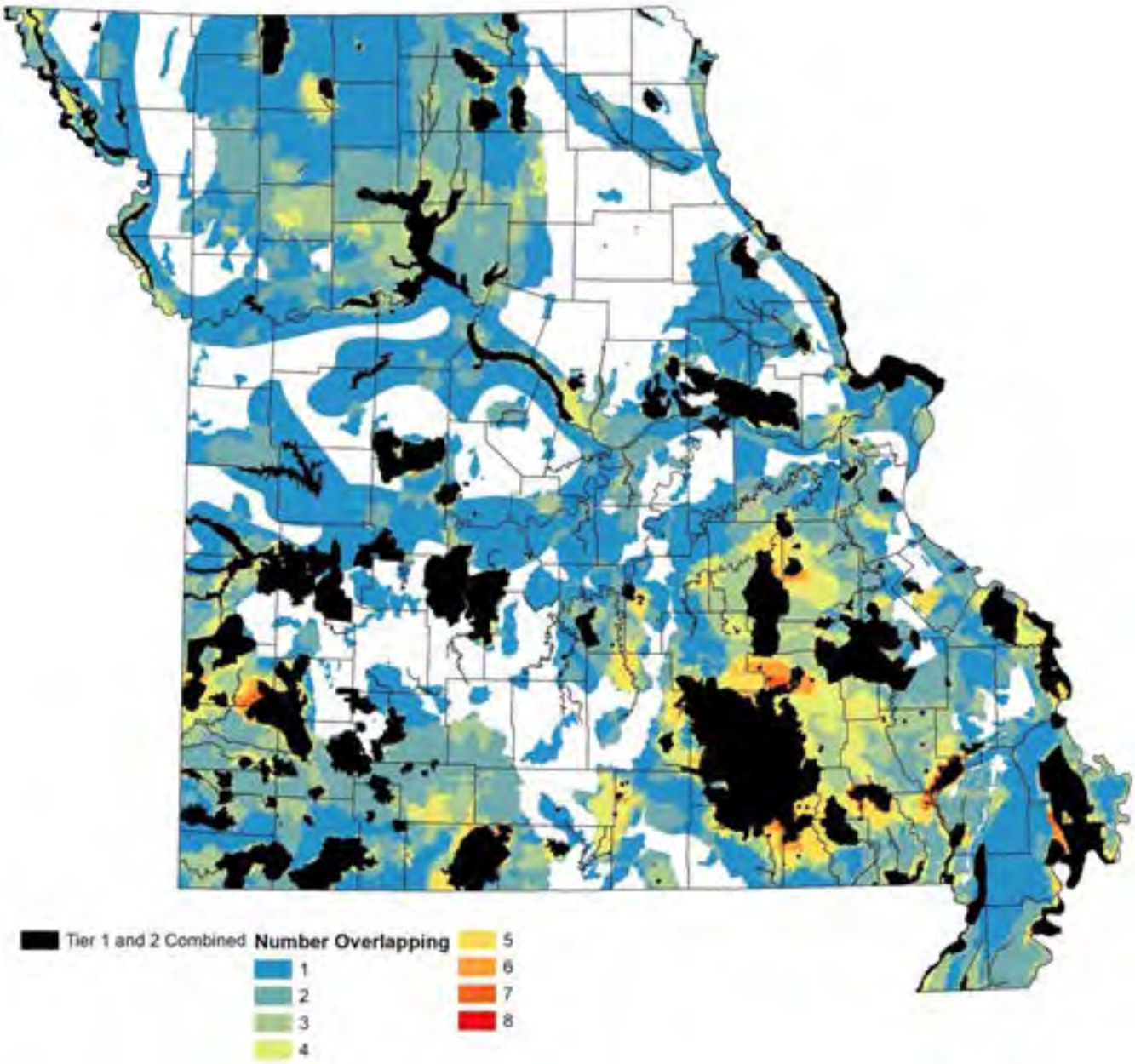


Figure 2.22 – Missouri 2020 COA Network Overlaid on Combined Landscape Priorities Heat Map



The Designation of Priority Geographies (Emphasized COAs)

All COAs are important to Missouri's conservation future; however, to initiate MDC's part in the implementation of the CCS, nine COAs were selected by MDC for increased conservation investment. These nine COAs are referred to as PGs and represent the initial stepping stones (case studies) in a strategic approach to investing in the implementation of landscape-scale conservation in Missouri. These nine PGs were selected based on a variety of considerations, including their remaining resource quality and connectivity, identification as a focal landscape in past planning strategies, landscapes of partner focus, presence of sensitive species or natural communities, threats to the resources, landowner interest and support, and more.

Within each PG, MDC has established a dedicated interdisciplinary team (i.e., with expertise in forestry, fisheries, wildlife, research, community and private lands assistance, protection, education, and communications) and challenged each team to employ proactive methods to deliver landscape conservation through both exemplary public land management and community and private land assistance and management. The team acts as a catalyst, working to help establish and empower a local conservation initiative, engaging in diverse partnerships with private landowners and businesses; federal, state, and local government agencies; and NGOs to deliver conservation action.

Setting a shared vision and desired future condition and working across disciplines toward shared objectives is a novel approach for many organizations, including MDC to some extent, and so a PG team charter has been developed to guide staff serving on the PG teams (see **Appendix F**). Working collaboratively, each PG team identifies shared vision, goals, and objectives. From this collaboration, each team establishes a defined mission statement and an identified desired future condition. The next step is working as to establish a common workplan to outline proactive, and in some cases, expedited conservation objectives that deliver upon the landscape's identified desired future condition.

Incorporating this approach, team members may be doing things that could have historically been perceived as outside an individual's or discipline's focus; however, that variety in expertise and background is the very key to success of these partnerships.

Though the nine PGs have been emphasized, or in some cases, initiated by MDC, they are not meant to remain MDC-centric. Regenerative and sustained landscape-level success hinges on partner and landowner interest and engagement and embracing a long-term conservation stewardship legacy in each geography.

As part of its new organizational model, MDC is embracing this concept within other work teams and priorities as well.

Figure 2.23 – Missouri PGs

MDC Tiered Approach to Natural Community and Habitat Management

An important tool resulting from internal and partner feedback during CCS development and incorporated into MDC's *Design for the Future* strategic plan is the development of a tiered approach to natural community and habitat management. The ideology necessitating the development of this tool is that not every parcel of land across Missouri offers equal potential for sustainable or regenerative conservation of the state's fish, forest, and wildlife resources – rather, there is a broad spectrum of potential ranging from outstanding to extremely poor. As such, and considering limited resources, it is important to strategically prioritize where it is most important to focus resources first, second, third, and so on until resources are exhausted.

The development of the tiered approach to natural community and habitat management is centered around landscape potential and incorporates all of Missouri's crucial landscape assessments described earlier in this section, as well as Missouri's Natural Areas, described in **Section Four**. The approach was recommended by conservation partners during a partner meeting in October of 2018 and subsequently developed by an interdisciplinary team of conservation professionals within MDC. Once drafted, this data was then presented for review to partners and stakeholders at a partner meeting in October 2019 and again during CCS review in March and April 2020.

Upon completion of the tiered approach, MDC again conducted a quality assurance (coverage) exercise to ensure the approach positively correlates with Missouri conservation partner interests and priorities.

Utilizing the same, previously generated and described heat map of overlapping Missouri conservation priorities, MDC overlaid the tiered approach landscapes.

The result of this quality assurance exercise, shown on **Figures 2.28 – 2.31**, illustrates that the areas of highest conservation interest are well represented, and almost completely covered, by the time MDC Tier 3 is overlaid, supporting MDC tiered approach as an important planning tool to focus collaborative work.

Though this tiered approach was initially developed for MDC-administered areas, conservation partners are encouraged to adopt this or a similar prioritization tool to inform their conservation planning and implementation through a unified approach.

An interactive map of the Tier 1–4 landscapes can be found on MDC website (**short.mdc.mo.gov/Z2s**).

Natural Community/Habitat Management Tiers for MDC-Administered Areas and Programs

1. The PGs ***and*** Natural Areas (NAs)

2. COAs not located within PGs or NAs

3. PFLs, QRLs, and PWs that overlap COA Stream Reach Watersheds for Reference; CWCS/Aquatic GAP landscapes within PWs and COA Stream Reach Watersheds for Reference; MO and MS River Alluvium and Riparian (Bootheel); and MDC lands adjacent to conservation landowner cooperatives not located within PGs, COAs, or NAs
   (***NOTE:*** Manyof these focal landscapes are represented in PGs/COAs.)
   and
   Remaining Missouri communities of conservation concern with state rank = SH, S1, S2
   (***NOTE:*** Many of these communities of concern are represented in PGs/NAs/COAs)
   and
   Remaining natural communities harboring federally threatened and endangered (T&E) species, state endangered species, or select high priority SOCCs (typically those with state rank = S1 or S2) when the habitat management contributes to the recovery or persistence of the species
   (***NOTE:*** Many of these communities harboring T&E species are represented in PGs/NAs/COAs)

4. Remaining PWs and CWCS/Aquatic GAP landscapes not located in the above-listed priority landscapes

5. Maintenance of high-quality natural communities

6. Areas striving toward natural community restoration/management that have high restoration potential

Management Guidance Note: Conservation Areas within the PGs/COAs and the NAs should strive for certification under the Sustainable Forestry Initiative® (SFI) program. SFI® is a voluntary commitment to responsible, regenerative management of resources through internationally recognized standards of measure, based on ecological, social, and economic principles. Its requirements include measures to ensure long-term forest management planning, forest health and productivity and to protect water quality, biodiversity, wildlife habitat, species at risk, and forests with exceptional conservation value.

Figure 2.24 – MDC Tier 1 (1,026,483 acres, 2.3% of the state)

Figure 2.25 – MDC Tiers 1 and 2 (5,922,330 acres,13.3% of the state)

Figure 2.26 – MDC Tiers 1, 2, and 3 (19,003,902 acres, 42.6% of the state)

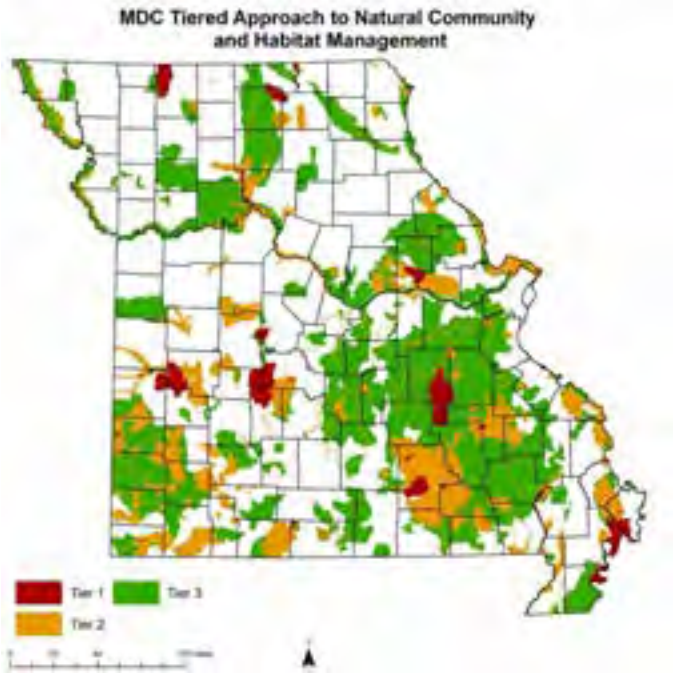
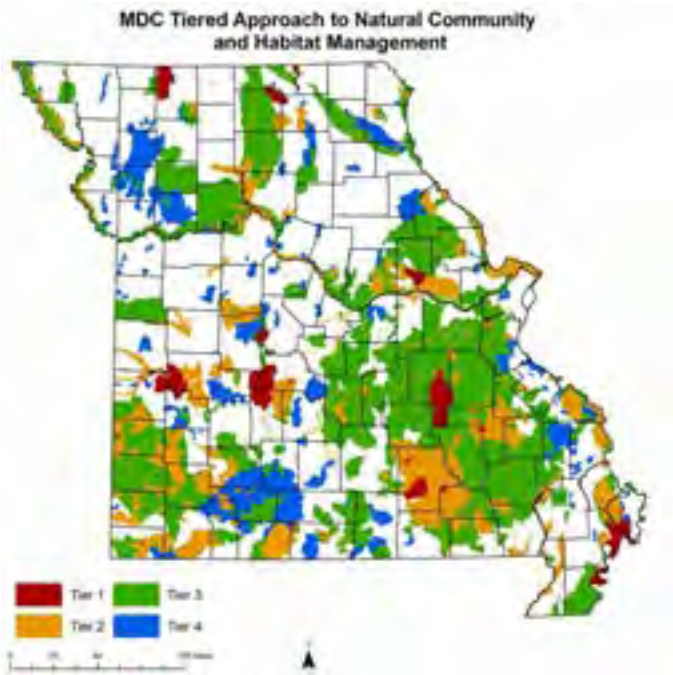


Figure 2.27 – MDC Tiers 1, 2, 3, and 4 (22,446,627 acres, 50.3% of the state)



MDC Tiered Approach to Natural Community and Habitat Management Overlaid on Missouri Landscape Priorities Heat Map

Figure 2.28 – MDC Tier 1

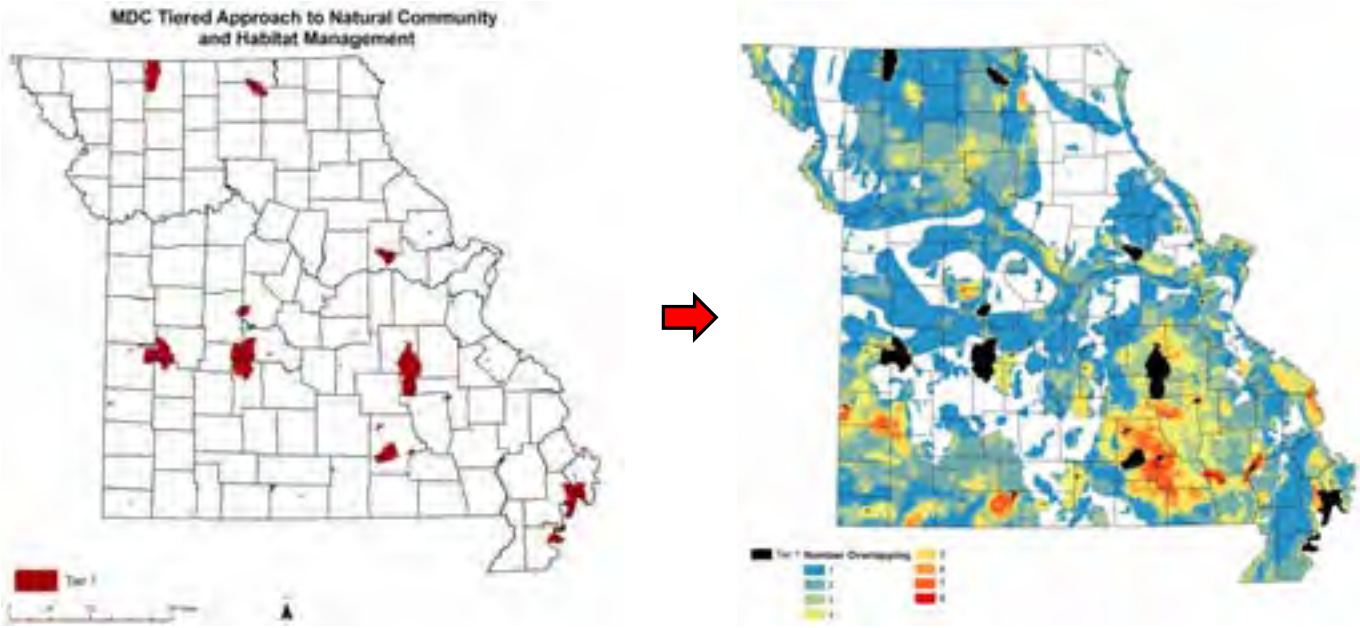
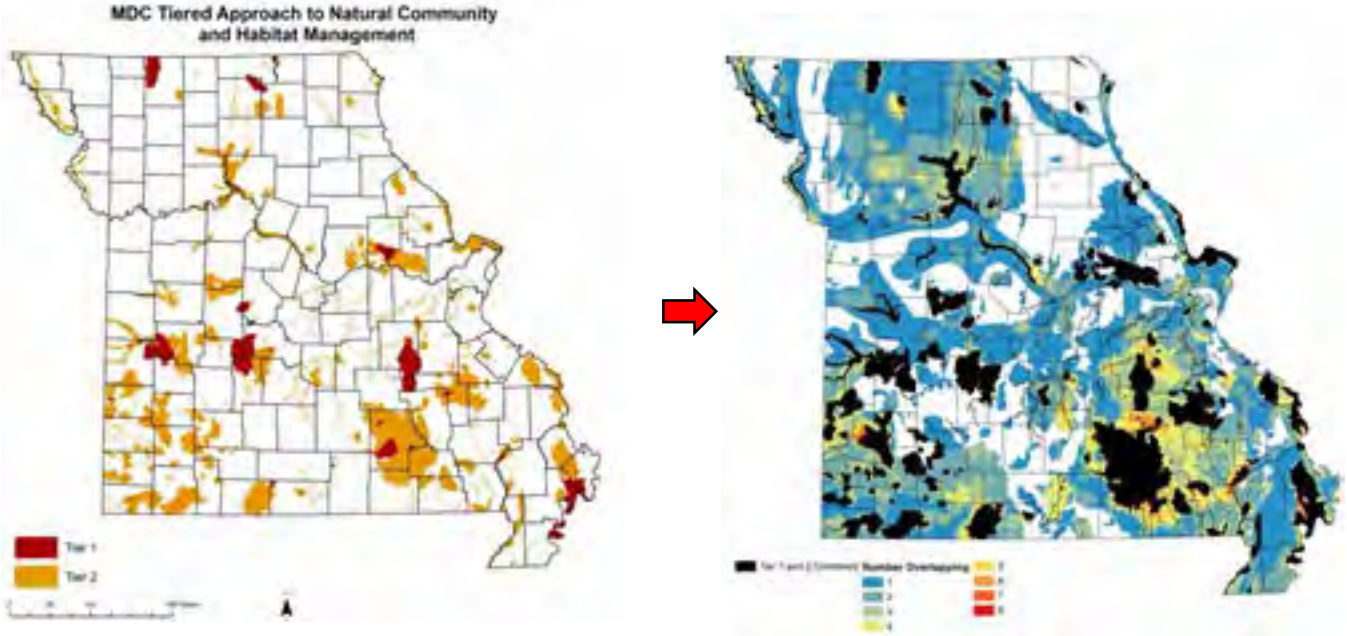


Figure 2.29 – MDC Tiers 1 and 2



MDC Tiered Approach to Natural Community and Habitat Management Overlaid on Missouri Landscape Priorities Heat Map

Figure 2.30 – MDC Tiers 1, 2, and 3

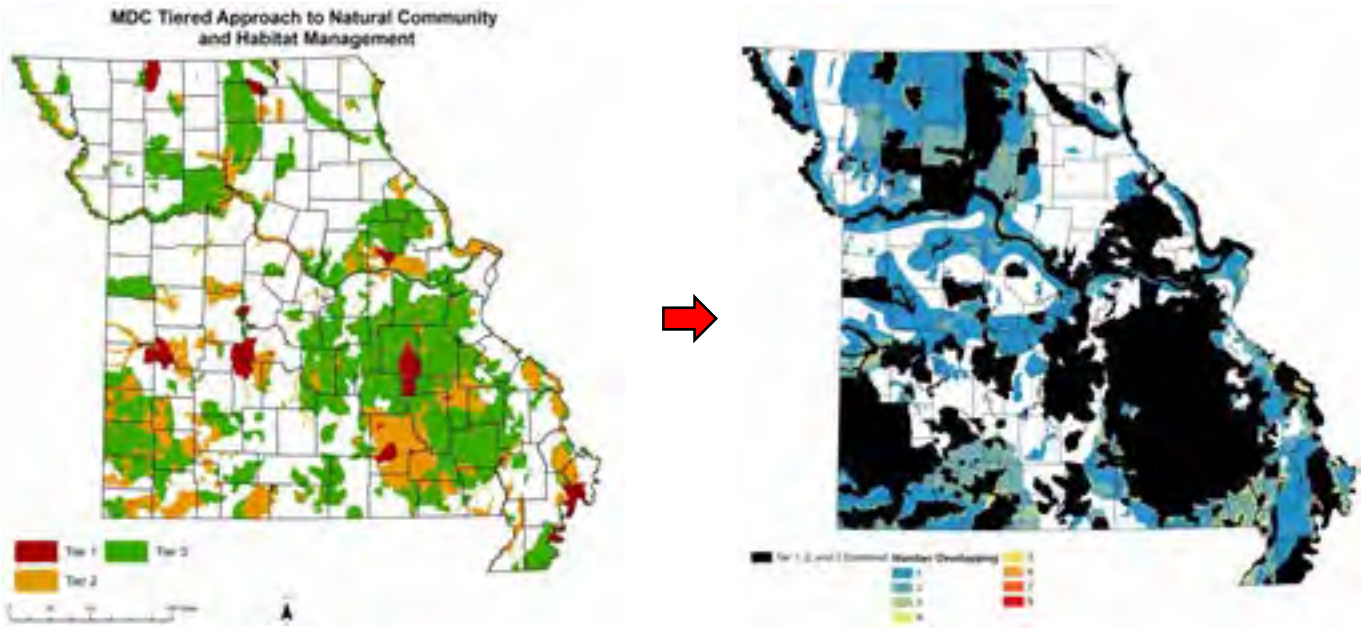
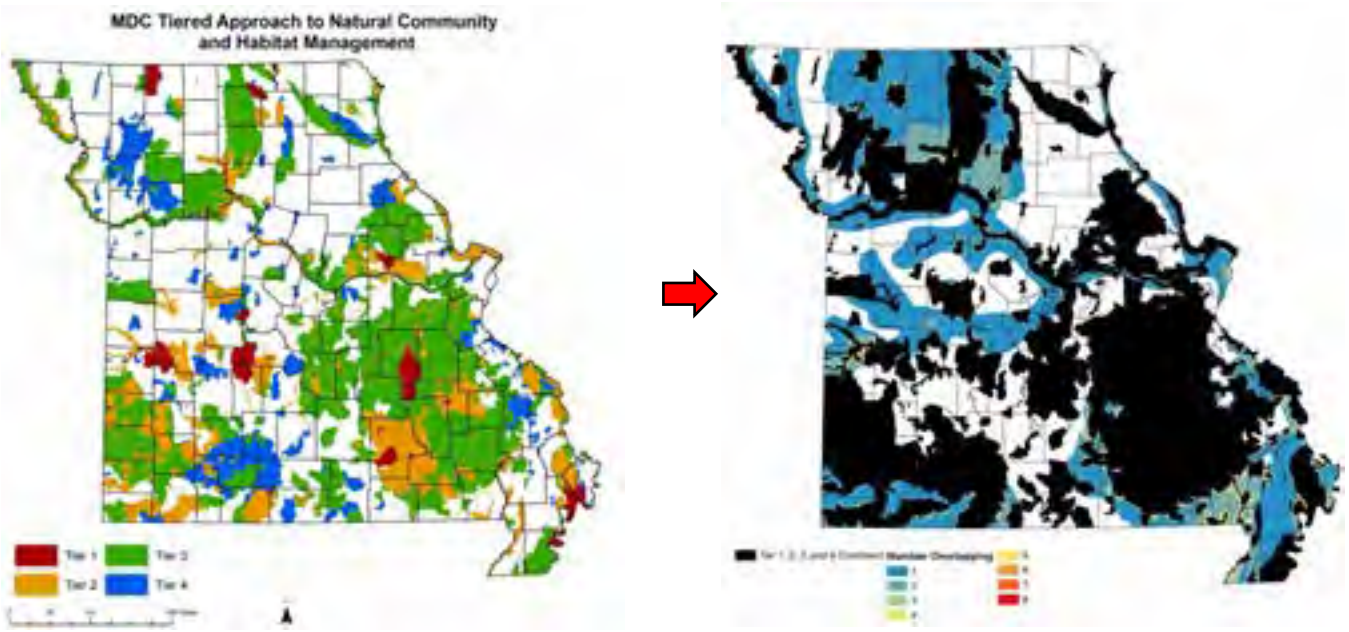


Figure 2.31 – MDC Tiers 1, 2, 3, and 4



Other Critical Tiered Approaches Needed to Fulfill CCS Implementation

The tiered approach to natural community and habitat management described above is focused solely on natural community, habitat, and species conservation prioritization across Missouri. To be fully comprehensive, the CCS must account for the importance of community conservation and public use opportunities, which connect and engage citizens with nature. However, to date, there has been no prioritization developed within Missouri identifying focal areas for these important conservation goals.

As Missouri looks to the long-range conservation plan, it is critical this need be addressed so these three important principles (i.e., natural community/species conservation, community conservation, and public use and access) work together to identify ALL conservation priorities. Once developed, these three tiered prioritizations can be used as a powerful tool to inform decision-making regarding the all-around greatest opportunities to improve Missouri's ecological resources and citizen connection with nature.

Community COAs (Tiered Approach – Forthcoming)

The majority of Missouri's approximately six million citizens live in urban areas. As the population continues to grow and urban and suburban areas expand, it is critical to maintain a conservation connection with urban residents. This connection not only engages this subset of citizens in the countless opportunities for conservation involvement within their community but also enhances their awareness and appreciation regarding the significance of Missouri's remote natural landscapes, potentially far from where they live, which harbor much of the state's remaining, incredible biodiversity.

Currently, Missouri has identified 16 areas (15 counties and 1 independent city) as the focus of community conservation effort (**Figure 2.32**).

Figure 2.32 – Sixteen Most Populous Counties and St. Louis City

Looking ahead, however, conservation partners are exploring further refinement of community conservation through the creation of community COAs and a tiered approach, which would more strategically focus conservation actions/collaboration and resource investment within these 16 and other areas. Once developed, the community COAs will be incorporated into this CCS.

More information about Missouri's community conservation programs, strategies, and actions can be found in **Section Five** .

Public Use Opportunity Areas (Tiered Approach – Forthcoming)

Much like the importance of prioritizing landscapes to focus natural community and species conservation, as well as community conservation, it is also important that Missouri identifies areas of the state critical for citizens to interact with nature via public access. Many

citizens depend on public access for engaging in nature-based activities, such as hunting, fishing, boating, hiking, wildlife viewing, nature photography, and much more. Missouri has approximately three million acres (about 7 percent of Missouri's total land area) of publicly owned land (**Figure 3.4.1** in **Section 3**). Of this publicly owned land, there are varying degrees of public access and infrastructure to support public access. Also, some nonprofit conservation organizations own private lands for conservation purposes and make them available for public use (e.g., L-A-D Foundation, MPF, TNC, Ozark Land Trust). The Missouri Outdoor Recreational Access Program, supported by MDC, allows public access to enrolled private lands for approved recreational uses, which differ among properties but can include hunting, fishing, and wildlife viewing.

Providing and maintaining public land and access across the state requires significant resource investment. Looking ahead, MDC is exploring the creation of public use opportunity areas and a tiered approach to public use management, which would help to more strategically focus conservation resource investment on public lands statewide and better inform infrastructure asset management to support public access. Once developed, the public use opportunity areas will be incorporated into this document.

Figure 2.33 – Placeholder

MDC's Use of Landscape Prioritization in the Land Conservation Strategy

As described, conservation partners have developed multiple assessments and prioritizations for Missouri's landscape. These landscape priorities are then used by organizations to focus resources into areas holding the greatest value in delivering their respective missions.

As an example, following the CCS approach, MDC has developed a method to strategically conserve key species, habitats, and public land access by creating the Land Conservation Strategy (LCS). The LCS provides a framework for prioritizing opportunities for land acquisition, conservation easements, lease agreements, cooperative agreements, grants, public access programs, and incentive programs. The goal is to enhance conservation efforts in focal landscapes, enhance conservation of imperiled species and habitats, expand existing priority conservation areas, close inholdings to maximize resource management efforts, and increase citizen access to the outdoors near where they live. The LCS provides an overview of natural community conservation priorities, urban and community access priorities, and recreational access opportunities. Additional work, based on the recommendation of the LCS, prioritizes conservation area property disposal recommendations.

The LCS holds the following as highest priorities when making recommendations:

- Increasing outdoor recreation opportunities in major metropolitan areas and highly populated counties
- Ensuring all citizens have outdoor recreation opportunities near where they live
- Maintaining support tools and partner projects that advance the LCS with a renewed focus on innovative partnerships
- Increasing efforts in PGs and other COAs identified by the CCS planning process
- Expanding efforts for imperiled species and habitats
- Closing inholdings and expanding existing conservation areas where appropriate

The CCS lays the foundation for MDC's approach to land conservation and protection, further expanding a singular approach of acquisition and disposal to a priority-focused, aligned, and comprehensive approach. When possible, MDC works with conservation partners toward land conservation of key properties within prioritized landscapes.

LCS goals will be achieved by strategically employing a variety of tools including fee title acquisition from willing landowners, leases, conservation easements, donations, voluntary and incentive-based protection/conservation, partnerships with individuals, foundations, government, not-for-profit organizations, and local communities, as well as carefully considered property disposals.

Multi-State and International Collaboration: Initiatives and Priority Areas

This section has explored Missouri's geographic priorities and why focused collaborative effort within these landscapes is key to the regenerative conservation of the state's invaluable natural resources. Improvement and sustainability of these resources at the state level is critical. However, it's also important to understand the value of Missouri's resources and conservation initiatives in context of delivering upon regional, national, and international conservation success.

Missouri is geographically situated at the intersection of significant landforms, where the vast plains meet the rugged Ozarks, and encompasses the confluence and significant floodplains of two continentally significant rivers – the Missouri and Mississippi. As such, Missouri's landscape offers substantial contributions to regional, national, and international conservation, including the recovery and sustainability of state and/or regionally endemic species (e.g., Niangua darter, Tumbling Creek Cave snail, Ozark hellbender, Ozark cavefish, and Missouri bladderpod, Geocarpon); critical stopover and breeding habitat for migratory species (e.g., monarch butterfly, neotropical migrant birds, shorebirds, and waterfowl). The ancient Ozarks that dominate southern Missouri and northern Arkansas support landscape features and species of regional, national, and even global significance with Missouri having two national scenic riverways (i.e., Current and Jacks Fork) and one national scenic river (i.e., Eleven Point); one of the nation's greatest concentrations of springs; and the White River dolomite/limestone glades, ranking among the largest in the world of their kind. Missouri also boasts substantial production of black walnut and a variety of oak trees, which are critical for a diversity of native species but also contribute to a thriving forest products industry.

Conservation planning occurs at multiple scales and Missouri's CCS is designed to fit into many of these as they scale up or down depending on use. For example, the Missouri COAs identified in the CCS were incorporated into the foundational construction of the Southeast Conservation Adaptation Strategy (SECAS). Further exemplified, the North American Bird Conservation Initiative establishes Migratory Bird Joint Ventures that establish regional bird conservation priorities. Missouri is part of three joint ventures (Central Hardwoods, Lower Mississippi Valley, and Upper Mississippi River/Great Lakes) and the CCS complements the regional priorities stepped down to the state level. Missouri is a partner in many regional planning and management initiatives including the Mississippi Flyway, and priorities identified by the flyway are incorporated into the landscapes important for waterfowl, shorebirds, and waterbirds. The Missouri Bird Conservation Plan's Technical Section steps down regional landbird conservation plans to outline the state's most threatened landbird species, including many neotropical migrants.

Beyond planning, management of our resources requires working beyond Missouri's borders on a regular basis. Many of the landscapes of our border COAs extend across Missouri's border and most SGCNs have ranges well outside the state, requiring partnerships with neighboring states and regional or international partners to accomplish needed actions to achieve shared goals. Watersheds and flyways often encompass all or parts of multiple states and require complex coordination among many partners and jurisdictions to improve conditions, regulate harvest and methods, and provide needed habitat. Recovery of declining species that have large ranges requires coordination throughout the species' range and with partners and agencies with interest and jurisdiction.

Much of this work may include efforts to protect and maintain migratory species' habitat throughout their annual cycles, which is called full life-cycle conservation. Full life-cycle

conservation of migratory species is one area of Missouri's commitment to cross-border conservation and is imperative to the improvement and long-term sustainability of Missouri's natural communities and species. Some key examples of this work (i.e., neotropical migrant birds, waterfowl, and monarch butterfly) are included in this section to build understanding of the importance of supporting these key partnerships beyond Missouri's borders.

Migratory Bird Full Life-Cycle Conservation Partnerships

One-third of Missouri's breeding birds are migratory and spend up to eight months of the year beyond the borders of the United States, some traveling thousands of miles each way. Considering recent research that quantified a net loss of 2.9 billion birds in the last 50 years (many of which are migrants; Rosenberg et al. 2019), we cannot afford to ignore the threats that many migratory birds face across their full life-cycle ranges.

Neotropical Migrant Bird Conservation Partnerships

When one considers the millions of migratory birds that breed across Canada and the United States packing into relatively small geographies within Mexico, Central America, South America, and the Caribbean during migration and the winter months, it puts in perspective the importance of this work.

Threats to these vital landscapes, ecosystems, and the birds that use them vary by country and region but include deforestation, commodity agriculture (palm oil), illegal logging, contaminants, and enforcement on protected areas. Intense poverty across this region of the world adds to the dire need for support from international partners that have a shared interest in the protection and conservation of shared avifauna. Conservation efforts on migratory stopover sites and the wintering grounds work to curb these threats through acquisition and protection of lands used as migratory pathways and wintering sites; education of landowners on regenerative agricultural and ranching practices including shade-grown coffee farming; the creation and maintenance of native tree nurseries and reforestation efforts; and others.

The Association of Fish and Wildlife Agencies' (AFWA) Southern Wings Program was created in 2009 after the concept was presented to AFWA by MDC. Southern Wings facilitates state fish and wildlife agency participation in the conservation of priority migratory birds across their annual life-cycle. Since that time, over 30 states have contributed $2.9 million to a variety of conservation efforts on stopover sites and wintering grounds in Mexico, Central America, South America, and the Caribbean. In 2006, Partners in Flight[1] overlaid weighted nonbreeding ranges of 42 priority bird species that breed in every state to identify the most impactful areas for conservation efforts on stopover sites and the wintering grounds (Missouri's map in **Figure 2.34**; Partners in Flight 2006). These maps will be updated in the coming year with the latest data to further target conservation efforts and dollars.

[1] Partners in Flight is a network of over 150 organizations across the Western Hemisphere to promote and advance landbird conservation through science, research, planning, land management, education, and others. These efforts work to halt or reverse bird population declines before species are listed as threatened or endangered.

Figure 2.34 – Partners in Flight Map of Weighted Nonbreeding Ranges of 42 Priority Missouri-Breeding Migratory Species Used to Identify the Most Impactful Full Life-Cycle Conservation Efforts on Stopover Sites and the Wintering Grounds

Focal countries for full life-cycle conservation of Missouri-breeding SGCNs include Belize, Guatemala, Honduras, Nicaragua, Costa Rica, Colombia, and Ecuador. These countries encompass key corridors and geographies that Missouri-breeding migratory birds use as migratory corridors or overwintering habitat. These countries include a variety of tropical forested habitats, including low- to highland rainforest, mangroves, and cloud forest.

Overall goals vary by project but include slow or reverse continued deforestation through reforestation efforts and implementation of regenerative agroforestry systems with local landowners; secure protection of core migratory bird habitat through protected area creation and management; improving or reestablishing shade-grown coffee practices that maintain or create migratory-bird foraging habitat.[2]

Full life-cycle conservation efforts in Central America and South America support over 150 species of neotropical migrants that migrate through or overwinter in these rich habitats, including these SGCNs that are also included in the Missouri Bird Conservation Plan as Missouri's most-threatened species: Cerulean warbler, wood thrush, Kentucky warbler, worm-eating warbler, blue-winged warbler, eastern wood-pewee, yellow-breasted chat, and ovenbird. Other neotropical migrant species documented using these areas during migration and overwintering months include threatened golden-winged warbler, hooded warbler, painted bunting, Louisiana waterthrush, yellow-throated vireo, white-eyed vireo, and yellow-billed cuckoo, among many others.

Hemispheric full life-cycle neotropical bird conservation partners include, but are not limited to, American Bird Conservancy, SELVA: Investigación para la Conservación en el Neotropico (Colombia), Fundacion para el EcoDesarollo y La Conservacion (FUNDAECO; Guatemala), El Jaguar Private Wildlife Refuge (Nicaragua), Red de las Reservas Silvestres Privadas de Nicaragua, La Asociación de Investigación para el Desarrollo Ecológico y Socio Económico (Honduras), and Fundación Jocotoco (Ecuador).

[2] Shade-grown coffee is grown in the shade of a tree canopy that provides foraging habitat for migratory birds rather than a monoculture of coffee grown in full sun. Traditionally, most coffee varieties were shade-grown under light-filtering trees that prevented direct sunlight and fallen leaves mulched the soil and maintained moisture.

Case Study: Restoration of Migratory Bird Habitat in Ecuador – Cerulean Warbler and Other

MDC is the sole state agency supporting conservation efforts with partners American Bird Conservancy and local Fundación Jocotoco in Ecuador since 2015. Ecuador has the highest deforestation rate in South America over the last 50 years. The goals of projects in Ecuador are to slow the rate of deforestation, to work with landowners to improve land-use practices, and to create better habitat connectivity in the buffer zones of existing protected areas in the Chocó-Canandé BirdScape that Cerulean warblers and 105 other neotropical migrant species use for overwintering habitat. Conservation efforts in Central America support Cerulean warblers on both spring and fall migrations, and work in Ecuador supports these birds through the winter months (**Figure 2.35**). Missouri's population of Cerulean warblers breed in riparian-associated forest gaps largely near Ozark streams, including in five PGs (Missouri River Hills, Big Buffalo Creek, Mahan's Creek, Huzzah and Shoal Creek Woodlands for Wildlife (SCWW), and Little Niangua River), Upper Niangua COA, Current River Hills Forest/Woodlands COA, and Little Black COA.

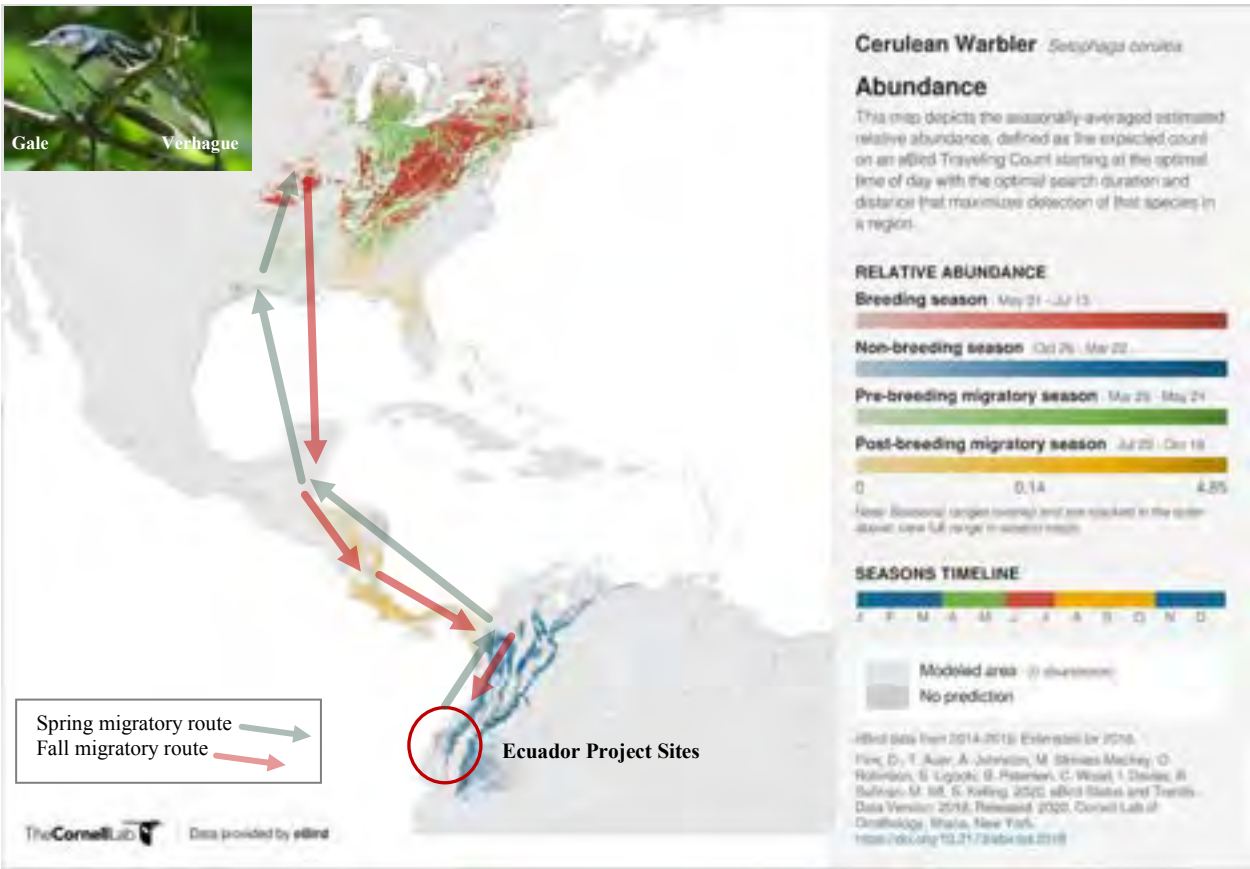


Figure 2.35 – Cerulean Warbler eBird Abundance Map. Ceruleans migrate through Central America and overwinter in northwestern South America, including Ecuador where Southern Wings projects work on reforestation with landowners to maintain and restore vital habitat (Buehler et al. 2020).

Case Study: Migratory Bird Wintering Grounds Conservation in Nicaragua and Honduras – Wood Thrush and Others

Along with key conservation partners American Bird Conservancy, El Jaguar Private Wildlife Refuge (Nicaragua), Red de las Reservas Silvestres Privadas de Nicaragua, and La Asociación de Investigación para el Desarrollo Ecológico y Socio Económico (Honduras), and others, Missouri supports habitat conservation projects in Nicaragua and Honduras that provide benefits for a broad suite of neotropical migrants. The most common threat in this region are land-use practices not compatible with forest preservation. These include human migration to the area, which is encroaching on indigenous lands, which are largely intact habitats. Increased human presence has led to habitat fragmentation via creation of homesteads, land grabs, and the deforestation associated with these impacts.

Project goals include slowing rates of deforestation in Honduras and Nicaragua by working with landowners and communities to adopt land-use practices that are compatible with forest preservation. Project successes include native plant and tree nurseries; regenerative land-use workshops for local landowners; and landowner agreement sign-ups outlining commitments to reduce the impact of cattle ranching through silvopasture techniques, tree planting, and the creation of feed banks and rotational grazing systems. Wood Thrush breed across Missouri forests but are most abundant across contiguous Ozark forests (**Figure 2.36**) including five PGs (Missouri River Hills, Big Buffalo Creek, Mahan's Creek, Huzzah and SCWW, and Little Niangua River) and several Missouri Forest/Woodlands COAs.

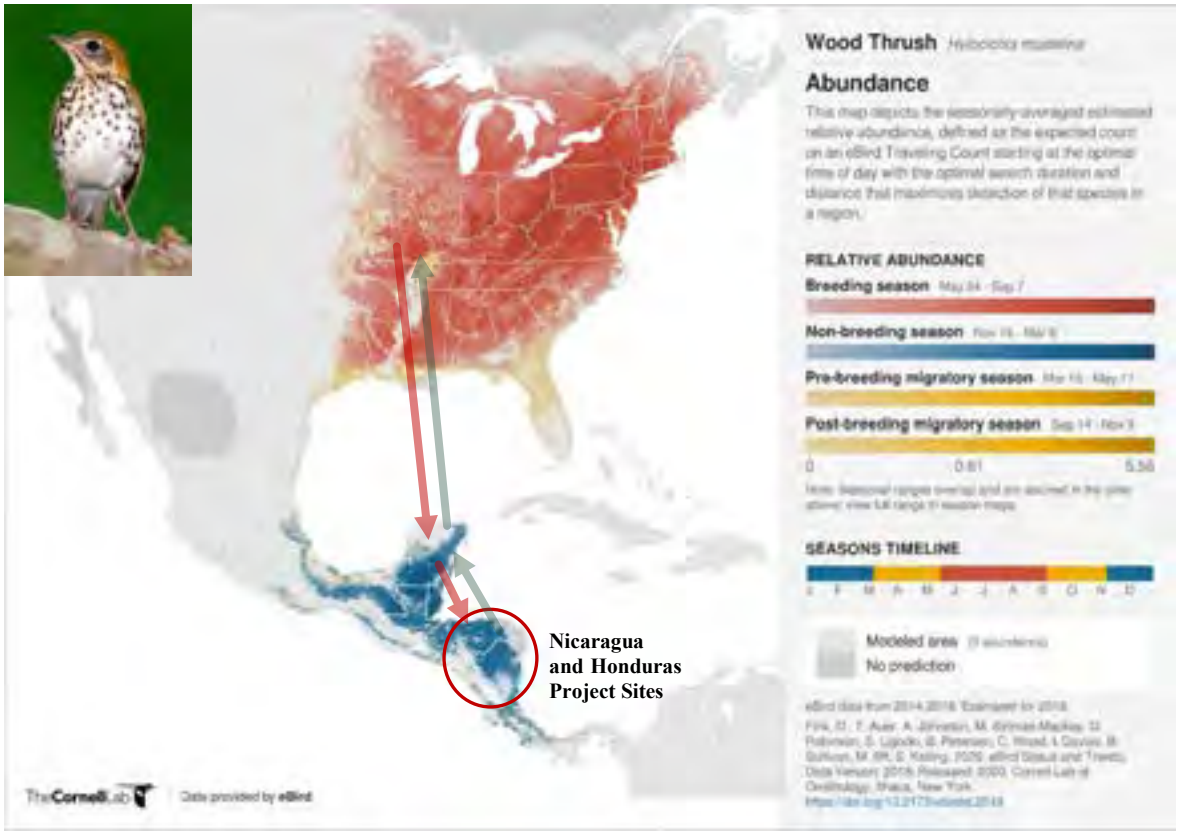


Figure 2.36 – Wood Thrush Breeding and Nonbreeding Ranges and Migration Routes

Conserving Critical Waterfowl Habitat in the Prairie Pothole Region of Manitoba

Missouri works in close partnership with other state and federal agencies and other conservation partners to achieve the NAWMP goals of:

1. Abundant and resilient waterfowl populations to support hunting and other uses without imperiling habitat
2. Wetland and related habitats sufficient to sustain waterfowl populations at desired levels, while providing places to recreate and ecological services that benefit society
3. Growing numbers of waterfowl hunters, other conservationists, and citizens who enjoy and actively support waterfowl and wetlands conservation

Achieving these goals requires partners to collaborate and pool resources to protect and conserve habitat in the regions most critical for waterfowl; this means directing resources to the breeding grounds in Canada.

AFWA approved a goal for states to collectively contribute up to $10 million per year to the NAWMP projects on the breeding grounds in Canada through the Fall Flights Program. An AFWA task force set state funding goals based on waterfowl hunter and harvest data. In this program, state funding provides nonfederal monies that are matched by Ducks Unlimited (DU). In turn, these dollars are matched by U.S. federal funds through the North American Wetlands Conservation Act (NAWCA) and finally by Canadian partner contributions. The end result is that each state's contribution is multiplied at least four- to fivefold.

Realizing the immense benefit for migratory waterfowl and other waterbirds, which use Missouri resources for part of their life cycle, MDC was one of the original state agencies at the 1991 AFWA meeting to step forward and contribute to NAWMP conservation projects in Canada.

Connections between the Prairie Pothole Region and Missouri

The connections between the Prairie Pothole Region (PPR) and Missouri's wetlands are apparent when examining band recoveries of waterfowl harvested in Missouri. Nearly 80 percent of the waterfowl harvested in Missouri were banded in Saskatchewan, Manitoba, North Dakota, South Dakota, and Minnesota (**Figure 2.37**). The highest densities of breeding ducks in North America occur in the PPR of Canada. As a result, the PPR is rated as the highest priority area for waterfowl conservation in North America. It is estimated that, dependent on habitat conditions, up to 70 percent of the continent's waterfowl breed in this region. This area is particularly critical for mallard, northern shoveler, gadwall, northern pintail, blue-winged teal, American wigeon, canvasback, and redhead. Waterfowl populations of the PPR of Canada in 2018 were estimated at 15.7 million birds, representing 38 percent of the annual breeding population in North America. There are 18 species that frequent this region. Mallards, at 23 percent of the breeding duck population, are the most abundant species. This region also supports 60 percent of the breeding gadwall, over 48 percent of blue-winged teal, and at least 62 percent of redheads.

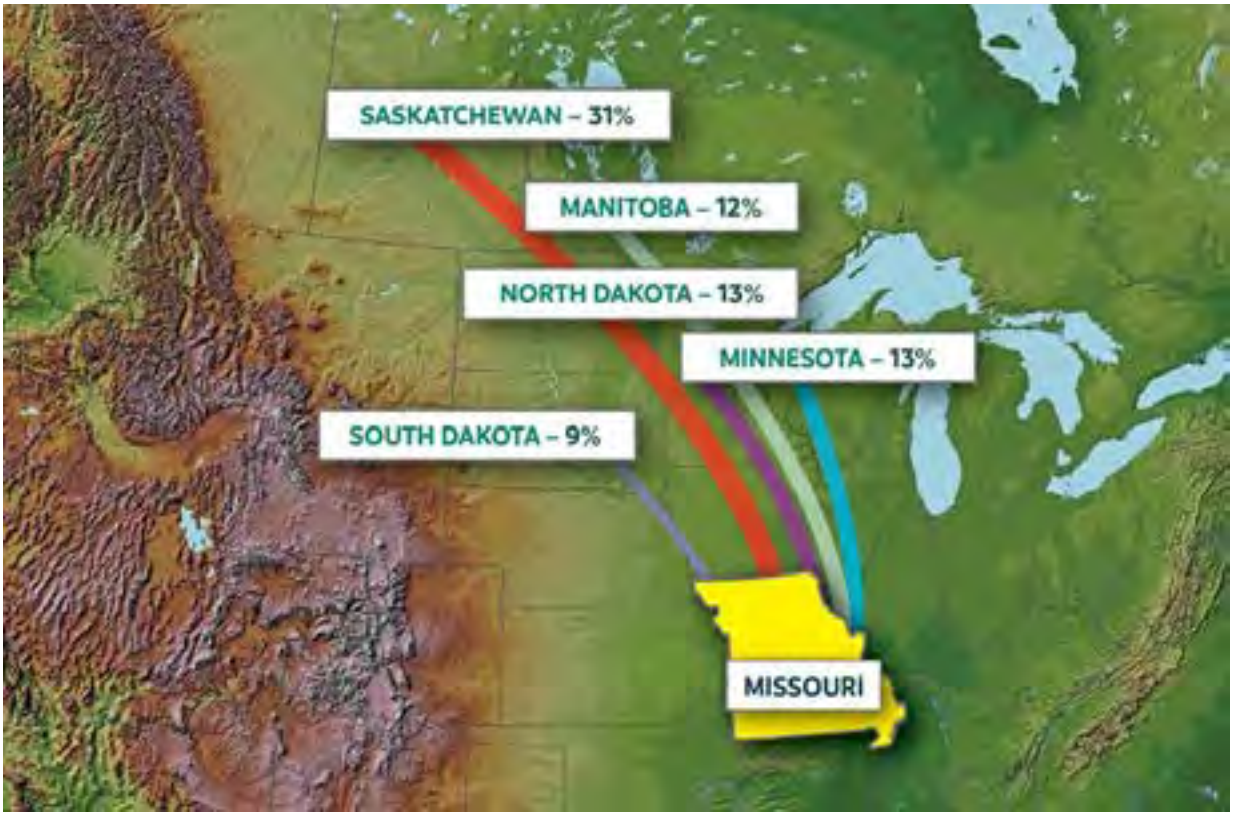


Figure 2.37 – Nearly 80 percent of the waterfowl harvested in Missouri were banded in Saskatchewan, Manitoba, North Dakota, South Dakota, and Minnesota. Data from 1986–2019. Note that this data is not corrected for banding effort.

The importance of the PPR is not limited to waterfowl. This region plays host to 314 different bird species, many of which rely on wetland habitats for breeding or for important rest stops during migration. The Prairie Habitat Joint Venture has identified species that rely on these habitats for breeding, including lesser scaup, piping plover, yellow rail, and horned grebe – all of which are listed as species at risk in Canada. The Prairie Habitat Joint Venture also has identified 12 waterbird and shorebird priority species that breed in the Boreal or Arctic regions but rely on wetlands in the Prairie/Parkland region as important places to rest and replenish reserves during migration. The Missouri CCS identifies 67 bird SGCNs. Of these, 19 are also listed as priority species in Bird Conservation Region 11, which is the Prairie and Northern Region of the Prairie Potholes of Canada.

A Focus on the Prairie Pothole Region of Manitoba

MDC focuses its Fall Flights resources on four high priority waterfowl areas located within the Prairie and Aspen Parkland ecoregions of Manitoba within the PPR. These priority areas include the Manitoba PPR including Minnedosa/Shoal, Killarney, Virden, and Alexander Grisold (**Figure 2.38**). MDC selected these priority areas because of their wetland density, risk and/or degree of habitat loss, and partnership opportunity. This targeted region serves as an important source for waterfowl that either migrate through or winter in Missouri, as evidenced by the high proportion of band

Figure 2.38 – MDC Focuses Its Fall Flights on Four High Priority Waterfowl Areas in the Manitoba PPR, including Minnedosa/Shoal, Killarney, Virden, and Alexander Grisold.

recoveries in Missouri of waterfowl banded in Manitoba. In addition to providing critical breeding and molting habitat for waterfowl, it is also an important stopover location for migrating waterbirds and shorebirds.

These target areas are recessional moraine landforms in the Manitoba PPR that offer the unique characteristics that make a landscape productive for waterfowl. They include an expanse of mixed grassland, shrubland, cropland, and wetlands. They are characterized by gently rolling to rugged hills that create high wetland densities. This area contains more than 500,000 wetlands including over 250 DU wetland projects. These habitat characteristics make this area key to waterfowl production and provide a basis to strategically deliver conservation programs. Based on USFWS survey data, PPR and particularly these priority areas continue to stand out as the "best of the best" breeding habitats in North America, despite ongoing and historic habitat loss.

MDC worked closely with DU-Canada to identify these locations based on science. DU-Canada developed a waterfowl distribution model to identify areas that have the highest duck pair densities. Direct programs are applied to areas that support a minimum long-term average of 30 pairs of breeding ducks (mallard, northern pintail, shoveler, gadwall, blue-winged teal, canvasback, and redhead) per square mile. The priority areas far exceed this minimum criterion over most of the landscape (**Figure 2.39**). DU-Canada, working with the Prairie Habitat Joint Venture, employs a waterfowl production model to project the outcomes of conservation programs – measured in hatched nests, landscape conditions, and species-specific population characteristics.

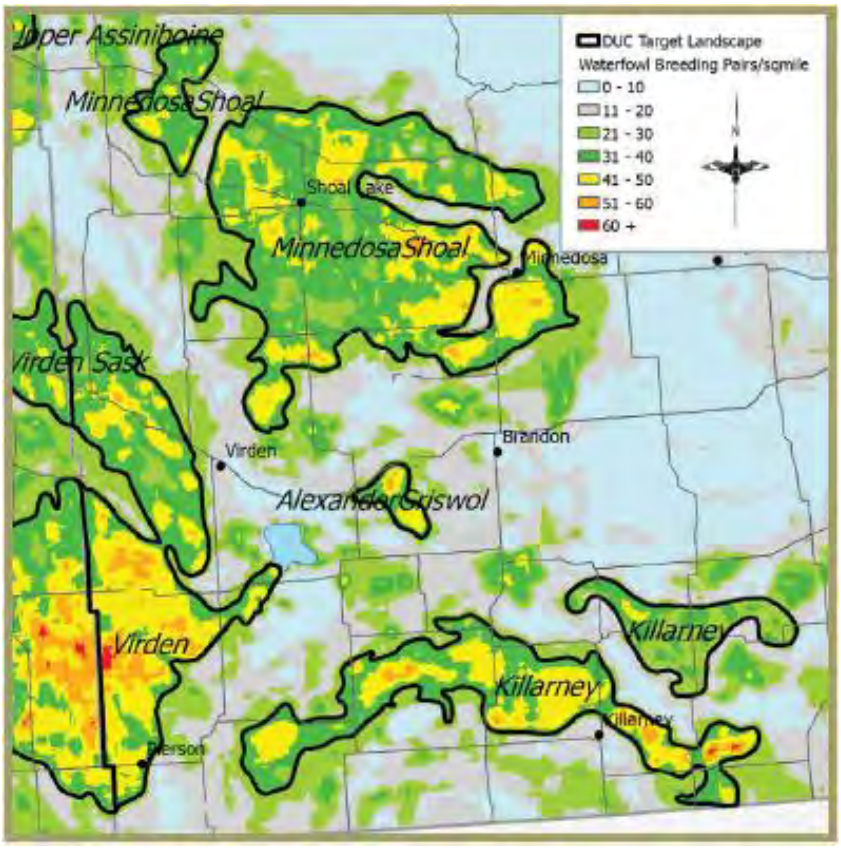


Figure 2.39 – DU-C's waterfowl Decision Support System map helps identify "hot spots" in which to direct efforts that will provide the greatest benefit to waterfowl.

Future Collaboration Supporting This Key Partnership

Conservation partners will continue to collaborate to help protect, conserve, and restore critical habitat in the PPR of Canada. This effort will ensure that waterfowl that migrate through and winter in Missouri have sufficient habitat to meet their life history needs.

Landscape conditions and land use in the PPR have changed since Missouri first selected this focal region in 1991. Next steps for Missouri will be to consider where best to direct future funds in the Canadian PPR. MDC will examine band derivation data for ducks harvested in Missouri and consider where the greatest potential threats to wetlands and associated wetland habitats are in the Canadian PPR. Missouri conservation partners will also consider goals and objectives associated with the Missouri Wetland Planning Initiative and the Missouri Bird Conservation Plan to ensure conservation efforts positively effect state priorities as well as influence larger flyway and population level goals.

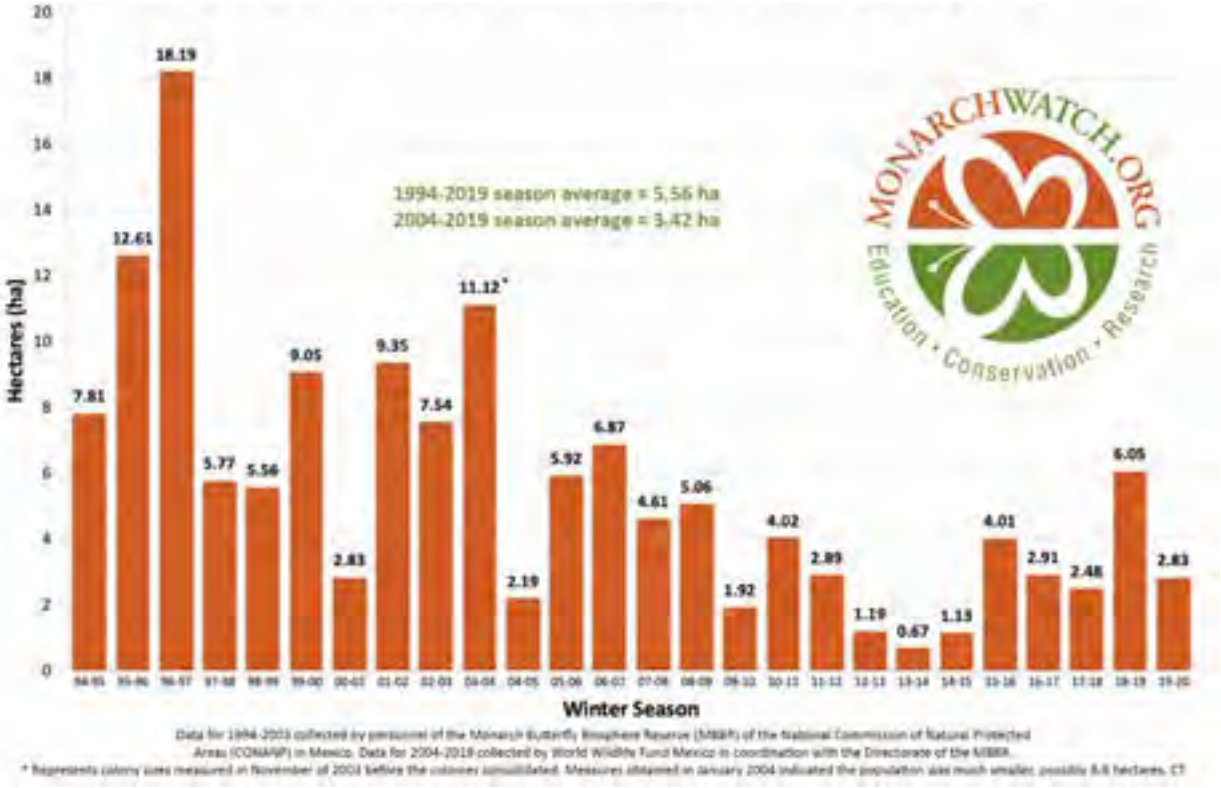
Financial contributions toward this effort have been beneficial for wetland conservation and the many organisms that depend on abundant and diverse wetland habitats, including those species and habitats that support the tradition of waterfowl hunting. Ecological and social challenges exist for future conservation efforts. Missouri's continuing commitment and leadership role in collaborative efforts like these are vital and have broader impacts than just within the state borders.

Monarch Butterfly Full Life-Cycle Conservation Partnerships

In recent decades, the eastern migratory population of monarch butterflies (*Danaus plexippus*), which are those monarchs located east of the Rocky Mountains that overwinter in the oyamel fir (*Abies religiosa*) forests of Mexico, has declined by more than 80 percent (Semmens et al. 2016). Extensive loss of habitat throughout their breeding grounds and migratory path due to land-use changes and untimely mowing or pesticide applications – combined with illegal logging, forest degradation, and harsh winter storms at their overwintering lands – has resulted in this significant population decline.[3] Monarch population size is assessed by measuring the total area occupied by monarch colonies at their overwintering site in Mexico. **Figure 2.40** represents the eastern migratory monarch population at those overwintering grounds every year since the 1994–95 winter.

The downward trend in the monarch population, as well other pollinator species' populations, prompted cooperative action from the presidents of the United States and Mexico and the prime minister of Canada. In June 2014, a presidential memorandum was issued from the White House directing federal actions to address the issue of pollinator conservation resulting in the creation of the Pollinator Health Task Force and the National Strategy to Promote the Health of Honey Bees and Other Pollinators. This strategy set a goal for the eastern migratory monarchs' population to increase to 225 million butterflies, occupying 6 hectares (15 acres) in the overwintering grounds in Mexico (White House 2014).

Figure 2.40 – Total Area Occupied by Monarch Colonies at Overwintering Sites in Mexico



[3] Land-use changes consist of commercial, residential, and agricultural development or conversion.

In August 2014, USFWS was petitioned to list the monarch butterfly as a threatened species under the Endangered Species Act of 1973 (ESA). In December 2014 USFWS published a 90-day substantial finding in the *Federal Register* stating protection of the monarch may be warranted. USFWS is currently conducting a Species Status Assessment for the global populations of the monarch butterfly (*Federal Register* 2014). A proposed decision from USFWS is scheduled for December 2020, as to whether a listing is warranted for the monarch butterfly under the ESA.

Missouri and Monarchs

Rather than wait for a listing decision to prioritize this conservation effort, Missouri recognized the importance of this issue and intensified its efforts in 2015 with the formation of the Missourians for Monarchs Collaborative and the creation of the Missouri Monarch and Pollinator Conservation Plan. The plan outlines specific goals and objectives within Missouri, which dovetails national and international goals, to assist in the conservation of monarch butterfly habitat. Specifically, one of the key goals established in Missouri is 385,000 acres of additional pollinator habitat consisting of 200 milkweed stems per acre. Missouri's geographical location is situated precisely in the middle of the monarch's migration corridor, which also serves as their breeding grounds, making Missouri vital to the monarch population and any establishment of those 385,000 acres incredibly impactful (**Figure 2.41**).

Figure 2.41 – Map of Monarch Annual Migration Inclusive of Corn Belt Region Where 40–50 Percent of Hibernating Monarchs Are Produced. Map courtesy of Monarch Watch.

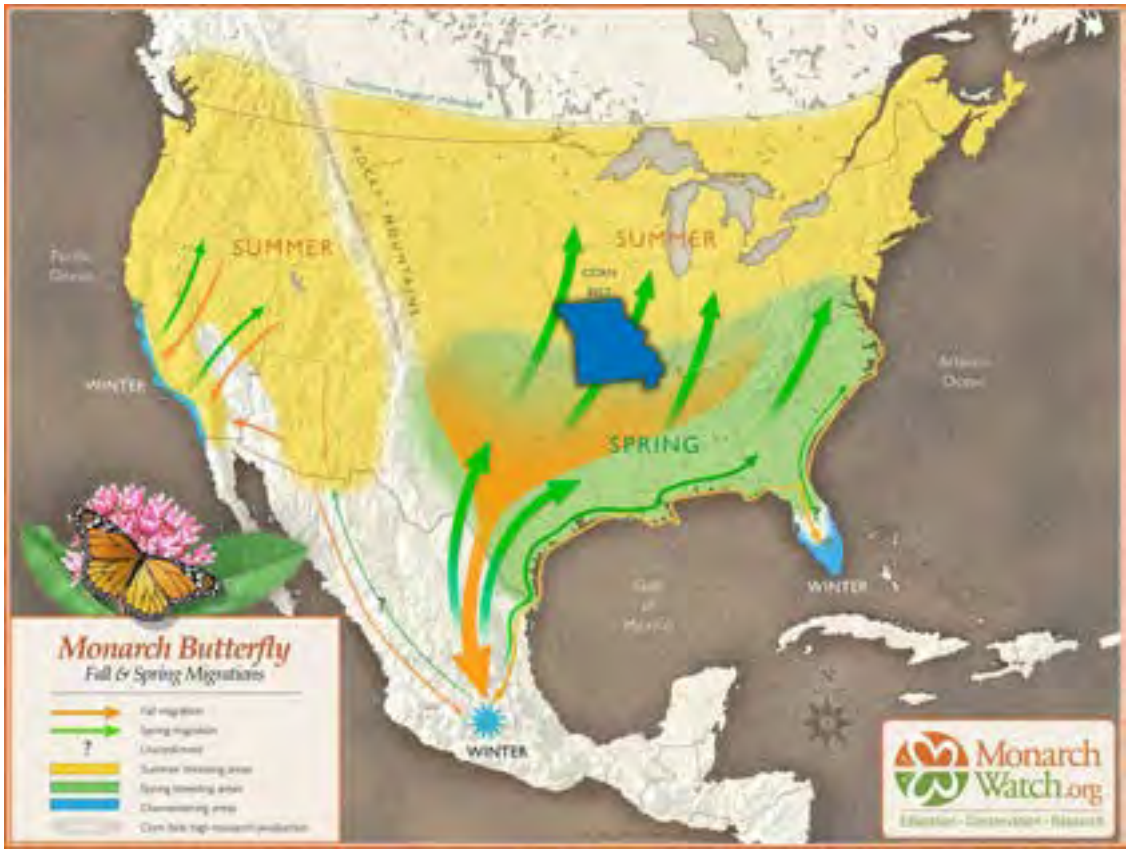
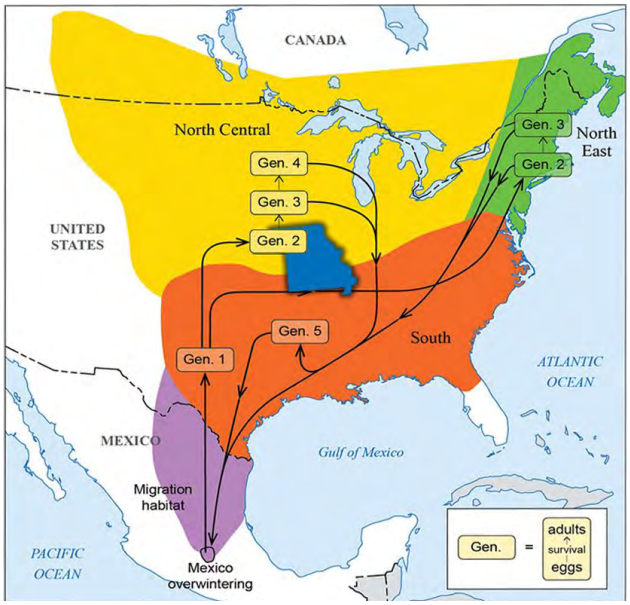


Figure 2.42 – Map of Monarch Annual Migration Inclusive of Regions Where the Various Generations Are Produced. Map courtesy of Oberhauser et al. 2017.



The eastern migratory population of monarchs undertakes what is arguably the most dramatic example of insect migration known. Every year, three to five generations of monarch butterflies are needed to successfully complete their migration efforts, traversing thousands of miles, spanning Mexico, the United States, and Canada. Due to Missouri's central location, more than one generation of monarchs is produced here every year (**Figure 2.42**). Missouri is host to monarchs twice a year. Each fall, millions of monarch butterflies travel through Missouri, feeding on available nectar from native plants, fueling their migration to their overwintering grounds in central Mexico. Then, as spring arrives and temperatures warm, monarchs begin their return journey north to their breeding range, once again gracing Missouri with their iconic beauty. This time, however, the monarchs are in search of milkweed to lay their eggs, giving birth to the subsequent generations of monarchs, which will continue their renowned migration.

Both native milkweed and nectar resources are essential for monarch survival. The decline in various native species of milkweed is troublesome as they are the monarch's host plant.[4] However, loss of nectar resources further complicates the monarchs' struggle since the final migratory generation born each year requires these resources to fuel the last leg of their migration flight to the overwintering grounds in Mexico.

Monarchs and the Need for Widespread Collaboration

The monarch's tri-national migration dictates the need for collaboration among states, regions, and countries. The Midwest Association of Fish and Wildlife Agencies (MAFWA) recognized the need for regional coordination of monarch conservation efforts and authored the *Mid-America Monarch Conservation Strategy* (MAFWA 2018). This strategy incorporates the various monarch conservation plans from states, wherein the core habitat areas of the eastern monarch population exist (**Figure 2.43**).

The strategy established regional monarch conservation goals and objectives. These regional efforts are especially important given recent scientific research using isotope data that showed 40–50 percent of hibernating monarchs at the overwintering grounds in Mexico were produced in the Midwest "corn belt" (Wassenaar and Hobson 1998; Flockhart

[4] The plants monarch butterflies lay their eggs and the only plants monarch caterpillars eat.

Figure 2.43 – Map of Monarch Annual Migration Inclusive of Regions Where the Various Generations Are Produced. Map courtesy of MAFWA.

et al. 2017) (**Figure 2.41**). However, combined conservation efforts need to extend not only beyond state borders but also beyond country borders.

The Monarch Butterfly Biosphere Reserve (MBBR) in Mexico, which serves as the overwintering grounds for the eastern monarch population, is equally critical to monarch survival. Without a secure location for hibernation, monarchs are unable to survive the winter elements. The MBBR serves as that harbor for the eastern population of monarchs. The MBBR was established in 2000 and has been inscribed on the World Heritage List since 2008. The 56,259-hectare site, located 100 km northwest of Mexico City (**Figure 2.44**) consists of eleven butterfly sanctuaries within a forested mountain range. Four of the sanctuaries within the states of Mexico and Michoacan are open to the public for ecotourism.

Every autumn hundreds of millions of monarch butterflies alight onto the oyamel fir trees in the Bioshphere seeking a haven for the coming winter months, but those lands, too, are at risk. Among the threats are illegal logging, forest fires, diseased trees, and climate change. Between 1971 and 1999, 44 percent of the forest was lost to illegal logging (Brower et al. 2002) and more recently, between 2012 and 2018, another 163.44 hectares of forest were lost to illegal logging and climate change (Flores-Martínez et al. 2019). In recent years, protections have been put in place to lessen illegal logging,

Figure 2.44 – Map of Monarch Butterfly Biosphere Reserve in Mexico. Map courtesy of IUCN-World Heritage Outlook.

but additional efforts are still needed not only to ensure those protections remain but to make significant strides against the other remaining threats.

Combined and coordinated conservation efforts serve only to strengthen the results. Missouri is a prime example of exceptional conservation action resulting from partnership and collaboration. The MBBR is not only another opportunity for Missouri to partner with new and existing international conservation organizations, focused on monarch habitat conservation; it's also an opportunity for Missouri to lead others within the monarchs' United States core habitat area to collaborate on an international COA for this species. One thing is certain. Continued investment in coordinated North American management of this migratory species is needed for a successful outcome and to ensure that future generations get to witness the monarchs' magnificent migration.

Monarchs clustering on oyamel fir trees at their overwintering grounds in Mexico. Photo copyrights Frans Lanting.

Multi-State and International Collaboration: Initiatives and Priority Areas

As proven in the previously described collaborations, Missouri sits at a critical geographic junction, hosts significant natural resources, and boasts strong state-level partnerships. Missouri's conservation partners lead or contribute significantly to many regional, national, and international conservation initiatives and working groups. Active engagement and leadership in these initiatives have advanced the critical conservation of grassland, glade, forest and woodland, karst, wetland, and riverine systems; rare, threatened, and endangered species recovery; monarch butterflies and pollinators; resident and migratory birds; landscape ecology; and much more.

Below is a noncomprehensive list of example multi-state collaborations, initiatives, and priority areas that Missouri conservation partners actively contribute to or have the potential to engage. Each of these examples stands to benefit significantly from multi-state conservation collaboration and a diversity of experience and expertise.

Table 2.3 – Existing and Potential Multi-State and International Initiatives and Areas

Name	States	Description
Association of Fish and Wildlife Agencies (AFWA)	All, plus Canadian Provinces and U.S. Territories	Represents North America's fish and wildlife agencies to advance sound science-based management and conservation of fish and wildlife and their habitats in the public interest.
Bentonville, AR/Joplin, MO Metropolitan Area*	AR, OK, MO	Urban conservation issues that transcend state lines.
Big Rivers Forest Fire Management Compact*	IA, IL, IN, MO	Promote and maintain effective fire management service through prevention, pre-suppression, and suppression of natural cover fires; and using prescribed fire.
Central Hardwoods Joint Venture*	AR, IL, IN, KY, MO, OK, TN	Maintain viability of native bird populations and habitats.
Grand River Grasslands	IA, MO	Restoration of biologically significant grassland landscape.
Kansas City Metropolitan Area*	KS, MO	Urban conservation issues that transcend state lines.
Karst Topography Areas*	IA, IL, IN, KY, MO	Water quality, bat habitat.
Loess Hills*	IA, KS, MO, NE	Maintain and restore unique forest/woodland/prairie habitat types; especially in Weston Bend/Iatan and Loess Hills Prairie Complex COAs.
Lower Mississippi River Bottomland Forest Restoration*	IL, KY, MO, TN,	Joint efforts toward protecting and restoring bottomland forests – especially in and adjacent to MDC's River Bends Priority Geography,
Lower Mississippi Valley Joint Venture	AR, KY, LA, MO, MS, OK, TN, TX	Recover and maintain viability of native bird populations.
Midwest Association of Fish and Wildlife Agencies (MAFWA)	IA, IL, IN, KS, KY, MI, MN, MO, ND, NE, OH, SD, WI, and Canadian Provinces of MB, ON, SK,	Represents the Midwest fish and wildlife agencies to advance sound science-based management and conservation of fish and wildlife and their habitats in the public interest.

Midwest Landscape Initiative (MLI)	IA, IL, IN, KS, KY, MI, MN, MO, ND, NE, OH, SD, WI	Identifies shared conservation and management priorities that require the development of scalable collaborative solutions to achieve healthy functioning ecosystems in the Midwest considering a landscape-scale approach.
Mississippi River Basin Healthy Watersheds Initiative (MRBI)	AR, IA, IL, IN, KY, LA, MN, MO, MS, OH, SD, TN, WI,	MRBI works with farmers and conservation partners to implement conservation practices that help trap sediment and reduce nutrient runoff to improve the overall health of the Mississippi River.
Missouri River corridor and watershed*	CO, KS, MO, MT, ND, NE, SD, WY,	Habitat restoration, water quality, and recreational opportunities.
Missouri/Mississippi Rivers Confluence*	IL, MO	Habitat restoration and recreational opportunities – especially in Missouri/Mississippi Rivers Confluence Wetland COA.
National Association of State Foresters	All, plus U.S. Territories and District of Columbia	Represents all U.S. state, territory, and D.C. forestry agencies united with a common cause of managing and protecting state and private forests, which encompass nearly two-thirds of the nation's forests
North American Bird Conservation Initiative and Partners in Flight	Multiple states/ countries	Recover and maintain viability of native bird populations in the Americas.
Northeast Midwest State Foresters Alliance (NMSFA)	20 northeastern states and District of Columbia	Represents New England, Mid-Atlantic, and Midwest state forestry agencies to achieve joint forest management, conservation, and protection goals. NMSFA facilitates regional efforts related to forest health, invasive insects and pests, wildland firefighting, urban forestry, development of best practices for the protection of lands near rivers and lakes, and a variety of other areas.
Ozark Highlands forest/woodland restoration*	AR, IL, MO, OK	Forest/woodland landscape restoration opportunities, including shortleaf pine restoration/expansion.
Southeast Association of Fish and Wildlife Agencies (SEAFWA)	AL, AR, FL, GA, KY, LA, MO, MS, NC, OK, SC, TN, TX, VA, WV, Puerto Rico and U.S. Virgin Islands	Represents the Southeast fish and wildlife agencies to advance sound science-based management and conservation of fish and wildlife and their habitats in the public interest.

Southeast Conservation Adaptation Strategy (SECAS)	AL, AR, FL, GA, KY, LA, MO, MS, NC, OK, SC, TN, TX, VA, WV, Puerto Rico and U.S. Virgin Islands	Collaboration around a bold vision for connecting the lands and waters of the Southeast and the Caribbean to support healthy ecosystems, thriving fish and wildlife populations, and vibrant communities using a data-driven spatial plan and an ambitious regional goal to accelerate conservation action in the places where it will make the biggest impact.
St. Louis Metropolitan Area*	IL, MO	Urban conservation issues that transcend state lines.
The Monarch Collaborative	Multiple states/ countries	Recover and maintain the viability of monarch butterflies.
Upper Mississippi River Watershed (including Upper Mississippi Forest Partnership) *	IA, IL, IN, MO, MN, WI	Joint efforts at addressing water pollution, loss of migratory bird habitat, forest loss, and fragmentation in Upper Mississippi Watershed.
Upper Mississippi/Great Lakes Joint Venture	IA, IN, KS, MI, MN, MO, NE, OH, WI	Recover and maintain viability of native bird populations.
White Oak Initiative	MW, NE, and SE U.S.	Promote sustainability, health, and regeneration of white oak.

***More details can be found in USFS report Multi-State Priority Areas of the Midwest and Northeast at** fs.usda.gov/naspf/sites/default/files/publications/multistatepriorityareas_final_20160707.pdf**.**

Section Three: Missouri Natural Systems Assessment: Conditions, Trends, Threats, Challenges, and Opportunities

Missouri Natural Systems Modifications – Background/Perspective

The environment and landscapes of Missouri have constantly changed. Humans have played a major role in shaping those changes for more than 12,000 years. (Nelson 2010; Ray et al. 1998). Initially, Native Americans altered many landscapes to meet their needs for survival. As the Native American populations grew from hunter gatherers to agricultural communities, the landscape in which they lived changed with them. They transformed entire ecosystems through widescale burning, agriculture, hunting, and by building settlements (Nelson 2010). Beginning in the mid-18th century, what is today Missouri began to be occupied by people of European descent.

Over the past 250 years, the human influence on the natural systems of Missouri has steadily increased with often dramatic consequences for native ecosystems and species. The most profound changes to natural systems across Missouri's 44.5 million total acres involve land clearing, plowing, development, hydrologic modifications to our stream and wetland systems and the overexploitation of species. Consider these points:

- Approximately 99.5 percent of Missouri's 15 million acres of original tallgrass prairie has been converted to other land uses, mainly row crop agriculture and nonnative fescue pasture.
- Missouri has lost over 80 percent of its original wetlands (including bottomland forests).
- 17 million acres of the state have been converted to nonnative cool-season grasses (mainly tall fescue).
- Over 10 million acres of the state is in intensive row-crop agriculture.
- Over half a million acres of the state are covered in suburban /urban /industrial/ transportation network developments.
- Missouri has lost about 50 percent of its original wooded habitats since 1800; today 15 million acres remain, about one-third of the state.
- From 1888 to 1920 most of the Missouri's Ozarks forests and woodlands were cut over to feed a growing nation's demand for wood. This, in combination with severe wildfires in the cutover slash, and heavy livestock grazing decimated the region's shortleaf pine forests and woodlands, reducing their extent by 75 percent and converting these to oak-hickory stands.
    - Between 1888 and 1910 more than 1.3 billion board feet were harvested from just Shannon County alone (Palmer 2000).
- Prior to the 1800s, shortleaf pine covered roughly 6 million acres in southern Missouri. Today there are approximately 1.5 million acres scattered across the Ozarks.
- Following deforestation, from roughly 1914 to 1928, an extensive network of engineered ditches, levees, canals, and detention basins were constructed in extreme southeast Missouri (the Bootheel) effectively draining around 1.2 million acres of wetland, swamp, and

cutover bottomland forest to convert the area for agriculture.

- By the mid to late 1800s and early 1900s, bison, elk, black bear, gray wolves, and mountain lions were considered extirpated, or nearly so, from Missouri.
- By 1937 it is estimated that approximately 100 ruffed grouse, 2,000 white-tailed deer, 3,500 wild turkey, and around 100 beavers remained on Missouri's landscape, due in large part to overexploitation from market hunting and loss of habitat (Bennitt and Nagel 1937).
- By the late 1900s, large reservoir construction at Lake of the Ozarks, Truman Reservoir, Mark Twain Lake, and others assisted in flood control, water supply, and energy production but also greatly altered the natural hydrology and ecology of many Missouri streams and associated wetlands.
- More than 70 percent of Missouri's public water supply is drawn from its rivers and streams.

Today, habitat fragmentation and destruction continue but at a much slower pace. Beginning with the introduction of Dutch elm disease to Missouri in the 1960s, invasive exotic species and pathogens have steadily increased in abundance in the state to the detriment of native species. After systemic ecosystem changes described above, invasive exotic species are recognized as the greatest alterations of natural systems. In addition to these changes, fire suppression and changes in fire regimes and the ripple effect from the elimination of large predators (e.g., wolves) and grazers (e.g., bison) have all had impacts on natural system function.

Compounding these challenges, presently, the growing season in Missouri has increased by an average of one week in both the spring and fall and the past decade has been marked by increased precipitation, especially extreme rain events. These and other possible impacts from climate change are expected to increase, further altering natural systems.

With such dramatic modifications to natural systems and species, managing for or attempting to restore past conditions is unrealistic; however, without collaborative conservation efforts, losing entire systems or species from Missouri's landscape remains a stark reality. Over the last eighty years, immense groundbreaking collaborative conservation efforts by conservation organizations and citizens have helped many game and non-game species to rebound and have protected critical habitat on both public and private land.

There have been amazing successes in conservation! However, modern conservation faces its own monumental challenges. Management of Missouri's natural systems must be adaptive and incorporate current landscape and social conditions. Understanding current and anticipated threats, challenges, and opportunities, as well as the evolution of society, is important when considering an improved and sustainable future for Missouri's natural communities and species.

Within this section we describe ten overarching themes that are important in considering the overall health, functionality, and sustainability of Missouri's natural systems under current conditions and projecting into the future.

Theme One: Species and Natural Systems Health and Conservation

In a nutshell: Missouri's natural communities include forests, woodlands, savannas, prairies, glades, cliffs and talus, streams and rivers, wetlands, and caves and other karst features. Though they differ in scale and abundance, each of these natural communities is vulnerable to invasive exotic species (e.g., plants, animals) and diseases, conversion (e.g., development), poor land use practices (e.g., nontarget pesticide impacts), extreme weather events, changes in ecological processes (e.g., fire or hydrologic regimes), and other environmental stressors. These stressors all pose serious threats to natural communities, both now and in the future. Within these systems, individual species also face unique threats, such as CWD in deer, white-nose syndrome (WNS) in bats, chytrid fungus in amphibians, and emerald ash borer (EAB) in ash trees. Science-based management decisions will help Missouri be proactive in minimizing the impacts of stressors and maintaining healthy habitat systems and plant and animal populations for the foreseeable future.

Desired Future Conditions

1. Missouri's natural communities provide valuable habitat to native species that depend on them.
2. Missouri's native flora and fauna maintain stable and resilient populations.
3. Missouri's natural communities and green infrastructure development sustainably provide important ecosystem services.
4. Missouri's natural communities function both locally and at a landscape scale.
5. Methods for effectively preventing and managing invasive species and diseases are known, utilized, and improved.
6. The future threats of invasive species, diseases, and other environmental stressors are well understood and mitigated during management decisions.
7. Missouri's natural communities are managed to enhance health, habitat value, and resilience and management options are not compromised by invasive species, diseases, and other environmental stressors.

Introduction to Invasive Exotic Species

Invasive exotic species are a tremendous threat to Missouri's natural communities, native species, agriculture, recreation, economy, and much more. These aggressive nonnative species directly and indirectly compete with native species for resources and, at this time, are the second greatest threat to native ecosystems worldwide, though the argument could be made for being the single greatest threat. Prevention is the best approach to invasive exotic species management and control; however, prevention is not always possible or practical as it greatly depends on immense outreach and education effort and then follow-through resultant from those efforts. Even with extreme measures for prevention, invasive exotic species continue to be spread worldwide, whether accidentally or intentionally, by a multitude of vectors. When prevention falls short, early detection and rapid response is the next best measure to curb potential infestations before they get out of hand, become established, and become costly to control or manage.

Ultimately, integrated pest management (IPM) is considered the best approach to combat invasive species. Under such an approach, a combination of methods including outreach and education, cultural practices, research, various control and management actions, and monitoring and evaluation are used in concert to strategically prevent or minimize impacts from invasive exotic species. Expanding the toolbox to aid these methods is essential. New research and survey methods must be developed and employed as science and technology advance, with examples including the effective use of drones and specialized dogs for identifying and monitoring for invasive species and the continued research into well-vetted and safe mechanical, chemical, and biological controls.

Invasive Plants

Missouri is now home to more than 800 exotic plant species, with 142 of those species being considered invasive (to some degree) to Missouri natural communities by the Missouri Invasive Plant Task Force (MoIP). Some of the most serious invasive plant threats to our natural communities currently include bush honeysuckle (*Lonicera maackii*), Japanese honeysuckle (*Lonicera japonica*), Callery pear (*Pyrus calleryana*), tree of heaven (*Ailanthus altissima*), autumn olive (*Eleagnus umbellata*), sericea lespedeza (*Lespedeza cuneata*), Japanese stiltgrass (*Microstegium vimineum*), garlic mustard (*Alliaria petiolata*), reed canary grass (*Phalaris arundinacea*), spotted knapweed (*Centaurea maculosa*), and hydrilla (*Hydrilla verticillata*) (MoIP 2020).

Many invasive plants exploit areas disturbed by human activities, overgrazing, and extreme weather events. Invasive plant populations tend to be highest around urban areas, but even rural locations are starting to see significant invasive plant infestations as people develop remote lands, install roads, and plant invasive exotic species on their property. Intensive livestock grazing can disturb soil and introduce invasive plant seeds through contaminated hay. Extreme weather events such as tornadoes and ice storms open the forest canopy, allowing invasive plants surviving on the forest edge to colonize formerly shaded, unsuitable habitat. Extreme rainfall and flooding can scour streambanks and riparian areas, opening the potential for invasion.

Invasive plant management is a key priority for today's land managers, which includes not only public land managers but also private landowners. Strategically delineating invasive plant populations and determining the best areas to target for management, suppression, and eradication are important. Since all control tactics take money and time, land managers often must set priorities on when and where to manage invasive plant populations. There are many scenarios to consider, but in some places invasive plant management may be inappropriate, simply because the area doesn't qualify as a high-quality natural community, or invasive plant pressure from nearby lands is too high. As invasive plants

continue to spread into Missouri's natural communities, better communication and coordination among public land managers and private landowners are crucial. Many known invasive plant species are still actively being grown, marketed, sold, purchased, and planted throughout Missouri. MoIP is working to raise awareness and educate producers and consumers regarding the immense threat and impacts from invasive exotic plants; however, the pipeline of invasive exotic species continues, contributing to increased new areas of invasion and thwarting control and management efforts. Currently (2020), MoIP is working with diverse stakeholder groups to investigate a potential rule to cease the sale of known invasive exotic plant species in Missouri as part of an IPM strategy.

Callery pear spreading along a Missouri roadside

Invasive reed canary grass threatens Missouri's wetland communities

Aggressive Native Plants

Unfortunately, some native plants can be aggressive, invading vulnerable natural communities and outcompeting other native plants. Aggressive native plants typically follow different distribution patterns than nonnative invasive plant species by encroaching on natural communities that have been excluded from periodic natural disturbance patterns such as widespread fire and large mammal grazing. Historically, these disturbance patterns kept aggressive native plant species in check before European influence in Missouri. Aggressive native plants in Missouri include species like eastern redcedar (*Juniperus virginiana*), honey locust (*Gleditsia triacanthos*), and smooth and winged sumac (*rhus glabra and copallinum*) encroaching on glades and prairies; and red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), ironwood (*Ostrya virginiana*), eastern redbud (*Cercis canadensis*), *Rubus spp.* (e.g., blackberry and raspberry), and even greenbriar (*Smilax spp.*) outcompeting oak regeneration in forest and woodland areas.

MDC staff clearing encroaching eastern redcedar from a glade in Warren County

Sugar maple taking over understory of an oak/hickory forest

Aquatic Invasive Species and Diseases

Aquatic invasive species, sometimes referred to as aquatic nuisance species, pose a serious threat to Missouri's aquatic natural communities. These aggressive nonnative species outcompete and displace native plants and animals; degrade the health and quality of aquatic communities; impede natural community management; impact local, state, and federal economies; affect aquatic industries like water treatment and commercial and sport fisheries; and reduce recreational opportunities. There are several types of aquatic invasive species, including plants, fish, crayfish, mussels, and snails.

Aquatic invasive species spread through a variety of vectors, both intentionally and unintentionally, including vessels, aquaculture, bait and pet dumping, and more. Control and management of these species is a high priority and an incredible challenge, as aquatic invasive species can be difficult to detect in waterbodies. Preventing their spread to additional bodies of water is key. Education, awareness, early detection, and rapid response is critical to ceasing or slowing their spread. Additional information and detail on aquatic invasive species can be found in Rivers and Streams Conservation in **Section Four**.

Invasive Insects and Diseases

In addition to invasive and aggressive plant issues, the natural communities of Missouri are vulnerable to several invasive insects and diseases not native to the state. Trees and forests face many nonnative threats, ranging from attacks by host-specific species like emerald ash borer (*Agrilus planipennis*) and walnut twig beetle (*Pityophthorus juglandis*) to species with wider host ranges such as root rot pathogen (*Phytophthora cinnamomi*) and gypsy moth (*Lymantria dispar*). Unfortunately, introductions of invasive forest pests continue through global trade (e.g., hitchhiking in pallets and packaging), despite international policies intended to limit the movement of destructive species.

Each invasive insect and disease concern has its own suite of prevention, detection, management, and suppression considerations that must be carefully weighed with respect to natural community health. Missouri's natural communities are facing both known and unknown insect and disease threats, so to encourage resiliency and long-term improvement and sustainability of these areas, it is imperative that Missouri:

- Maintain a high diversity of tree and plant species within natural communities
- Plant or maintain species that are well suited to the natural community type, site, and soil
- Promote overall natural community health through appropriate management techniques (e.g., keeping forests/woodlands thinned to appropriate stocking levels)
- Monitor insect and disease outbreaks
- Work with state and federal partners to mitigate impacts of invasive insects and diseases
- Encourage the public to avoid transporting invasive insects, diseases, and animals (e.g., obtaining firewood locally)

The following links provide three case studies of invasive insect and disease issues that Missouri is currently dealing with:

- Emerald ash borer case study (**Appendix G**)
- Gypsy moth case study (**Appendix G**)
- Chestnut blight and Ozark chinquapin restoration case study (**Appendix G**)

Native Insects and Diseases

Missouri's natural communities are home to thousands of native insect and disease species. These species have evolved with other native plant and wildlife species and can serve important functions in healthy ecosystems. For example, many Missouri wildlife species depend on dead trees and patches of forest disturbance caused by native insects and diseases. While some native insects and diseases do cause or contribute to animal or plant stress and death, they typically only become major concerns when paired with other stressors such as habitat loss, intense drought, or site disturbance. Natural community managers must consider the potential impacts of such stressors when planning resource management activities (from timber harvests to prescribed burns), as outbreaks of some species may disrupt the intended management goals for a specific natural community.

Native insect outbreaks tend to be cyclic, such as widespread jumping oak gall or defoliating caterpillar events, with natural controls generally returning outbreak populations to normal levels within one to two years. Disease outbreaks are often the result of abnormal weather patterns, especially long periods of wet conditions or extended periods of drought. Variation in weather patterns from year to year serves to balance out native disease outbreaks, thus reducing their severity within a year or two.

Unfortunately, the role of some native insect and disease species in natural communities is beginning to change as the result of human interference and climate change. While these insects and diseases coevolved within Missouri's natural communities, massive and rapid changes in their influence are occurring that are disrupting the balance of these systems. Native insect and disease species that historically were considered secondary attackers on stressed trees, for example, may become primary damaging agents due to shifts in weather, host species composition, habitat fragmentation, and increased human-caused stressors. It is important to consider the potential pest pressure of native insects and diseases as well as climate-related stresses when planning for healthy natural communities of the future.

The following link provides a case study for the impacts of one significant suite of native insects and diseases impacting Missouri's forests and woodlands:

- Red oak decline and shortleaf pine restoration case study (**Appendix G**)

Feral Hogs

Feral hogs represent a serious current threat to Missouri's natural communities, especially fen and seep wetlands, springs, and glades. Hogs degrade habitat by causing erosion, contributing to soil compaction, trampling native plants and tree roots, and reducing water quality. In addition, feral hogs impact Missouri's wildlife directly by competing for forage and acorns, eating ground-dwelling and nesting wildlife species, disrupting tree and plant regeneration, and spreading disease. The disturbance they cause in natural communities also allows invasive plants to gain a foothold in some locations. The Missouri Feral Hog Elimination Partnership and private landowners are working together to eradicate feral hogs from the Missouri landscape. The following table (**Table 3.1.1**) shows the impact of these ramped up efforts in recent years.

Table 3.1.1 – Number of Hogs Removed in Missouri by Conservation Partners Since 2015

Year	Number of hogs removed
2020 (through November)	11,151
2019	10,495
2018	9,365
2017	6,567
2016	5,358
2015	3,649

Top: Feral hog in Missouri forestland; Bottom: Forestland damaged by feral hogs

Deer and Chronic Wasting Disease

CWD is a deadly illness in white-tailed deer and other members of the deer family, called cervids. CWD belongs to a family of diseases called transmissible spongiform encephalopathies, or prion diseases. The disease has been found at low prevalence in 16 counties throughout Missouri since 2012. This sustained low prevalence is attributed to ongoing proactive efforts to limit the impacts of the disease. CWD has the potential to greatly reduce deer numbers, deer hunting, and deer watching over time for Missouri's nearly 500,000 deer hunters and almost two million wildlife watchers.

MDC will continue to focus on managing the disease where it has been found and reducing the risk of introducing the disease to new areas of the state.

Bats and White-Nose Syndrome

A white fungus, *Pseudogymnoascus destructans*, that infects the skin of hibernating bats is the causal factor of WNS, a disease that is devastating to bat populations. No cure is known. Once it appears in a cave, WNS can kill more than 90 percent of the bats living in the cave. Missouri is currently experiencing WNS bat mortality of cave-utilizing bat species.

USFWS has recommended actions to slow the spread of WNS by having cave managers place a voluntary moratorium on caving in significant bat caves until more is learned about WNS. They recommend that the only caving that should go on in significant bat caves be agency-sanctioned research and monitoring cave trips with appropriate decontamination protocols. The transfer of the fungus is primarily bat to bat; however, there is the possibility of human transference of fungal spores between caves without proper decontamination of clothing, shoes, and equipment. Keeping caves closed to human entry also limits human disturbance to bat populations that are already stressed by WNS. MDC and other agencies with caves in Missouri, such as MTNF, have closed all their caves to recreational caving.

Native and Nonnative Grazing Pressure

Prior to European influence in Missouri, a combination of fire and grazing by native bison, elk, and white-tailed deer was prominent across much of Missouri's landscape. In the 1800s, European influence in Missouri meant the end of large mammal grazing by native herbivores and the beginning of grazing by domesticated species including cows, horses, goats, and hogs. Though most of Missouri's large native herbivorous mammals are greatly diminished in population and geographic area, grazing by those that remain, as well as domestic livestock, has important implications to the current and future health and function of some of Missouri's natural communities and habitats.

Present-day livestock are no longer free-ranging on the landscape, but many private landowners still graze their animals in natural communities, particularly forests, woodlands, savannahs, and prairies. The implications of this grazing range from highly detrimental impacts to crucial positive benefits depending on what natural community type the grazing occurs on, the stocking rate, timing, and duration. From a production standpoint, livestock receive very few benefits from grazing in wooded communities, and some may even be harmed by consuming poisonous plants or large quantities of acorns. From a forest and woodland perspective, livestock can harm the long-term health of these systems by destroying tree regeneration, compacting soil and damaging tree roots, causing erosion, spreading invasive plant species, and avoiding unpalatable aggressive plant species that may eventually take over the community (e.g., eastern redcedar, honey locust, multiflora rose). Similar effects described for livestock can also be caused by high white-tailed deer populations, particularly in urban and Wildland Urban Interface (WUI) areas where hunting is not as prevalent. In such wooded areas, it is common to see all vegetation browsed within reach of a deer. In these areas, encouraging hunting can help to improve the health of these habitats and other wildlife species that depend on them.

Though there can be negative effects, properly managed and prescriptive grazing can be beneficial in certain natural communities (e.g., prairies, savannas). For instance, prescriptive grazing of cattle and goats is being used more extensively, in combination with follow-up treatments, to set back invasive plant and aggressive native shrub infestations so as to restore natural communities or maintain an open understory. In certain native grassland settings, livestock grazing can be a beneficial tool for improving wildlife habitat and plant structural diversity when managed carefully; however, in some instances it may have negative consequences, primarily in situations involving overgrazing native grasses and forbs. It is important to keep livestock out of or limit their access to riparian areas, streams, and other habitats they have potential to damage.

Problematic Pesticides

Pesticides, particularly herbicides and insecticides, are a common component of modern agriculture and invasive species management. While pesticides are important tools for farmers and land managers alike, they can also be detrimental to native species and natural communities when used improperly or excessively. In some cases, pesticides originally considered harmless were found to be ecologically disruptive after years of use. An historic example is DDT, an insecticide widely used from the 1940s through the early 1970s that was largely responsible for the drastic reduction of bald eagles (USFWS 2020b). In recent years, ubiquitous use of crop seeds coated with neonicotinoid insecticides has been implicated in reduced populations of pollinators and wetland invertebrate species while new formulations and application timing of herbicides containing dicamba have been blamed for off-target injury to trees and plants. As the science and understanding of pesticides evolve, it is important to ensure Missouri's native species and

natural communities are protected from unintended consequences of pesticide use.

Extreme Weather Events

Weather data provided by the University of Missouri Climate Center indicate that Missouri has experienced a 33 percent increase in heavy rain events (more than three inches of rain in one 24-hour cycle) over the last 30 years (1986–2015).[5] The increasing frequency of large rainfall events is potentially linked to climate change, described in **Theme Five**. Many climate models project that weather events will become more extreme – large rainfall events followed by longer periods without rain being one example. This wide fluctuation in water availability is likely to stress natural communities, especially aquatic systems. More research is needed to better project the impacts that extreme weather events and climate change will have on Missouri's natural communities and to better understand the management strategies that can be used to keep fish and wildlife and habitats healthy in the future.

Altered Hydrology, Sedimentation, and Nutrient Enrichment (eutrophication): stressors of rivers, streams, and wetlands

Over the past two hundred years, the network of Missouri's streams, rivers, and wetlands have been altered by a variety of land management and stream modification practices that often have been detrimental to fish and wildlife species. MDC's internal Watershed and Stream Management Guidelines (MDC 2009) and Missouri's Wetland Planning Initiative (MDC 2015) outline several of the stresses to wetland and aquatic systems and their sources in the modern landscape:

Sources of Hydrologic and Water Quality Stressors for Wetlands and Streams:

- Stream diversions (e.g., Castor River diversion ditch)
- Stream channelization
- Levees
- Ditching and tiling
- Locks and dams, including small impoundments
- Navigation improvements (e.g., wing dikes)
- Poor soil and water conservation practices across watersheds
- Urbanization
- Intensive row crop agriculture without adequate soil and water conservation best management practices (BMPs)
- Lack of adequate riparian corridors/buffers
- Excessive fertilization
- Livestock access to streams
- Stream passage barriers (e.g., poorly designed stream crossings)
- Improper in-stream sand and gravel mining practices
- Altered hydrologic patterns (e.g., lack of flooding, extreme flooding, etc.)
- Sedimentation
- Increased nutrient loading
- Aquatic organism population isolation and inbreeding
- Lack or disturbance of aquatic organism spawning grounds
- Increasing water withdrawal from streams and aquifers for municipal and agricultural water supplies

Land Conversion

Land is still being converted from natural communities into buildings, roads, row crops, fescue pasture, and other nonnative land cover

[5] Data provided by Dr. Pat Guinan at the University of Missouri Climate Center.

categories. Unfortunately, recent land cover change analyses have not yet been completed for Missouri, but at the national level for the coterminous United States, the NLCD has been analyzed for land cover changes from 2001 to 2016 (Homer et al. 2015; Dewitz 2019). Their analyses showed a 6 percent increase in developed lands (impervious surfaces), a loss of 8 percent of pasture/hay land to row crops, an increase of 0.3 percent in wooded wetlands and a 0.6 percent decrease in herbaceous wetlands. Figure 8 within their report clearly shows a large amount of hay ground converted to row crop in north Missouri and the western one-third of the state.

Theme Two: Pollution Prevention, Control, and Mitigation

In a nutshell: Pollution refers to the introduction of a contaminant into the environment that causes detrimental effects. There are various pollutants, which can include chemicals, gases, litter (trash), and sediment, but also things like heat, light, and noise. All these pollutants have implications for human health and the health of and benefits provided by Missouri's natural resources. There are numerous BMPs, many supported by cost-share options, that can be employed to eliminate and/or mitigate sources and impacts of pollution.

Desired Future Conditions:

1. Pollution threats in Missouri are minimized or mitigated through voluntary actions, regulatory protections, enforcement, and willing adoption.
2. Research is improved to gain better understanding of existing and potential pollution threats with adaptive BMPs employed accordingly.
3. Missouri's natural communities are maintained in a healthy and resilient manner that can assist with rebounding from pollution impacts.
4. Missouri's natural communities help buffer and mitigate the social, ecological, and economic impacts of pollution.

It is important to understand that pollution and sources of pollution occur throughout Missouri and can be found in urban, suburban, and rural landscapes. Identifying the source of pollution underscores the connection between land management and water quality. Sources of pollution across the state include energy production, mining, urban and agricultural runoff, urban and septic wastewater, urban and infrastructure development and lighting, inappropriate pesticide and fertilizer use, litter and waste, and transportation systems. This threat is exacerbated, particularly in aquatic and cave/karst systems, by increased impervious surfaces, development and site grading, compaction, and the loss and degradation of riparian corridors, cave and spring recharge buffers, and wetlands that function to remove pollutants and slow the discharge of both surface water and groundwater from watersheds.

Many species associated with rivers/streams or cave/karst systems, such as mussels, crayfish, fish, amphibians, and cave invertebrates, are particularly sensitive to chemical contamination, thermal pollution, nutrient-loading, and sedimentation. The impact of pesticides on terrestrial and aquatic insects, especially pollinators, is currently a focus of much research. The conservation community is working to reduce the application of insecticides on conservation lands and is conducting several studies that will examine the impacts of such chemicals on terrestrial and aquatic invertebrates. These pollutants also have connections with human health. Some of the most prevalent pollutants on the impaired waters list identified by MDNR are *Escherichia coli* bacteria, mercury, and chlorophyll-a, as well as dissolved oxygen that is above or below the threshold ranges for aquatic life (**dnr.mo.gov/env/wpp/waterquality/303d/docs/2020-303d-list-for-cwc-approval.pdf** and **dnr.mo.gov/env/wpp/waterquality/303d/index.html**).

Conservation partners are also working to restore and improve stream riparian corridors (ideally a minimum of 50–100 feet in width) and to maintain appropriate buffers around cave entrances, sinkholes, and springs to protect groundwater quality. Partners are working to promote stabilized stream crossings and reliable alternative water sources for livestock to keep them out of streams and off streambanks.

MDNR is the lead state agency with regulatory authority over pollution prevention and control through various programs within the

Division of Environmental Quality, including air pollution control, environmental remediation, environmental services, public drinking water, soil and water conservation, waste management, water protection, and water pollution control. These programs offer regulatory direction and guidance and assistance on BMPs to prevent, limit, or mitigate potential sources of pollutants to air, soil, surface and groundwater, and other natural resources. In addition, and often in partnership with state agencies and other partners, the U.S. Department of Agriculture – Natural Resources Conservation Service (NRCS) administers a multitude of programs that offer guidance, BMPs, financial and technical assistance, and more to assist landowners with the protection and conservation natural resources.

In addition to the resources offered by MDNR and NRCS, MDC and many partners worked together to develop *The Missouri Forest Management Guidelines: Voluntary Recommendations for Well-Managed Forests* (MDC 2014), which includes chapters on forested watersheds, pesticide use, and BMPs for protecting cave/karst features. Also, MDC *Missouri Watershed Protection Practice Guidelines* (MDC 2020) have been established to

promote voluntary guidelines for ensuring that forest management activities keep sediment and other pollutants out of streams.

Many of the actions described above focus resources in rural areas; however, some programs include urban and suburban areas that are also significant sources of pollution and require resource investment to prevent and treat pollution/pollutants. Emissions from increased traffic volume, stormwater and wastewater contamination, soil contamination, heat, noise, light, etc. are all of great concern in urban and suburban landscapes. These communities and a variety of partners are working to address the negative effects of these pollutants and to improve air, soil, and water quality as well as quality of life and health for residents and the environment.

As an example, stormwater treatment has become a significant source of investment in urban and suburban communities. Improved filtration systems and bioengineering, which includes the use of engineered soils and native plants to slow, reduce, and filter stormwater runoff are becoming increasingly common in lawns, ditches, medians, etc. Further, replacing concrete channels with reconstructed natural stream channels and riparian areas is being retrofitted into several communities in Missouri. Community forestry, green infrastructure, and pavement reduction are becoming more commonplace to reduce the heat island effect.

In addition to these sources of pollution, there is growing concern over and the need for additional study around the impacts of light pollution on Missouri's citizens and native species. Light pollution has tremendous effects on predator/prey interaction, feeding and breeding behaviors, migration, and more.

Preventing, limiting, and mitigating pollution is a universal responsibility. Conservation partners play key roles in identifying types and sources of pollutants; informing and educating citizens, businesses, and industry; planning and implementing BMPs; monitoring the effectiveness of BMPs over time; and ensuring innovation in these processes.

Theme Three: Private Lands

In a nutshell: The clear majority of Missouri's landscape is privately owned, with only 6.6 percent of Missouri's acres in public ownership for conservation purposes.[6] These private acres are owned for diverse purposes such as agriculture, business, conservation, recreation, and residential use. **Figure 3.3.1** demonstrates just how significant privately owned lands are in Missouri and their distribution by cover (land use) type. The National Conservation Easement Database (NCED) reports that Missouri has 202,805 acres of private lands protected by conservation easement (NCED 2020). Some nonprofit conservation organizations own private lands for conservation purposes and make them available for a variety of public use benefits (e.g., L-A-D Foundation, MPF, Ozark Land Trust, TNC). Since NCED reporting is voluntary and data on acres owned and managed by nonprofits for conservation purposes is incomplete, the total acreage of private acres under long-term conservation protection is uncertain. However, available data paints a clear picture that most of Missouri is comprised of privately owned land that is not under legal protection from influences that can negatively impact conservation (e.g., commercial and residential development, deforestation, etc.).

While private landowners may be the greatest beneficiaries of the lands they own, it is important to recognize the incredible public values Missourians depend on from privately owned lands as well. These benefits include things like wildlife habitat and diversity; healthy watersheds that provide clean, affordable drinking water, flood mitigation, and recreation; pollinator habitat, protection of soil and agricultural lands, carbon sequestration, forest products, aesthetic beauty, and much more. AFWA reported in 2019 that the majority of SOCCs (which include 75 percent of T&E species) and many economically important game species all require habitat on North America's private lands. The future health, productivity, and sustainability of Missouri's natural landscapes and the diverse societal benefits they provide rest largely in the hands of private landowners and the land management decisions they make. To address the potential opportunities for private land conservation, Missouri has one of the most robust toolboxes of state and federal cost-share programs in the nation, which in part helps address wildlife habitat and diversity. In this chapter we look at several trends concerning private lands and how they are used, as well as implications these trends have toward conservation.

[6] Calculated using MDC's public lands GIS data.

Desired Future Conditions

1. As privately owned lands change ownership, affected natural communities transition smoothly to new owners who will maintain or initiate regenerative management.
2. PGs, COAs, and other focal landscapes maintain or increase in total acreage of functional natural communities and become less vulnerable to fragmentation.
3. Privately owned tracts remain sufficiently large to maintain various management options, or such management can be achieved across multiple adjoining ownerships.
4. Future residential and commercial development is well planned to encourage green infrastructure and avoid destroying or negatively impacting important natural communities and landscapes.
5. Private landowners understand the basics of natural resource management and practice informed, regenerative management.
6. Qualified foresters, biologists, contractors, and loggers are readily available who can help private landowners manage their property for healthy, regenerative natural communities.
7. Voluntary incentives and markets make it simple and cost effective for private landowners to manage healthy, regenerative natural communities.
8. Societal benefits of Missouri's privately owned natural habitats (e.g., water quality, biodiversity, forest products, etc.) are recognized by private landowners and appreciated by the public.

Figure 3.3.1 – Missouri's Privately Owned Land and Cover Type Distribution – 2016
(Source: NLCD 2016 and MDC public land data)

Missouri's private lands are highly diverse and cover a variety of cover types, including agriculture, residential, urban, forest and woodland, wetland, grassland, etc. These private lands come in a multitude of shapes and sizes and are owned by an array of landowners (e.g., agricultural producers or recreational owners, absentee landowners or resident, etc.). The following subsections provide a brief glimpse into the dynamics and considerations of private landownership of several key land cover types and landowner groups.

Agriculture Lands

Missouri's agricultural lands, sometimes referred to as working lands, are a key element to restoring landscape health, including water quality, soil health, and wildlife habitats and diversity. These lands constitute a large percentage of Missouri, and proportionally, Missouri's PGs, COAs, and other focal landscapes. Over 160,000 agriculture producers manage nearly 28 million acres of Missouri's 44.6-million-acre land base according to the 2017 USDA Census of Agriculture. The majority of the 28 million acres are in cool season (predominantly tall fescue) pasture and row crops, such as soybeans and corn.

The total number of Missouri agricultural farms has declined by 15 percent since 1997, and only 9 percent of Missouri agriculture producers are currently under the age of 35. These data suggest a future with larger farms and fewer agricultural producers, which may mean less time and resources to devote to the care and management of natural habitats on these farms. However, smaller farms are increasing in number, with farms of less than 50 acres

comprising 30 percent of the total number of farms in Missouri. With increasing small-acreage farms, the average size of a Missouri farm has remained relatively stable over the last 20 years.

A Duke University study (Bonnie et al. 2020) found that rural Americans view where they live as being an important part of how they define themselves. In turn, this shapes their views, including those on environmental policy. While they may care for the environment where they live, the study suggests that direct engagement and collaboration with rural resident landowners is the best way to encourage their participation in managing Missouri's unique habitats and diversity of wildlife. This approach is the basis for addressing private land conservation in Missouri's CCS, emphasizing the importance of developing a plan in partnership with landowners for improving and managing the habitat on private property, while also ensuring thoughtful protection of landowner rights, interests, and the bottom line.

Regenerative Agriculture

The agriculture industry continues to find innovation, as society (consumers) looks to find an improved balance among agricultural production and natural resource conservation. Much of this innovation is centered around the concept of regenerative agriculture. The concepts behind regenerative agriculture include incorporating farming and grazing practices that combat and seek to reverse the impacts of climate change by increasing soil health through practices that rebuild soil organic matter and water-holding capacity, improve water quality, and conserve biodiversity both above and below ground. These concepts incorporate the idea that agricultural practices (e.g., no-till, cover crops, crop diversity, crop and grazing rotation, reduced fertilizers and pesticides, etc.) can partner with nature for mutual benefit and increase the economic resilience of communities reliant on agriculture production.

Market-Based Conservation – A Consumer-Driven Approach to Regenerative Agriculture

Market-based conservation, simply put, is an approach that certifies the conservation benefits of specific production practices, markets those benefits to consumers, and rewards participating producers with a higher price in the marketplace. Many possible approaches exist, but the common theme is that conservation-minded producers receive a higher price for their products than those who follow conventional, sometimes environmentally detrimental, methods; and that conservation-conscious consumers are educated to understand that their purchases of certified products directly benefit the health of the landscape and native species.

MDC initiated studies and landowner surveys to begin in understanding the linkage between conservation benefits and the cost of production in beef production systems in the early 2000s. The motivation was that dominant approaches to grazing management in Missouri are largely incompatible with quality grassland bird habitat, and traditional approaches to incentivizing conservation have proven ineffective at changing grazing management. Subsequent consumer surveys, industry feasibility studies, and work with several Missouri producers indicated likely success for a market-based approach to improving grazing management for the benefit of grassland birds.

This work led to a market-based conservation partnership led by the National Audubon Society, referred to as the Audubon Conservation Ranching Program (ACR). See **audubon.org/conservation/ranching**. The National Audubon Society leads marketing, consumer education, and program administration for the ACR. MDC involvement focuses on working with the Missouri River Bird Observatory (MRBO) to monitor grassland bird population responses on cooperating ranches and to provide coordination and technical habitat management assistance and expertise to landowners. By 2018, ACR had enrolled 800,000 acres on 60 ranches in 11 states, and certified

beef and bison products were available to consumers through 44 restaurants and retailers. The objective is to enroll 2.5 million acres by 2022.

The Haubein Family's Round Rock Ranch, located in Dade County, Missouri, was the state's first Audubon certified producer. Working with conservation partners to develop grassland management plans to reach their conservation and production objectives and to secure financial assistance from federal and state conservation programs, the Haubeins have done a tremendous amount of work to improve the structure and diversity of their pastures and to control invasive species. Their work amounts to true ecological restoration far beyond pasture improvement.

Native prairie restoration and cattle from Round Rock Ranch, Dade County, Missouri.

The ACR partnership provides a model for the creation of other conservation partnerships to explore the potential for new market-based initiatives that benefit producers and the wildlife that share their land. Conservation partners within Missouri and throughout the United States are seeking similar partnerships to certify the conservation benefits of other production systems, including the Xerces Society's Bee Better Certified Program (**beebettercertified.org**), which emphasizes the protection and conservation of bees and other pollinators in agricultural lands, or Regenerative Organic Certification (**regenorganic.org**), which emphasizes practices and standards for soil health, animal welfare, and farmworker fairness.

Regardless of emphasis, effective programs must address the economic needs of producers who want to share their land with wildlife. These program initiatives need to provide a market-based financial incentive to producers who improve habitat. As such this approach introduces a new source of support for conservation efforts that complements traditional state and federal programs. Consumers literally have an opportunity to help farmers and ranchers improve habitat on their land.

Native Prairie

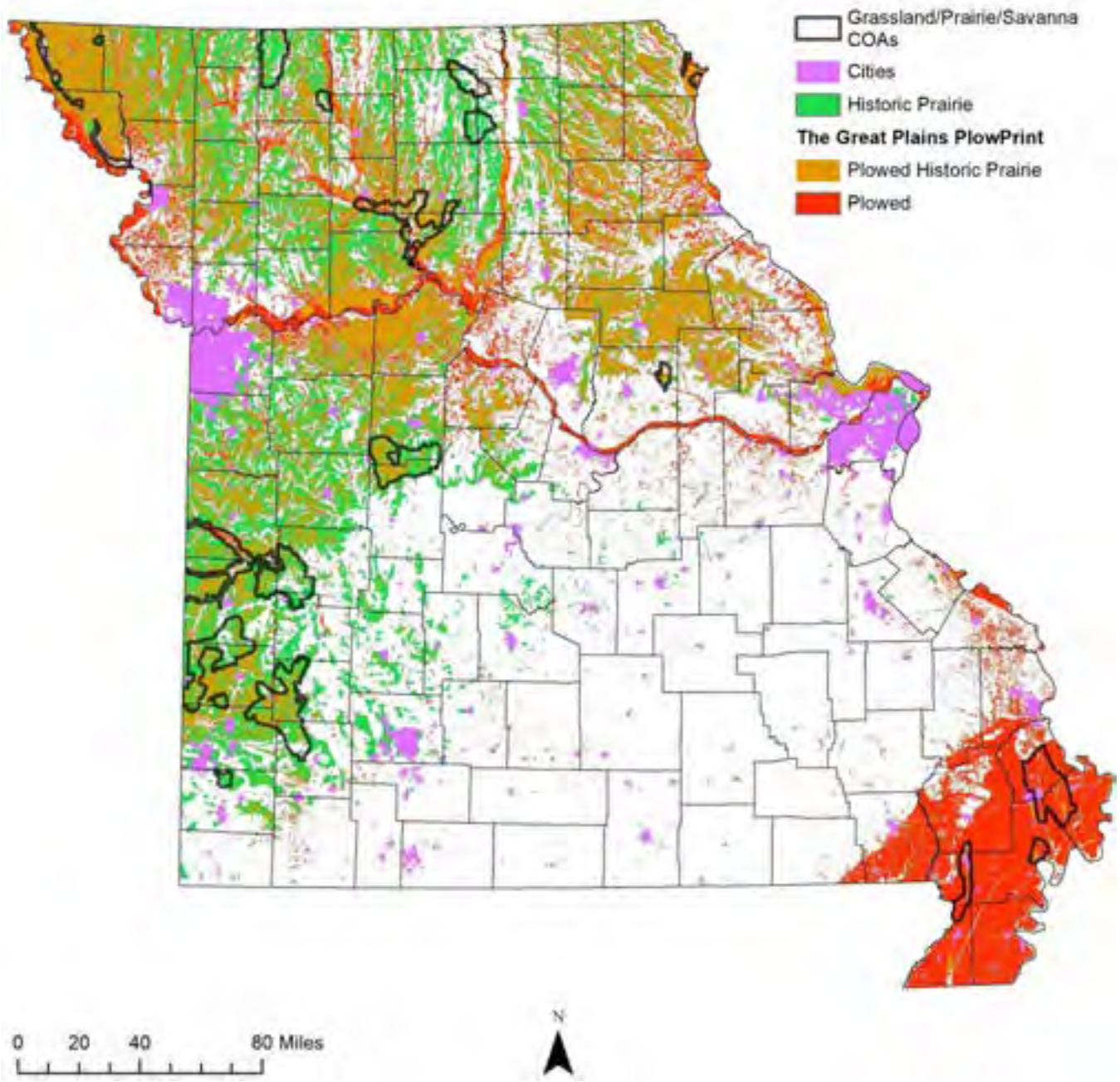
Historically at least one-third of Missouri (15 million acres) was covered in tallgrass prairie. Today approximately 99.5 percent of Missouri's prairie has been converted to other uses, primarily agriculture and development. The Missouri Natural Heritage Database tracks around 50,000 acres of remnant (unplowed) tallgrass prairie, of which about half are still privately owned. Approximately 12,000 acres of what remains on private land is under conservation easements and long-term rentals through the NRCS and other partners. These biologically important remnants depend on the stewardship of the private landowners who own them – and this management of remnant prairies is to be commended! In many cases they are managed as

hay meadows and/or livestock pastures or simply for their aesthetic beauty. Many landowners anecdotally report a sense of family heritage in maintaining their prairies. However, with changing landowner demographics and land use patterns (e.g., urban/suburban sprawl), the future of many of these privately owned prairie remnants is uncertain.

Figure 3.3.2 illustrates the loss of original (pre-European influence, i.e., plowing) Missouri prairie (depicted in gray) to plowed agricultural land (depicted in pink). The plowed lands do not cover 99.5 percent of the original prairie area because much of the original prairie area shown as unplowed has been converted to nonnative tallgrass fescue, which contributes very little benefit to native species and resource conservation. Regarding cropland expansion, the conversion and loss of grasslands has accelerated in the last 10 years as commodity prices peaked in 2009/2010 and CRP acres expired and were converted back to corn and soybeans. This most recent grassland loss is a mixture of native remnant prairie, cool-season (primarily fescue) pastures, and CRP fields. This loss in turn is greatly impacting grassland species, especially songbirds and pollinators.

Private landowners play a key role in protecting, restoring, and managing imperiled prairie systems, from the sand prairies of southeast Missouri to the loess hill prairies of northwest Missouri. Missouri has state and federal programs, resources, and expertise to help those landowners manage and restore their native grasslands.

Figure 3.3.2 – Great Plains Plowprint Map (Illustrating Tilled/Plowed Ground)

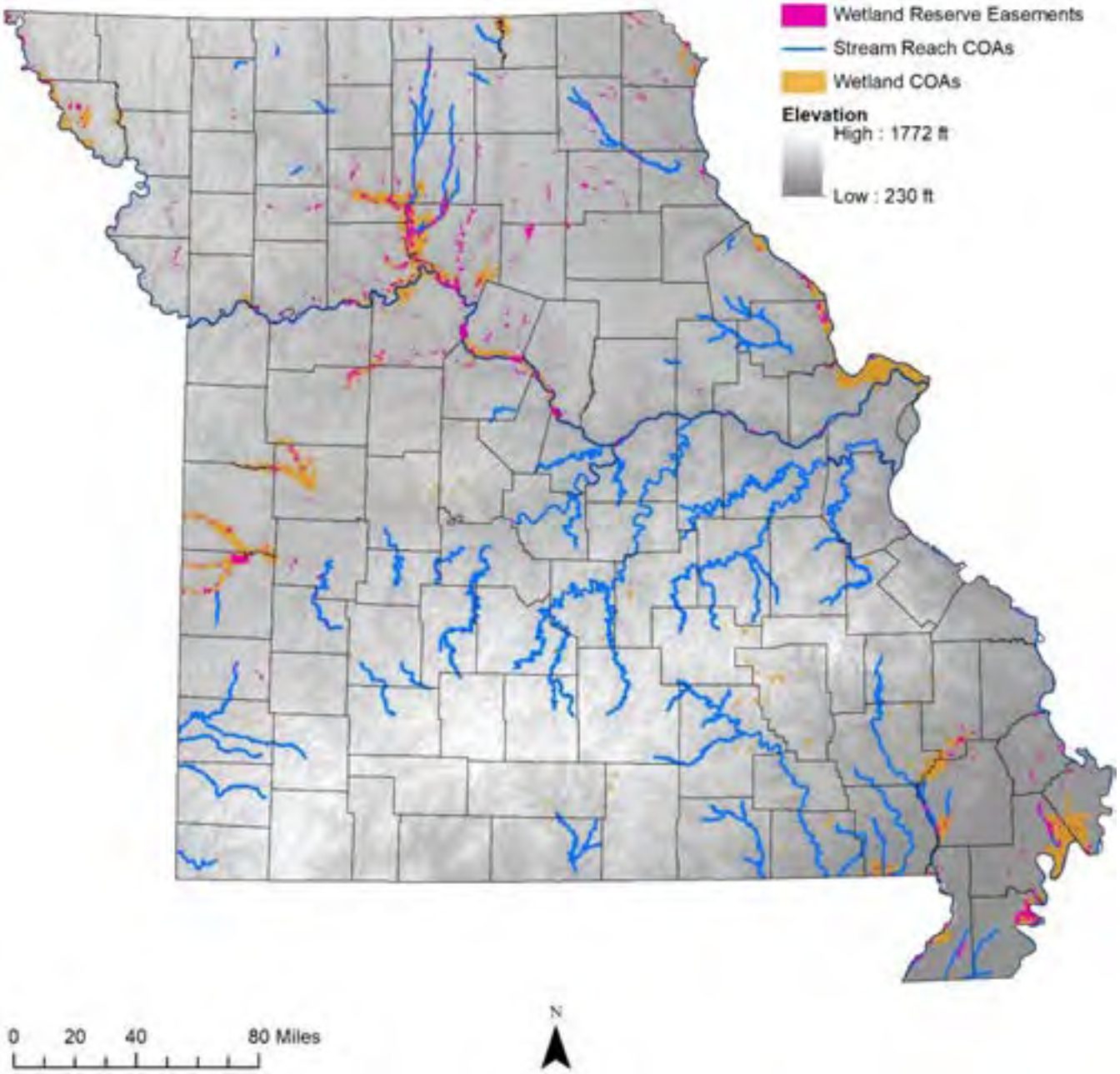


Wetlands

Prior to the 1990s it was estimated that less than 2.5 percent of Missouri's original 4.8 million acres of wetlands remained, and those that did consisted primarily of small, difficult to drain wetland remnants in the floodplains along major rivers. Recognizing the severe implications of the loss of America's wetlands, actions in the early 1990s helped slow the loss and created programs to restore wetlands on a large scale. A very successful program for Missouri wetland restoration and/or reconstruction has been the USDA's Wetland Reserve Easement Program (WRE). To date, this program has restored or created over 184,000 acres of privately owned wetlands in Missouri. These wetlands provide multiple benefits (ecosystem services), including denitrification, flood control, sediment retention, and fish and wildlife habitat. Wetland biologists assisting with the program have ensured that these wetland restorations benefit a diversity of fish and wildlife. For example, in 2018 the MRBO documented over 37,000 birds of 190 species on a sample of 17,600 acres of WRE marsh habitat, including several SOCCs, such as king and virginia rails and American bittern.

WRE has proven to be a valuable tool in helping Missouri partners address resources in several PGs and wetland COAs. The following heat map (**Figure 3.3.3**) shows WRE easements amassed across Missouri and their concentration and high alignment with Missouri's key focal wetland landscapes (COAs).

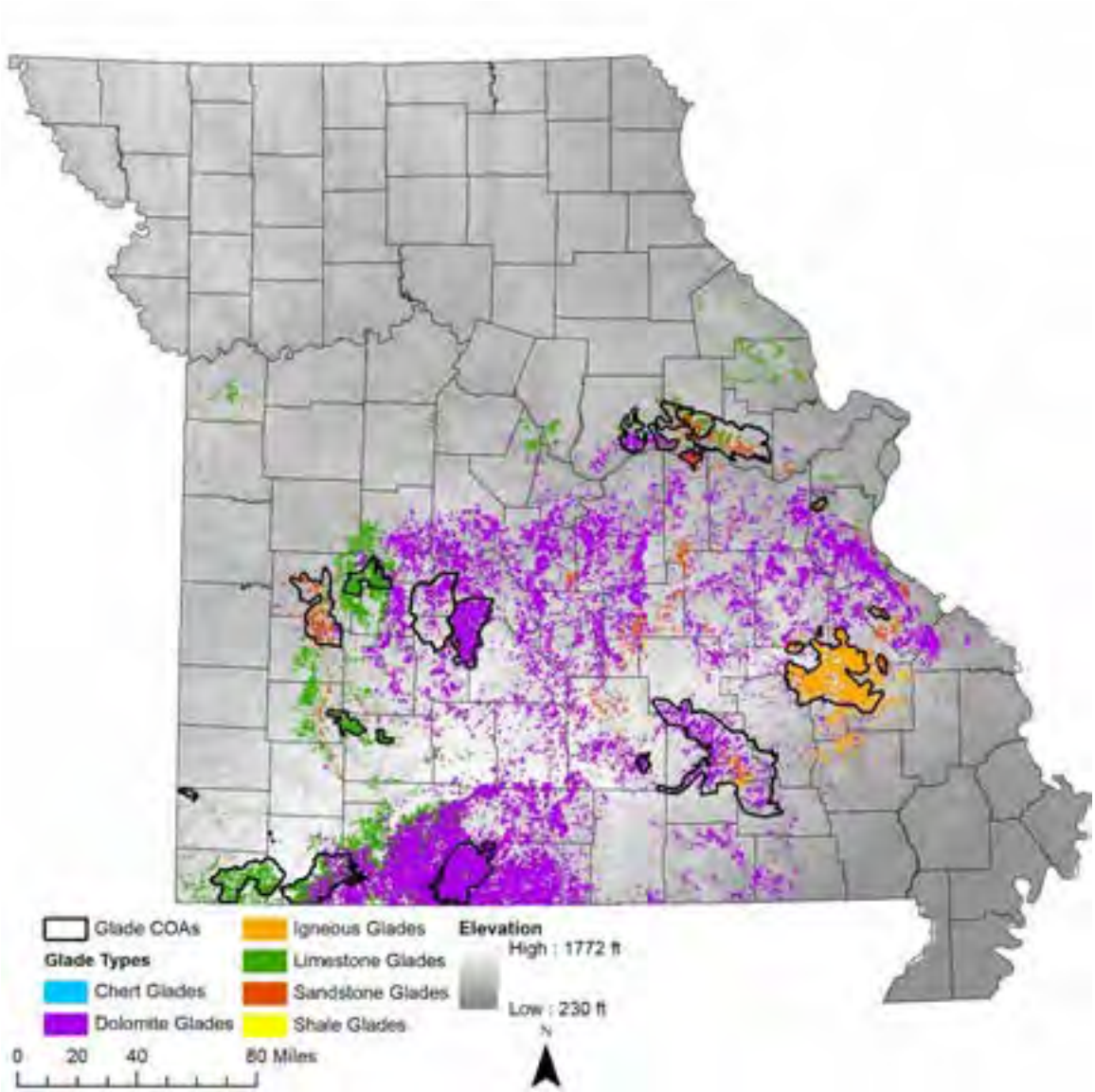
Figure 3.3.3 – Missouri Wetland Reserve Easements (1993–2017)



Glades

Over 180,000 acres of glades have been identified via a combination of remote sensing and ground truthing across Missouri (Nelson 2018). Of these, 63 percent occur on privately owned lands. There are tremendous opportunities for glade restoration on private lands in Missouri and, given that many landowners have interest in wildlife habitat enhancements, glade restoration is often a project they can undertake at a reasonable cost and with a quick community restoration response time. Glade restoration opportunities are often associated with woodland restoration potential as well (see next subsection). Opportunities for glade restorations are covered in both state and federal cost-share programs to help address this habitat in priority landscapes.

Figure 3.3.4 – Missouri Glade Types and Locations (Note: Glade boundaries have been greatly exaggerated to illustrate general areas of concentration at a statewide scale.)



Forests and Woodlands

It's estimated that Missouri was blanketed by approximately 30 million acres of wooded land (consisting of at least some tree coverage, ranging from sparse to dense) in the 1600s. This was approximately two-thirds of the land area of the state. In 1907, nearing the end of the major part of the great timber liquidation harvest in the Missouri Ozarks, forest and woodland area in Missouri had declined to a little over 17 million acres. Forest and woodland area continued to wane until reaching the ultimate low of 12.5 million acres in 1987 (Oswalt et al. 2014). Much of the continued reduction in forest and woodland was due to attempted agriculture on very marginal lands, which had been opened up by the initial timber removal. Specifically, the reduction in forestland between 1963 and 1977 was a result of the conversion of woodland to pasture and thinning other wooded areas to a low enough density to let some grass and forbs grow for livestock grazing, as well as conversion of many bottomland forests to row crop production. Other factors included highway rights-of-way, urban and suburban development, and recreation (Spencer and Essex 1976).

Forest and woodland area began to rebound in the late 1980s. The increase continued until the late 2000s when the 2012 statewide forest inventory by the USFS's Forest Inventory and Analysis (FIA) Program showed approximately 15.5 million acres of wooded land in the state, then it plateaued off with the 2019 inventory showing 15.3 million acres of forest and woodland acreage (USFS FIA 2020). The story is shown graphically in **Figure 3.3.5**.

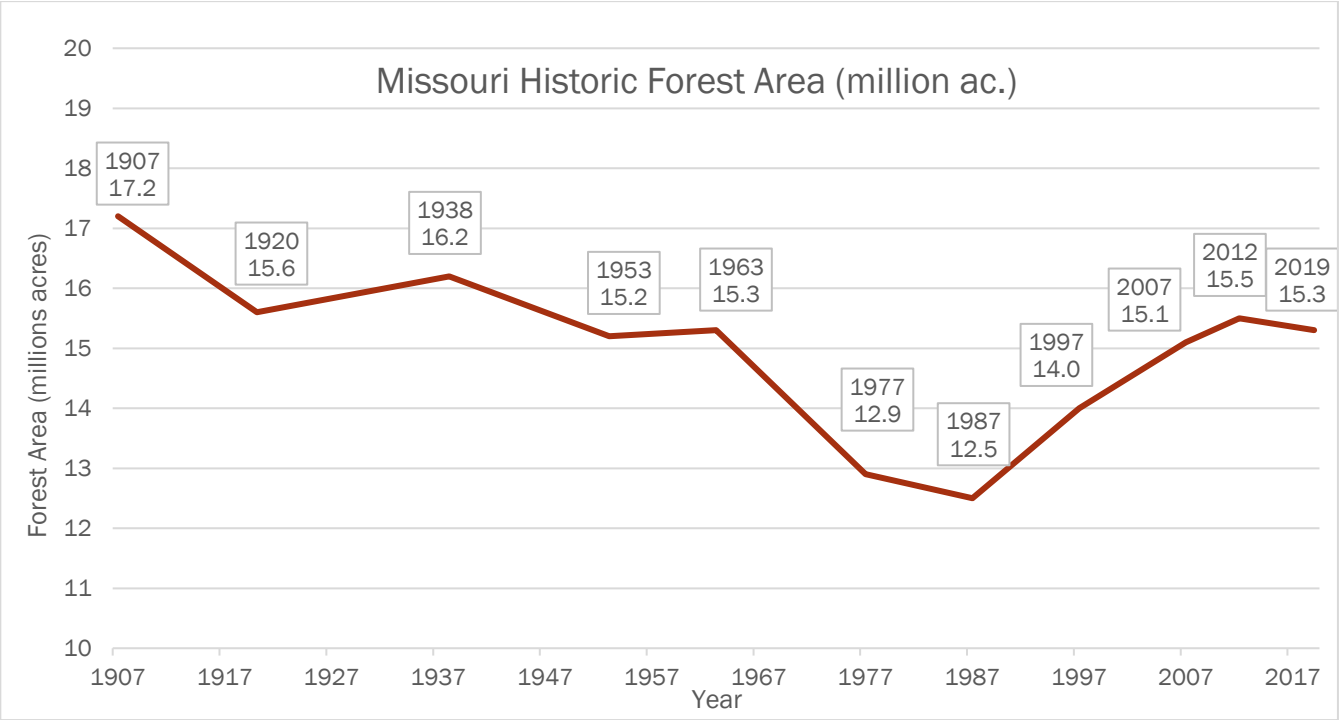


Figure 3.3.5 – Missouri Historic Forest Area (Oswalt et al. 2014, USFS FIA 2020)

Some land use changes are reversible over time. For example, trees can be removed from a woodland to create pasture; but then later that pasture can be abandoned and will usually return to a wooded condition in time. Other types of land use change are more permanent. Chief among these is the conversion of forestland (as well as other natural communities) to urban

development. **Table 3.3.1** illustrates this concept for the period from 1982 to 2015 when approximately 306,000 acres of forests and woodlands were converted to urban developed (built-up) land, with only 2,400 acres returning to forest from urban for a net loss of forest of 303,800 acres.

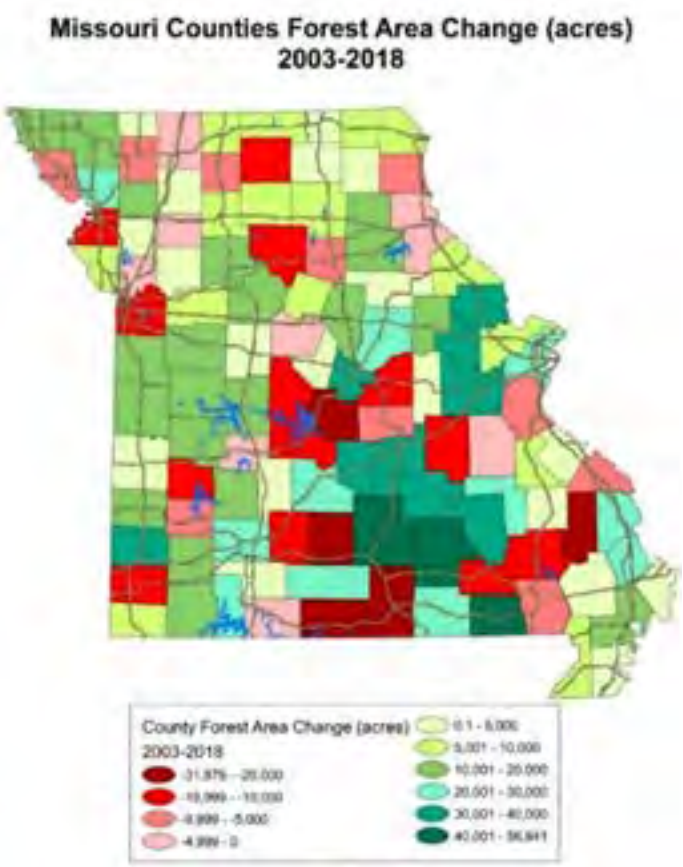
Table 3.3.1 – Missouri Land Use Change (1,000s of acres), 1982–2015

Land Use	Forest Lost To	Forest Gained From	Net Change
Pasture Land	498.9	1,799	1,300.1
Crop Land	117.3	236.2	118.9
Urban Built-up	306.2	2.4	–303.8

(Source: NRCS, National Resources Inventory)

From 1997 to 2012 the total forest and woodland area in Missouri increased by 1.5 million acres to 15.5 million acres (Oswalt et al. 2014). Changes like this usually do not happen uniformly across a state. This is demonstrated by **Figure 3.3.6**, which shows forest and woodland change in acres per county from 2003 to 2018. Note that there were "winners" and "losers" during this time. Some counties gained forest and woodland, and some incurred loss. Some of the factors causing the change are shown in **Figure 3.3.6**.

Figure 3.3.6 – Forest Area Change by County



(Source: USFS FIA 2019)

Until 1924, when Missouri's first state park was established at Big Spring, all of Missouri's forestland was privately owned. In 1938, the Missouri Conservation Commission purchased its first forested property, Rockwoods Reservation, near St. Louis; and in 1939 the Clark National Forests and MTNF were established. Public lands play a large role in Missouri's modern society, providing many benefits for all citizens. However, they only contain 18 percent of the state's forests and woodlands, with the clear majority (82%) on private lands.

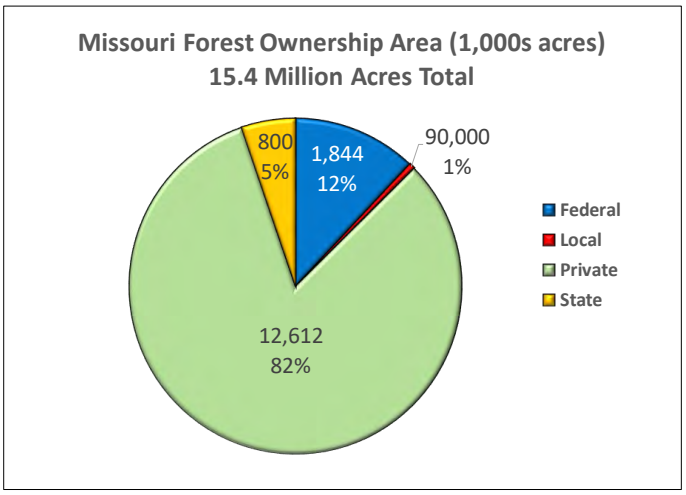


Figure 3.3.7 – Missouri Forestland Ownership
(Source: USFS FIA 2019)

Missouri's Private Forest Landowner Statistics and Trends

The USFS periodically conducts a survey of the nation's private forest landowners called the National Woodland Owner Survey (NWOS). This survey provides valuable insights into demographic and private land parcel trends. While this information is specific to forest and woodland, similar trends are being observed across the state in other Missouri natural community types as well. Much of the following information regarding Missouri's private forest landowners comes from NWOS conducted in 2006 and 2013. The most recent survey was conducted in 2018, but finalized data is not available from it at this writing (2020).

Figure 3.3.8 shows the acreage of Missouri's private family forestland by the size of the ownership, comparing values from 2006 and 2013 within each ownership size class. Change between the two survey dates is evident, particularly in the smaller ownership classes. There are noticeable increases in the amount of land in the 1–9 and 10–19 acres classes, with a corresponding decrease in acreage in the 20–49-acres class. This phenomenon is known as parcelization, and it has a significant impact on some forest and other natural community management practices. For example, landowners typically need to own at least 30 acres of woods to make a timber harvest commercially viable. In this way, parcelization influences the amount of raw materials available to support Missouri's forest products industry. Similarly, as tracts get smaller it can make the use of prescribed fire increasingly impractical. As management tools such as timber harvesting and prescribed fire are made unavailable, it becomes increasingly difficult to create or manage certain types of wildlife habitat.

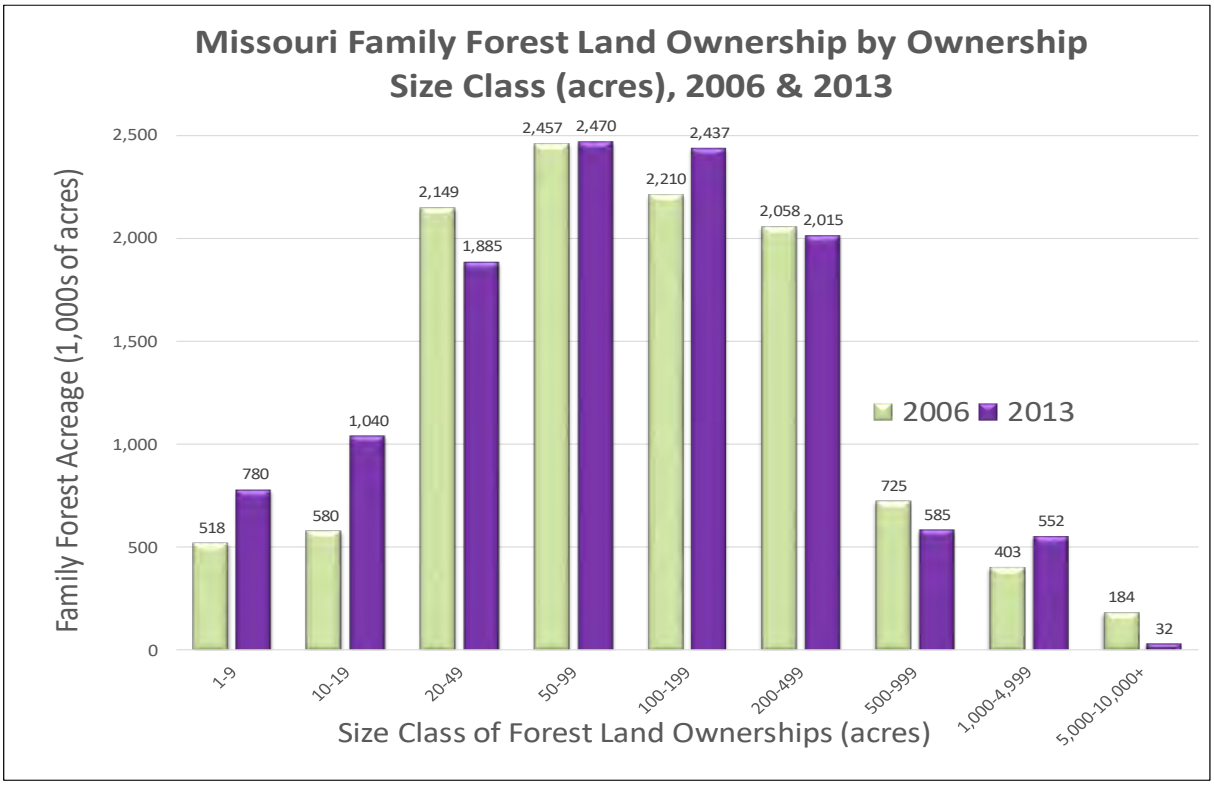


Figure 3.3.8 – Family Forest Ownership by Ownership Size Class, 2006 and 2013
(Source: USFS, Northern Research Station, NWOS)

Another effect of parcelization is the sheer numbers of landowners it creates and, with this, an increase in the variability among landowner beliefs toward land use and management. **Figure 3.3.9** illustrates this point. The number of family forest landowners in Missouri increased from 328,000 to 438,000 between 2006 and 2013. The category of landowners owning less than 10 acres alone increased by about 90,000 people.

Over 50 percent of Missouri's family forest landowners own less than 10 acres each, jumping up 10 percent between surveys. If the two smallest ownership classes are added together, over 70 percent of Missouri's family forest landowners own less than 20 acres, while owning just over 15 percent of the private forest.

The large group of small landowners creates both a problem and an opportunity. The problem lies in trying to communicate with and serve a large group of people (approximately 306,000 landowners) who control only 15 percent of the resource, much of which is very difficult to manage due to its small size. Understanding these landowners and figuring out how to communicate with them cost effectively and then meet their needs is a pressing concern.

The opportunity comes from having an increasing number of people in closer contact with forest and woodlands who can be engaged and can engage in forest and woodland conservation.

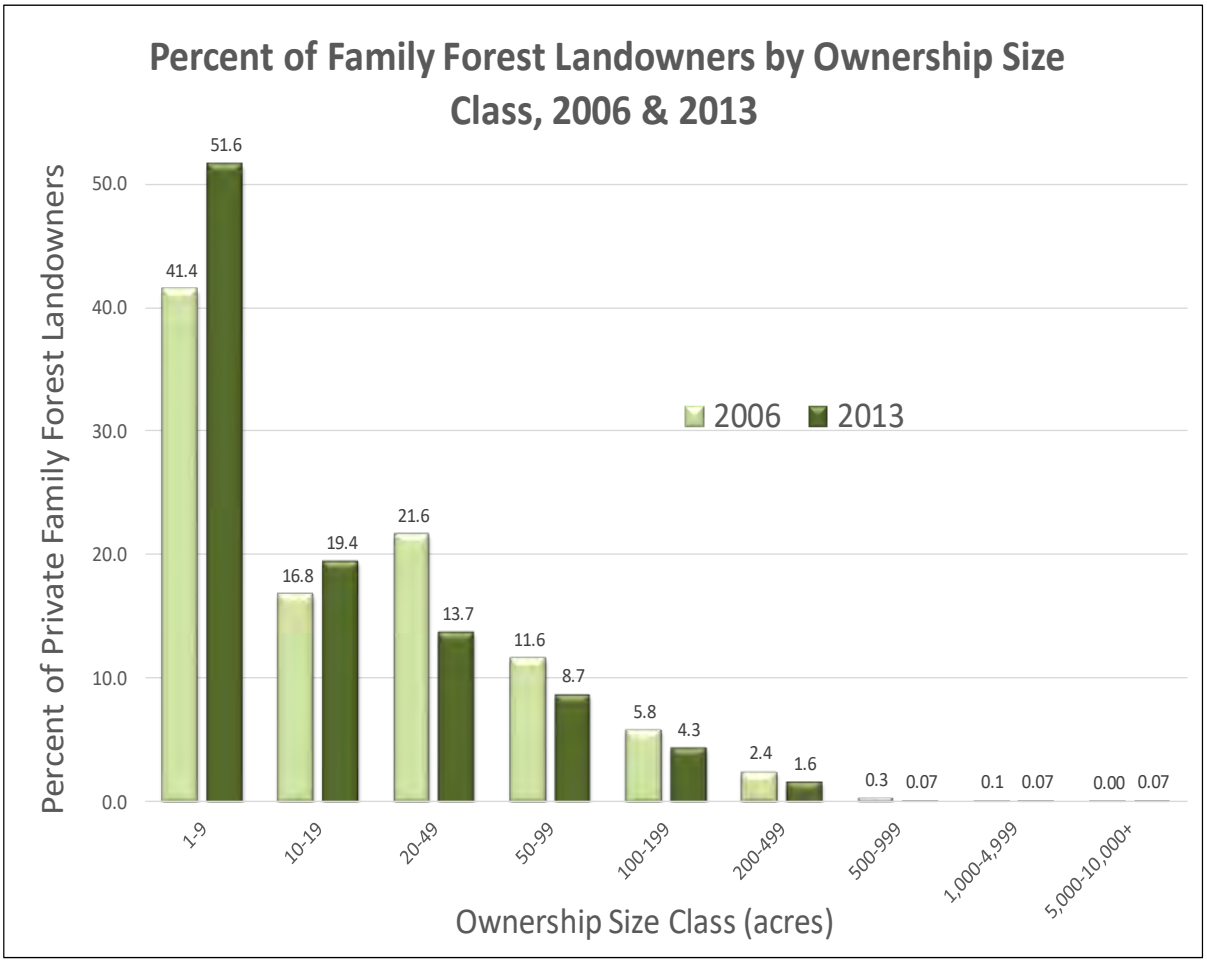


Figure 3.3.9 – Proportion of Family Forest Landowners by Ownership Size Class
(Source: USFS, Northern Research Station, NWOS)

Reasons for Owning Wooded Land

Given the role private landowners play in managing Missouri's forest resource (and other natural communities) it is helpful to know why they own their land and what their goals are. NWOS helps answer this by asking landowners what their reasons are for owning forest/wooded land (results provided in **Table 3.3.2).** One particular insight from the results is that relatively few landowners own their land for timber production purposes. Many of these family forest owners have little knowledge and experience with the timber sale process, even among those who indicate that as a reason for owning their land. It is important to have sources of information and advice about timber sales readily available and easy to tap into when an unforeseen life event pushes a landowner toward the possibility of a timber sale on their land.

Table 3.3.2 – Landowner Reasons for Owning Wooded Land, 2013

Landowner Reasons for Owning Forest/Wooded Land	% of Landowners[7]
To enjoy beauty or scenery	77
To protect or improve wildlife habitat	72
For privacy	71
To protect nature/biological diversity	68
To pass land to children/heirs	62
Is part of home site (primary residence)	61
To protect water resources	59
For land investment	52
For hunting	48
To raise my family	46
For recreation other than hunting	46
Is part of my farm or ranch	37
For firewood	29
For timber products	18
Is part of my cabin or vacation home site	13
For nontimber forest products	9
Other	18

(Source: USFS, Northern Research Station, NWOS)

Table 3.3.3 goes a step further to indicate what activities private forest landowners actually do or plan to do on their properties. In combination, **Tables 3.3.2** and **3.3.3** help reveal landowner intentions, motivations, how natural resource professionals can most effectively work with private landowners, and how private landowners may shape Missouri's forest resources and other natural communities in the future.

7. Items ranked as "Very Important" or "Important" by the landowner. More than one item could be chosen per ownership.

Table 3.3.3 – Forest Management Activities – Accomplished and Planned, 2013

Type of activity	Past 5 years activities, % of owners	Next 5 years planned activities, % of owners
Cut and/or removed trees for sale	13.6	12
Cut and/or removed trees for own use	51.7	53.7
Collected nontimber forest products	16.3	22.6
Reduced fire hazard	11.6	24.3
Controlled burn/prescribed fire	14	17
Eliminated or reduced invasive plants	26.2	32.7
Eliminated or reduced unwanted insects or diseases	5.7	25.1
Road construction or maintenance	11.6	17.9
Trail construction or maintenance	17	29.2
Improved wildlife habitat	22.9	48.6
Livestock grazing	26.4	32
None of the above	19.7	13.6

(Source: USFS, Northern Research Station, NWOS)

Urban Sprawl and Landscape Fragmentation

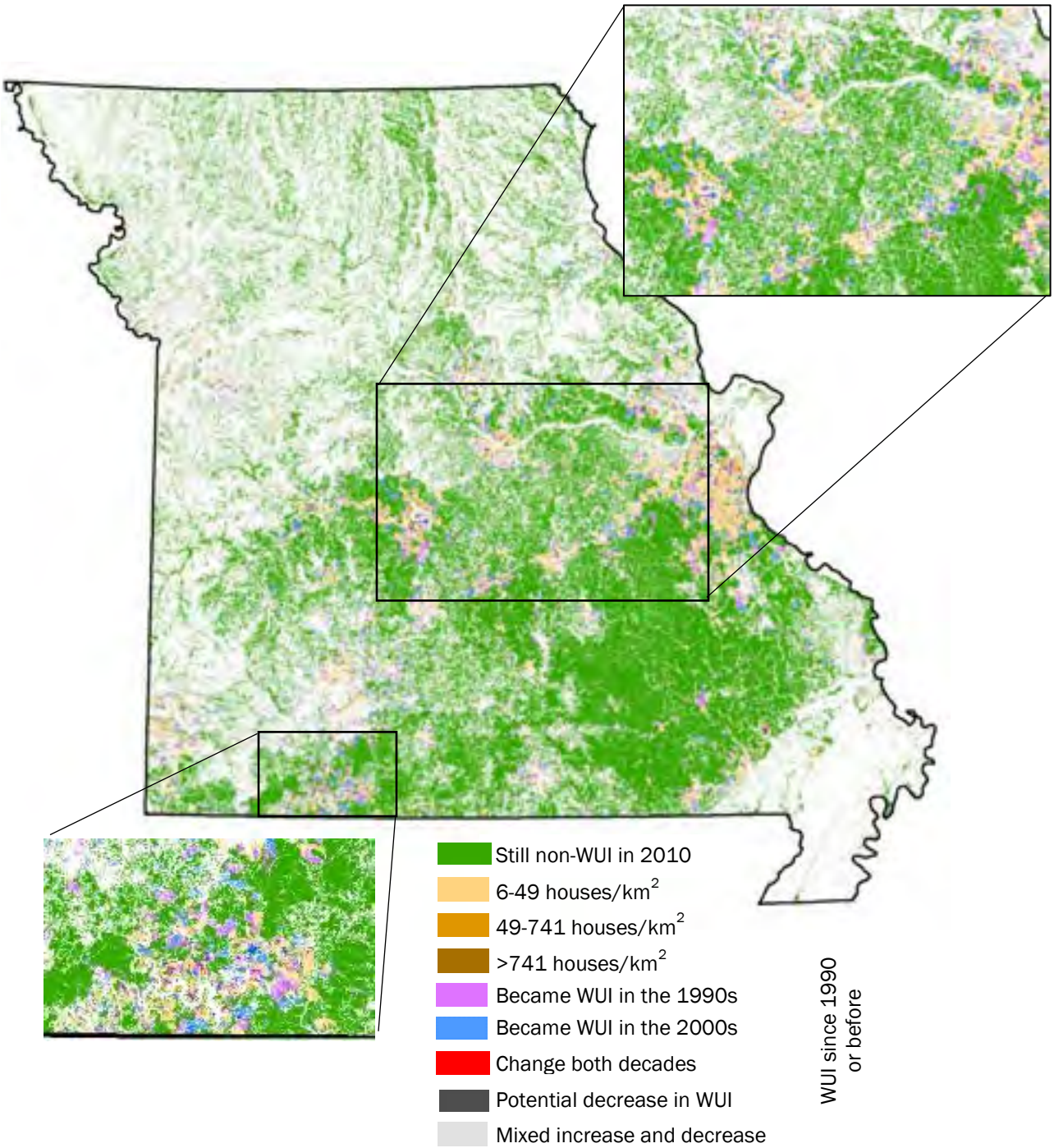
Natural community conversion results in landscape fragmentation. Landscape fragmentation refers to the breaking up of larger blocks of intact habitat into smaller disconnected patches; and the increase of habitat edge created when nonnatural community land uses intrude into previously intact communities and landscapes (e.g., new roads, residences, etc.). Most modern fragmentation is caused by residential and commercial development, expansion of utility infrastructure and transportation networks, and expansion of agriculture.

Some of the negative impacts of landscape fragmentation include increased stressors and potential decline of species requiring large continuous blocks of habitat, such as greater prairie chickens or Cerulean warblers; increased vulnerability to insect and disease pests (e.g., oak wilt); introduction of aggressive opportunistic species like brown-headed cowbirds, which thrive on forest and woodland edges; and introduction of invasive exotic plant species such as sericea lespedeza, spotted knapweed, Callery pear, and bush honeysuckle. Fragmentation can also change species behavior and cut off migration corridors for flora and fauna – such corridors are becoming increasingly important, given projected changes in climate. Habitat fragmentation also increases the frequency of negative encounters between people and wildlife such as vehicle collisions and wildlife damage to crops and landscaping.

Figure 3.3.10 shows Missouri's forested WUI, revealing the transition over time through 2010 (the last U.S. census). Areas in tan have been considered WUI prior to the 1990s, areas in

purple became WUI in the 1990s, and areas in blue became WUI in the 2000s. The map enlargements show this data at a closer scale for areas west of St. Louis and in the Branson/Table Rock Lake area of southwest Missouri, which have seen significant transitions.

Figure 3.3.10 – Forested WUI Progression Over Time, 2010



Use of Natural Resource Professionals

Across the state, conservation partners conduct approximately 15,000 site visits a year, developing around 8,000 conservation plans for a variety of Missouri landowners and habitat types. Landowners whose main source of income is derived from the farm have traditionally been difficult for conservation partners to engage. As indicated by the Duke University study (Bonnie et al. 2020) it is important to engage and collaborate with these landowners. In Missouri that is key, because agricultural producers manage large amounts of the state, including priority conservation landscapes.

According to NWOS, 5.4 percent of Missouri's family forest and woodland ownerships have a plan for their woods. Approximately 31 percent of those plans were produced by a qualified forester. That works out to just 1.7 percent of all family forest and woodland ownerships larger than 10 acres (7 percent of family forest/woodland area) having a forester-written plan.

NWOS also conveys that approximately 11 percent of family forest and woodland owners who have had a timber sale at some point since they've owned their woodlands used a professional forester during their timber sale process. This equates to approximately 17,000 landowners who control 1.3 million acres of forest and woodland.

These statistics show that there is much work to be done in making natural resource professionals available to private landowners and increasing their utilization. Especially in forests and woodlands, management decisions can have significant impacts to the landscape for one hundred years or more. Having trained professionals who can help guide these decisions is key to ensuring Missouri's natural landscape remains as healthy and productive into the future as possible.

Landowner Succession

At the beginning of this chapter we gave a glimpse of the demographics of Missouri's agricultural producers by pointing out that only 9 percent are under the age of 35. NWOS shows similar trends for Missouri's family forest landowners. **Table 3.3.4** shows the age distribution of Missouri's forest landowners in 2006 and 2013 as a proportion of the acreage of privately owned forestland, and as a proportion of private forest and woodland landowners. In 2013, 17 percent of Missouri's family forest acres are owned by people over 75 years old, and 74 percent are owned by landowners over 55 years old.

Table 3.3.4 – Missouri Family Forest Landownership, by Age Group, 2006 and 2013

Age Group	2006 Survey Acres %	2013 Survey Acres %	2006 Survey Owners %	2013 Survey Owners %
<45	11	7	12	10
45–54	20	19	19	19
55–64	28	32	28	32
65–74	24	25	22	19
75+	18	17	19	19

(Source: NWOS)

As tracts of private land, including those managed with natural resource professional assistance, are passed on to heirs or sold to new owners, any changes in the way they are managed could affect us all. Management decisions affecting natural systems may have profound implications for soil health, clean air and water, fish and wildlife habitat and native species populations, aesthetics, production of forest products, and numerous other services.

While most landowners share a deep respect for their land and a desire to do "the right thing," many may not know just what this means or how to go about achieving their goals. Important keys to guaranteeing the future improvement and sustainability of Missouri's natural communities and native species include ensuring that landowners have easy access to professionals and programs that can help them achieve conservation goals as well as offer financial and technical assistance to make conservation management reasonably attainable, all while protecting the landowner's bottom line.

Theme Four: Missouri's Public Lands Managed for the Greatest Public Good

In a nutshell: Public lands and other protected lands are important assets that are highly valued by society. Beyond the normal benefits and services provided by Missouri's natural landscape, acres under public ownership are especially important because they are managed under agency mandates for wildlife, recreation, water quality, regenerative production of forest products, and other public conservation values. Public lands offer many of Missouri's best opportunities to protect and enhance these values and ensure they persist into the future. Sustaining or improving the benefits of public lands requires maintaining sufficient funding for management and staffing; carefully balancing the diverse demands of society; and meeting the management needs of healthy, resilient natural communities.

Desired Future Conditions

1. Public lands are managed appropriately to provide multiple benefits (recreation, wildlife habitat, ecosystem services, watershed protection, timber, aesthetics, etc.).
2. Public lands are inviting and provide convenient and desirable opportunities to enjoy nature and the great outdoors.
3. Citizens are aware of public lands and their importance and availability.
4. Public lands provide sufficient infrastructure (e.g., parking lots, trails, etc.), which can be maintained efficiently and sustainably.
5. Public land management serves as a model for private landowners to view sustainable or regenerative management practices and outcomes.
6. Citizens understand the need to actively manage public lands (e.g., forest thinning, invasive species control, prescribed fire) to improve and maintain their health and benefits.

The clear majority of Missouri's landscape is privately owned. Only 6.6 percent of Missouri's acres are in public ownership for conservation purposes, and 83 percent of these public conservation lands are wooded. The rest is a mix of wetlands, grasslands, cropland, rivers, lakes, and miscellaneous other habitats.

Though comprising a relatively low percentage of the state, publicly owned lands are one of Missouri's most important and valuable resources and are treasured by Missouri citizens. This is well demonstrated by Missouri's 2013 Conservation Opinion Survey, which reveals that 47 percent of Missouri citizens feel MDC does not own enough land, 28 percent weren't sure if MDC owned enough land, 23 percent felt MDC owned the right amount of land, and only 2 percent felt MDC owned too much land. The same survey concluded that 89 percent of Missouri citizens feel it is important for outdoor places to be protected even if they don't plan to visit the area, and that 71 percent of Missouri citizens feel additional land should be acquired in Missouri for fish, forest, and wildlife conservation (Rikoon et al. 2014).

Public lands are protected and managed for a wide variety of public values, including wildlife habitat, outdoor recreation, regenerative production of forest products, clean water and air, scenic beauty, and much more. Unfortunately, Missouri's public lands and natural resources face many threats including existing and emerging insect and disease issues; an ever-growing expansion of invasive plants; feral hogs; aging infrastructure paired with increasing demand for outdoor recreation opportunities; aging forests; lack of disturbance in natural communities that depend on fire; a lack of adequate staffing; and more. Ensuring Missouri's public lands continue to provide the benefits we expect of them will require continued management, diligence, and investment.

Recommended BMPs for healthy and regenerative public lands that can continue to meet public demands into the future include:

- Maintaining, restoring, or enhancing the biodiversity of natural communities
- Managing productive forests that are diverse in age, canopy structure, and species composition
- Encouraging public and community involvement
- Promoting science and research to improve natural community management practices
- Protecting important values such as water quality and wildlife habitat
- Protecting lands with ecological, geological, historical, or cultural significance
- Providing convenient and desirable recreational opportunities
- Providing adequate staffing to ensure public lands are managed for the greater good

Who Owns Missouri's Public Lands?

Missouri's publicly owned lands are held and managed by several different public agencies. All these agencies have slightly different missions and management protocols. This administrative "diversity" helps ensure that a wide variety of opportunities, benefits, and services are derived from public lands, but all these agencies highly value healthy natural communities and ecosystem improvement and sustainability. Below, **Figure 3.4.1** and **Table 3.4.1** show the distribution of public conservation lands in Missouri owned by state and federal agencies and a brief description of each of these agencies. Local governments own and manage some conservation lands in Missouri as well, but the acreages they cover are relatively small compared to state and federal lands, so they are not included in this summary.

Though not publicly owned, some nonprofit conservation organizations own private lands for conservation purposes and make them available for a variety of public use benefits (e.g., L-A-D

Foundation, MPF, Ozark Land Trust, TNC). These private lands are critical to the integrity of Missouri's conservation network and to the health and connectivity among key conservation landscapes.

Figure 3.4.1 – Map of Missouri's Publicly Owned Lands

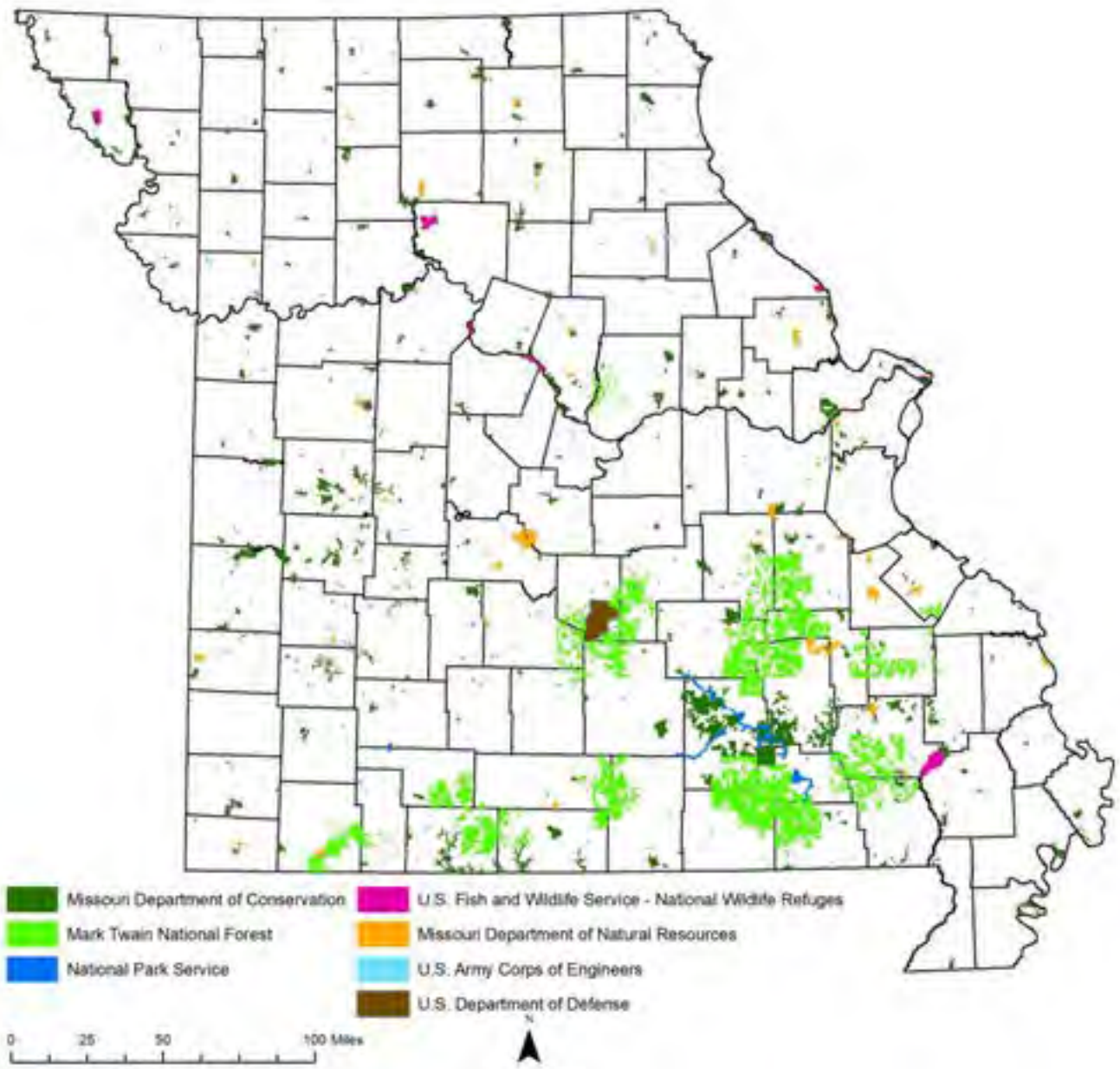


Table 3.4.1 – Public Land Acreage Owned/Managed by Public Agency

Public Agency	Total Acres
USFS – Mark Twain National Forest	1,507,540
MDC – Conservation Areas	1,028,657
MDNR – State Parks	153,693
NPS – Ozark National Scenic Riverways	85,126
U.S. Deptartment of Defense	84,450
USFWS – National Wildlife Refuges	71,085
USACE	28,888
Total	**2,959,439**

- The **USFS's Mark Twain National Forest** encompasses 1.5 million acres of public land in 29 counties in Missouri divided into six ranger districts. Each district includes a concentration of several tracts with various in-holdings scattered throughout. The USFS mission is to "sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations" (USFS 2020c). To advance this mission MTNF strives to "maintain a healthy, working forest and restore Missouri's natural communities" (USFS 2020b).

- The **Missouri Department of Conservation** manages over 1,025,000 acres across the state. These areas vary widely – from stream accesses of 1 or 2 acres to large conservation areas of >40,000 acres. The MDC mission is to "protect and manage the fish, forest, and wildlife resources of the state and enhance their values for future generations; to serve the public and facilitate their participation in resource management activities; and to provide opportunity for all citizens to use, enjoy, and learn about fish, forest, and wildlife resources" (MDC 2020).

- The **Missouri Department of Natural Resources** manages 91 **State Parks** and **Historic Sites** scattered across the state with more than 150,000 acres available to the public. The mission of the MDNR State Park System is to "preserve and interpret the state's most outstanding natural landscapes and cultural landmarks, and to provide outstanding recreational opportunities compatible with those resources" (MDNR 2020).

- The **National Park Service** (NPS) manages the 85,000-acre **Ozark National Scenic Riverways**, which includes significant stretches of Jacks Fork and Current Rivers and adjacent forestlands. The NPS mission is to "preserve unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations. NPS cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world" (NPS 2020a). Ozark National Scenic Riverways was created by an act of Congress on August 27, 1964, to protect 134 miles of the Current and Jacks Fork Rivers in the Ozark Highlands of

southeastern Missouri. Ozark National Scenic Riverways was the nation's first "scenic riverways" (NPS 2020b).

- The **U.S. Department of Defense – Army Environmental Command Program** "supports military readiness by helping to shape the training mission landscape and by providing superior and sustainable training opportunities for America's warfighters. Army forests are recognized as an integral part of Army training lands, supporting the mission while providing biological diversity, wildlife habitat, air and water quality, soil conservation, watershed protection, and recreational opportunities."[8] In doing so, they "advance their mission of Delivering cost-effective environmental services globally to enable Army readiness and vision of Providing premier environmental solutions for our Army and nation" (U.S. Department of Army 2020). The Army's largest public landholding in Missouri is Fort Leonard Wood.

- The **U.S. Forest and Wildlife Service** manages nine **National Wildlife Refuges** in Missouri. The Mission of USFWS's National Wildlife Refuge System is to "administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans" (USFWS 2020a).

- The **U.S. Army Corp of Engineers** owns and manages numerous lakes in Missouri, including adjacent forestlands, and owns several major river bottomlands, some of which are leased to MDC. The Civil Works Operations Division Mission of the U.S. Army Corp of Engineers includes "Serving the public by providing the Nation with quality and responsive development and management of the Nation's water resources; supporting commercial navigation; restoration, protection and management of aquatic ecosystems; flood risk management; and engineering and technical services in an environmentally sustainable, economic, and technically sound manner with a focus on public safety and collaborative partnerships" (USACE 2020).

Public Perception of Public Land Management Activities

Although public land agencies conduct natural community management activities (e.g., prescribed fire, timber harvests, controlling invasive plants) and make infrastructure management decisions for important, well-thought-out reasons, these reasons are not always obvious to and understood by the public. It is essential that public land managers clearly communicate to citizens regarding the need for conservation management, the expected timeframes and outcomes of the management, and provide opportunity for public feedback. For example, when conducted in a sustainable or regenerative manner, harvesting trees can help restore critical habitat for sensitive migratory bird species, improve forest health, and facilitate the regeneration of important tree species that need a lot of sunlight. These harvests also mimic historic disturbances such as wildfires, which

[8] This is not an official U.S. Department of Army Mission Statement. Instead, this information was provided upon request by Army Environmental Command as direction for their Forestry Program.

traditionally created the diverse habitat needed by many wildlife species. Without proper communication, citizens could assume that such harvests, especially regeneration harvests (sometimes referred to as clearcuttings), are simply being done to make money.

It is unlikely that every citizen will agree with every decision made by a public land management agency; but by maintaining an open dialogue, land management agencies can increase mutual understanding and respect with the public.

Balancing Competing Interests and Demands

One tricky aspect of managing public land in Missouri is that there are essentially over 6.1 million stakeholders (citizens), and each one may have a different vision for how public lands should be managed. Some people want more equestrian trails while others don't think there should be any. Some people want more timber to be harvested while others don't think any harvesting should be allowed. Some people want to have increased opportunities to hunt while others are adamantly opposed to it. Usually, there is a middle ground that can satisfy most people. However, it will never be possible to fully satisfy the interests of everyone. These competing demands underscore the importance of the previously described agency mission statements, which allow decisions to be based on and supported by predetermined guiding principles.

An example of an additional approach being employed by MDC to advance continuous improvement and build public trust is participation in the SFI forest certification program. Forest certification utilizes independent third-party audits to certify that lands are being managed sustainably by following agreed upon principles and standards of sound ecological, social, and economic management. These principles provide assurances such as forest health and productivity, protection and maintenance of water resources, conservation of biological diversity, protection of special sites, visual quality, and recreational benefits.

Funding, Staffing, and Availability

Land management agencies commonly have significant funding and corresponding staffing limitations. Funding requests for public land management are in competition with those from other programs and other agencies and organizations. This competition results in limits on the services and amenities that agencies can provide. Competition for, or insufficient funding, can also reduce the ability to complete important practices for improving the health and quality of habitat and can inhibit needed maintenance of existing infrastructure. Considering these factors, as well as public interest, it is critical that public agencies incorporate strategic work planning and develop and implement a prioritization scheme to inform resource allocation toward those efforts and landscapes offering the greatest return on investment.

Ensuring that all Missourians have reasonable access to public lands and outdoor recreation opportunities, and that these public lands continue to provide the public benefits demanded of them, requires adequate and sustained funding and staffing over time.

Public Lands – Key Pieces of a Complex Puzzle

Much of Missouri's biodiversity, including everything from monarch butterflies and bobwhite quail to elk and black bear, needs large areas of connected tracts of habitat to survive and thrive. State and federally owned conservation lands make up under 7 percent of Missouri's land area. Not all publicly owned lands provide quality habitat, and even those that do are scattered throughout the state. These fragmented habitats, as well as those of other conservation partners, are not enough to support and maintain Missouri's biodiversity. Quality, functional, and connected habitat on both public and private lands is the key to conserving the fish, forests, and wildlife resources in Missouri.

Theme Five: Climate Change

In a nutshell: Climate change is now widely recognized as a major threat to fish and wildlife and the natural communities on which they depend. Climate change is a particularly challenging threat because of the ways in which it may interact with other threats such as invasive species and disease, as well as the degree of uncertainty regarding the timing, seasonality, intensity, and sometimes even direction of the impacts that may occur as a result of a changing climate. If global climate change continues on the current trajectory, the world can expect to see a decrease in benefits provided by terrestrial, aquatic, and wetland ecosystem services, an increase in biome transformations, continued loss of range for many species, increased extinction rates, changes in ecosystem phenology, and an overall disruption of ecosystem functions and regulating services (Hoegh-Guldberg et al. 2018). While benefits provided by ecosystems services such as coastal buffers and clean air and water are continuing to degrade, the quality and quantity of value derived from wood and fiber, crop pollination, hunting and fishing, tourism industry, and cultural identities are all at risk of degradation as a consequence of the impacts of climate change (USGCRP 2018).

Photo credit: The Missouri Prairie Foundation's Schwartz Prairie. Photo by www.HenryDomke.com

Desired Future Conditions

1. Ecosystem services are improved or sustained as Missouri's natural communities successfully adapt to a changing climate.
2. Healthy natural communities and regenerative agricultural/working lands significantly contribute to mitigation of global climate change.
3. New scientific information, tools, and technology increase understanding of climate change impacts, adaptation and mitigation options, and risks and uncertainties.

A Closer Look at Missouri Climate Trends

On June 4, 2019, Pat Guinan, Missouri state climatologist at the University of Missouri–Columbia, gave a presentation entitled "Missouri Climate Trends and Future Possibilities" at an MDC-sponsored workshop on grassland management. Key points from his presentation include:

- Missouri's growing season has increased by approximately 2 weeks over the past 20 years with the occurrence of our last spring frost happening a week earlier combined with the first fall frost occurring a week later.
- Missouri's most recent warm annual temperature trend began in the mid 1980s and most notably, since 1998, where 15 out of the past 21 years (76%) have been above normal; 2012 was the warmest year on record.
- Seasonally, Missouri winters and springs have experienced the greatest warming trend; 20 out of the past 30 winters (67%) and 17 out of the past 21 springs (81%) have been above normal.
- Beginning in the 1980s an unprecedented wet period has evolved in Missouri. Since 1981, 23 out of 38 years (61%) have had above normal precipitation.
- Over the past few decades, all four seasons have witnessed more above normal precipitation years in Missouri.
- Over the past few decades, Missouri has witnessed an above normal trend in heavy (≥ 1″) and extreme (≥ 3″) daily precipitation events compared to the long-term average.
- The 2012 and 2017–2018 droughts resulted in numerous impacts, but they were both short-lived when compared to other historic droughts (i.e., 1952–1956).
- Extended dry and wet periods can change abruptly and there are numerous occasions where Missouri transitioned from one extreme to another in a short period of time.

Weather patterns in Missouri can be highly variable, both in precipitation and temperature. Missouri natural communities and native species have evolved with this variability and generally recover after significant weather events. However, several extreme weather events have taken place across parts of the state recently, including a massive ice storm in the southwest (2007), a derecho that leveled 113,000 acres of forest in the Ozarks (2009), one of the worst statewide droughts on record (2012), and record flooding in many locations (2015, 2017, 2019). The extreme flood events ravaged affected watersheds, causing severe erosion, substantial harm to riparian areas, immense gravel/alluvium deposition, and invasive species establishment in some areas. Collectively, these and other events have placed additional stress on Missouri's ecosystems, making it imperative that management decisions focus on creating healthy, resilient natural communities.

The National Oceanic and Atmospheric Administration's climate summary states that Missouri has experienced an increase in heavy rainfall events. This trend is projected to continue, which poses the threat of increased flooding along the many rivers and streams within the state. The damaging floods of 2019 provide a consummate example of this trend. Although an increase in rainfall is projected to continue, severe droughts are also projected to pose an increased threat. Droughts are a natural phenomenon of Missouri's climate. However, due to higher temperatures, increases in evaporation rates may increase the intensity of droughts. Increased rainfall and increased drought intensity pose threats not only to natural communities but also to Missouri's agriculture industry (Frankson et al. 2017).

Beginning in 2011 the USFS, Northern Research Station, began a project to incorporate climate change considerations into forest management for the Central Hardwoods Region, which includes the unglaciated forest regions of southern Missouri, Illinois, and Indiana. The assessment was published in 2014 (see Brandt et al. 2014) and included input from Mike Leahy and Steve Westin of MDC. The assessment evaluated the vulnerability of terrestrial ecosystems in the Central Hardwoods Region to a range of future climates. Key findings of the report include:

- Climate trends projected for the next 100 years by using downscaled global climate model data indicate a potential increase in mean annual temperature of 2 to 7 °F for this region.
- Projections for precipitation show an increase in winter and spring precipitation; summer and fall precipitation projections differed by model.
- Temperatures will increase (robust evidence, high agreement).
- The nature and timing of precipitation will change (robust evidence, high agreement).
- Model projections suggest that northern mesic species such as sugar maple, American beech, and white ash may fare worse under future conditions compared to current climate conditions, but other species such as post oak and shortleaf and loblolly pine may benefit from projected changes in climate. Changes in northern red, scarlet, and black oak differ by climate model.
- Mesic upland forests were determined to be the most vulnerable, whereas many systems adapted to fire and drought, such as open woodlands, savannas, and glades, were perceived as less vulnerable to projected changes in climate.
- Current major stressors and threats to forest ecosystems in the region include the following, which will be influenced and interact with a changing climate with uncertain results:
    - Fragmentation and loss of forest cover
    - Loss of historical fire regime in fire-adapted systems
    - Nonnative species invasion
    - Insects and disease
    - Loss of soil
    - Overgrazing and over-browsing
    - Reduced diversity of species and age classes
    - Lack of management on private lands
- Fish and other aquatic organisms are also expected to be affected by a combination of both direct and indirect climate change effects. Many fish species in the region are sensitive to even slight changes in water temperatures and experience negative effects on growth at extremely high water temperatures.
- Many migratory species, such as mallards and other dabbling ducks, rely on temperature cues to signal northward and southward migration each year. As temperatures warm and precipitation patterns change, some wildlife species may experience a shift in breeding and migration dates, as has already been observed for North American wood warblers.
- Many potential impacts on wildlife and their habitats remain unknown.

- The effects of climate change on cave-dwelling species are also unknown.
- Changes in climate will also create additional management challenges as conditions become more favorable for invasive plant species not currently prevalent in the assessment area.

Examples of how some species ranges could change as a result of climate change are depicted well by the USFS's Climate Change Tree Atlas (Prasad et al. 2014) and Climate Change Bird Atlas (Matthews et al. 2014), which show projected changes in climate condition suitability for several different tree and bird species. **Figures 3.5.1–12** include examples from these atlases for 2 tree species and 2 bird species. **Figures 3.5.1–3** show that climate conditions favorable to shortleaf pine could expand to a much larger portion of Missouri in the future (albeit depending on local soil conditions and competition) whereas **Figures 3.5.4–6** show that climate conditions supporting the dominance of white oak in Missouri could subside significantly. **Figures 3.5.7–12** show that the summer range of summer tanager could expand into a much larger portion of Missouri in the future whereas prime habitat for red-headed woodpeckers could shift farther to the north and occupy a much smaller portion of Missouri. These future projections are only models, which can't perfectly predict the future. Just because species suitability may change doesn't mean that the actual dominance (or lack thereof) will change to the same extent or on the same timeline. Such changes depend on many variables such as how long existing trees survive, whether better-suited tree species are in the vicinity and able to regenerate, etc. However, these models still give valuable insights into how Missouri's species and natural communities could change over time in the face of climate change if all other conditions (e.g., soils, aspect, competition, etc.) are favorable for their persistence.

Figure 3.5.1 – Present distribution of shortleaf pine

Figure 3.5.2 – Projected future habitat suitability of shortleaf pine (high emissions models averaged)

Figure 3.5.3 – Projected future habitat suitability of shortleaf pine (low emissions models averaged)

Figure 3.5.4 – Present distribution of white oak

Figure 3.5.5 – Projected future habitat suitability of white oak (high emissions models averaged)

Figure 3.5.6 – Projected future habitat suitability of white oak (low emissions models averaged)

Figure 3.5.7 – Present summer range for summer tanager

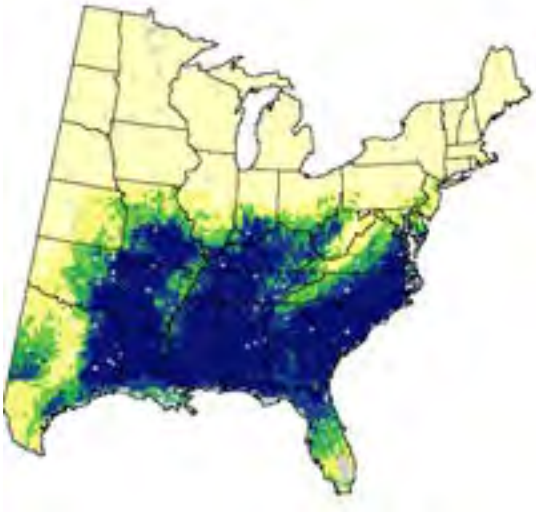


Figure 3.5.8 – Projected future summer range suitability for summer tanager (high emissions models averaged)

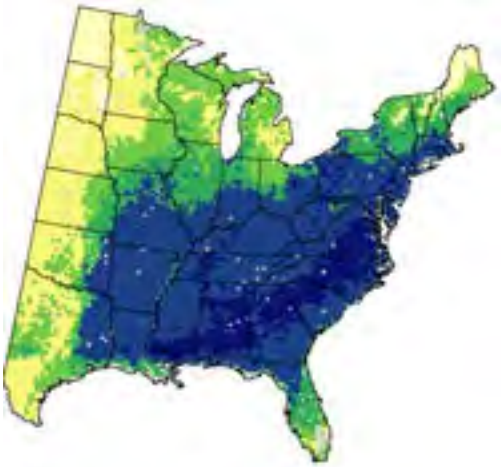


Figure 3.5.9 – Projected future summer range suitability for summer tanager (low emissions models averaged)

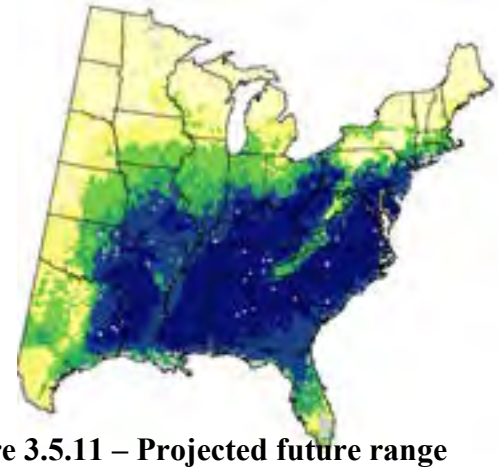


Figure 3.5.10 – Current range for red-headed woodpecker

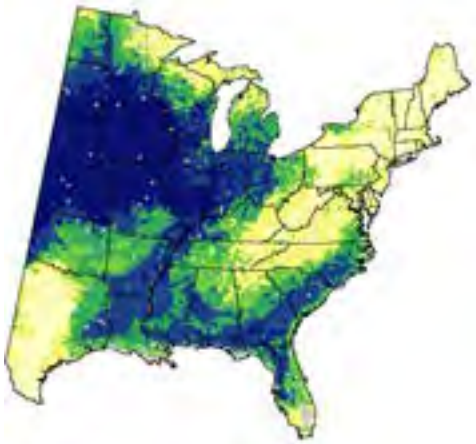


Figure 3.5.11 – Projected future range suitability for red-headed woodpecker (high emissions models averaged)

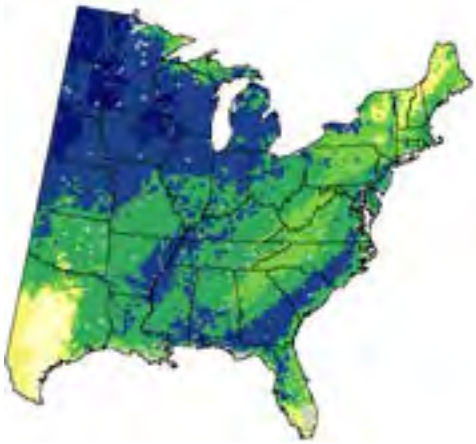
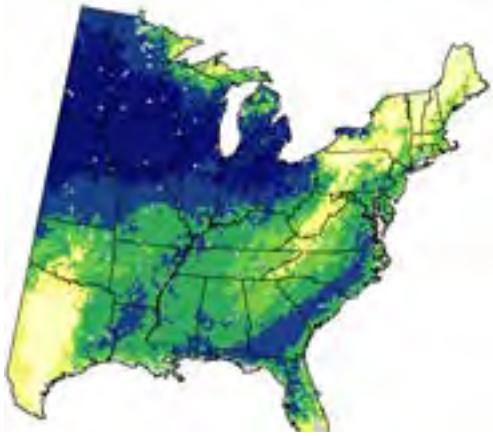


Figure 3.5.12 – Projected future range suitability for red-headed woodpecker (low emissions models averaged)



Missouri Species and Natural Communities with Potential Climate Change Vulnerability

In general, there is great concern for potential impacts to Missouri's native species and natural communities resulting from current observed trends and projected climate change scenarios. Increased threats from invasive species, disease, and parasites are all understood as potential stressors. But what effect will climate change have on fire regimes, algae blooms, species migration and survival, and precipitation extremes, including drought? What new species may migrate to or away from Missouri? These are all valid questions, and unfortunately there are no guaranteed answers but, rather, a multitude of interconnected variables that affect the responses to them.

The degree of interconnectivity and interdependibility in nature is immense, which bolsters the inability to answer such questions with confidence. For instance, starting with a known – Missouri is experiencing an extended growing season resulting in earlier springs and later falls, which has begun to shift the timing of phenological events (e.g., flowering and migration). Numerous native species depend on phenological cues to fulfill important life history needs. Beginning to explore the hypothetical, consider earlier plant blooms and the potential ripple effect of just this one change. Many native pollinators, as well as nonpollinating species, depend on specific plants for food and other needs, and in return, those plants rely on specific pollinators to carry out reproduction. As plant phenology shifts, the corresponding pollinators and other species must also adapt to this shift to stay in sync, so the system can persist. Beyond the immediate impact for the plant and associated species, the compounded consequences of a breakdown in this synchronization are unknown but are cause for concern through all trophic levels (i.e., the food web), which includes concerns for people.

In addition, range contraction/expansion, timing of migration, and impacts to feeding, breeding, and brood rearing of many bird species is of significant interest. In a recent report, *Survival by Degrees: 389 Species on the Brink*, the National Audubon Society describes birds as early responders to climate change that can be important indicators of ecological change. Further, a rapidly changing climate could lead to population declines, local extinctions, and a reshuffling of bird communities causing unpredictable interactions. Within the document, Audubon reports Missouri has 13 highly vulnerable, 27 moderate, and 29 bird species of low vulnerability to climate change, as well as 70 reported as stable (**nas-national-prod.s3.amazonaws.com/briefs_mo_final_0.pdf**).

Most birds have the benefit of flight, many capable of long-distance migration and dispersal. Yet, even with this adaptation, there is great concern for bird populations due to the impacts associated with a changing climate. Now consider how current and projected climate changes may affect species with less mobility who must navigate potential dispersal barriers, such as insufficient or absent natural community or suitable habitat connectivity, infrastructure and development, dams, etc. These are challenges that many animals such as herptiles, land mammals, fish, mussels, and others may face.

There is significant concern for species with low mobility and dispersal capacity. For example, Missouri has a number of "glacial relict" species, more common to the north and east of the state, that were more common in Missouri thousands of years ago when the climatic conditions were cooler and wetter at the end of the last glaciation period. Today these species – such as the cherrystone snail (*Hendersonia occulta*) and harebell (*Campanula rotundifolia*) – persist in shaded, moist, and cool microenvironments of north-facing cliff and talus communities. Likewise, other glacial relict species inhabit fen natural communities. These glacial relict species may be more vulnerable to a warming climate and precipitation variation,

especially droughts, in concert of course with other stressors (Mattingly and Leopold 2018).

Species that rely on cold or cool water, including aquatic biota such as the Ozark sculpin (*Cottus hypselurus*), coldwater crayfish (*Faxonius eupunctus*), and Ozark hellbender (*Cryptobranchus alleganiensis bishopi*) may also find increasing temperatures and precipitation variability from climate change to be additional stressors (Lynch et al. 2016; Nickerson et al. 2017). Amphibians in general as a group are vulnerable to the impacts of climate change as an additional stressor (Struecker and Milanovich 2017). Likewise, cave fauna, including cave-dwelling bats, are vulnerable to changes in cave thermal regimes (Furey and Racey 2016).

Missouri Efforts

With the threat from climate change, the natural resource field has increasingly focused on a new paradigm to conservation, one that emphasizes coordination among partners across large scales, increasing connectivity and resiliency. For instance, the U.S. Department of Interior's Northeast Climate Adaptation Science Center, USDA's Northern Forests Climate Hub, and USFS's Northern Institute of Applied Climate Science (NIACS) are federal organizations that work with natural resource managers to gather the scientific information and build the tools needed to help fish, wildlife, and ecosystems adapt to the impacts of climate change. Missouri has been an important partner in these efforts and has helped adapt planning approaches to incorporate climate change impacts. As an example, Missouri has been involved in the development of landscape planning tools that can integrate projected future changes in landscapes and ecosystems from climate and land-use change. These tools were based on Missouri's CCS and extend to modeling responses of wildlife populations to conservation scenarios under these changes, thus overcoming many of the uncertainties and complexities that are inherent in the process of long-term, large-scale conservation planning (Bonnot et al. 2019). NIACS has worked with a variety of Missouri conservation partners, including the Middle Blue River Watershed in Kansas City, the City of Columbia, L-A-D Foundation's Pioneer Forest, the Ozark National Scenic Riverways, and MTNF. Case studies describing these innovative projects can be referenced at **forestadaptation.org/adapt/demonstration-projects**.

Results from these partnerships and tools provide evidence that Missouri's natural community-based approach, focused on landscape-level health and resiliency, is an important component in a larger approach to mitigate the threat of climate change. The CCS identifies and assists in prioritizing the best opportunities for conservation throughout the state and targets landscapes for focused conservation effort. Efforts to enhance, restore, reconstruct, and maintain healthy and connected habitat systems, such as riparian corridors, wetlands, prairies, and forests, as well as implementing practices that increase regenerative working lands in these areas may result in more resilient natural systems and floral and faunal communities, all of which also benefit the people who are a part of these landscapes. Increasing resilience has been identified as a primary method for minimizing the impacts of climate change on natural resources.

Missouri's approach also promotes connectivity within and among habitat systems by prioritizing those areas that are larger, more intact, nearer to other conservation landscapes, and/or where there is more opportunity to expand conservation action. Improving connectivity will facilitate potential range adjustments that may occur in many species adapting to climate change. Monitoring will be necessary to detect changes in communities as a result of management actions or the impacts of threats and stressors and will enable conservation partners to respond to emerging threats in a timely and effective manner.

As mentioned throughout the CCS, though Missouri primarily takes a natural community

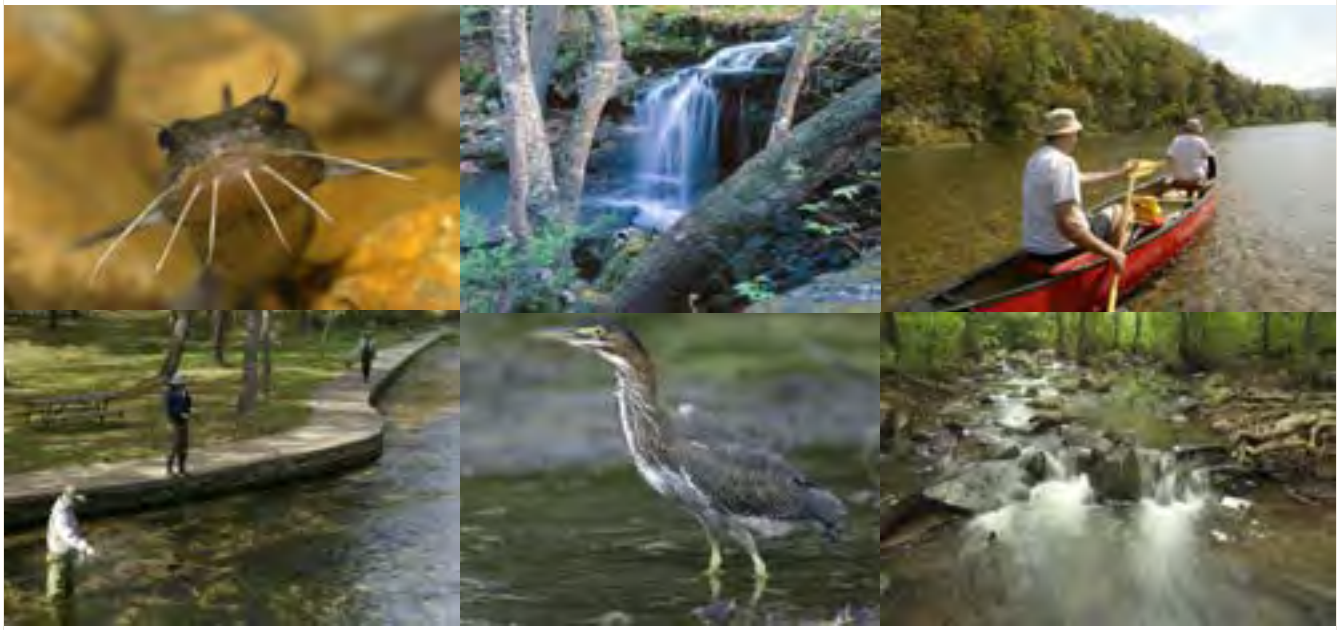
and landscape approach to habitat and species conservation, there are many efforts and resources devoted to ensuring conservation and further understanding of species-specific considerations. This concept must also be employed in monitoring the effects of climate change on species or species guilds, especially those most vulnerable to such stressors.

Increasing partnerships and seeking opportunities to reduce causes of climate change, mitigating climate change impacts, and building resiliency within urban and suburban landscapes is key. Projects such as the previously noted Middle Blue River Watershed in Kansas City and the City of Columbia, as well as similar efforts in St. Louis, Springfield, and other areas, are critical components of the global challenge to enhance, restore, retrofit, and construct projects that are climate smart. Examples of climate smart urban projects and low impact development may include reduction of paved and impervious surfaces while increasing green spaces and permeable surfaces, which will improve stormwater infiltration, reduce runoff, and combat the heat island effect. Also, increasing reliable trail networks and promoting foot and bike traffic among neighborhoods and key social attractions, stores, and schools has multiple benefits including reduced emissions.

Climate change is an evolving science and much remains to be studied. Additional scientific study and resources will be necessary to understand and mitigate (where possible) the implications of climate change. Missouri partners must work together in developing the resources, partnerships, and support needed for a comprehensive look at climate change/climate resiliency and its impact on human and natural communities. As an example, Missouri is not currently a part of the U.S. Climate Alliance (**usclimatealliance.org/alliance-principles**), but there is intriguing work coming out of this group, including the Natural and Working Lands Challenge Initiative (**usclimatealliance.org/nwlchallenge**). It will be important to monitor the effectiveness of the strategies and actions of this group and consider Missouri's future involvement, as well as in similar national and global initiatives.

Theme Six: Improving and Maintaining High-Quality Soil and Water Resources

In a nutshell: Missouri is blessed with beautiful and biologically diverse streams, rivers, springs, lakes, and other aquatic features that provide everything from habitat to recreation to drinking water. Missouri also has productive soils (some more so than others) depended upon for food, timber, natural communities, and wildlife. Healthy soils and natural communities act as both reservoir and filter for water, which in turn provide improved water quantity and quality. Clean water and healthy soils sustain all life and are an economic boon as well. To maintain and enhance healthy soil and water benefits, vegetative cover (especially native vegetation found in most of Missouri's natural communities) and green infrastructure development must be carefully and strategically protected, planned for, and managed.



Desired Future Conditions

1. Aquatic ecosystems, and the plants and animals they support, are maintained and enhanced by healthy soils and intact natural communities and landscapes.
2. Soil and water resources are protected and enhanced through the widespread use of native vegetated riparian buffers and many other widespread best management practices.
3. Soil productivity and water quality are maintained through regenerative agriculture and forest management practices.
4. Urban stormwater runoff is minimized by planting and maintaining native grasses and forbs, trees, forests, and green infrastructure and through use of other BMPs.
5. Intact natural communities and landscapes maintain and enhance water-related recreation opportunities (boating, fishing, wildlife viewing, aesthetics, etc.).
6. Intact natural communities and landscapes provide healthy soils that support high quality, cost-effective drinking water.

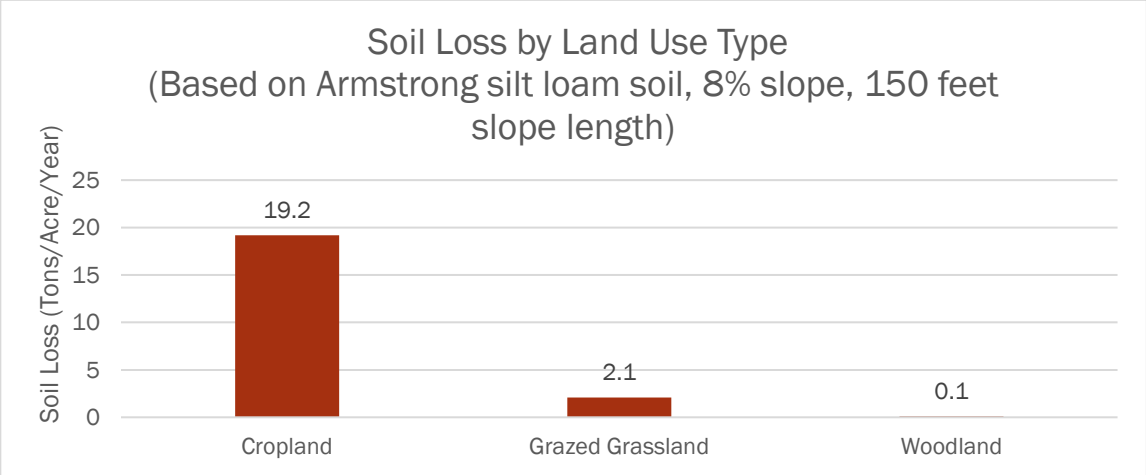
The Role of Natural Communities and Green Infrastructure Development in Maintaining Soil and Water Resources

Natural vegetation cover and green infrastructure development help protect soil, maintain water resources, and provide many other hydrologic benefits. A few prime examples follow.

Natural Vegetation and Leaf Litter

Forest, woodland, prairie, and other natural vegetation and leaf litter do a terrific job of armoring soil to protect it from forces that cause erosion. They do so well, in fact, that erosion from these systems is virtually non-existent compared to row crop fields. This is demonstrated in **Figure 3.6.1,** which shows estimated soil loss rates for three land-use types on the same soil type and percent slope.

Figure 3.6.1 – Soil Loss by Land Use Type9



Natural vegetation offers other soil and water protections as well. By intercepting precipitation, allowing it to infiltrate the soil, and releasing it slowly into groundwater and streams, natural vegetation helps filter water and moderate stream flow. This is essential for maintaining more natural volumes, frequencies, durations, timings, and rates of change for streams that in turn promote improved and sustainable aquatic habitat, quality drinking water, reliable water quantity, and reduction of flooding and erosion.

Riparian Areas (Buffers)

Riparian buffers are naturally vegetated zones along streambanks that are especially important for protecting soil and water resources. Of Missouri's 2,661,070 acres of riparian area (estimated based on land within 100 feet of all streams order 1 and larger), approximately 1,568,337 acres (62%) are currently in a vegetative cover type, whether native or not.[10] Revegetating nonvegetated riparian areas to

[9] These figures were generated by Doug Wallace, former state forester of Missouri NRCS, using the Universal Soil Loss Equation. All figures were based on an Armstrong silt loam soil, 8 percent slope, 150 feet slope length. Cropland = minimum tillage (30% cover after planting), corn-soybean (drilled) rotation, up and down tillage; Grassland = 80% ground cover, grass with some weeds and brush, continuously grazed; Woodland = no grazing, low management, 90% duff cover, 90% canopy cover.

[10] Calculated using NLCD data and MDC stream GIS data.

forest or native grasses, forbs, and shrubs would significantly benefit soil and water resources. Where natural vegetation cover exists in Missouri's riparian areas today, it is predominantly forested/treed. However, in small order streams on native prairies and grasslands, the riparian areas may be comprised of only native grasses, forbs, and shrubs.

Naturally vegetated riparian areas, ideally a minimum width of 50–100 feet, help armor and reinforce streambank stability, thereby preventing streambank erosion. They can filter out pesticides, nutrients, and sediments before these can reach streams. They provide shade important for maintaining water temperatures conducive to a healthy and functional aquatic ecosystem. Vegetation and large woody debris from riparian corridors initiate a large portion of the aquatic food chain and provide habitat needed by many aquatic organisms. Riparian buffers also provide important wildlife travel corridors and can be highly productive for forest products, though careful harvest considerations must be followed.

Prairie Vegetation

Stream flow, runoff, and water quality – Flint Hills and Osage Plains Tallgrass Prairie study

A USGS study (Heimann 2009) was conducted to identify and quantify the effects of prairie conversion on the hydrology and water quality of small streams in eastern Kansas and western Missouri. Streamflow data, precipitation data, and water quality samples were collected from East Drywood Creek at Prairie State Park, Missouri, and Kings Creek near Manhattan, Kansas, at the Konza Prairie Biological Station and were compared to data from similar-sized agricultural streams in watersheds once covered in tallgrass prairie.

The base flow (streamflow contributed from groundwater) and runoff components of the tallgrass prairie and agricultural sites were compared. Base flow from the tallgrass prairie sites was greater than that from similar-sized agricultural streams. The lower proportion of direct runoff from the tallgrass prairie sites may be attributed to greater infiltration into the noncultivated native prairie watershed soil compared to the watersheds primarily with agricultural land cover; therefore, an increase in the percentage of land with tallgrass prairie vegetation has the potential for substantially decreasing direct runoff and the severity of downstream flooding.

The study also compared the water quality of the prairie watersheds versus the agricultural watersheds. **Figures 3.6.2** and **3.6.3** detail the much larger runoff of nitrogen and phosphorous from the agricultural watershed compared to the native prairie watershed. In addition, the pesticide atrazine was measured at maximum base flow concentrations in the Prairie State Park watershed and compared to two of the agricultural watersheds. In this analysis, the prairie watershed had an atrazine concentration of 0.41 micrograms per liter, compared to 3.24 and 3.52 micrograms per liter in the two agricultural watersheds.

Figure 3.6.2 – Nitrogen Runoff in Prairie vs. Crop/Fescue Pasture Watersheds

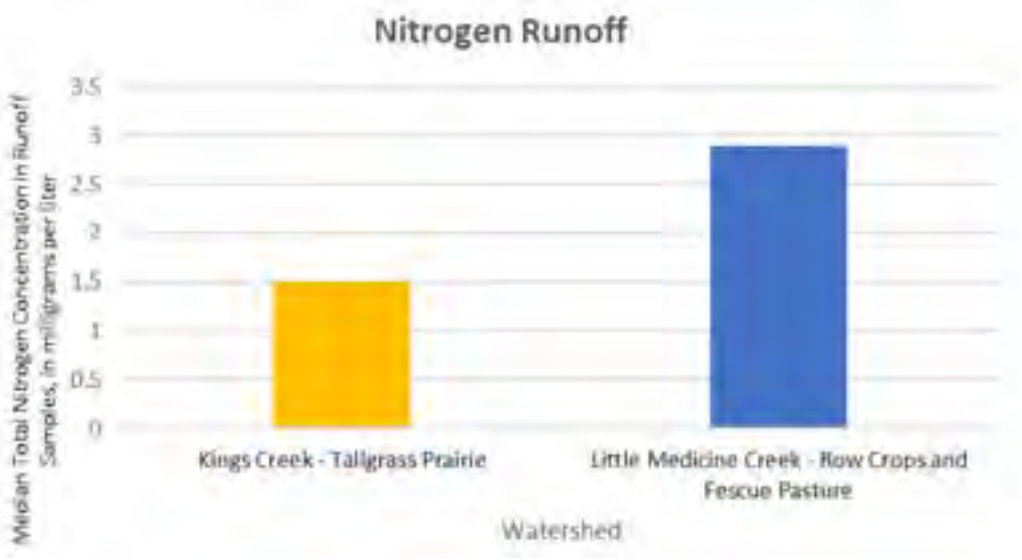
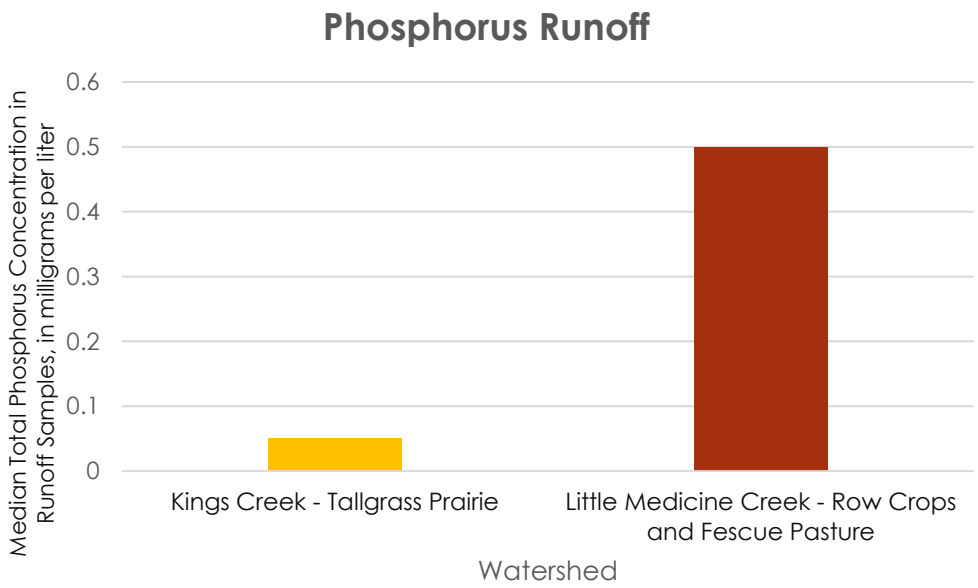


Figure 3.6.3 – Phosphorus Runoff in Prairie vs. Crop/Fescue Pasture Watersheds



Wetlands

Wetlands are also powerhouses when it comes to protecting water resources and sustaining biodiversity. Wetlands filter out sediments, nutrients, fertilizers, and pesticides from adjacent areas before these reach streams. They help moderate and maintain stream flows and minimize flooding potential. Wetlands have terrific wildlife value and can be highly productive for forest products when managed properly. Unfortunately, throughout the 19th and 20th centuries, 80 percent of Missouri's historically forested wetlands have been drained and converted to agriculture. A prime example is Missouri's Bootheel, which was historically dominated by forested wetlands and is now dominated by row crop agriculture. Although most of Missouri's wetlands have been lost,

Missouri still has many quality wetlands remaining and many areas with strong restoration potential. The USDA NRCS administers the WRE program, which has proven highly effective in the restoration and creation of wetlands and an essential tool in the conservation toolbox. For more information on wetland natural communities see **Section Four**.

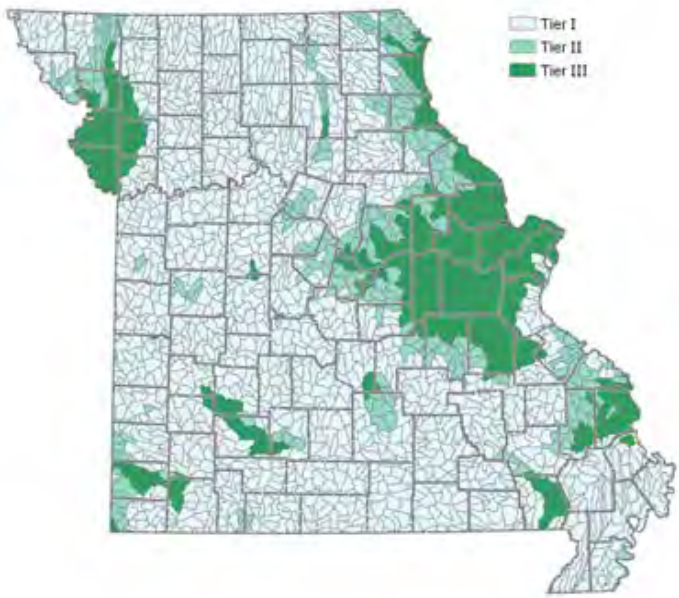
Community Trees, Forests, and Green Infrastructure

Urban and community trees, forests, and other green infrastructure (e.g., native plantings, rain gardens, bioswales, infiltration basins) are of great importance in minimizing stormwater runoff and flooding in urban and community areas. For example, the Heartland Tree Alliance estimates that in Kansas City, Missouri an estimated 605,702,000 gallons of rainfall per year is intercepted by street trees, saving the city ~$16,416,000 per year (Bridging the Gap 2020). These benefits are not exclusive to the communities in which the trees are located but are also realized by local stream systems.

Natural Communities and Drinking Water: USFS Forests to Faucets Assessment

Few resources, if any, are as important to the health and well-being of people as clean drinking water. Since healthy, intact natural communities produce Missouri's cleanest and most cost-effective drinking water, it is important to know the most important watersheds for protecting these resources. This is exactly the purpose of the USFS's Forests to Faucets Assessment, which was just updated in 2019 (**fs.fed.us/ecosystemservices/FS_Efforts/forests2faucets.shtml**). As the name implies, this assessment focuses on forests and woodlands, but the same concept applies to other natural communities as well. The Forests to Faucets project uses GIS to model and map the land areas across the United States that serve as surface drinking-water-supply sources for most of the population, as well as to identify forested areas important to the protection of this drinking water. Forests to Faucets data can be analyzed and utilized in a variety of ways. For the purposes of the CCS, MDC focused on two data sets provided through Forests to Faucets – the "Ability to Produce Clean Water" and "Important Areas for Surface Drinking Water." Both layers were combined and equally weighted to produce a composite map of the most important places to invest in conserving natural communities for drinking water (**Figure 3.6.4**). On this map, the darkest green watersheds represent the greatest opportunities, light green areas represent the second tier of opportunities, and white areas represent watersheds in which such investment has comparatively less benefit.

Figure 3.6.4 – Map of Important Watersheds for Protecting Natural Communities for Drinking Water (USFS 2019)



One way by which water quality and quantity can be negatively altered is when natural communities are replaced by housing and commercial development with associated roads, parking lots, and driveways; when they are converted to cropland or nonnative grass pasture; or when they are managed unsustainably. At a broad scale, **Figure 3.6.4** reveals places where investment in land conservation, land use planning, and other conservation activities will pay the biggest dividend in protecting drinking water for the most people, while also protecting aquatic habitat, recreation, and more.

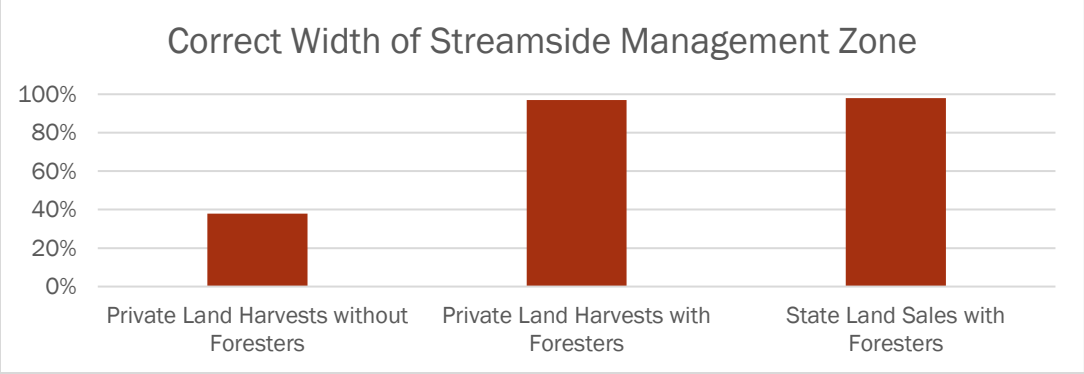
Best Management Practices

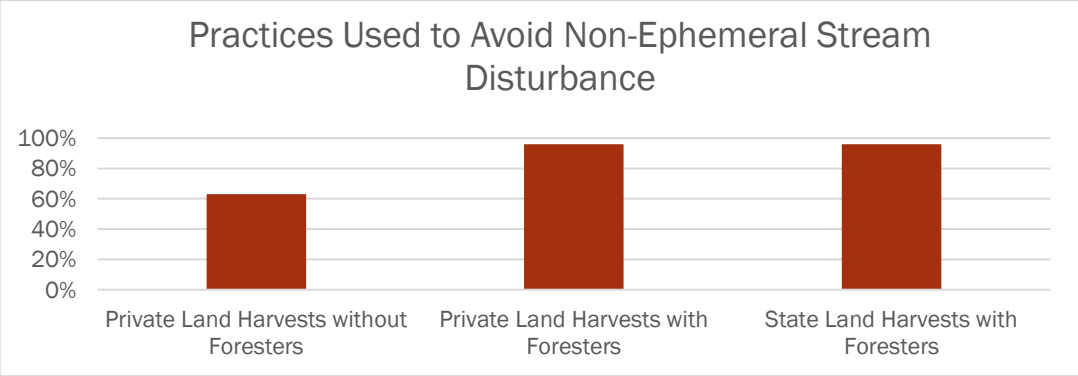
Forest/Woodland BMPs

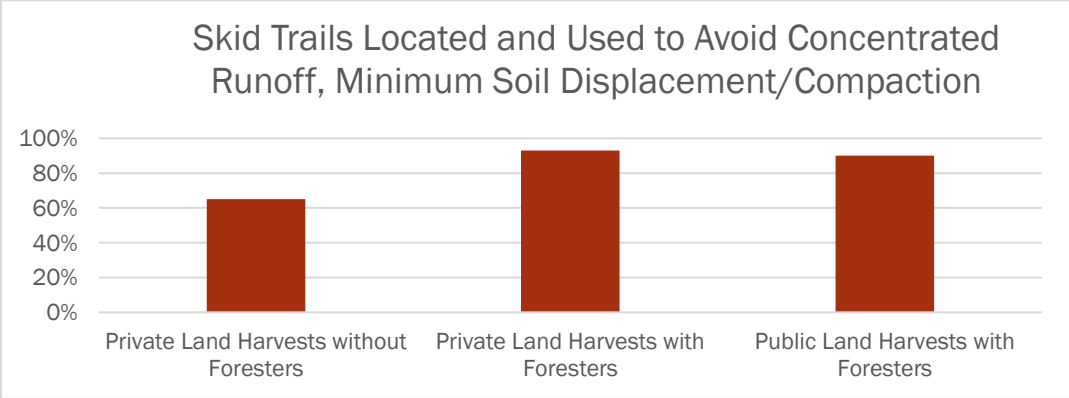
When done correctly, forest management activities such as harvesting, forest stand improvement, and prescribed fire have minimal impact on soil erosion or water quality. However, to ensure protection of soil and water quality during such activities it is necessary to follow BMPs. MDC and various partners have established three sets of voluntary BMPs: Missouri Watershed Protection Practices, Missouri Forest Management Guidelines, and BMP's for Harvesting Woody Biomass. These BMPs describe procedures for how and where to construct, use, and retire logging roads; how to avoid over-harvesting biomass to the detriment of soil productivity; other things to consider when conducting a prescribed burn or applying herbicide; and more.

A good way to help ensure BMPs are followed, maintained, and used properly is to utilize the services of trained loggers and foresters. Loggers who have attended Missouri Forest Product Association's Professional Timber Harvester Training have been trained in using and installing BMPs. Most state and federally employed foresters and some private consultant foresters have been trained in inspecting harvests for compliance with BMPs. The advantages of using forester expertise when conducting a timber harvest are clearly demonstrated below. In all cases, the presence of consulting or management foresters improved compliance with the voluntary guidelines and resulted in less potential for erosion, sedimentation, and stream disturbance.

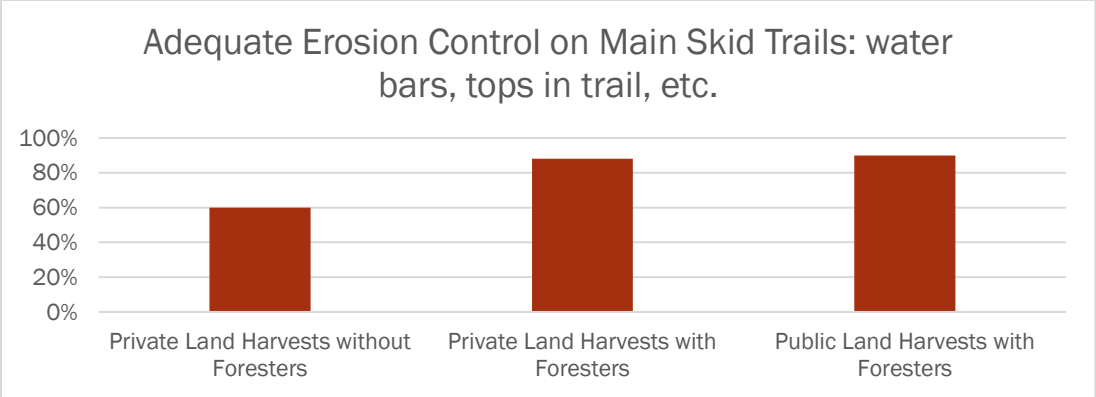
Figure 3.6.5 – Use and Effectiveness of BMPs in Missouri – 2000s[11]

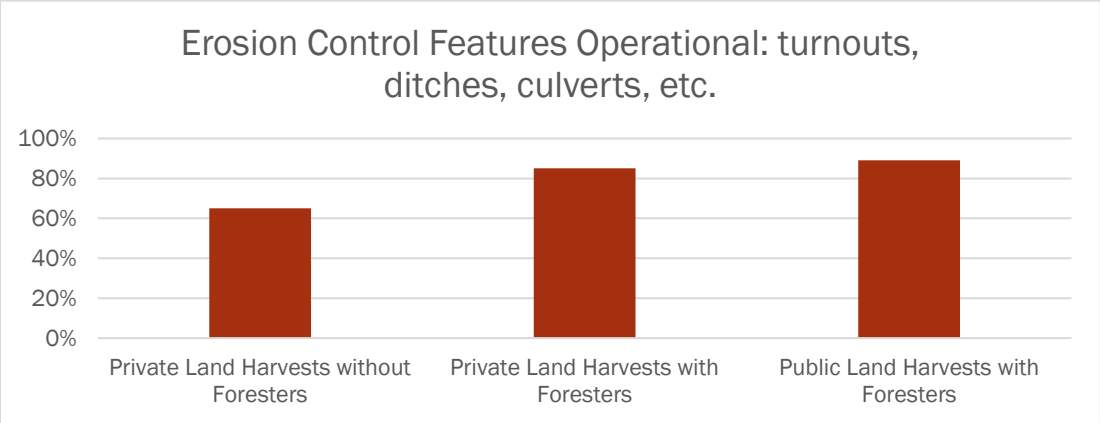






[11] During the 2000s, MDC and MFPA conducted BMP monitoring on three types of harvests: (1) state land harvests, (2) private land harvests that used a forester, and (3) private land harvests that did not use a forester. Applicable BMPs are described in Missouri's Watershed Protection Practices linked earlier in this section.





Crop Land BMPs

Even with flat well-drained cropland, agricultural fields are susceptible to the effects of runoff and erosion. The average erosion from cropland in Missouri is about 5.1 tons per acre per year (NRCS 2018). According to Stan Buman, head of Land O Lakes Sustain program, under the very best-case scenario it would take 24 years to naturally rebuild this amount of soil we average losing in a year (Lawton 2017). Sheet erosion can go almost undetected for years, often causing great losses in productivity before anyone becomes concerned. Beyond the concern of sustainable or regenerative food production, sedimentation, lost nutrients, and pesticides have significant implications for the health of our rivers and streams. The NRCS and local MDNR Soil and Water Conservation Districts (SWCDs) are available to assist private landowners with recommendations for numerous agricultural BMPs that reduce non-point sources of pollution and promote soil and water conservation. A few examples follow.

Cover Crops – use of cover crops within crop fields has proven to reduce soil erosion, reduce soil compaction, decrease runoff, build soil organic matter, increase the soil's water-holding capacity, improve soil nutrient health (reducing fertilizer dependence), improve drought resistance, and increase crop yield. At the same time, an increasing number of producers are grazing cover crops, providing quality forage for livestock and reducing dependence on hay.

No-till or Conservation Tillage – leaving crop residue (plant materials from past harvests) on the soil surface reduces runoff and soil erosion, conserves soil moisture, helps keep nutrients and

pesticides on the field, and improves soil, water, and air quality.

Crop Nutrient Management – comprehensive measuring, managing, and accounting for all nutrient inputs helps ensure nutrients are available to meet crop needs while reducing movement off fields. It also can prevent excessive buildup in soils and protect air quality.

Pest Management – varying methods for keeping insects, weeds, disease, and other pests below economically harmful levels while protecting soil, water, and air quality.

Conservation Buffers and Agroforestry Practices – installing or expanding grassed waterways and forested (where appropriate) riparian areas can provide protection from potential pollutants that might otherwise move into surface waters. Additional agroforestry practices such as windbreaks and alley cropping also benefit soil and water conservation.

Alternative Watering Systems – provide livestock the ability to get water without needing direct access to streams. Restricting livestock from streams and ponds keeps them from damaging streambanks, avoids direct animal waste deposits into aquatic systems, and allows riparian vegetation to establish and hold the soil and banks in place.

Crop Land and the Multiple Ecosystem Benefits of Native Prairie Vegetation

– Iowa "Prairie STRIPS" Study

In an experiment in central Iowa (Schulte et al. 2017), investigators used experimental watersheds wherein standard Iowa soybean and corn row crop production practices were established on either 100, 90, or 80 percent of the watersheds. On those watersheds with less than 100 percent row-cropping, diverse native prairie planting strips were established either on contours or on foot slopes at the base of the watershed. Significant differences were found between prairie and fully cropped control treatments among investigated response variables, with prairie treatments conferring benefits at levels greater than expected based on the spatial extent of prairie vegetation.

Compared with catchments containing only crops, integrating prairie strips into crop land led to greater pollinator abundance (3.5-fold), reduced total water runoff by 37 percent, retention of 20 times more soil and 4.3 times more phosphorus. Researchers concluded that replacing even just 10 percent of cropland with prairie strips increased biodiversity and ecosystem services with minimal impacts on crop production.

Grazing BMPs

Every livestock production operation is different, with its own real-world limitations, but there are opportunities that help producers custom-fit grazing practices to benefit livestock as well as soil health and water quality. Grazing BMPs that optimize animal production while maintaining long-term vegetative cover have been developed by the NRCS (**nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_046596.pdf**) to reduce the potential negative effects of grazing, typically attributed to overgrazing.

Within the NRCS guidance, planned grazing systems are described that consider grazing dates, duration, stocking rate, length of rest periods, forage quality, water sources, and nutrient cycling. These considerations significantly affect both the benefits to the grazing animal and the resulting condition of the pasture/grassland, including increases in the nutritional value of the forage as well as nutrient cycling (including manure and urine) within the pasture.

According to the NRCS, well-managed grazing increases soil health and water quality through:

- Increasing soil organic matter, which increases water available for plant growth
- Improving water infiltration
- Increasing nutrients available for plant growth
- Improving soil conditions for germination, seedling establishment, vegetative reproduction and root growth
- Improving the ability of the soil to act as a filter, protecting water and air quality
- Increasing plant production and reproduction
- Reducing soil erosion from water
- Increasing carbon sequestration from air

For more in-depth pasture and grazing management, see the NRCS National Range and Pasture Handbook at **nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/rangepasture/?cid=stelprdb1043084**.

Road/Trail BMPs

Roadway and trail systems are important travel networks, whether transporting goods across the state/country or allowing access to the most remote natural areas. While important for these and many other reasons, road and trail networks also dissect the landscape, creating connectivity concerns, offering vectors for invasive species introductions, and presenting potential for erosion and water quality concerns.

Road and trail systems, especially those constructed of gravel or soil, have been identified as major contributors to erosion and sources of sedimentation. Incorporating environmentally sound practices into the construction and maintenance of roadway and trail networks can effectively alleviate many erosion and water management problems. To aid in effective rural roadway construction and maintenance, the USFS has created the Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads, which can be referenced at **fs.fed.us/eng/pubs/pdf/11771802.pdf**.

Development BMPs

Runoff from construction sites can significantly impact water quality. Bare soil at these sites is highly vulnerable to erosion by wind and water. Eroded soil endangers water resources by reducing water quality and causing siltation that can have an adverse effect on aquatic habitat and species. Typical sediment loading rates from construction sites vary from 100 to 200 tons per acre per year and can range up to 1,100 tons per acre per year (Broz et al. 2020). **Figure 3.6.6** shows areas of the state at greatest risk of development pressure through 2040.

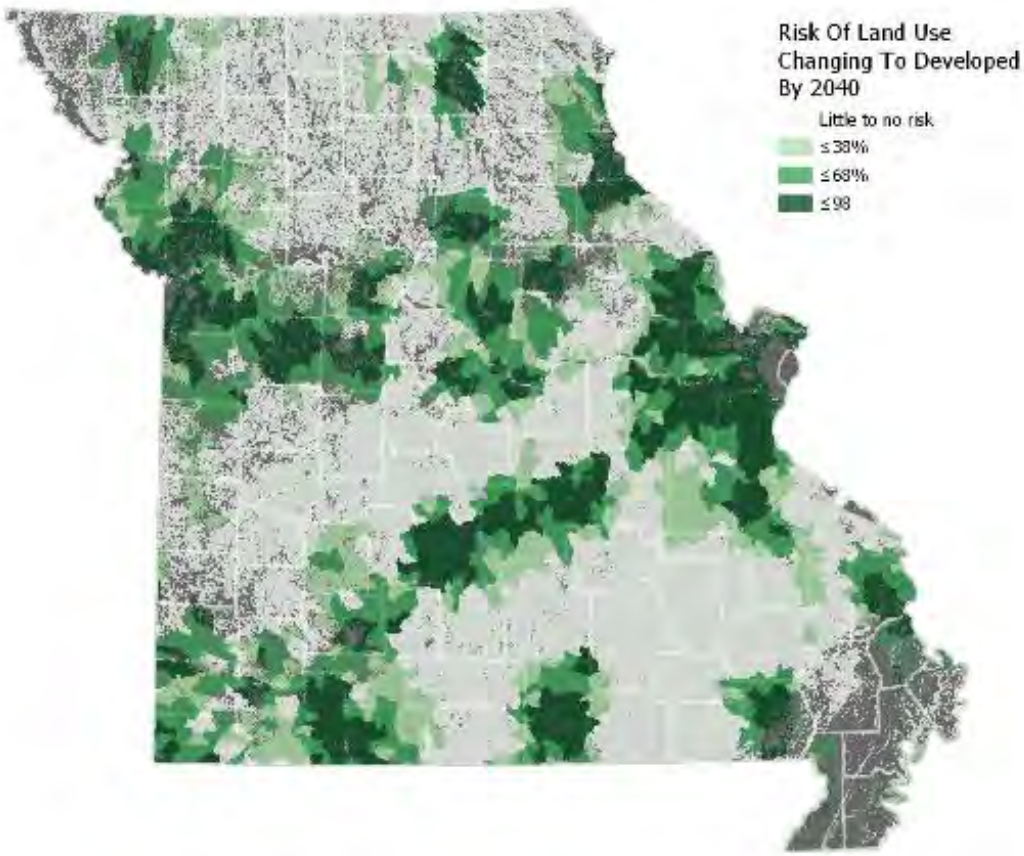


Figure 3.6.6 – Watersheds of Increased Risk to Development Pressure
(US EPA 2017)

The use of vegetated buffers, silt-fences, ditch checks, berms, phased construction, detention basins, along with minimizing earthwork and promptly reseeding or mulching, can significantly reduce the amount of construction sediment reaching streams and lakes. Additional runoff and stormwater BMPs can be used to help manage runoff and stormwater not just during construction but also to help mitigate the increased impervious surface that will persist from the development. Some of these BMPs include wet ponds, wetlands, infiltration basins and dry swales, surface sand filters, permeable concrete, and bioretention and organic filters (Metropolitan Sewer District 2012).

Theme Seven: The Role of Fire – Historic, Wild, and Prescribed

In a nutshell: Historically, fire, whether human or weather ignited, has played a large role in shaping and manipulating Missouri's natural landscape. It is estimated that humans have utilized fire for more than 70 different purposes such as to clear the landscape to plant crops, as a weapon against enemies, as a hunting tool, and as a tool to improve grazing for big game (Lewis 1973).

Today, conservation professionals recognize two primary categories of fire on Missouri's landscape: wildfire and prescribed fire. **Wildfire** can be defined as an intentionally set or accidental fire that burns uncontrolled and exhibits destructive characteristics to natural resources or property. Arson, escaped open burning, and on occasion, lightning may all be sources of ignition for wildfires. These are the types of fires Missouri and other states work to suppress. Alternatively, **prescribed fire** is a valuable management tool intentionally ignited for the purposes of fulfilling specific objectives. Prescribed fires are implemented according to defined prescriptions. For example, prescribed fires may be used by conservation professionals and private landowners as an efficient way to maintain and reinvigorate open grasslands and savannas, glades, and woodlands. In addition, livestock producers may use prescribed fire to improve forage production, especially in pastures comprised of native grasses and forbs, and to manipulate livestock grazing behavior.

The prevention and suppression of fire in Missouri over the last 50+ years has significantly modified the structure, diversity, and function of many natural communities, benefiting some, while at a detriment to others. For the protection of people, structures, and natural resources, wildfire can no longer be tolerated. However, in its absence, proactive management, including the responsible use of prescribed fire, is often needed to restore and/or maintain Missouri's natural communities in a healthy, productive, and wildlife-friendly condition.

Photos clockwise from top left: Photo One: Elk Pen Fire, H Hwy, Texas County, Missouri, summer 2012. Photo Two: Excess property trucks supplying water for Martin Fire, Christian County, Missouri, summer 2012. Photo Three: Demonstration prescribed burn in shortleaf pine stand, fall 2016. Photo Four: Prairie regeneration after prescribed fire.

Desired Future Conditions

1. Frequency and size of wildfires is kept to a minimum to protect people, structures, and natural resources.
2. Homes, structures, and communities are "Firewise." Fire departments and communities develop Community Wildfire Protection Plans (CWPPs) to best manage the threat of wildfire emergencies.
3. Forest resources and natural communities are not adversely affected by wildfires but benefit from appropriate prescribed fires.
4. Conservation professionals, volunteer firefighters, and other partners spend less time fighting wildfires and can direct time and financial resources to other natural resource priorities, which include the use of prescribed fire.
5. Fire-adapted landscapes and natural communities are restored and/or maintained through prescribed fire and/or other management tools.
6. Prescribed fire techniques are refined and practiced that maximize the benefits of prescribed fire while minimizing potential negative impacts.

Missouri's Fire History and the Evolution of Wildfire Suppression

For thousands of years, fire has been an important influencer in Missouri's landscapes and natural communities. Historically, Native Americans used fire frequently for improving wildlife habitat and hunting opportunities, enhancing travel conditions, and as defense against rival tribes. These fires resulted in a rich mosaic of prairie, glade, savanna, open and closed, woodland and forest communities across the state.

As European immigrants displaced Native Americans in the early 1800s, they not only continued the fire tradition but increased it substantially to improve grazing opportunities for their free ranging livestock. In the late 1800s/early 1900s these fires were combined with a massive and unsustainable logging of Missouri's forests, largely to support the building of the transcontinental railroad (Guyette et al. 1999). These were bleak times for Missouri's forests, woodlands, and associated plants and animals.

Eventually, the dire effects of unsustainable harvesting and wildfire on forest and wildlife resources became apparent and was no longer acceptable. A highly successful prevention and suppression campaign ensued. The Forestry Division of MDC was created in 1940, in large part because of wildfire.

George O. White, MDC's first state forester, knew that sustainably managing the forest resource of the state would require the cessation of uncontrolled wildfires that were burning approximately one-third of the Ozarks each year (Conservation Commission 1944). Fire prevention started with a traveling road show bringing a motion picture fire prevention message into the very heart of the rampant wildfire area. Smokey Bear would follow this up and introduce wildfire prevention to a new generation of future landowners. Attitudes started changing slowly at first, but noticeably.

The next big change started in the 1960s with the formation of Volunteer Rural Fire Departments. This was made feasible by utilizing both state and federal funds and a program that made excess military equipment available to developing fire departments. Growth was slow initially but really picked up in the 1980s. These new fire departments not only provided a trained consistent resource of firefighters but also created new attitudes. Now, it was not as

acceptable for a person to start an uncontrolled fire knowing that their neighbor or brother would be coming out to extinguish it.

These rural fire departments expanded significantly through the 1980s and 1990s and into the 2000s; and Missouri citizens benefited greatly from their services. Unfortunately, with the local economic challenges in many rural communities and competing demands for an individual's time, many of the volunteer fire departments are now struggling to find enough volunteers. The image below showing the distribution of fire departments across Missouri is continually changing, but put simply, the number of volunteer firefighters and fire departments are both decreasing.

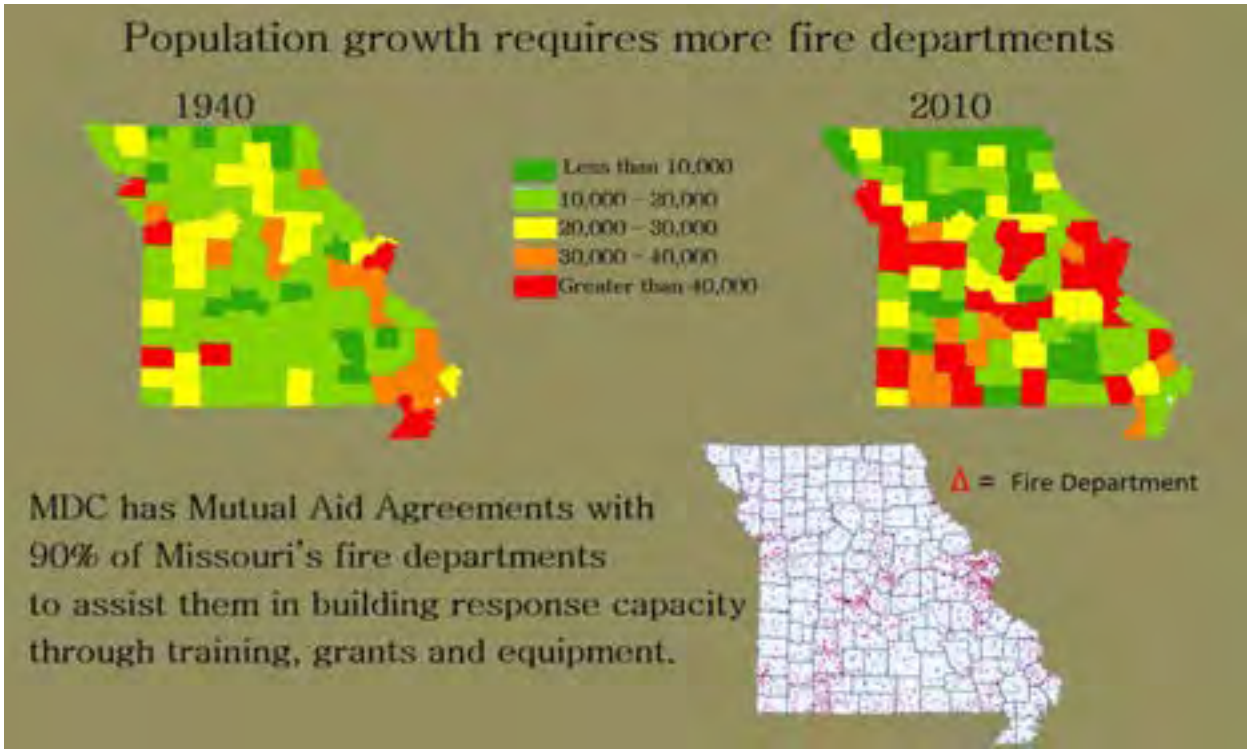


Figure 3.7.1 – Missouri's Population Growth by County (1940–2010) and Fire Department Distribution. (Source: Data from U.S. Census Bureau)

Missouri's Modern Wildfire Status

Although Missouri's acreage burned by wildfire has diminished greatly, wildfires have not gone away completely. Today, about 0.1 percent of Missouri (63,441 acres) burns each year on average by wildfire.[12] **Figures 3.7.2–4** below show important statistics regarding how much of Missouri was exposed to wildfire from 2003 to 2019, how these fires started, and how Missouri wildfires vary in size. However, it is important to note how widely fire seasons can vary in Missouri from year to year depending on weather patterns.

[12] Data from Missouri fire reports received by MDC.

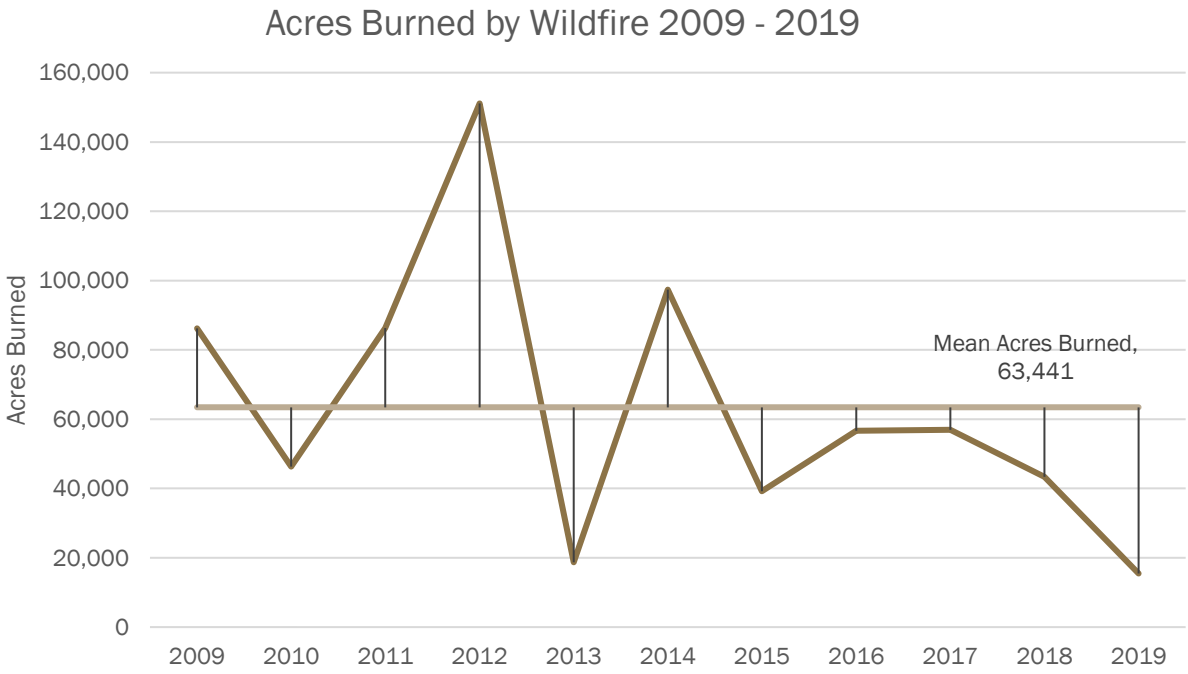


Figure 3.7.2 – Annual Acres Burned by Wildfire (averaged over 2009–2019)
(Source: Data from MDC's Missouri fire reporting system.)

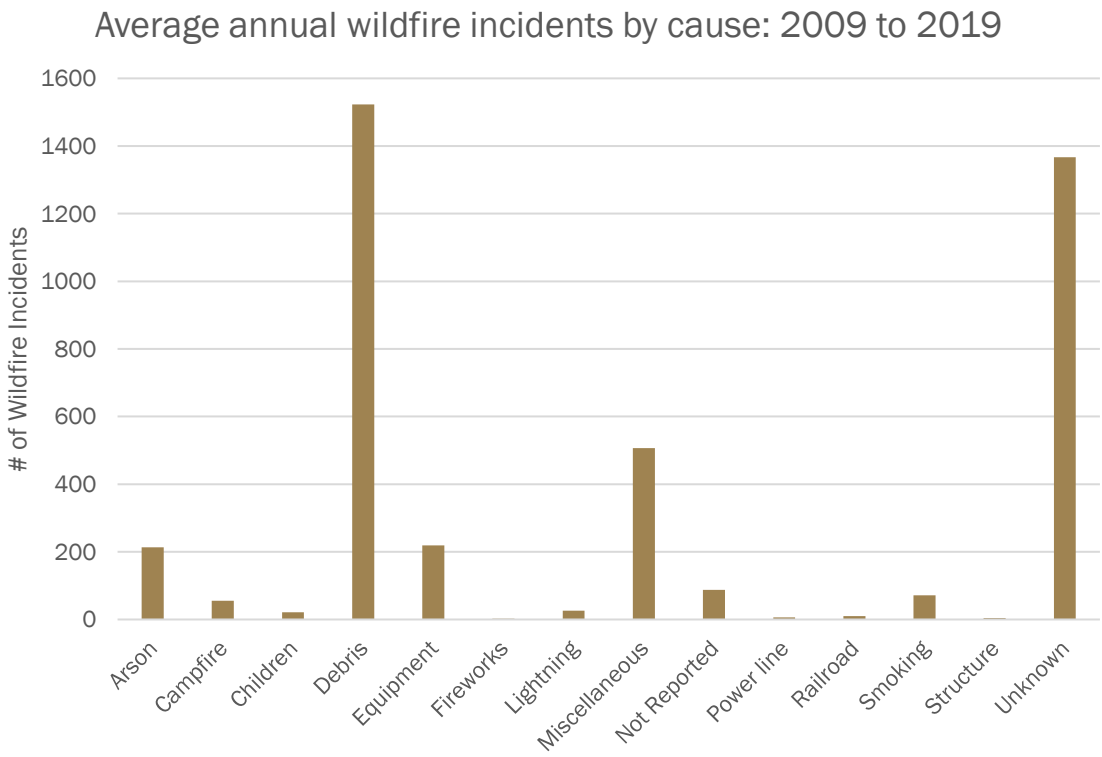


Figure 3.7.3 – Annual Number of Wildfire Incidents by Cause (averaged over 2009–2019)

(Source: Data from MDC's Missouri fire reporting system.)

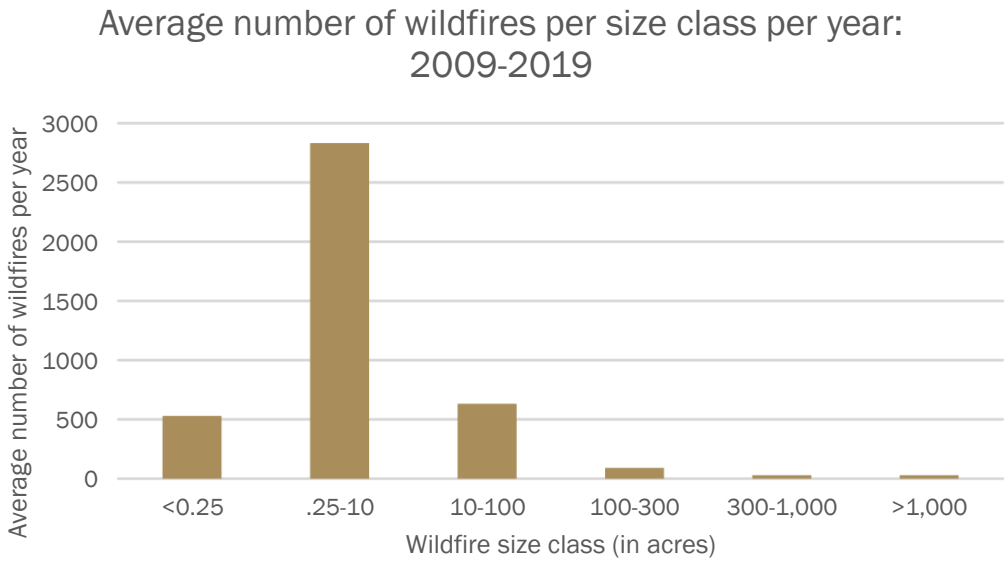


Figure 3.7.4 – Wildfires per Year by Size (averaged over 2009–2019)
(Source: Data from MDC's Missouri fire reporting system.)

In modern times, most Missouri wildfires are fought by the 800 local fire departments scattered across the state. However, MDC still fulfills an important role in fire suppression efforts:

- MDC staff serve as primary responders on 6–10 percent of Missouri's wildfires. This mostly includes larger fires beyond the capacity of local volunteers and in geographic areas with limited fire department coverage. MDC maintains a wildfire training curriculum to develop initial attack incident commanders to manage large fires. MDC also maintains and runs a fleet of 36 wildfire suppression bull dozers.

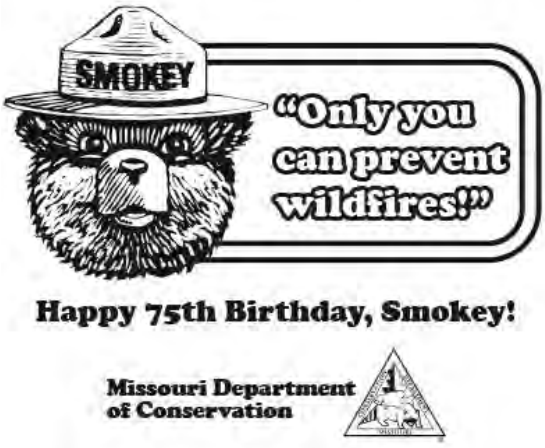
- MDC responds to mutual aid requests for smaller, less complex fire incidents when volunteers are simply not available or do not have the number of volunteers needed to safely suppress a wildfire. There are also times when the sheer number of wildfires requiring suppression resources outnumber the number of volunteers.
- MDC provides wildfire suppression training to volunteer fire departments.
- MDC provides about $385,000/year of matching grant funds to an average of 174 fire departments per year for purchasing wildland fire suppression equipment.
- MDC administers two federal excess property (i.e., equipment, vehicles, etc.) programs:

Federal Excess Personal Property (FEPP)

Firefighter Property (FFP)

  - Federal Excess Personal Property (FEPP) program. This program provides excess federal property on loan to fire departments. MDC obtains the property, makes it available to fire departments, and then performs needed tracking and administration. On average, MDC obtains approximately $120,000 of equipment annually for distribution to rural fire departments through the FEPP program.
  - The Firefighter Property (FFP)program has largely taken the place of the FEPP program. Equipment acquired through the FFP program is of better quality, and ownership of the property is given to the fire department. Equipment obtained through this program will range from emergency clothing, power generators, trailers, and wildfire/emergency response vehicles. On average, MDC obtains approximately $7 million worth of equipment annually for distribution to rural fire departments through the FFP program.

- MDC and other conservation partners conduct and assist with numerous wildfire prevention efforts. MDC and partner staff remain active within local communities and organizations to promote wildfire prevention and wildfire safety. Each year, through a variety of events, these programs reach thousands of Missouri citizens with Smokey Bear's message of wildfire prevention.



The Future of Wildfire Suppression in Missouri

The nature of wildfires in Missouri is changing. Perhaps the biggest change has been the unprecedented expansion of the WUI in the last couple of decades (**Figure 3.7.5**). According to the University of Wisconsin's SILVIS Lab, Missouri's acreage of vegetated WUI increased from 5.7 percent of Missouri in 1990 to 8.6 percent in 2010 (Radeloff et al. 2020). The WUI has had significant impacts on wildfire trends – some good, some bad. On the one hand, the increased number of people living in or next to the forest has created the greater opportunity for fires to ignite and spread to areas that threaten people and their property. On the other hand, the added presence of people and improved communications mean that wildfires in or near the WUI tend to be reported more quickly and can often be extinguished before they reach large size and pose greater threat to citizens or their property.

With the ever-increasing population growth in the WUI, MDC and other partners continue to work with rural fire departments and rural communities in the development of CWPPs and educational programs to provide the information and knowledge required to protect people, property, and natural resources.

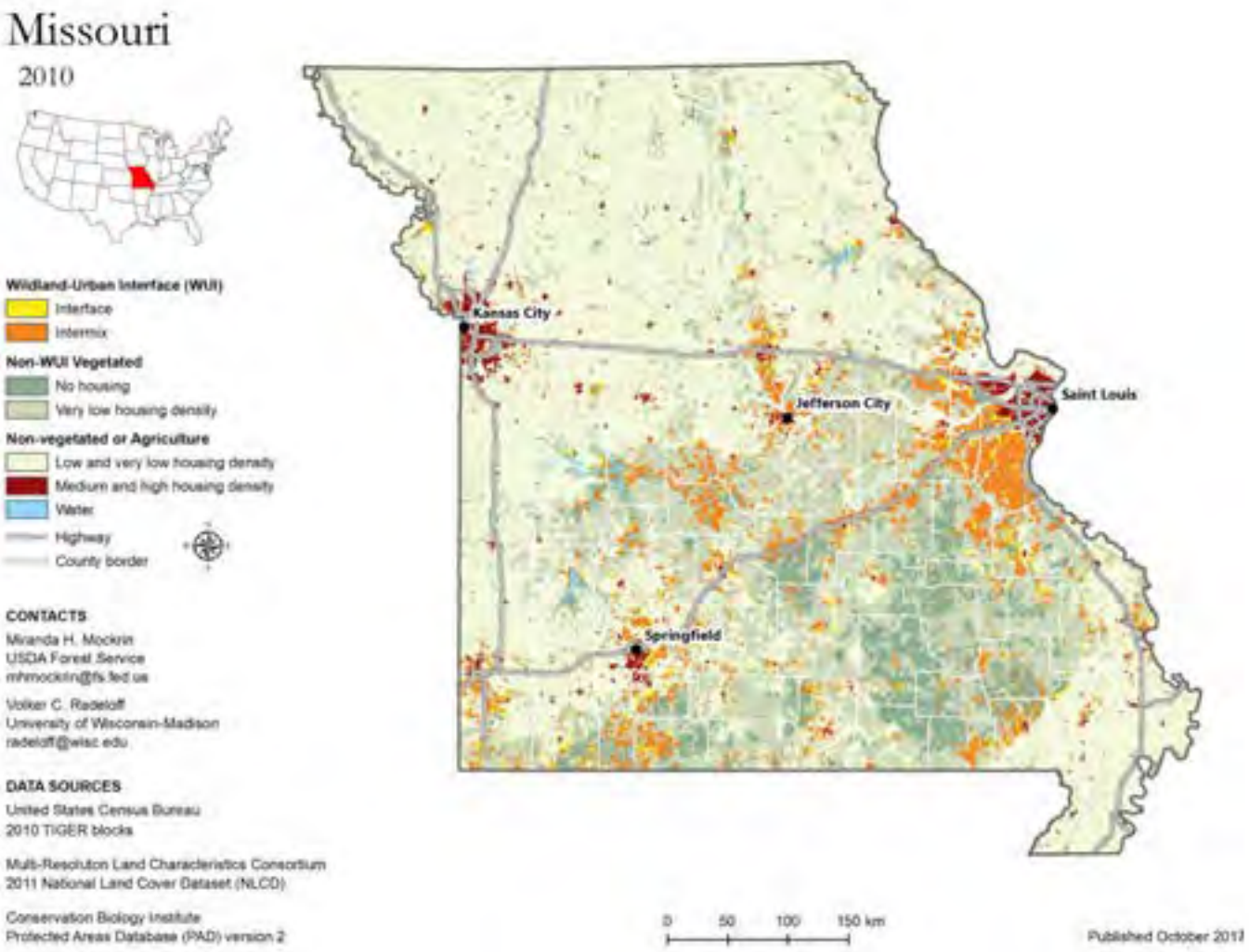
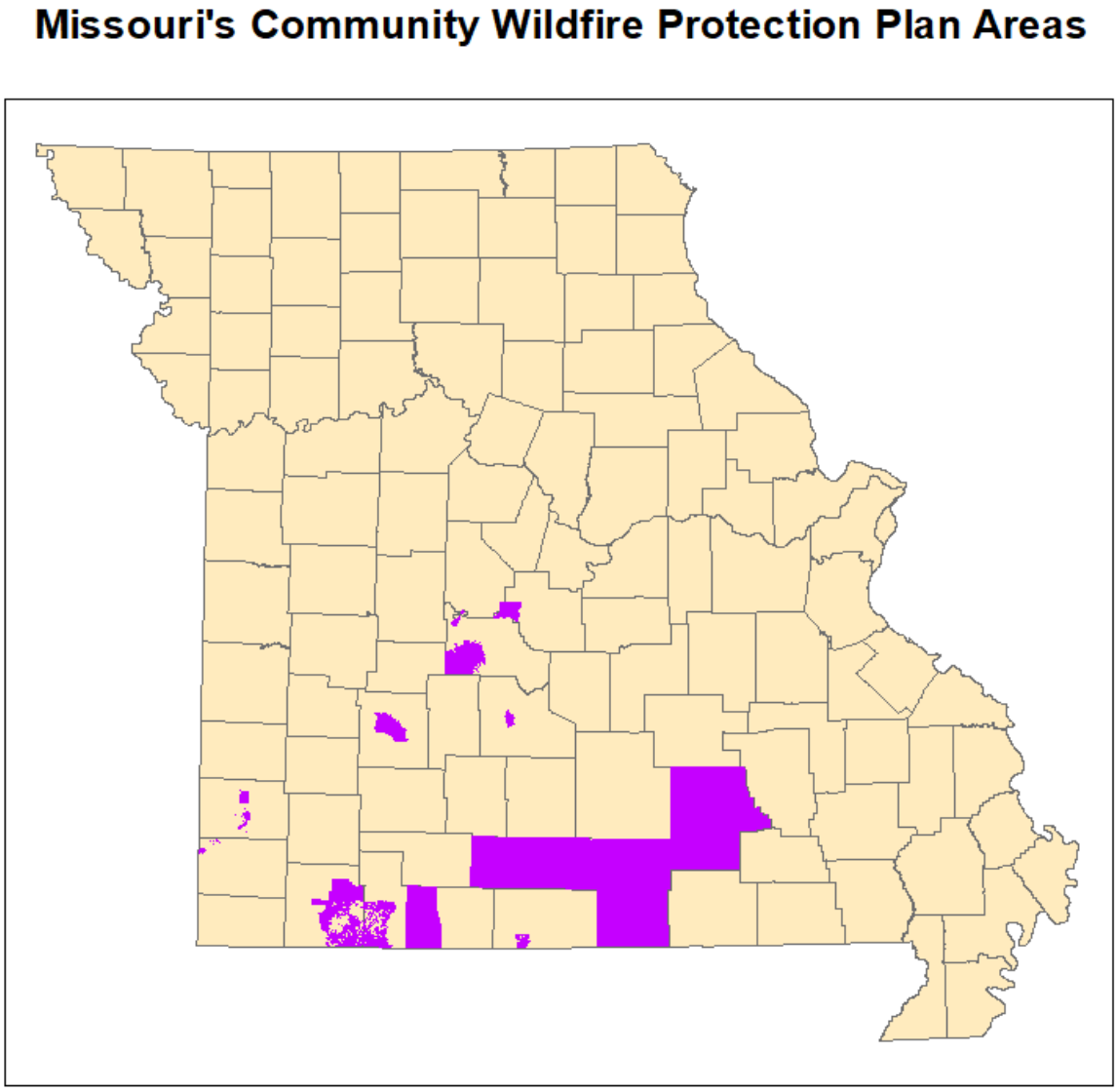


Figure 3.7.5 – Missouri Wildland Urban Interface Map – 2010
(University of Wisconsin–Madison SILVIS Lab 2020)

Figure 3.7.6 – Community Wildfire Protection Plans within Missouri



The Role and Importance of Prescribed Fire

Although it is no longer reasonable or socially acceptable to allow wildfires to burn across Missouri uncontrolled, it is important to note that most of Missouri's natural landscape developed historically under the significant influence of fire – especially prairies, glades, savannas, and woodlands, whose very health and functionality depends upon it. The complete removal of fire from Missouri's landscape would have significant negative implications to wildlife habitat and plant and animal diversity. For this reason, the success of fire suppression in Missouri has come at a cost to the health and quality of many of Missouri's natural communities, and it must be replicated through responsible use of prescribed fire. For example, in the absence of fire, glades typically are taken over by eastern redcedar trees; woodland canopies grow densely enough that ground layer vegetation is shaded out; and prairies and savannas can be overtaken by shrubs and trees, suppressing floristic diversity and creating

unsuitable habitat for many grassland wildlife species. In addition to habitat gains, prescribed fire can also be used to manage fuel loads, in combination with thinning, such that the risk of catastrophic intense wildfires is diminished in forest and woodland stands.

Many of the state's most imperiled plant species such as the federally listed Mead's milkweed (*Ascleapis meadii*), Missouri bladderpod (*Physaria filiformis*) and the western prairie fringed orchid (*Platanthera praeclara*) do best when their populations are managed with prescribed fire. Prairies, the state's most imperiled natural community type, require prescribed fire for optimal ecological health. Indeed, many of the plant species and significant numbers of animal species (e.g., eastern collared lizard, regal fritillary) of conservation concern (**Appendix H**) greatly benefit from prescribed fire. Without it, many imperiled species and communities of conservation concern would decline and diminish.

To restore natural community health and wildlife habitat, state and federal partners, NGOs, and private landowners are making greater use of prescribed fire to replicate past disturbances in a safer, controlled manner. Controlled burns are typically conducted under the guidance of a professionally prepared burn plan, following carefully selected weather conditions, and using pre-established firelines, trained crew members, and fire equipment.

Prairie regeneration in central Missouri, 2nd growing season after prescribed burn

While prescribed fire has proven to be a highly valuable tool for managing many Missouri habitats, prescribed fire is also an evolving science. Managers and researchers are continuing to learn the best timing, methods, and management practices to allow prescribed fire to achieve maximum benefit while minimizing risk. Actions are also being taken to find the best ways to make controlled burning a realistic and safe tool for private landowners.

One such action is the development of the Missouri Prescribed Fire Council. To address the application of fire on privately owned lands, several partners (including MDC, the NRCS, USFS, USFWS, TNC, Pheasants Forever and Quail Forever (PFQF), the NWTF, MDNR Division of State Parks, and several prescribed burn contractors) formed this group in 2012. Currently the Council is working with individual private landowners, prescribed fire burn associations/coops, and contractors to provide training in the form of classes and workshops and to obtain grants for training and equipment.

According to the Council, prescribed fire is an affordable and effective management tool to accomplish land management goals including

reducing fuel loads to reduce the intensity and chance of wildfire, restoring native plant communities, enhancing wildlife habitat, improving livestock forage production, regenerating merchantable trees, and controlling invasive species. The responsible use of fire can benefit the people and resources of Missouri.

The Missouri Prescribed Fire Council

The Missouri Prescribed Fire Council is dedicated to promoting and protecting the responsible use of prescribed fire as a natural resource management tool in Missouri.

The Missouri Prescribed Fire Council assembles those concerned about prescribed fire into an established organization so as to:

1. Promote and enhance the ability to use prescribed fire as a land management tool
2. Increase expertise in prescribed fire by sharing technical and biological information
3. Promote safety, training, and research in the art and science of prescribed fire
4. Review prescribed fire practices, regulations, and policies and actively work to make improvements
5. Promote public education about the beneficial effects of prescribed fire
6. Encourage the development and establishment of local prescribed fire associations

Theme Eight: Missouri's Growth, Harvest, and Consumption of Forest Products

In a nutshell: Missouri's forest products industry is an important contributor to Missouri's economy and supports diverse economic, social, and environmental values. Ensuring these values are maintained into the future means carefully balancing harvest and consumption rates with available growth and making sure that harvest practices account for long-term productivity and sustainability of all forest and woodland benefits and services, including native plant and animal species, soil productivity and health, and water quality.

Desired Future Conditions

1. Missouri's forests and woodlands and forest industry provide forest products demanded by the public and contribute significantly to Missouri's economy.
2. The harvest of forest products, including potential new markets, is improved and sustainable both statewide and regionally.
3. Best harvesting practices are utilized to maintain and enhance the health and productivity of forests and woodlands, and to ensure harvesting does not compromise other forest and woodland services and benefits, especially on privately owned lands.
4. Forests and woodlands are resilient to potential stressors (insects and disease, invasive plant species, drought, climate change) to ensure improved or sustained growth and yield over time.
5. Forest industry and communities that depend on it remain viable into the future.
6. Trees are grown and utilized to their highest value.
7. Missourians are aware of how they use wood, how much they use, and where it comes from.

Missouri's forests and woodlands are an important supplier of numerous wood products used not only in our state but worldwide. Some of the many products originating from Missouri's forests and woodlands are furniture and cabinets, flooring, barrels, tool handles, charcoal, pallets, ties, shavings, firewood, and much more. Through the production of these and other wood products, Missouri's forest products industry contributes approximately $10.3 billion to Missouri's economy annually, supports around 46,000 jobs, and generates $95 million each year in state sales tax (Treiman 2017a).

Besides the social and economic benefits of Missouri's forest products industry, there are some less obvious benefits as well. When done properly, the harvest of forest products can provide an economical means of improving forest and woodland health and wildlife habitat. Harvesting can be used to mimic historic disturbances that maintained diverse structure and composition, important to both forest and woodland health and wildlife.

Forest products can have several environmental advantages over alternative resources:

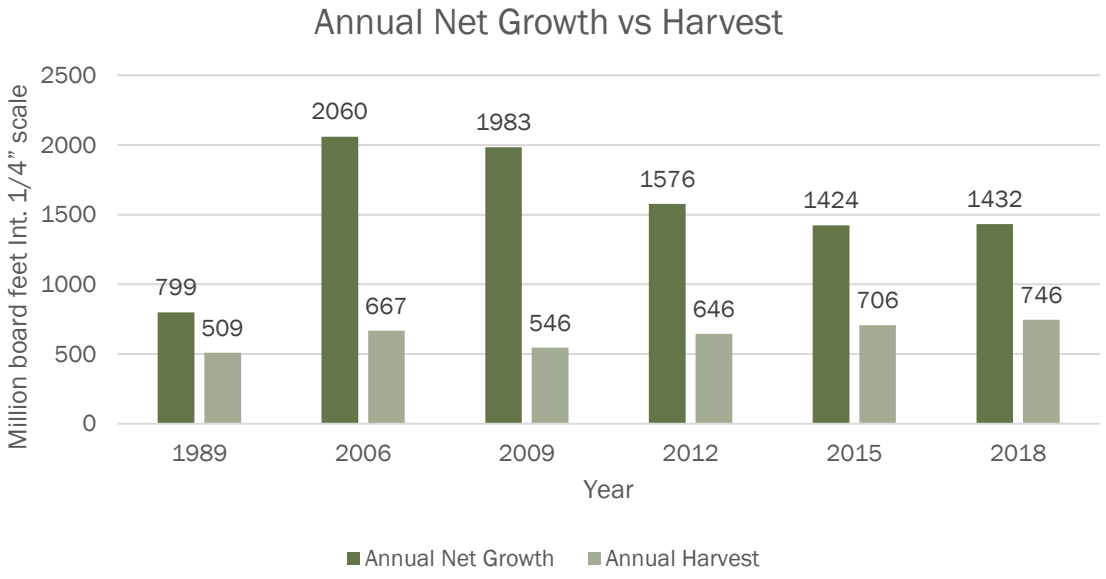
- Trees and forests are renewable resources. As trees are harvested, new trees quickly emerge and fill in the gaps left behind.
- Harvesting trees is generally much easier and leaves less of a human footprint compared to the extraction of other resources such as metals, coal, and oil.
- Forest products are generally biodegradable and/or recyclable.
- Forest products and biofuels help reduce greenhouse gases (GHGs) through carbon storage in forest products and through avoided use and extraction of fossil fuels. Carbon released from tree harvesting is taken back up by new forest growth.

Despite all the benefits and opportunities associated with forest products, making sustainable use of this resource requires careful planning and management. There is a limit to how much volume of timber can be harvested without reducing opportunities for future generations. MDC and USFS conduct surveys annually to keep tabs on how much volume Missouri's forests and woodlands are growing and how much is being harvested to ensure harvesting is being done within sustainable limits. These trends will be discussed below. The harvest of forest products is only beneficial if it is done using management practices that ensure the long-term health, sustainability, and productivity of the forest. Forest and woodland management decisions need to ensure that all the benefits forests and woodlands provide can be improved or sustained into the future.

Growth, Yield, and Consumption

Improving or sustaining the economic, social, and biological benefits of Missouri's forest products industry requires maintaining a careful balance of forest and woodland growth, natural mortality, harvesting, and consumption. Missouri's forests and woodlands grow more wood than is removed annually (**Figure 3.8.1**). While this is good for sustainable forest product harvesting, it is important to note that our growth rate is slowing.

Figure 3.8.1 – Annual Net Growth (Total Growth Minus Natural Mortality) of Missouri's Sawtimber Vs. Annual Harvest in Million Board Feet (Treiman and Morris 2018)



Using USFS FIA data on net growth along with MDC's mill survey data, Missouri mills harvested 52.1 percent of net annual growth in 2018.[13] However, this rate varies widely across the state. **Figure 3.8.2** shows this variation by MDC region.

Table 3.8.1 – Percentage of 2018 Net Growth (total growth minus natural mortality) of Sawtimber on Forestland Harvested, by MDC Region in Missouri, 2018 (Treiman and Morris 2018).

Region	Annual Harvest Volume	Net Annual Growth Volume	% of Net Annual Growth Harvested
Southeast	168,478	249,811	67.6
Ozark	252,099	378,219	66.7
Northeast	64,700	97,530	66.3
Southwest	81,228	190,083	42.7
Northwest	31,456	80,332	39.2
St. Louis	62,374	160,628	38.8
Central	64,032	189,670	33.8
Kansas City	21,610	85,426	25.3
Total	**746,246**	**1,431,700**	**52.1**

[13] Note: Log volume exported to other states (6% of the statewide figures) is estimated based on log volume imported into Missouri from other states. As actual export data becomes available these figures will be revised as needed.

While this increasing growing stock volume is certainly encouraging, it is important to keep a few things in mind. First, not all this added growth is available for harvest:

- Some growth takes place on forests and woodlands that are inaccessible for harvesting due to steep slopes, road access, etc.
- Some growth takes place on forests and woodlands in which harvesting is either not allowed or not desired by the
- [14] The 2013 survey changed to 18 percent (Butler et al. 2016).
- Some of this growth is in trees that will never grow to a merchantable size.

Furthermore, although we have experienced some positive net volume growth in recent years, this trend is slowing and could change soon:

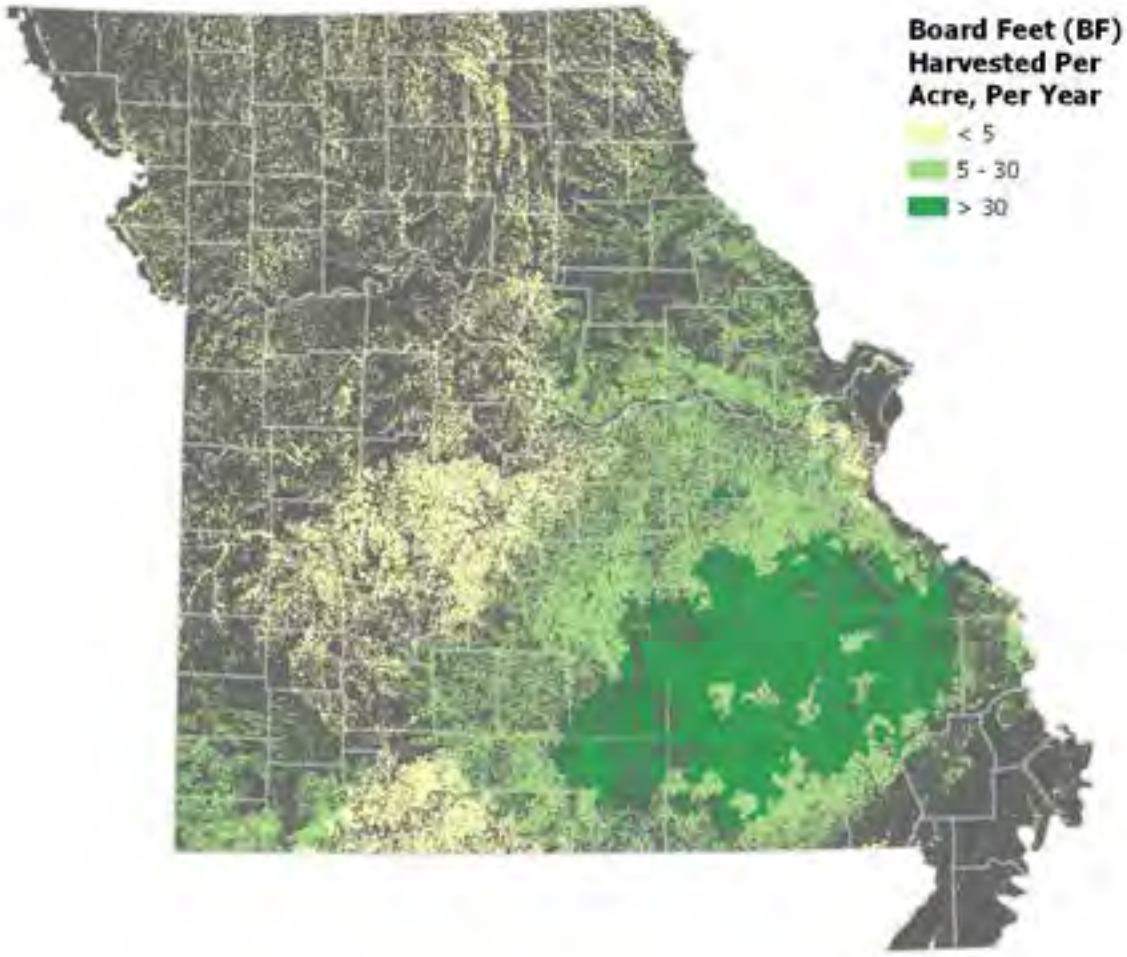
- Anecdotally, forestry professionals have observed significant increases in red oak decline and rapid white oak mortality (RWOM). Current and projected decline and mortality will likely have a significant impact on net forest growth over the next 10 years.
- There continues to be a significant amount of "highgrade harvesting" across Missouri's forested landscapes. Highgrade harvesting involves removing the most valuable and productive trees, leaving behind the least valuable and least productive trees. Since these are the landowner. The 2006 NWOS reveals that only 13 percent of family forest owners planned to harvest timber in the next 5 years. In 2013 that number was 12 percent. The same 2006 survey also states that only 22 percent of family forest owners considered production of sawlogs or other timber products to be an important reason for owning forestland.

  trees that will dominate the future forest or woodland, Missouri's future productivity and average tree quality could decrease significantly as a result.

Finally, it is important to also look at harvest rates at smaller scales within the state. The following map (**Figure 3.8.2**) shows that harvesting levels are much greater in some parts of the state than others. Thus, some locations in Missouri may experience severe harvest pressure while other locations likely have an abundance of added net growth. Potential overharvest is especially of concern in the heart of the Missouri Ozarks in southeast Missouri. If harvesting outpaces net growth for long, there may not be much of a resource left to work with in the future. Many communities in this area are highly dependent on the forest products industry and could suffer if there were a major decline in available growth for harvesting.

[14] Data includes landowners who ranked production of forest products as very important (1) or important (2) on a seven-point scale.

Figure 3.8.2 – Harvest Pressure on Missouri's Forested Land – 2018
(average harvest pressure in board feet harvested per year, per acre, over time)
(Source: Created by George Kipp of MDC using Timber Product Output Data)



The trends described in this section underscore the need for Missourians to think about our forest product needs, and how they will be met into the future. With the demands we place on our forests and woodlands growing daily, methods are needed to ensure our forest product needs will continue to be met. Some of these methods could include:

- Wise use and recycling
- Increased forest and woodland growth through improved management
- Increased number of forested acres in production through tree planting, natural regeneration, and agro-forestry
- Increase, through sustainable methods, of the volume of wood being harvested
- Increased efficiency of converting wood into products
- Engineer products that extend the utility of a given amount of harvested timber (Shifley 2007)

Maintaining Demand for Missouri's Forest Products

Missouri has enough volume of timber to support a productive and sustainable forest products industry. Equally important, however, is ensuring that our forest and woodland resources can provide the types of products that consumers demand; and consumers are made aware of underutilized resources that could be of significant value (e.g., shortleaf pine markets). As with all other durable goods, people have needs and preferences for certain products over others. If the trees grown in Missouri's forests and woodlands cannot satisfy public demands, then our forest products industry and the economic, social, and biological benefits associated with it could suffer significantly.

One emerging example is the increasing demand for "green-certified" forest products. "Green-certified" forest products are tracked from the time they are harvested from the woods to the time they are placed on the store shelf to ensure that they have been harvested in a sustainable manner. With heightening interest and awareness in environmental issues, consumer demand for certified forest products has grown substantially and will likely continue to grow. Even if trees are harvested in a completely sustainable manner, they cannot qualify as certified unless the forest/woodland is enrolled in a certification program such as the SFI, Forest Stewardship Council, or American Tree Farm System, and the logs have gone through a rigorous "chain of custody" tracking system. Missouri currently has over 630,000 acres of public forests and woodlands enrolled in the SFI certification program. An additional 27,000 acres of privately owned lands are certified through the American Tree Farm System. These acres provide a pool of forest and woodland acres for the industry to use as an entry into the certified wood products markets.

Maintaining demand for Missouri's forest products will also require assurance that Missouri's forests and woodlands can supply logs of desired species, size, and quality. Proper management of forests to maximize per log size and quality and preferred species composition will not only help maintain our current market share but increase its value as well.

Mortality Issues

Trees die from many other causes besides harvesting, even in healthy well-managed forests and woodlands. Common causes can include insects and diseases, severe weather events, excessive competition, and age. As trees die from natural causes, they quickly degrade to the point that they are unavailable for harvesting. Under ideal conditions, natural mortality is kept at a low but stable level that is low enough to avoid significantly impacting timber resources but high enough to meet other forest and woodland needs such as snags for wildlife.

The rate of mortality in Missouri's forests and woodlands is increasing. In 2013, the USFS FIA program estimated that 189.8 million cubic feet per year of merchantable growing stock died of natural causes. In 2018 this number increased to 220.9 million cubic feet per year (Goff 2020). Our forests and woodlands are aging, and older forests/woodlands have increased mortality rates.

Unfortunately, we sometimes do not have much control over mortality in the short term. A prominent example is red oak decline, which primarily affects scarlet oak, black oak, and northern red oak. It is caused by several factors including the maturity and density of these trees, red oak borers, armillaria root rot, periods of drought, and the fact that many of these trees are growing on droughty sites that historically were dominated by shortleaf pine. While it may be possible to improve the health and vigor of some of these trees, many of them are past the point of no return. The resulting spike in mortality and decline has and will continue to have a significant impact on the forest products industry.

As trees decline, they must be harvested quickly or else they will become too rotten or degraded for utilization. With a large influx of red oak decline–caused mortality, a lot of

Missouri's red oaks need to be harvested in a short period of time if they are ever going to be utilized. However, as the harvest of red oak increases, supply outstrips demand and prices plummet. It becomes uneconomical to harvest such trees, so many of them will be left in the woods to eventually rot away and recycle back into the soil. These trees will still serve other critical and useful purposes such as providing wildlife habitat and soil fertility. However, because of red oak decline, a considerable volume of growing stock will no longer be available in the future.

Although we cannot stop mortality, there are things we can to do to keep our woods as healthy and resilient as possible to minimize future large-scale die-offs. Some examples include:

- Maintaining a high diversity of tree species. Many insects and diseases are species-specific. By maintaining greater diversity in the trees in both the overstory and the understory vegetation, our forests and woodlands will not be totally devastated if one species is heavily impacted by a forest health problem.
- Maintaining appropriate stocking. Crowded forests and woodlands are much more vulnerable to decline and mortality. Every acre only has so much water, nutrients, sun, and space. Trees in crowded stands vigorously compete and have less energy available to fight off insect and disease issues, etc.
- Maintaining diverse forest and woodland canopy age structure. By maintaining forest and woodland landscapes as complex mosaics of forest/woodland age structures we help ensure a steady supply of forest products and avoid the unsustainable boom-and-bust pattern that was experienced in the late 1800s/early 1900s.
- As forests and woodlands are harvested and new forests and woodlands emerge, it is important that methods are used to ensure that tree species which inhabit the new forest/woodland are desirable and well suited to the site. This process does not always happen on its own. A common example includes oak-dominated forests and woodlands that have developed understories of sugar maple due to the elimination of wildfire. As overstory oaks are harvested in such forests or woodlands, the remaining sugar maple trees quickly gain dominance unless management practices are used to avoid this conversion. While sugar maples are native and are attractive in the fall, they rarely produce quality forest products on Missouri soils and have much less wildlife value compared to the oak forests that traditionally dominated these sites.

Sustainable vs. Unsustainable Forest Management Practices

Management decisions made for a forest or woodland tract can have a profound impact on its health, long-term productivity, and the benefits that the forest/woodland will provide for years to come. If management decisions and actions are well informed and planned, they can improve the health and value of a forest or woodland significantly. However, poor management decisions such as highgrade harvesting can have equally negative impacts.

Management decisions that promote healthy, productive, and sustainable forests and woodlands typically:

- utilize the guidance and expertise of a professional forester
- are based on long-term goals and values
- consider many variables such as wildlife habitat, water quality, and recreation

- incorporate best management practices and other investments that will increase long-term values derived from forests
- use trained loggers that have proven to do low-impact harvesting

Regenerative and sustainable forest management practices maximize profitability for a private landowner. Long-term planning establishes a periodic income stream, while providing continuity of wildlife habitat and a myriad of other benefits when high quality forests and woodlands are maintained. Building and sustaining natural resource value in forests and woodlands promotes private land conservation across generations.

Establishing Trust Among Landowners, Foresters, Loggers and Mill Owners

One issue that significantly influences the process of buying and selling timber is trust or the lack thereof. Landowners, foresters, loggers, mill owners, and consumers are often worried they are getting taken advantage of by someone else. In most situations, this lack of trust is unwarranted. In fact, the whole issue of trust in this business is somewhat ironic considering that the forest products industry built itself quite successfully on a series of handshakes. However, reassuring all partners of the integrity of a transaction is essential to improving the viability of the forest products industry.

The creation of the Missouri Master Logger Certification program has made great strides in improving the trust between landowners and loggers. Certified Master Loggers agree to abide by a set of standards, and their performance is verified by independent third-party auditors. Additional recognition programs such as MDC's Logger of the Year Award let landowners and other loggers know who is doing outstanding work. These two programs demonstrate success by producing demand for these loggers to work across the state.

Ensuring the Long-term Viability of Loggers in Missouri

According to the Missouri Forest Products Association (MFPA), the average age of a Missouri logger is around 60 years old. It is critical for the industry to recruit new loggers to continue supplying logs to mills. Changing attitudes and work ethics are challenges to recruitment. The MFPA is starting a logging school in Missouri to train the next generation of loggers. Students receive Professional Timber Harvester certification, as well as experience working with and maintaining equipment; learning forest and woodland management practices; understanding BMPs to protect water quality; and working with landowners. The program is just beginning, but it is an important step to the future of logging. MFPA, in partnership with MDC, also provides several five-day Professional Timber Harvester training courses each year across the state. Collectively, these programs will help recruit and train Missouri's next generation of loggers.

Theme Nine: Recreation, Human Health, and the Relevance of Nature

In a nutshell: Public support for Missouri's natural resources and conservation efforts has been strong for decades. But the playbook for how Missourians interact with nature is changing. Keeping up with that change is a challenge that can't be ignored. Demand for outdoor recreation opportunities still exists, but a transition is underway as population demographics shift and the pull of technology continues to shape everyday life. Getting Missourians to see great value in the state's natural landscapes means taking a fresh look at what matters to them most. It means helping them understand the connection between time in nature and their physical and mental well-being. It means helping them see the relevance of nature to their everyday lives. But it also means that conservation and natural resources experts need to understand how changing perspectives will alter how people spend time in nature and how the resources are managed. This focus is critical for maintaining or improving a statewide conservation ethic; ensuring Missouri's natural landscape sustainably provides the public benefits and quality of life we all depend upon; improving or maintaining ongoing political and financial support; and improving the long-term health and sustainability of Missouri's natural communities and native flora and fauna.

Desired Future Conditions

1. All Missourians, including new and underserved audiences, have plentiful opportunities to learn about and connect with nature and understand the human health benefits of doing so.
2. All Missourians, including new and underserved audiences, have good access to quality outdoor recreation opportunities close to home.
3. Missouri citizens have widespread understanding and appreciation for the value and diverse public benefits (quality of life, human health, environmental) of Missouri's conservation resources and the need for proactive investment, management, and protection.
4. Missouri citizens understand the role they play in determining the future improvement and sustainability of Missouri's conservation resources and engage through volunteerism, advocacy, and personal actions.

Population and Demographics

Missouri's Population Is Getting Older

According to the Missouri Office of Administration (MOA), Missouri is home to nearly six million people and growing steadily at 6 percent population increase per decade. Projections indicate the growth rate will continue, but Missouri's demographics are changing. By 2030, the United States will face a turning point in its history when the population of adults age 65 and older will outnumber children under age 18. That shift will be consistent through Missouri as well, as the state's baby boomers age. Missouri's senior citizens are expected to increase 87 percent between 2000 and 2030. By 2030, more than one in five Missourians (1.4 million people) will be over the age of 65 (MOA 2020). The aging of Missouri's population will have a profound effect on the services, facilities, outreach, and programming related to outdoor recreation.

Missouri's Minority Populations Are Growing

Minority populations are growing faster than the general population, increasing over the past decade three times as fast as the state population as a whole (MOA 2020). The U.S. Census Bureau's 2018 population estimates for Missouri indicate that its minority population accounts for almost 21 percent of the total population. African Americans account for the highest percentage in the state, at 11.8 percent of the total population, and Hispanic and Latino populations as the second highest minority percentage, at 4.3 percent (U.S. Census Bureau 2018).

Minority populations in Missouri will continue to grow, although projections indicate at a slower rate than the national estimate. A 2015 report by the Center for American Progress, the American Enterprise Institute, and the Brookings Institution projects that Missouri's minority population will equal nearly 36 percent by 2060 (Teixeira et al. 2105).

Historically, encouraging minority participation in outdoor recreation activities has been a challenge. A 2018 report by the Outdoor Foundation found that of the 151 million Americans participating in outdoor activities, the overwhelming majority (73%) were white (Robbins 2020). Various national studies attempt to explain the reasons for lack of minority participation, ranging from cultural to socioeconomic to historical. Regardless, attracting new audiences to outdoor activities means working to make opportunities to overcome the various barriers that prevent those populations from participating. It also means paying special attention to emphasizing the relevancy of nature to those audiences.

Urban and Rural Population Shifts

Missouri's population density is heavily weighted to urban areas. While Missouri is a mostly rural landscape, nearly three out of four Missourians live in the 3 percent of the land that is classified as urban. Over the next thirty years, the largest population growth is predicted in the suburban counties classified as "urban fringe," surrounding Kansas City, St. Louis, and Springfield. A significant decline is expected for St. Louis County and agricultural counties (MOA 2020).

According to population projections from MOA, natural change and in-migration will accelerate the population shift in these areas. St. Charles County is expected to grow its population 76 percent by 2030, with a net gain of 215,000 people. In the Kansas City area, Cass, Clay, and Platte counties combined may grow their populations as much as 62 percent. Both Christian County (south of Springfield) and Lincoln County (northwest of St. Louis) are expected to more than double in population size by 2030 (MOA 2020).

Except for St. Louis County, the top ten counties of greatest population decline are rural. New Madrid County could lose more than one-third of its population (about 7,500 people) by 2030, and both Iron and Gentry counties could lose 30 percent (MOA 2020).

For most Missourians, the state's natural resources are not a few steps from their doorway. Trends indicate that the growth in suburban and

urban populations will make this even more so. As Missourians find themselves less connected to nature, it will be critical to offer plentiful outdoor recreation opportunities and share the stories of the beauty and benefit of the Missouri's natural landscapes, many of which may be far removed from the population centers.

These facts also reinforce the need for continued efforts toward increased community conservation opportunities in Missouri's urban and suburban areas. Such efforts are well underway and described in detail within **Section Five** and include emphasis in community forestry, native gardening and pollinator habitat, stream restoration and enhancement, and much more.

Table 3.9.1 – Missouri's Population Distribution Between Rural and Urban Land (2000 Census)

Missouri's Population Distribution Between Rural and Urban Land (2000 Census)				
Geography	**Rural Land Classification**	**Rural Population**	**Urban Land Classification**	**Urban Population**
Missouri	97.4 percent	31 percent	2.6 percent	69 percent
United States	97.4 percent	21 percent	2.6 percent	79 percent

Source: Conservation planning tools for Missouri communities, MDC, 2018, at **mdc.mo.gov/sites/default/files/downloads/Conservation%20Planning.pdf**.

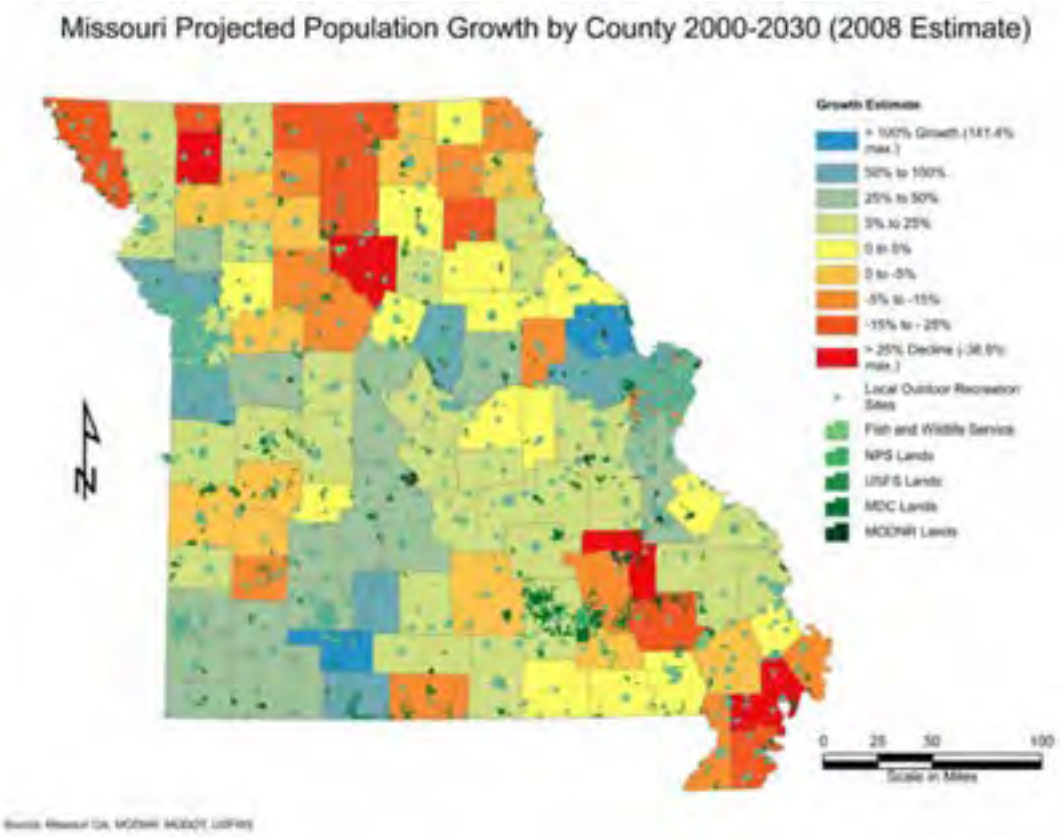


Figure 3.9.1 – Map courtesy of the Missouri Statewide Comprehensive Outdoor Recreation Plan (Misoouri SCORP 2018). Data sources include MOA, MDNR, Missouri Department of Transportation, USFWS.

Recreation

Examining the future for Missouri's natural landscapes should include considerations of how people recreate in the outdoors. In this section we evaluate what land exists for public recreation and the trends, opportunities, and threats to those activities.

In Missouri, outdoor recreation looms large in terms of economic impact. According to the Outdoor Industry Association, it creates 133,000 direct jobs and generates $14.9 billion in consumer spending. It also generates $4.6 billion in wages and salaries and $889 million in state and local tax revenue (Outdoor Industry Association 2020).

Outdoor recreation also takes many forms – from hunting in the woods to the family picnic in a local park. While at least half of the U.S. population participated in some form of outdoor recreation in 2018, that means about half did not. According to the most recent research, the number of people making regular efforts to do so is dropping. The research also shows that over 63 percent of outdoor participants report that they recreate within 10 miles of their home (Outdoor Foundation 2020).

National trends indicate that the frequency of outdoor recreation among youth is dropping. According to the 2019 Outdoor Participation Report, kids went on 15 percent fewer annual outings in 2018 than they did in 2012. Since youth participation is a strong indicator of future activity, that decline is a serious concern (Outdoor Foundation 2020). Missourians' participation in outdoor recreation reflects national trends, as detailed below.

Public Land

Missouri has over three million acres of public land. In addition to land owned by state and federal agencies, thousands of Missouri's cities and towns manage parks and other outdoor recreation facilities for public use – an estimated 112,000 acres belong to local communities (MDNR 2018).

State Land

State-owned properties fall under the purview of MDC and MDNR, encompassing over 1.1 million acres. MDC manages over 1,000 properties, offering fishing, hunting, trapping, wildlife viewing, hiking, camping, and gun or archery target practice, and more. MDC also operates seven nature centers and seven interpretive sites, both bringing in more than 800,000 visitors each year and hosting almost 187,000 programs.

Missouri State Parks, a division of MDNR, provides parks, open spaces, and cultural opportunities throughout the state. The purpose of the state park system is to preserve and interpret landscapes and cultural features of statewide or regional significance and provide compatible recreation. The park system includes 2,000 structures, 3,500 campsites, 194 cabins, almost 2,000 picnic sites, and nearly 1,200 miles of trail for hikers, backpackers, bicycle riders, off-road vehicle users, and horseback riders.

Federal Land

Various federal agencies maintain over 1.7 million acres of property in Missouri as well. The National Wildlife Refuge System, part of USFWS, includes 71,085 acres. The USFS manages MTNF, covering 1.5 million acres in 29 counties. Both the National Forest and the Refuge System offer a wide variety of recreational opportunities. The USACE operates 12 lakes in the state with some of the surrounding recreational lands leased and managed by other recreation providers.

Outdoor Recreation Needs and Barriers as Reported in the Missouri SCORP

MDNR's Division of State Parks produces a five-year statewide comprehensive outdoor recreation plan (SCORP) for the state. The most recent edition covers 2018–2022 (Missouri SCORP 2018) and assesses outdoor recreation issues of statewide significance and evaluates the supply and demand of public outdoor recreation resources in the state.

A significant portion of the 2018–2022 SCORP is dedicated to assessing the outdoor recreational needs of children, particularly those who live in urban areas. To gather data and background on the recreational needs of all of Missouri's children, they conducted focus groups and surveys to hear directly from young people and their parents regarding their attitudes about outdoor recreation, current and desired outdoor activities, motivations for and barriers to spending time outdoors (Missouri SCORP 2018).

What do urban youth think about the outdoors? The focus groups show young people know that being outdoors is good for their physical health, but they were far more focused on emotional benefits. Their input focused on being outside to feel calm, peaceful, and unconstrained. They liked being outdoors for the friendship and fun, the sense of adventure, risk-taking, and achievement of trying something new. They also expressed an interest in being fully enveloped in nature – noting that even favorite city parks have noise and crowds but being "lost in the woods" is a rare and valuable occasion.

Urban youth enjoy an array of outdoor activities, from sports and games to "just hanging out." But they are interested in activities that allow challenge and risk – target shooting, hunting, ATV riding, archery, horseback riding, and rock climbing were mentioned frequently. They also indicated that activities allowing quieter enjoyment of the outdoors appealed to them – fishing, hiking, canoeing, or picnics. These results are on par with the most basic values of Aldo Leopold's conservation ethic, which grew out of his understanding that large undeveloped areas provide for hunting, fishing, hiking, horseback riding, and especially the experience of solitude. There are ample opportunities to experience outdoor adventure, quiet, and solitude in Missouri, including eight wilderness areas totaling 86,000 acres (managed by MTNF and USFWS) and twelve wild areas totaling 23,000 acres (managed by MDNR Division of State Parks).

When the focus group shifted to questioning parents of these urban youth, they discovered that parents value outdoor activities that teach useful, essential life skills, including responsible gun usage and gardening. They also like to see their children do many of the same activities they enjoy/enjoyed themselves, such as fishing, bike riding, archery, hiking, etc.

When covering barriers between youth and the outdoors, urban youth and their parents often feel that the recreational areas most accessible to them are violence-prone and neglected. Older teens feel that outdoor parks and other urban spaces cater only to younger kids. Most respondents want more trails and sidewalks, more age-appropriate spaces, and more organized activities near to them. One of the biggest barriers? Too much screen time. The lure of games, television, and apps is strong for kids of all ages and backgrounds.

The focus groups conducted for the SCORP documented that in Missouri, going to a different part of the state is a rare occurrence for many urban youth. They want to get away from the city, experience something new, and take advantage of the trails, natural areas, and organized outdoor recreation programs that Missouri has to offer, but the distance, even just 30 miles away, is a barrier (Missouri SCORP 2018).

Surveys from the SCORP provided some compelling data from a statewide perspective. Nearly all of the youth respondents (92%) describe the outdoors as fun. Most said that their most fun times have been spent outside, and they wish they could spend more time outside. A majority (63%) did say that, despite their interest in outdoor activities, being inside is more comfortable due to bad weather, bugs, etc.

Parents surveyed for the report are eager for their children to spend time outdoors but seek low and no-cost programs that work with their schedules. They are also looking for activities they can enjoy together, close to home.

Figure 3.9.2 – Chart from Missouri SCORP 2018, 56.

The SCORP survey also assessed activities and interests from an urban, suburban, and rural perspective, including the most common locations for outdoor activities. Regardless of where they live, most respondents said their outdoor recreation happens in their own yards, driveways, and nearby sidewalks. Rural youth are statistically more likely to use fields, woods, and streams near their homes. Urban and suburban youth are more likely to recreate in a neighborhood park or playground, on residential streets, or at a community pool or lake.

When survey respondents were asked which areas they would most like to visit, regardless of where they live, youth across the state would like to visit areas where they could participate in more adventurous activities. Horseback riding was a top desire, as well as boating, target shooting, and trails for motorized vehicles.

Figure 3.9.3 – Chart from Missouri SCORP 2018, 61.

Both parents and youth were asked why they didn't spend more time outside, and what barriers preventing them from doing so. Parents reported that their kids simply prefer doing indoor activities. Youth respondents said the same, with over one-half saying they would rather watch TV or play video games and use apps (Missouri SCORP2018).

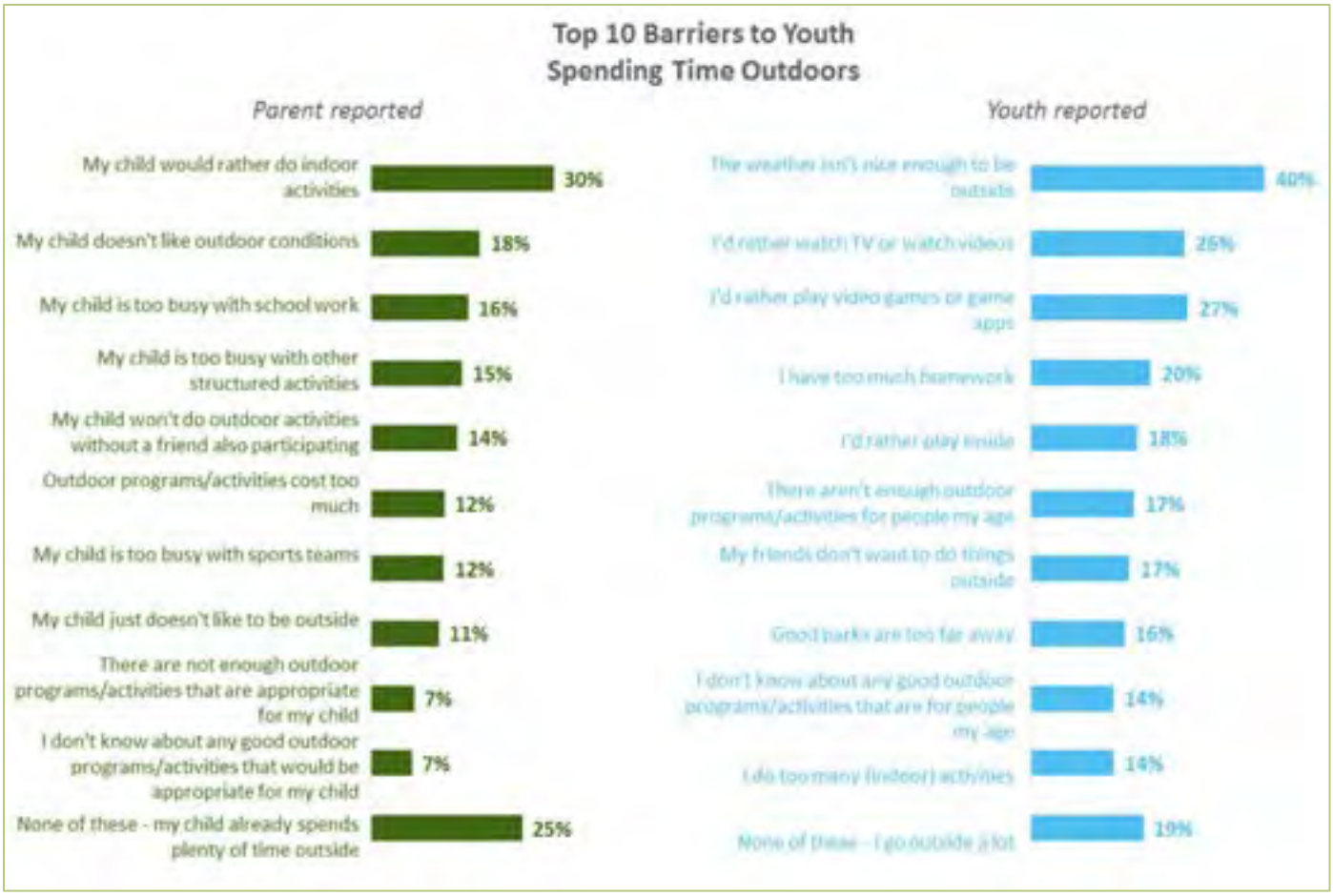


Figure 3.9.4 – Chart from Missouri SCORP 2018, 62.

One other interesting result from the SCORP survey centered around what constituted a reasonable walk. While parents reported that access to free outdoor programs would be the greatest determining factor for helping to get kids outside, both youth and parents agreed that the second most important factor is to have outdoor recreation opportunities within walking distance. Most parents (83%) report that a reasonable walk is less than 15 minutes.

Responsible Recreation

There are multiple benefits associated with engaging in outdoor recreation and many opportunities to enjoy the outdoors throughout Missouri; however, consideration for potential impacts to the long-term health of Missouri's natural resources is important. The multitude of outdoor recreational activities available can range from no or minimal impact to high impact. Before engaging in an activity, it is important to understand potential impacts and how to avoid or minimize them. Following are a few examples of outdoor activities and considerations before engaging in them.

- Canoeing/kayaking
  - Missouri is home to world-class opportunities for canoeing and kayaking. Whether on a pristine Ozark stream or a family lake, it is every user's responsibility to take care of Missouri's water while engaging in these activities. Ensuring that the vessel and oars are free of hitchhiking invasive species, mud, and plant debris is an

important first step prior to moving the vessel to the next waterbody. Securing cargo in case of accidental capsize and ensuring all trash/waste is secured and properly disposed of can aid in keeping Missouri waterways clean and enjoyable for future generations.

- Hiking/Nature Walks
  - Missouri offers ample statewide opportunities for hiking and scenic nature walks. These activities are enjoyable for all ages and a great way to introduce new users to nature. However, it is important to ensure hiking boots are free of mud and debris, especially within the tread, as seeds from many invasive plant species are easily transported. Some trailheads even offer boot cleaning stations to clean debris from boots before/after hiking. Also, adhering to designated trails where possible limits impact from foot traffic, especially in high-use areas. It's important to pack out what is packed in and leave no litter behind.

- ATV/UTV/Side-by-Side Use
  - The use of ATVs and UTVs has become a favorite pastime among Missouri outdoor enthusiasts, private landowners, hunters, and more. These off-road vehicles offer great sport and benefit in transporting gear and crews but can cause severe impacts to the environment such as soil disturbance and accelerated erosion, water quality issues, spread of invasive species, and destruction of sensitive plant communities and wildlife. Because of these potential impacts, it is important to minimize soil disturbance and stay on trails and roads where possible, cross streams only as necessary, avoid wetlands and wet meadows, and drive responsibly to protect the environment.

Missouri abounds with opportunities for outdoor recreation. Whatever the preferred activity, enjoy nature, but please consider potential impacts and limit the footprint left behind for the benefit of all Missourians, present and future.

Nature's Impact on Human Health

While the average person understands that trees and nature provide broad environmental benefits, not many are attuned to how nature can affect them on a very personal level – more specifically, their health. A growing body of research is documenting how spending time in nature offers great benefit to people's physical and mental health. For conservation-focused agencies and organizations, this provides a new angle and an important opportunity to connect with people who might not ordinarily be interested in the state's natural resources.

Missourians' Physical Activity, Health and Wellness

In Missouri, there is much to be gained by encouraging people to spend time outdoors for their well-being. Sedentary lifestyles are putting Missourians at risk for obesity and poor health. The Centers for Disease Control and Prevention (CDC) recommend at least 150 minutes of physical activity per week and estimate fewer than half of all Americans meet that recommendation. About one-third of Missourians report participating in no leisure-time physical activity at all. Under half report engaging in at least 150 minutes per week of

moderate-intensity aerobic physical activity (CDC Nutrition).

Many chronic health conditions can be improved or prevented by being physically active, including heart disease, diabetes, arthritis, and high blood pressure. Heart disease is the leading cause of death in Missouri, killing 15,000 people every year (Missouri Department of Health and Senior Services 2020). In 2017 it was estimated that 492,000 adults in Missouri had diabetes (MDHSS 2020), and arthritis currently affects 1.4 million Missourians (Missouri Regional Arthritis Centers 2020).

Research Supports Nature/Health Connection

The link between nature and good health is more than just anecdotal. Scientists and doctors alike now believe that regular outdoor activity can serve as a method of preventative care. They also recognize that green space, whether rural or urban, can make a positive difference for people's physical and mental health.

A recently published study of almost 20,000 adults in England showed that people who spent two hours a week in green spaces such as local parks or other natural environments were substantially more likely to report good health than those who don't (White et al. 2019). Strenuous exercise during that outdoor time wasn't necessary for a positive impact. The results were consistent across different occupations, ethnic groups, financial stability, and age groups.

That study, along with many others, has shown that time in nature is an antidote for stress as well. Direct exposure with nature can lower blood pressure and stress hormone levels, reduce nervous system arousal, enhance immune system function, increase self-esteem, reduce anxiety, and improve mood. It can even reduce symptoms of ADD and aggression and can speed the rate of healing (Robbins, 2020).

USFS published a document in February 2018 that outlines cumulative research related to the health benefits of urban trees and green space (USFS 2018). It cites over 150 references for research on pollution and physical health, active living, mental health, stress reduction, social health and resilience. The document concludes that "the evidence of the link between nature, health, and preventive medicine will hopefully spur more direct collaboration between the health, urban planning, education, and natural resource communities. With growing pressures of modern life, these are critical connections to pursue."

From a natural resources perspective, it is critical to remember that the health benefits of connecting with nature aren't just relegated to spending time in remote wooded locations. As Missouri's population centers within mostly urban areas, establishing the value of urban green space can be as important and effective as more traditional consumptive use of more rural areas. Finding a way to help urban dwellers experience nature as a part of their everyday life means focusing an effort on urban forest canopy, green stormwater infrastructure, and other opportunities to connect with nature.

When the main goal is conservation of natural resources, things like blood pressure, obesity, and mental wellness aren't typically central to the decision-making processes. As conservation organizations evolve, it will be important to consider the human/nature connection in a way most aren't used to doing. It means getting people to understand the importance of, care about, and be involved in the natural landscapes they rarely see and the green spaces that surround their everyday lives. Making nature relevant to their health and relevant to their personal lives must be incorporated into conservation activities.

Relevancy of Nature

It may seem an odd consideration, relevancy of nature. Surely nature is relevant to everyone, because we are all part of the natural world. But many people are increasingly isolated from nature, separated from the natural wonder that exists outside their doors. It's easy to take the

natural world for granted, or to not think of it at all.

At the same time, when people take time to get outside, the natural world inspires awe and wonder. While some might think that only happens in great landscapes, it's important to remember that authentic, special experiences can happen anywhere, in a back yard or a natural area. For children particularly, experiencing nature can be digging a hole in the backyard to look for worms or watching a squirrel gather acorns.

In Missouri, the aesthetic and scenic value of nature – forests, woods, creeks, prairies, caves, glades, wetlands – are precious resources we have committed to conserving. Keeping that commitment on the forefront means staying relevant to the people who support conservation efforts and becoming more relevant to those who don't.

Relevancy Roadmap

In 2015, AFWA convened a Blue Ribbon Panel on Sustaining America's Diverse Fish and Wildlife Resources. The panel recognized an urgent need for additional funding but also focused on the lack of conservation relevancy in the lives of many Americans. To make sure that state agencies across the country remain relevant, the panel developed a relevancy roadmap for adapting to the nation's changing demographics and values (Dunfee et al. 2019).

In September 2019, the Blue Ribbon Panel released the *Relevancy Roadmap*, intended as a practical guide for conservation agencies to use to overcome barriers to broader relevance, public engagement, and support. The roadmap provides multiple pathways to respond to the diverse social, economic, demographic, political, and environmental changes that states face.

The roadmap cites five major actions that conservation agencies need to address to remain relevant. These actions would impact numerous relevancy barriers and increase agency capacity to implement new strategies. The actions are as follows (Dunfee et al. 2019):

- **Agency leadership and governing bodies must recognize the need for conservation agencies to adapt to changing societal conditions and demonstrate support for adaptation efforts**. Without guidance and support from leadership, an agency is unlikely to undertake the type of adaptive changes needed in response to societal trends.

- **Agency leadership and governing bodies need to demonstrate commitment to being more inclusive of diverse perspectives and interests in fish, wildlife, their habitats and outdoor recreation activities**. An agency's public trust responsibility extends to all members of current and future generations. Leaders must set the example and expectation that the agency will engage and serve broader constituencies.

- **Agencies need to increase acquisition and application of social science information (stakeholder engagement, stakeholder inquiry, marketing, education, outreach, communications, economics, and evaluation) to identify, better understand, engage, and serve broader constituencies**. The human dimensions of fish and wildlife conservation must be informed by science that is as robust and comprehensive as the ecological information relied upon in the past. Social science needs to have equal consideration with biological science in funding priority and decision-making.

- **Agencies need to commit to assessing, evaluating, and improving agency structures, processes, practices, and programs and to share lessons learned about their experiences in engaging and serving broader constituencies**.

Albert Einstein said, "We cannot solve today's problems with the same kind of thinking that created them." To address the challenges of the coming decades, agencies need to be strategic and adaptive.

- **Agencies need to commit to increased and improved partnering and collaboration to increase engagement with, and service to, broader constituencies**. The demands on fish and wildlife agencies today exceed their individual capacity. There are numerous current and potential partners with tremendous experience, resources, and expertise, eager and willing to assist agencies to fulfill their missions. Agencies need to leverage their experience and relationships with current partners and build additional partnerships to broaden their reach and collective conservation impact.

Barriers to engaging and serving broader constituencies were boiled down to five major categories: agency culture, agency capacity, constituent culture, constituent capacity, and political/legal constraints. Here are some examples of how Missouri is addressing those challenges.

Agency Culture

Barriers related to agency culture focus on nature-based values and outdoor interests that don't align with broader audiences. Agency culture can also prevent adaptation to changing interests and can inhibit collaboration due to a competitive and siloed culture.

In Missouri, one way to address that barrier is to prioritize the development of partnerships that engage broader audiences. The MDC has begun hosting annual partners meetings, which are one-stop shops for conservation partners to learn about and offer direct feedback regarding MDC's strategic plan, key issues, and priorities, while also offering a forum for the public to ask questions and provide feedback to help guide conservation work. These partner roundtables are excellent opportunities for Missouri's conservation network to engage with peers, share ideas and challenges, and build vision for the future.

Each year, Missouri's conservation network engages in the Missouri Natural Resources Conference (MNRC). MNRC is an annual meeting organized and sponsored by the Missouri Chapter of the American Fisheries Society, The Missouri Chapter of the Society of American Foresters, Missouri Chapter of The Wildlife Society, and the Show-Me Chapter of the Soil and Water Conservation Society. This unique blend of disciplines, represented by the four societies, promotes wise use and management of Missouri's natural resources. Each year the conference hosts approximately 1,000 established and aspiring natural resource professionals who meet to exchange information and ideas and encourage continued cooperation among resource professionals, agencies, and other natural resource stakeholders. Cooperating agencies include MDC; the University of Missouri, School of Natural Resources; the Missouri Cooperative Fish and Wildlife Research Unit; USFS; and NRCS (**mnrc.org**).

Constituent Culture

Barriers to constituent culture focus on perceptions among the general public that conservation agencies only care about and serve hunters and anglers. It also includes fears, concerns, or beliefs that prevent people from engaging with nature. It highlights the fact that constituents may not recognize the threats facing Missouri's natural resources.

Missouri conservation partners are employing several tactics to build constituent understanding and involvement with nature. For example, there is an immense amount of outreach generated among conservation partners regarding the importance and role of nature and its benefits to quality of life. Moving forward, it is crucial this outreach be consistent. Another tactic is heightened emphasis on community

conservation practices and activities to engage citizens in conservation near where they live. Finding and/or providing opportunities for citizens' engagement within minutes of their home is important in today's culture. Community planners understand that to connect urban citizens with nature, three factors are key: proximity, accessibility, and comfort. It is important to ensure an equitable distribution of greenery across the city to provide proximity and daily exposure to nature for all. Additionally, equitable design of greenspace is important to provide accessibility for all and to ensure everyone can be comfortable when experiencing nature.

While experiencing nature's benefits close to home may be important, people must also care about key natural landscapes, potentially far removed from where they live, that provide critical natural communities and habitats that support Missouri's incredible biodiversity and yield irreplaceable ecological services. One tactic Missouri is using to help people visualize these key landscapes and natural communities is through the identification of the COA and Natural Area (NA) networks. These mapped networks of key lands and waters allow the public to relate a location of these conservation landscapes to where they live and aid in associating a spot in Missouri with awe-inspiring photos they see in various outreach materials.

Political and Legal Constraints

Barriers related to political and legal constraints can be extremely challenging. Decision-making processes, high-level executive support, lack of legislative support, and policies, practices, or funding restrictions may all play a role.

Missouri conservation partners and citizenry have faced political and legal challenges and opportunities together for nearly a century. At the forefront of conservation advocacy is The Conservation Federation of Missouri (CFM). Formed in 1935, CFM originated during the low point of conservation history. The Great Depression gripped America. Unregulated hunting, fishing, and trapping and unrestrained timber harvest had decimated natural resources. Solutions were elusive.

Across the nation, state legislatures controlled game laws. Instead of protecting wildlife, laws often served the very interests that were responsible for despoiling wildlife resources. Hunters, anglers, and conservationists were disgusted, but their efforts at reform were thwarted in the political arena.

On September 10, 1935, about 75 sportsmen met at a hotel in Columbia, Missouri, to discuss what could be done. They formed the Restoration and Conservation Federation of Missouri and envisioned a solution that was as simple as it was revolutionary.

Newspaper publisher E. Sydney Stephens summed things up this way: "If you get a law passed, what have you got? The next legislature could repeal or amend it, and the politicians take over. By the same token, if you attempt to get a constitutional amendment through the legislature, you won't recognize it when it comes out. But if you write the basic authority exactly as you want it, put it on the ballot through the initiative and let the people vote it into the constitution, then you've got something permanent."

That sentiment inspired the group to draft Amendment 4. If passed, it would create a nonpolitical conservation agency. Sportsmen fanned out across the state and gathered signatures to put the proposal on the ballot. On November 3, 1936, voters approved the measure by a margin of 71 percent to 29 percent. That was the largest margin by which any amendment to the state constitution to that date had passed. It gave Missouri the nation's first nonpolitical conservation agency. It would be governed by a four-person bipartisan commission with exclusive authority over fish and wildlife.

Over the next 40 years, the "Missouri plan" allowed the Show-Me State to build what was universally acknowledged to be the nation's top conservation program, with decisions based on science instead of political pressure.

America's brush with ecological disaster kindled a passion for wildlife stewardship. Aldo Leopold, who is known as the "father of modern conservation," noted that this zeal seemed to burn most intensely in Missouri. The excerpt below is powerful recognition for and a tip of the hat to the citizens of Missouri.

Speaking at a gathering in 1947, he said: "Conservation, at bottom, rests on the conviction that there are things in this world more important than dollar signs and ciphers. Many of these other things attach to the land, and to the life that is on it and in it. People who know these other things have been growing scarcer, but less so in Missouri than elsewhere. That is why conservation is possible here. If conservation can become a living reality, it can do so in Missouri. This is because Missourians, in my opinion, are not completely industrialized in mind and spirit, and I hope never will be."

CFM's growth confirmed Leopold's opinion. From the original 75 members, the Federation's ranks grew to the tens of thousands. CFM took politics out of conservation, secured stable, adequate funding for the nation's leading conservation program, and still keeps a watchful eye on the state's wild resources.

Forty years after its initial achievement of locking politics out of conservation, CFM concluded that a broad, stable financial base was necessary for effective long-range conservation efforts. Missouri's conservation agency received almost all of its funding from the sale of hunting, fishing, and trapping permits. That was enough for minimal forest, fish, and wildlife programs, but CFM members saw a need for better, more comprehensive resource management. They believed Missourians needed a network of publicly owned areas where people could enjoy outdoor activities. Such areas also would preserve representative examples of the state's diverse ecological systems. They envisioned hundreds of public accesses where Missourians could reach the state's lakes and streams. They foresaw nature centers in urban areas where communities could enjoy the natural world. They wanted all people to be stakeholders in nature so that they would want to protect it.

To achieve this bold conservation vision, CFM produced another revolutionary idea. They proposed a one-eighth of 1 percent sales tax to be used exclusively by MDC. Again, Federation members carried petitions to every corner of the state, and the public put the proposition on the ballot as a proposed constitutional amendment. In 1976, Missouri voters approved Amendment 1, establishing the permanent conservation sales tax. Results of the sales tax are visible in every county today.

Though these efforts strengthened the capabilities and stability of MDC, it was only possible through the power of partnership and citizen engagement. This tradition of comradery and passion for Missouri's conservation resources still thrives today and can be witnessed in the continued strength of partnerships and citizen involvement. In Missouri, partner and citizen feedback as well as sound science continue to shape conservation policies and regulations outlined within the *Wildlife Code of Missouri*. Every year MDC's Regulations Committee reads hundreds of letters and email messages from Missouri's hunters, trappers, anglers, and other outdoor enthusiasts who have suggestions or comments about fish and wildlife and natural community management or regulations. Each year, committee members also look at hunting and fishing surveys and opinion polls from Missourians across the state. They then seek the expert opinion of professional research biologists and managers to learn how Missouri's natural resources are faring under current regulations.

Out of this process comes recommendations to the director and the Missouri Conservation Commission on changes to next year's *Wildlife Code of Missouri*. These regulations are established to manage Missouri's valuable plant and animal communities, to provide equal opportunity to share and enjoy these resources, and to promote public safety.

Building Relevancy Takes Time

The work of expanding relevancy is not easy and success can be hard to measure. Change can be nonlinear and there are factors outside the sphere of control that may affect success. But following the national relevancy roadmap allows Missouri to better focus efforts on making the human connection to natural resources. The fate of Missouri's natural resources will rest on our ability to collaborate as one community to support conservation efforts and draw in participation from a much larger swath of the public.

Theme Ten: Logistical Framework for Improvement and Sustainability

In a nutshell: Today's actions will largely determine the future health and sustainability of Missouri's natural communities, green infrastructure in Missouri's towns and cities, and the benefits these collective resources provide. Regenerative and sustainable conservation of natural resources requires adequate funding and a diversity of partnerships and people collaborating on the implementation of strategies that are efficient, effective, and synergistic. Above all, improvement and sustainability of Missouri's conservation resources require that Missouri citizens understand and appreciate the value of these resources, the threats and challenges these resources face, the opportunities they present, and the role people play in determining their future integrity.

Desired Future Conditions

1. Public agencies, NGOs, and private industry work strategically, collaboratively, efficiently, and effectively toward the regenerative conservation of Missouri's natural resources and the services they provide.
2. Conservation stakeholder organizations collaborate effectively to increase dialogue, feed off each other's strengths, advance conservation science and techniques, and increase synergistic partnerships.
3. Sufficient funding and legal backing are available and widely supported by Missouri citizens to ensure the regenerative conservation of Missouri's natural resources and the services they provide.

Public Awareness and Support

Perhaps the most significant factor in ensuring the improvement and sustainability of Missouri's natural resources is achieving citizen awareness and support for Missouri's natural resources and their conservation. In order for Missouri citizens to support conservation, they need to understand and appreciate its importance to their life, the threats and opportunities to enhancing and sustaining the benefits of nature, and the role people must play. Needed support includes a conservation mindset in day-to-day actions and consumption habits, volunteerism and charity, environmental literacy and spreading this knowledge to future generations, financial support of conservation agencies and NGOs, and much more. The success of the CCS depends on an effective collective communication strategy to spread these important messages to the public.

Partnerships

Ensuring a regenerative future for Missouri's natural resources will also require a strong collaboration among people and organizations. No single organization could adequately address the issues and opportunities identified in CCS on its own. Success is only possible through effective use of collaborative and synergistic partnerships. This includes working with statewide umbrella organizations (e.g., Missouri Forest Resources Advisory Council [MOFRAC], Missouri Soybean Association [MSA], Missouri Bird Conservation Initiative [MoBCI]) and partner collaboratives (e.g., MoIP, Shared Stewardship Initiative); local partnerships (e.g., PG teams, Scenic Rivers Invasive Species Partnership [SRISP]); individual agencies, NGOs, and businesses; and individual citizens, landowner cooperatives, and citizen groups.

Financial Considerations

Providing a regenerative future for Missouri's natural resources is not a cheap endeavor; however, it is far less costly than trying to mimic or re-create the ecological services these resources provide after they've disappeared. Reliable funding is needed for outreach and education efforts, natural community management expenses, implementation of conservation-friendly agricultural practices, land conservation costs, research, wildfire suppression, maintaining recreational opportunities, and more. While there are some great financial resources currently available to assist with these efforts, with Missouri supporting one of the best funding models, these resources come short of what is truly needed to ensure long-term enhancement and sustainability. Regenerative conservation of natural resources will require maintaining or improving existing funding sources and tapping into many new funding opportunities. Future funding sources could include developing new consumer-driven markets for ecosystem services, climate change adaptation funding, increased state or federal funding, new forest product markets, private grants, donations and volunteerism, and more. There are no silver bullets, and a diverse portfolio of conservation investment will be needed.

Legal Framework

Missouri's legal framework for conservation includes a diverse mosaic of both regulatory and voluntary approaches. Missouri's *Code of State Regulations* provides the legal framework for a variety of environmental protection laws, including air, water, soil, and other pollution controls and natural resource protections administered by MDNR. Missouri's Wildlife Code provides the legal groundwork for regulations concerning hunting, fishing, trapping, and allowable activities on Conservation Areas. Missouri's State Forestry Law provides MDC the legal mandate and right to fight wildfires on both public and private lands. However, Missouri also relies heavily upon landowners and citizens to willingly "do the right thing." For example, compared to many states, Missouri has almost no regulations regarding forest management. Instead of taking a heavy-handed legal approach to ensuring that Missouri's forests are well managed, Missouri

relies almost entirely on the goodwill of private forest landowners to steward their land for the best interest of conservation. This approach has advantages and disadvantages, and supporters and detractors. But this complex mix of regulations and reliance on volunteerism is the reality within which CCS operates.

Bringing It All Together

Achieving the goals laid out for CCS is a complex and challenging venture. Success will only be achieved through the cooperation of many different organizations and the support and engagement of Missouri's citizens. Missouri is fortunate to have such a diversity of impressive natural resources in our backyard. We have too much to lose to not fully embrace this challenge. The ten Assessment Themes reveal that Missouri's conservation resources abound with both challenges and opportunities. The CCS provides a framework for best addressing these assessment findings to ensure a regenerative future for the conservation of Missouri's natural resources and the benefits derived from them.

Section Four: Missouri Species of Greatest Conservation Need and Natural Community Conservation

Species of Greatest Conservation Need

Purpose and Application

Missouri supports a rich diversity of wildlife, including more than 400 native bird species, nearly 70 mammal species, nearly 50 species of amphibians, more than 70 species of reptiles, more than 200 kinds of fishes (more than most neighboring states), more than 60 mussel species, and countless other invertebrate species, as well as thousands of species of plants. A small percentage of these species are imperiled to the extent that a species-specific recovery plan is required to ensure their persistence in the state. For the vast majority, Missouri's approach to wildlife diversity conservation is natural community/habitat-based. Missouri's CCS is designed to build upon this successful tradition of habitat-based conservation, to incorporate the research and monitoring needed to evaluate the success of this approach, and to facilitate adaptive management decisions as new information is gained.

The USFWS definition of SGCNs incorporates two groups of species: those with low and declining populations and those that are indicative of the diversity and health of the state's wildlife. Missouri recognizes the value in representing both types of species in the CCS. The needs of rare and declining species must be prioritized in management planning efforts to ensure their resource needs are met and to minimize potential negative impacts from management actions. However, because they are rare and declining, such species are often difficult to monitor and may naturally be rare on the landscape. When taking a habitat-based approach, it is essential to regularly monitor the effectiveness of management actions by tracking response of both plant and animal species. Characteristic species, those that are indicative of the diversity and health of the wildlife characteristic of a specific habitat type, are ideal for monitoring management effectiveness and overall community health. Some characteristic species may be rare, but many are expected to be relatively abundant in high-quality habitat. Because they are representative of the health of the overall community, such characteristic species are often management targets, especially if they are easily monitored. Some may be somewhat generalist in their habitat requirements, but most will have one or a few specific habitat associations as well as specific resource requirements (e.g., food sources and breeding sites).

For these reasons, Missouri's SGCN list includes both rare and declining species and characteristic species (some species may fit both categories). In the SGCN table (**Appendix H**) characteristic species are indicated as such. The SGCN list is designed to assist conservation partners with planning, implementing, and monitoring habitat management activities for the benefit of Missouri's full suite of flora and fauna. Each natural community chapter in this section contains a list of SGCNs associated with that habitat system. With an awareness of the SGCNs that currently or potentially occur on an area, managers can design management plans that provide for the needs of these species and minimize potential risks to them.

The CCS provides a statewide and landscape-level perspective for identifying and prioritizing conservation opportunities. Other resources should be consulted for detailed information on

the habitat and management requirements of individual species or groups of species.

The SGCN list is also being used in the development of monitoring tools, such as the Community Health Index (CHI) that will aid in tracking and evaluating management effectiveness and the overall health of an area.

Missouri Natural Heritage Database – A Powerful Resource

Missouri's SGCN list was built using the state list of SOCCs as a starting point. The SOCC list identifies species that are rare and/or declining in Missouri and is used to track the status and occurrence of these species through the Missouri Natural Heritage Database (Heritage Database). The Heritage program was created in 1981 by TNC, MDNR, and MDC to identify the animal, plant, and natural communities of conservation concern within the state, track their locations and associated information, and provide that information to help guide effective conservation action. Today, the Heritage Database is maintained by MDC. Heritage information provides an understanding of the current distribution, abundance, condition, and conservation needs of these sensitive species and natural communities and is used for natural resource management, conservation planning, scientific research, land acquisition, development project planning, establishing species protection priorities, and targeting recovery activities. Identifying, mapping, and understanding Missouri's biodiversity is essential to protect Missouri's natural heritage.

The Heritage Database has been and continues to be used extensively to inform the CCS and its multitude of contributing components. It is critical that the Heritage Database continue to be updated and maintained to support strategic conservation investment.

The Process

In the 2005 CWCS, the SGCN list was identical to the SOCC list. During revision efforts, it was determined that the SOCC list was a great starting point for rare and declining species; but to serve the intended purposes of the SGCN list it needed to be both refined and expanded. MDC staff and partners with expertise in specific taxa refined the list by removing historic, extirpated, and select edge-of-range species that are not conservation targets. The base list was further refined by removing most species that are either apparently secure or secure, ranked S4–S5 and/or G4–G5.

Table 4.1.1 – Global and State Species Ranks

Scale	Rank	Definition
GLOBAL		
	G1	Critically Imperiled
	G2	Imperiled
	G3	Vulnerable
	G4	Apparently Secure
	G5	Secure
STATE		
	S1	Critically Imperiled
	S2	Imperiled
	S3	Vulnerable
	S4	Apparently Secure
	S5	Secure
	SU	Unrankable

Additional sources were used to identify characteristic species to be added to the base SGCN list. Sources for vertebrates, excluding fish, included:

- The 2005 CWCS Directory of Conservation Opportunity
- Nelson's *Terrestrial Natural Communities of Missouri* (2010)
- International Union for Conservation of Nature (IUCN) Red List (added species listed as near-threatened or above) system
- Partners in Flight regional scores greater than 12 (for birds)

Resources for plants, fish, and invertebrates were much less abundant than for other taxa. Therefore, base lists for these taxa were

developed primarily by experts in these taxa, starting from the SOCC list. Other resources included:

- *Steyermark's Flora of Missouri* (Yatskievych 1999 2006 2013)
- *The Crayfishes of Missouri* (Pflieger 1996)
- *A Guide to Missouri's Freshwater Mussels* (McMurray et al. 2012)
- *The Fishes of Missouri* (Pflieger 1997)

Once the SGCN base list was developed, it was distributed more broadly for review by individuals with appropriate expertise, including taxonomic experts, natural history biologists, and other peer-acknowledged experts. Reviewers removed species that are neither low nor declining in Missouri nor characteristic of healthy Missouri natural communities. Reviewers also added species that fit the criteria but were missed in development of the base lists.

Habitat associations were assigned for each species on the draft SGCN list, using the references previously identified (particularly Heritage) as well as expert input. For the purposes of the CCS, "primary habitat" refers to the habitat system in which the species is most commonly found in Missouri. "Secondary habitat" is not assigned for all species but was used to indicate an additional habitat system used to such an extent that a single habitat association could not be assigned. Where appropriate, a more specific sub-habitat type is indicated in parentheses (e.g., Wetland [fen] for species specifically associated with fens exclusively or much more commonly than other types of wetlands). Some species are fairly generalist and occur in multiple habitat systems or use different habitat systems during different portions of their life history; for these, the two habitat systems in which they most commonly occur in Missouri are listed. For fishes that occur primarily in headwater streams, creeks, or small streams, the primary habitat association is assigned as the terrestrial habitat system in which the creek or stream occurs. For example, Topeka shiners inhabit prairie headwater streams, so their primary habitat association is "grassland." Other fishes may be listed as Big Rivers (occurring primarily in the Missouri and/or Mississippi River) or Mississippi Lowlands (Missouri occurrence is primarily in the lower Mississippi and associated sloughs, backwaters, and wetlands of southeastern Missouri). Note that for all species the habitat associations were assigned based on species occurrence in Missouri and may not be reflective of a species' habitat associations in other parts of its range.

The complete SGCN list is included in **Appendix H**. Each natural community chapter in the CCS also includes a list of SGCNs associated with that habitat system. A total of 683 species are listed as SGCNs, including both SOCCs and characteristic species. The SGCN list is arranged by major taxonomic category in the same order as the SOCC list (Plants, Invertebrate Orders, Vertebrate Classes) and then alphabetically by scientific name within each major taxonomic category.

Information on the distribution and abundance of SOCCs is found in the Heritage Database. While not fully summarized within this document, the state Heritage rank (S-rank) of SOCCs is included in the SGCN table, as is the listing status (federal endangered, federal threatened, federal candidate, state endangered). Some SOCCs are also considered characteristic. Information on the abundance and distribution of characteristic species that are not SOCCs (not tracked in Heritage) is less available; however, for those species included in CHI models, the implementation of CHI monitoring will provide information on distribution over time.

MDC has an active research program and a Science Branch dedicated to filling high-priority research, survey, and inventory needs for management of Missouri's fish, forest, and wildlife resources. MDC's interdisciplinary Wildlife Diversity Team is currently refining a process for prioritizing species inventory needs to better focus available resources.

Partner input is an important component to maintenance of the SOCC list; MDC regularly consults with partners (e.g., USFWS, Missouri Botanical Garden, Native Plant Society, multiple universities, and others) to discuss changes to the SOCC list.

The SGCN list is updated upon each revision of the CCS. In the present case, the SGCN list has been updated from the 2015 SWAP. Upon each revision, the SGCN list gets vetted through taxonomic experts and natural history biologists on the Wildlife Diversity Team and contains updates on species' state status through our natural heritage SOCC list as well as updates on species' federal status through species listed or delisted from the Endangered Species Act list of threatened or endangered species. Species listed in Class Aves (i.e., birds) have been updated based on species included in MDC's new publication *Missouri Bird Conservation Plan*, which provides context for which breeding bird species in Missouri are the most threatened and information on their habitat needs (Missouri Bird Conservation Plan Technical Team 2019).

Insects are found in nearly every ecosystem worldwide and often play outsize roles in ecosystem function. However, they are also understudied compared to other animal groups, due in part to their small size and incredible diversity. Studies have demonstrated shocking declines in insects worldwide, but current data are insufficient to determine which invertebrate taxa are most at risk or which natural communities are experiencing the greatest declines in insect populations. However, conservation partners are seeking to understand and address key threats to insect communities, such as the growth in the use of neonicotinoid pesticides (See **Assessment Theme Two**). Efforts to restore and maintain diverse natural communities and to increase connectivity are expected to benefit most SGCN, including insects. Work is underway, particularly in grassland ecosystems, to evaluate whether habitat restoration efforts are leading to the expected increased diversity of insect communities. Results of this research can then be used to adapt management efforts to promote diverse insect communities. Key insect groups, such as solitary native bees, are also being incorporated into the Landscape Health Index (LHI). Because of increased national attention on the decline of pollinators, bee and butterfly species known to occur in Missouri were ranked using the NatureServe rank calculator, and those with an S-rank of 1–3 were added to the SGCN list during this revision as well. Additional work to identify and prioritize other orders of insect SGCN is needed and is planned for future revisions.

The current iteration of the SGCN list also includes new species associated with cliff and talus natural communities. These species were not included in the 2015 list because management plans do not include the active management of this natural community type. The inclusion of the cliff and talus natural community completes the comprehensive coverage of Missouri's natural communities in the CCS and helps bring attention to and provide protection for the unique species that inhabit this unique natural community, despite the lack of active management taking place. The cliff and talus SGCN list was developed using most of the same processes used to develop SGCN lists for the other natural communities in Missouri, with the only difference being there was no habitat team created to tackle this assignment.

Missouri Natural Communities Background

Key to the success of Missouri's CCS is the natural community– or habitat-based approach to conservation implementation. Natural communities are assemblages of native plants and animals that occur in repeatable places in the landscape with similar soils, topography, geology, hydrology, and natural disturbance regimes.

But why take a natural community–based approach? The Missouri SGCN list contains 683 species of plants, arachnids, insects, and terrestrial and aquatic vertebrates. This is far too many for an approach focusing on individual species, or even groups of species, to be effective, especially with limited resources available. By identifying and prioritizing locations on the Missouri landscape that have the greatest opportunity for regenerative conservation of fish, forest, and wildlife resources, and effectively managing and building connectivity within and among these areas, populations of SGCN will stabilize or increase. Monitoring is key to evaluating the response of SGCNs to management actions and adapting management strategies as needed.

The ideology behind the CCS is to identify Missouri conservation priorities to inform decision-making regarding the greatest opportunities for regenerative conservation of natural resources. The approach to natural community and habitat management, simply stated, was to identify all conservation opportunities on the Missouri landscape, highlight those areas of greatest conservation opportunity (termed COAs), and then better focus conservation efforts to guide strategic decision-making regarding conservation actions within the COAs.

In the following excerpt, taken from *Discover Missouri Natural Areas—A Guide to 50 Great Places*, the author, Mike Leahy, describes the classification of Missouri into its primary ecological regions:

> "Missouri is made up of four major ecological regions, or ecoregions—large geographic areas having distinctive topography, geology, soils, vegetation, and climate patterns (**Figure 4.1.1**). Ecoregions are defined by characteristic natural communities. Plants and animals don't respect anthropogenic boundaries, and neither do ecoregions. Each encompasses thousands of square miles and spills over into adjacent states. The following descriptions offer brief introductions to Missouri's ecoregions. *The Atlas of Missouri Ecoregions* by Timothy Nigh and Walter Schroeder (2002) offers more detailed information.
>
> "The Central Dissected Till Plains, or glaciated plains, ecoregion of north Missouri stretches into Illinois, Iowa, Nebraska, and Kansas. Glaciers sculpted this region about 500,000 years ago, leaving behind deep, rich soils when they retreated. The landscape is characterized by gently rolling hills dissected by broad floodplains, though rugged topography exists near the Grand, Chariton, Missouri, and Mississippi rivers. Historically the region was a mix of tallgrass prairies, savannas, and wetlands. Today, many acres have been converted to agriculture, forming the corn belt of the Midwest. The largest unplowed prairies in the region are found in northern Harrison County, Missouri, and Ringgold County in Iowa. Remnant wetlands dot the Missouri, Mississippi, and lower Grand River floodplains, providing crucial habitat for migratory waterfowl, shorebirds, and other wildlife.
>
> "The Mississippi River Alluvial Basin ecoregion, or Missouri's Bootheel, is part of the vast, flat floodplain of the Mississippi River that extends all the way to New Orleans. The only blip in the landscape's uniformity is Crowley's Ridge, a long, narrow ridge that runs from Cape Girardeau to Helena, Arkansas. Historically the area was an immense mosaic of bottomland forests and wetlands with tiny patches of sand prairie scattered throughout and small areas of upland forest on Crowley's Ridge. Some

distinctly southern species, such as bald cypress and water tupelo, occur here. Humans have altered this landscape more than any other ecoregion in Missouri. Most of its wetlands have been drained and thousands of acres of forest have been cleared. However, important remnant wetlands, cane thickets, and bottomland forests are tucked away throughout the region, offering oases of habitat for a suite of wildlife.

"The Osage Plains ecoregion of west-central Missouri is an unglaciated plain that extends west into Kansas. Named for the Osage, a Native American tribe who lived in the area until 1808, the region is characterized by flat to gently rolling topography. Sandstone, shale, and limestone provide the raw materials from which Osage Plains soils develop, the latter two producing soils generally productive for agriculture. Historically, this ecoregion was dominated by tallgrass prairie, but it also contained extensive savannas and wetlands. Although the largest unplowed prairies east of the Kansas Flint Hills can be found here, most of the landscape has been converted to agriculture.

"The Ozark Highlands ecoregion spills into five states but occurs primarily in Missouri and Arkansas. The region got its start more than two billion years ago when volcanic eruptions formed the St. Francois Mountains. About 1.5 billion years later, shallow seas washed over what is now Missouri, flooding everything except the highest of peaks. During that time, Taum Sauk Mountain, Missouri's highest point was part of a chain of islands jutting out of the sea. Ocean water receded from and reflooded the area repeatedly, each time depositing layers of limestone, sandstone, dolomite, and shale. During the past 300 million years, these sedimentary rocks were uplifted and eroded to create the topography of hills, plateaus, and deep valleys we see today in the Ozarks.

"Historically, the Ozarks also included a mix of prairies and savannas on the broad plains surrounding present-day Springfield, Lebanon, West Plains, and Salem. Rugged hills rising above large rivers, such as the Gasconade or Current, contained a mix of forests, woodlands, and glades. Outside the narrow floodplains, Ozark soils are typically rocky, droughty, and not very fertile. Although the region has changed significantly in the past century, the Ozarks contain the greatest concentration of Missouri's remaining wild lands. Most of Missouri's caves (more than 7,000) are found here, and springs, fens, and sinkhole ponds provide other unique habitats. At least 150 species living in the Ozarks are found nowhere else in the world." (Leahy 2011)

Missouri's four primary ecological regions can be further broken down using an ecological classification system (ECS). An ECS is a framework that allows natural resource managers to identify, describe, and map units of land with similar physical and biological characteristics at scales suitable for natural resources planning and management. Once in place, an ECS serves as a basis for an inventory of the number, size, location, and status of natural communities. An ECS allows planners and managers to assess the capability of land to produce resources and respond to management. Finally, an ECS is a common communication tool for considering the conservation of multiple resource values.

Missouri's ECS was developed by a team of interagency experts from state, federal, and private natural resource organizations and academia. This team developed the ecological units at the subsection scale (10–100s of square miles) and finer. The Missouri ECS ties directly into multi-state and subcontinental scale units already developed by USFS (e.g., Ozark Highlands Section of the Eastern Broadleaf Forest Province). Missouri has 32 ecological subsections and multiple LTAs in its ECS, which

are described in Nigh and Schroeder (2002) and contained within GIS data.

In 2015 the ECS project completed its first version of Missouri's ecological sites GIS data layer – the finest level of resolution in the ECS hierarchy. Ecological sites are available as a layer on the NRCS web soil survey site at **websoilsurvey.sc.egov.usda.gov/App/HomePage.htm**.

Missouri's ECS is a hierarchical map that assesses vegetation patterns, both current and historical, based on regional climate, superficial and bedrock geology, hydrology, soils, and topography. It provides context and information on the potential productivity of a site or landscape for things such as timber production and natural community restoration. It assists with natural resource management planning at scales from a forest stand (100 acres) up to 1,000s of acres. Within MDC, ECS is utilized for conservation area planning, in the development of COAs, forest inventory, NAs inventory, and private lands management plans. For more detailed information on the geologic natural features of Missouri that form a substantial component of the ECS, please see the following resources:

Geologic Natural Features Classification System for Missouri (2019): **share.mo.gov/nr/mgs/MGSData/Forms/AllItems.aspx**.

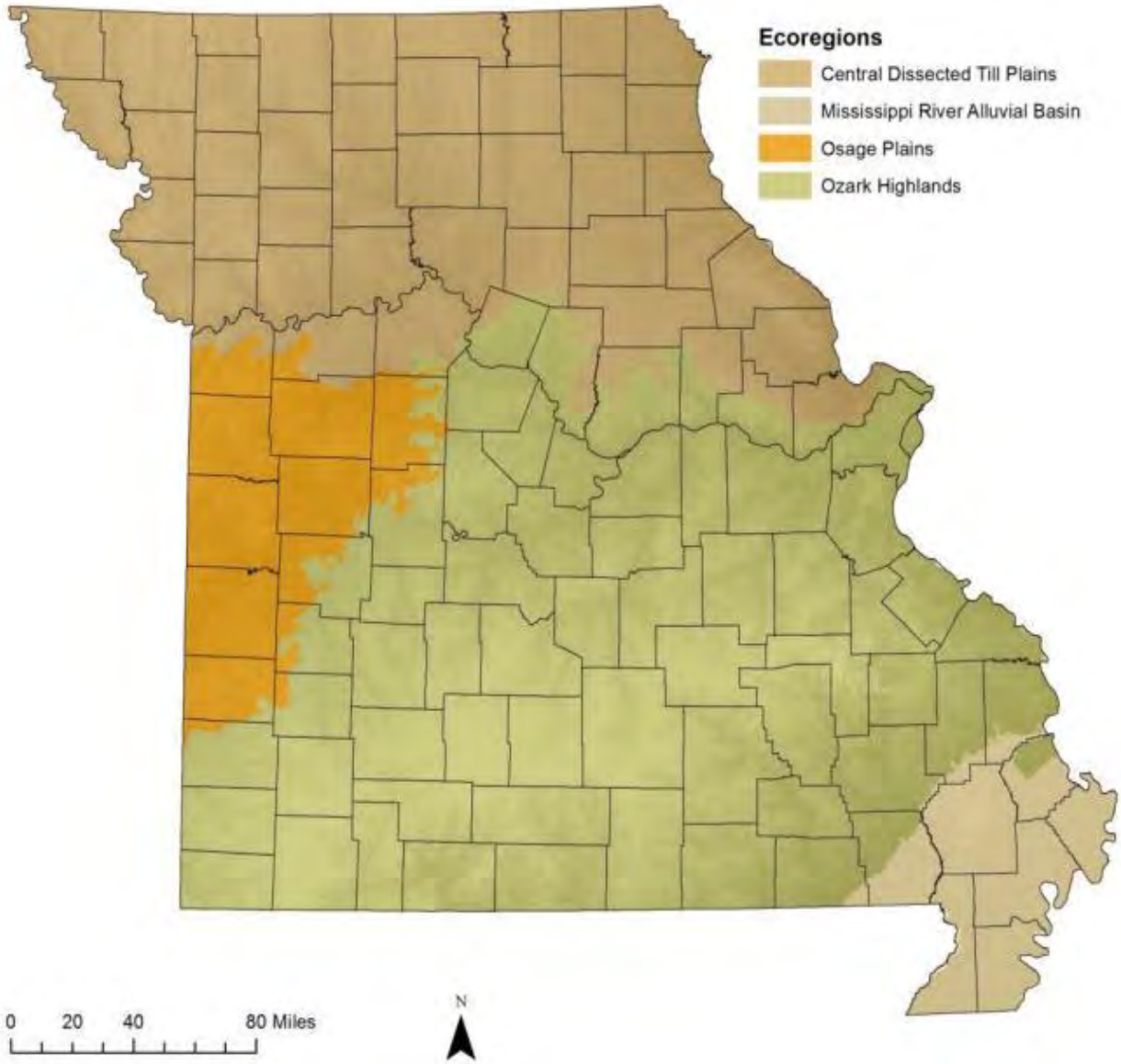
An overview of Missouri's outstanding geologic features is found in the 2019 Missouri Natural Areas Newsletter: **nature.mdc.mo.gov/sites/default/files/downloads/NANewsletter2019.pdf**.

These valuable ECS resources assist conservation professionals and private landowners in managing Missouri's landscape appropriately, based on the types of natural communities present. For the purposes of the CCS, Missouri's natural community types are grouped into seven primary habitat systems based on Nelson's (2010) classification in *The Terrestrial Natural Communities of Missouri*. These are:

- Grassland/prairie/savanna
- Forest/woodland
- Glade
- Cave/karst
- Wetland
- Rivers/streams
- Cliff/talus

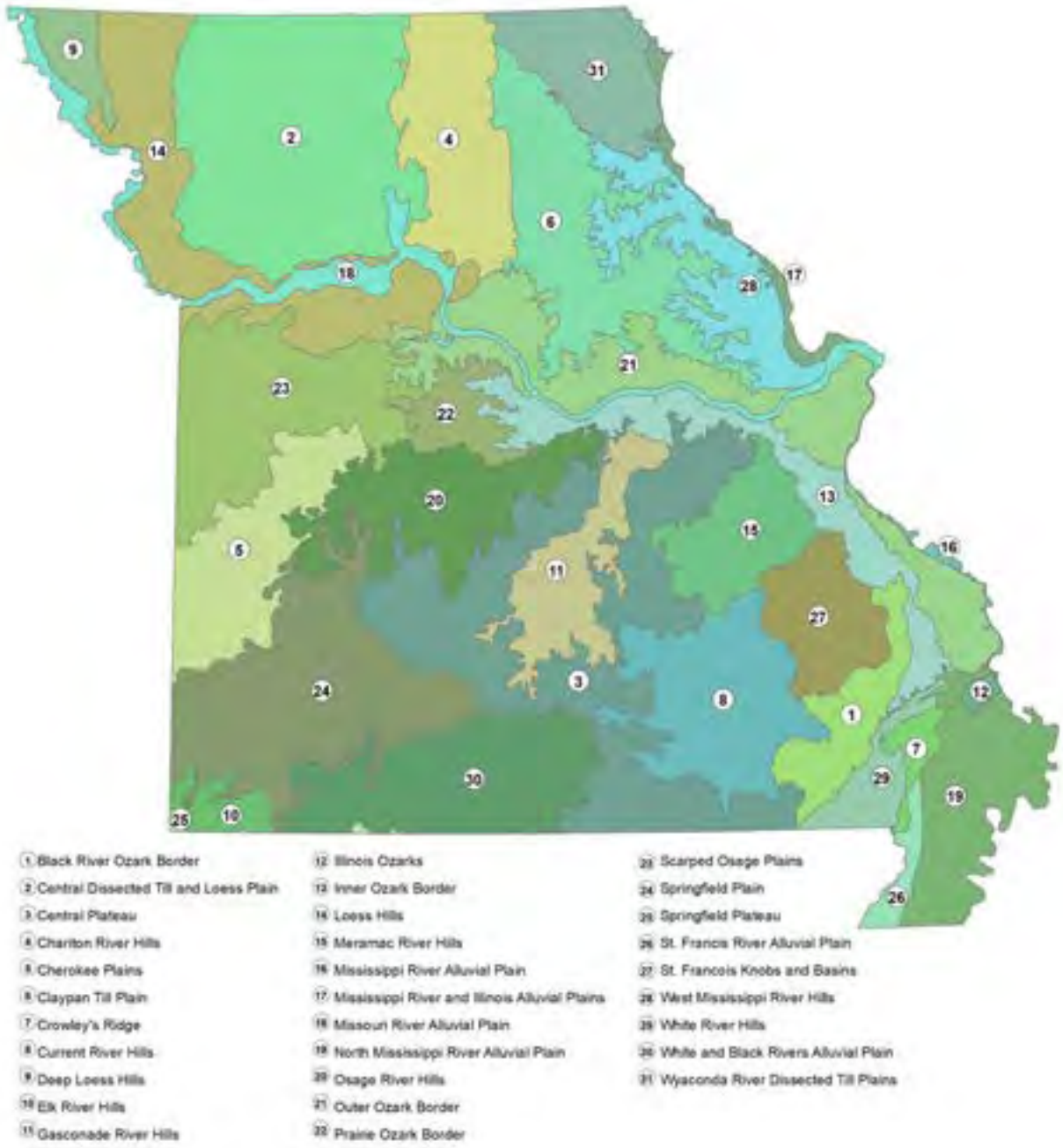
Each of these primary habitat systems is further broken down into more specific subtypes within each habitat system chapter. For example, the primary habitat system glade is subcategorized by bedrock type into 5 categories: chert glades, dolomite glades, limestone glades, sandstone glades, and igneous glades, each offering varying habitat characteristics, which support a diversity of generalist, as well as specialist species.

Figure 4.1.1 – Understanding Missouri's Primary Ecological Sections



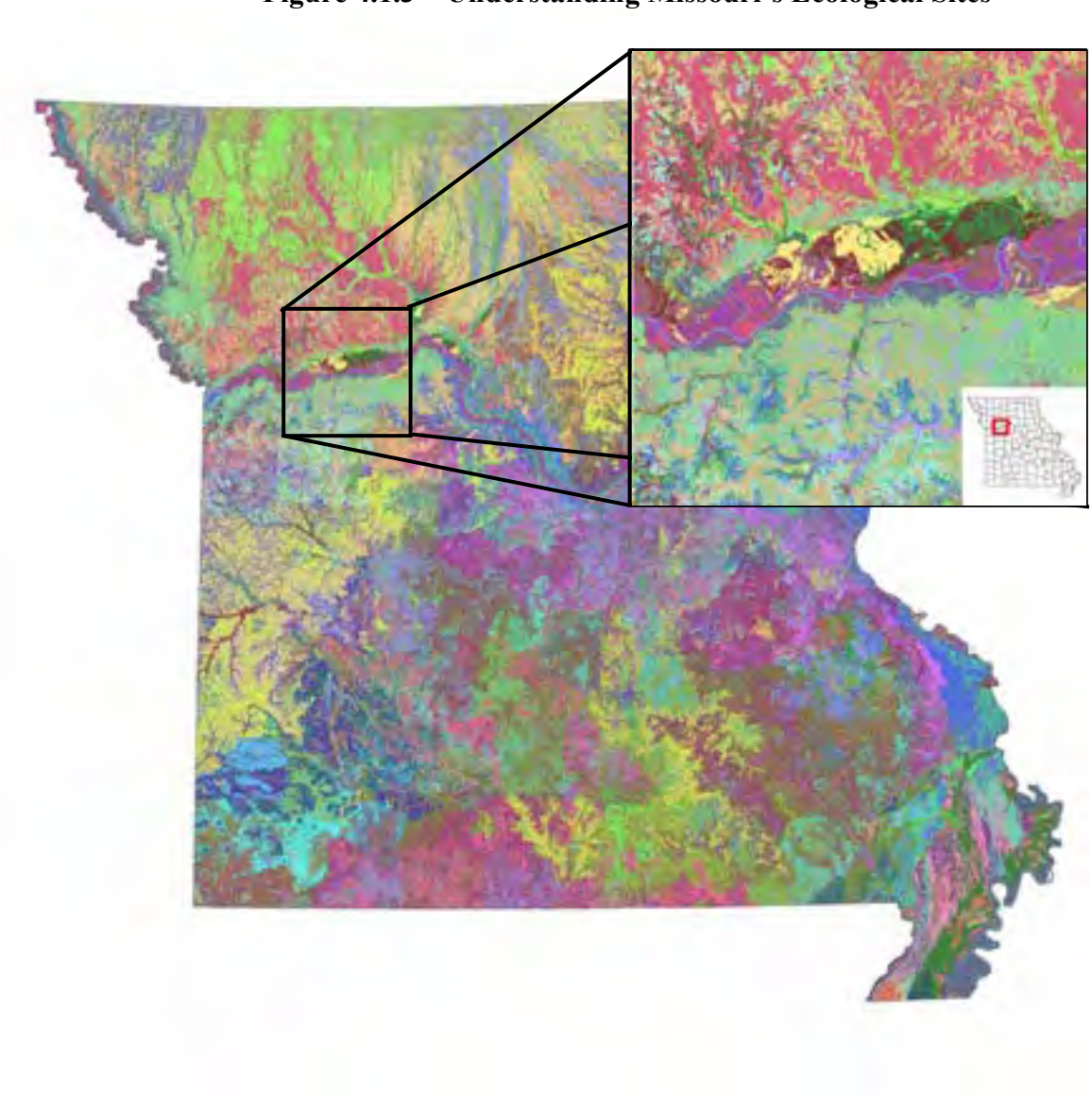
Ecological sections are areas of lands and waters that cover parts of a state and are typically around 1,000 square miles in size. Sections are based on regional climate data, geomorphology, major soil groups, and historic and current vegetation patterns. Missouri consists of four ecological sections as shown above.

Figure 4.1.2 – Understanding Missouri's Ecological Subsections



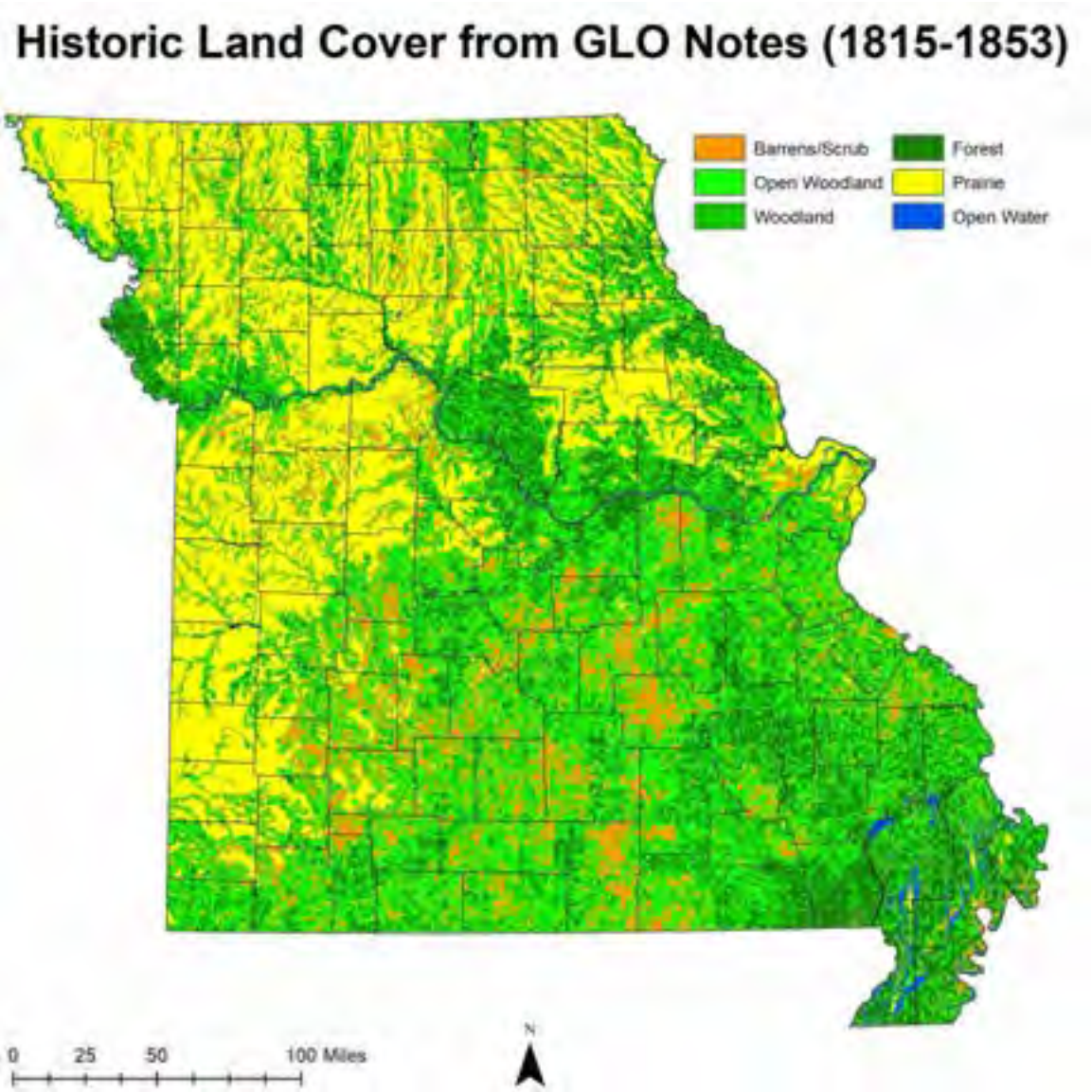
Ecological subsections are areas of lands and waters that cover portions of a state and are anywhere from ten to hundreds of square miles in size (typically three to five counties in Missouri). They are based on geology, topography, soils, hydrology and vegetation patterns. Missouri has 31 ecological subsections.

Figure 4.1.3 – Understanding Missouri's Ecological Sites



An ecological site is a distinctive kind of land, with specific physical characteristics, that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation, and in its ability to respond to management actions and natural disturbances. These sites are defined by differences in vegetation, soils, and ecological processes. Ecological sites are often synonymous with natural community types and include most of the major natural community types; that is, there are ecological sites associated with forests, woodlands, prairies, wetlands, etc.

Figure 4.1.4 – Understanding Missouri's Historic Land Cover/Land Use



Between 1815 and 1853, surveyors with the U.S. government's general land office walked or rode on horseback a mile-by-mile grid across the entire state. They established section corners and the township, range, and section lines of our public land survey system. At each section and quarter-section corner they would indicate the types of vegetation they saw, and if trees were near enough, they would mark two witness trees for future land subdivision. After traversing each mile of section line, they would take notes on the vegetation and the land's productivity for agriculture. These written records were archived with the Missouri State Archives. Researchers at the University of Missouri–Columbia used these records to develop a GIS database of all these data to produce a snapshot of what the state's major vegetation types were just before widespread conversion of the prairie regions of the state. The map above gives us that valuable snapshot of the major historic vegetation patterns of the state.

Figure 4.1.5 – Understanding Missouri's Current Land Cover/Land Use

This map of Missouri's land cover in 2016 is based upon Landsat satellite imagery and other supplementary databases. This land cover modeling effort provides a rough overview of the land uses in the state and is useful for conservation planning.

An In-Depth Look at Missouri Natural Community Conservation

Within this subsection, we describe the development and implementation of the natural community and habitat-based portion of the CCS. This section is divided into chapters for each of the seven primary natural communities: Grassland/Prairie/Savanna, Forest/Woodland, Glades, Cave/Karst, Wetland, Rivers/Streams, and Cliff/Talus. Each natural community chapter contains:

- An overview of the specific natural community and each of its subtypes
- Map(s) displaying specific locations for the COAs per each natural community
- Decision criteria used to determine the COAs
- Listing of the SGCNs associated with the specific natural community
- Natural community threats and challenges relative to each natural community
- Habitat management actions and opportunities required to restore and maintain a healthy habitat system
- Natural community subtype descriptions
- Case studies that feature specific examples of conservation actions being applied to benefit each habitat system subtype

Maps showing COAs for all natural communities combined may be found in **Figures 2.16** and **2.17**.

Grassland/Prairie/Savanna Conservation and Case Studies

Overview

Grasslands have existed in North America between five to seven million years due to a long drying trend in our climate. However, the tallgrass prairies we see today in Missouri have existed for only the past 11,000 years. Increased aridity, anthropogenic fires, and warming conditions allowed the tallgrass prairies to expand from the Great Plains to Ohio, and as far south as southern Texas, to as far north as southern Manitoba. Missouri's native grasslands can be divided into two broad categories: prairie and savanna. Prairie consists of perennial grasses and forbs with few trees and interspersed shrubs. Missouri prairies are classified as tallgrass prairies due to the height of native warm season grasses resulting from higher regional precipitation amounts than are received by western mixed and shortgrass prairies. Species richness and diversity is enhanced due to a broad diversity of perennial forbs, and native plant diversity within prairies is vast. For example, in Missouri, on just a 100-acre, high quality upland prairie parcel, at least 200 native species of vascular plants can flourish. This diversity of plant species and structure is crucial to Missouri's grassland wildlife.

Missouri boasts several unique prairie types. Deep-soiled loess hill prairies parallel the Missouri River in the far northwestern portion of the state, whereas drier, shallow-soiled unglaciated prairies are characteristic of the Osage Plains region. Glaciated prairies, though once common across the northern third of the state, today are only interspersed in this same region. Only small remnants of sand prairies can be found in Missouri today in the far southeastern Bootheel and along the Mississippi River. Wet prairies can still be found along a few of Missouri's rivers. There are just a handful of savanna landscapes where prairies transition into woodland. Although these grassland types once dominated one-third of Missouri's landscape, the combined acreage of these six distinctive grassland habitats today total less than 1 percent of Missouri's landscape.

Despite their limited size, Missouri's grasslands provide essential habitat for many plant and animal species. Within the prairie habitats, characteristic species include the Henslow's sparrow (*Anmodramus henslowii*), grasshopper sparrow (*Anmodramus savannarum*), dickcissel (*Spiza americana*), Bell's vireo (*Vireo bellii*), eastern meadowlark (*Sturnella magna*), blacknose shiner (*Notropis heterolepis*), prairie grass pink (*Calopogon oklahomensis*), skeleton plant (*Lygodesmia juncea*), and the federally threatened Mead's milkweed (*Asclepias meadii*). Savanna characteristic species are fewer, but include red-headed woodpecker (*Melanerpes erythrocephalus*) and northern bobwhite (*Colinus virginianus*). Plains box turtle (*Terrapene ornata ornata*) and tall agrimony (*Agrimonia gryposepala*) are two species characteristic of both prairie and savanna habitats.

Figure 4.2.1 – Missouri Grassland/Prairie/Savanna COAs

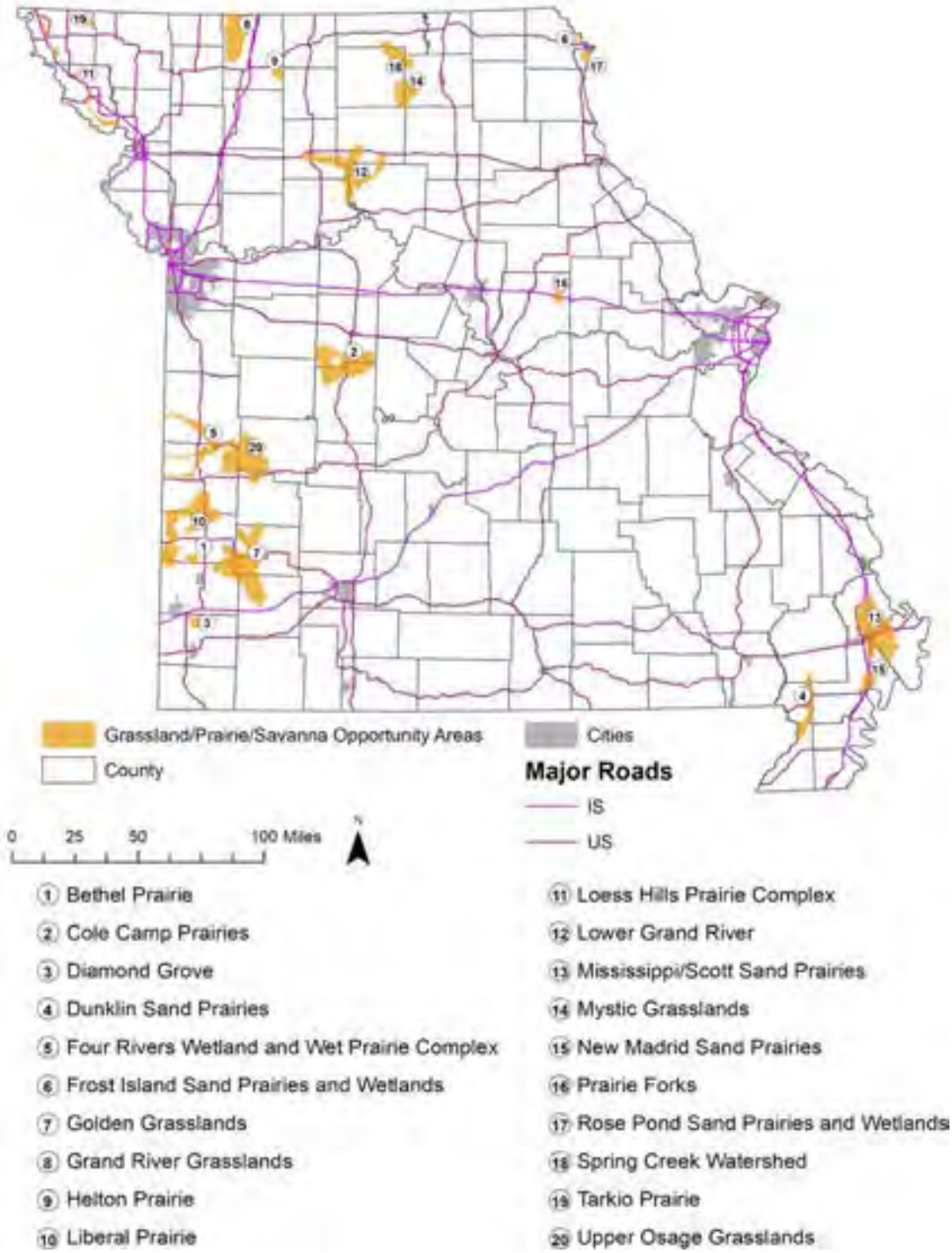


Figure 4.2.2 – Estimated Extent of Historic Prairie in Missouri

This map identifies the potential historic extent of grassland/prairie/savanna communities in Missouri created by Missouri Spatial Data Information Service (MSDIS) from Dr. Walter A. Schroeder's "Pre-settlement Prairie of Missouri" (Schroeder 1981). Information including Missouri's historic prairie extent, current land conditions from the NLCD, and the Heritage Database were used to identify grassland/prairie/ savanna COAs.

Scoring Criteria

1. "Pre-settlement" HUC 16 containing <50% grassland/pasture from NLCD 2016
2. "Pre-settlement" HUC 16 containing ≥ 50% grassland/pasture from NLCD 2016
3. "Pre-settlement" HUC 16 containing ≥ 50% grassland/pasture, AND 1 recent* grassland/prairie Heritage record
4. "Pre-settlement" HUC 16 containing ≥ 50% grassland/pasture, AND >1 recent* grassland/prairie heritage record
5. HUC 16 within a grassland/prairie opportunity area
6. HUC 16 within a grassland/prairie opportunity area, AND contains >1 recent* grassland/prairie heritage record
7. HUC 16 within a grassland/prairie opportunity area, AND contains a grassland easement and/or conservation network lands

{ Decisive selection criteria for COAs }

* Recent Heritage Database records are considered since 1981 for community records and after 1989 for species records

Species of Greatest Conservation Need

Plants

Prairie false foxglove (*Agalinis heterophylla*) * Purple false foxglove (*Agalinis purpurea*) * Green false foxglove (*Agalinis viridis*) * Thimbleweed (*Anemone cylindrica*) * Curly three-awn (*Aristida desmantha*)* Brown bog sedge (*Carex buxbaumii*) * Field sedge (*Carex conoidea*) * Lake bank sedge (*Carex lacustris*) * Sartwell's sedge (*Carex sartwellii*) * Wavy leaved thistle (*Cirsium undulatum*) * Joint grass (*Coelorachis cylindrica*) * Hale's corydalis (*Corydalis micrantha subsp. australis*) * Narrowleaf rushfoil (*Croton michauxii*) * Bristly flatsedge (*Cyperus hystricinus*) * Teasel-like cyperus (*Cyperus retrofractus*) * White lady's slipper (*Cypripedium candidum*) * Sand tick trefoil (*Desmodium strictum*) * Velvetleaf tick trefoil (*Desmodium viridiflorum*) * Church's wild rye (*Elymus churchii*) * Closed gentian (*Gentiana andrewsii var.andrewsii*) * Round-head rush (*Juncus validus*) * Blazing star (*Liatris scariosa var. nieuwlandii*) * Pitcher's sandwort (*Minuartia muscorum*) * Evening primrose (*Oenothera clelandii*) * Small sundrops (*Oenothera perennis*) * Scarlet gaura (*Oenothera suffrutescens*) * Eastern prairie fringed orchid (*Platanthera leucophaea*) * Western prairie fringed orchid (*Platanthera praeclara*) * Dwarf chinquapin oak (*Quercus prinoides*) * Double-formed snoutbean (*Rhynchosia difformis*) * Narrow-leaved marsh pink (*Sabatia brachiata*) * Kansas arrowhead (*Sagittaria ambigua*) * Elliott's sida (*Sida elliottii*) * Eastern blue-eyed grass (*Sisyrinchium atlanticum*) * Bristly blue curls (*Trichostema setaceum*) * Carolina clover (*Trifolium carolinianum*) * Soapweed (*Yucca glauca*)

Characteristic:

Rough false foxglove (*Agalinis aspera*) * Eared false foxglove (*Agalinis auriculata*) * Tall agrimony (*Agrimonia gryposepala*) * Mead's milkweed (*Asclepias meadii*) * Hairy grama (*Bouteloua hirsuta*) * Blue hearts (*Buchnera americana*) * Clustered poppy mallow (*Callirhoe triangulata*) * Prairie grass pink (*Calopogon oklahomensis*) * Prairie hyacinth (*Camassia angusta*) * Downy yellow painted cup (*Castilleja sessiliflora*) * Nine-anthered prairie clover (*Dalea enneandra*) * Wolf's spike rush (*Eleocharis wolfii*) * Downy gentian (*Gentiana puberulenta*) * Skeleton plant (*Lygodesmia juncea*) * Barbara's buttons (*Marshallia caespitosa var. caespitosa*) * Bunch flower (*Melanthium virginicum*) * Locoweed (*Oxytropis lambertii*) * Silvery scurfy pea (*Pediomelum argophyllum*) * Royal catchfly (*Silene regia*)

Insects

Bumblebee-like digger bee (*Anthophora [Melea] bomboides*) * A bee (*Anthophorula [Anthophorisca] pygmaea*) * Dusted skipper (*Atryonopsis hianna*) * Arogos skipper (*Atyrone arogos*) * Southern plains bumblebee (*Bombus faternus*) * Yellow bumblebee (*Bombus [Thoracobombus] fervidus*) * American bumblebee (*Bombus [Thoracobombus] pensylvanicus*) * Porter's cuckoo leafcutter bee (*Coelioxys [Boreocoelioxys] porterae*) *Red-legged cuckoo leafcutter bee (*Coelioxys [Boreocoelioxys] rufitarsis*) * A leafcutter bee (*Coelioxys [Syncoelioxys] texana*) * A solitary bee (*Diadasia afflicta*) * A long-horned bee (*Eucera [Synhalonia] fulvohirta*) * A melittid bee (*Hesperapis carinata*) * Ottoe skipper (*Hesperia ottoe*) * A bee (*Hoplitis [Robertsonella] micheneri*) * Wide-mouthed sweat bee (*Lasioglossum [Dialictus] heterognathum*) * Pale-marked sweat bee (*Lasioglossum [Dialictus] testaceum*) * A sweat bee (*Lasioglossum [Evalaeus] fedorense*) * Bald-spot sweat bee (*Lasioglossum [Lasioglossum] paraforbesii*)

* Evening primrose sweat bee (*Lasioglossum [Sphecodogastra] oenotherae*) * A woodborer bee (*Lithurguis [Lithurgopsis] gibbosus*) * An oil-collecting bee (*Macropis steironematis*) * Relative leafcutter bee (*Megachile [Megachile] relativa*) * A leafcutter bee (*Megachile [Xanthosarus] ingenua*)* A leafcutter bee (*Megachile [Xanthosarus] mucida*) * A cuckoo bee (*Nomada asteris*) * A cuckoo bee (*Nomada fervida*) * Placid cuckoo nomad bee (*Nomada placida*) * A cuckoo bee (*Nomada sclestus*) * A mason bee (*Osmia [Diceratosmia] subfasciata*) *Texas mason bee (*Osmia [Helicosmia] texana*) * A mason bee (*Osmia [Melanosmia] illinoensis*) * Shiny-faced mason bee (*Osmia [Melanosmia] inspergens*) * A miner bee (*Panurginus potentillae*) * Byssus skipper (*Problema byssus*) * A longhorned beetle (*Svastra [Epimelissodes] compta*) * An anthophorid bee (*Tetraloniella albata*) * An anthophorid bee (*Tetraloniella paenalbata*) * An anthophorid bee (*Tetraloniella spissa*)

Characteristic:

A concealed-tymbal cicada (*Beameria venosa*) * Monarch butterfly (*Danaus plexippus*) * Prairie mole cricket (*Gryllotalpa major*) * Regal fritillary (*Speyeria idalia*)

Fishes

Least darter (*Etheostoma microperca*) * Northern plains killifish (*Fundulus kansae*) * Blacknose shiner (*Notropis heterolepis*) * Topeka shiner (*Notropis topeka*)

Characteristic:

Plains topminnow (*Fundulus sciadicus*) * Brassy minnow (*Hybognathus hankinsoni*) * Common shiner (*Luxilus cornutus*)

Amphibians

Illinois chorus frog (*Pseudacris illinoensis*) * Eastern spadefoot (*Scaphiopus holbrookii*)

Characteristic:

Small-mouthed salamander (*Ambystoma texanum*) * Eastern tiger salamander (*Ambystoma tigrinum*) * Western narrow-mouthed toad (*Gastrophryne olivacea*) * Northern crawfish frog (*Lithobates areolatus circulosus*)

Reptiles

Northern scarletsnake (*Cemophora coccinea copei*) * Kirtland's snake (*Clonophis kirtlandii*) * Dusty hog-nosed snake (*Heterodon gloydi*) * Prairie massasauga (*Sistrurus tergeminus tergeminus*)

Characteristic:

Western slender glass lizard (*Ophisaurus attenuatus attenuatus*) * Western foxsnake (*Pantherophis ramspotti*) * Eastern foxsnake (*Pantherophis vulpinus*) * Bullsnake (*Pituophis catenifer sayi*) * Great plains skink (*Plestiodon obsoletus*) * Southern prairie skink (*Plestiodon septentrionalis obtusirostris*) * Northern prairie skink (*Plestiodon septentrionalis septentrionalis*) * Plains box turtle (*Terrapene ornata ornata*) * Plains gartersnake (*Thamnophis radix*) * Lined snake (*Tropidoclonion lineatum*)

Birds

Barn owl (*Tyto alba*)

Characteristic:

Henslow's sparrow (*Ammodramus henslowii*) * Grasshopper sparrow (*Ammodramus savannarum*) * Short-eared owl (*Asio flammeus*) * Upland sandpiper (*Bartramia langicauda*) * Northern harrier (*Circus hudsonius*) * Northern bobwhite (*Colinus virginianus*) * Prairie warbler (*Dendroica discolor*) * Bobolink (*Dolichonyx oryzivorus*) * Orchard oriole (*Icterus spurius*) * Loggerhead shrike (*Lanius ludovicianus*) * Dickcissel (*Spiza americana*) * Field sparrow (*Spizella pusilla*) * Eastern meadowlark (*Sturnella magna*) * Brown thrasher (*Toxostoma rufum*) * Greater prairie chicken (*Tympanuchus cupido*) * Eastern kingbird (*Tyrannus tyrannus*) * Bell's vireo (*Vireo bellii*) * Blue-winged warbler (*Vermivora pinus*)

Mammals

Black-tailed jackrabbit (*Lepus californicus*) * Long-tailed weasel (*Mustela frenata*) * Least weasel (*Mustela nivalis*)

Characteristic:

Thirteen-lined ground squirrel (*Ictidomys tridecemlineatus*) * Plains pocket mouse (*Perognathus flavescens*) * Franklin's ground squirrel (*Poliocitellus franklinii*) * American badger (*Taxidea taxus*)

Threats and Challenges

Nearly 15 million acres of native prairie and 6.5 million acres of savanna historically existed in Missouri. Today, approximately one-half of 1 percent of these diverse grasslands remain.

Habitat Conversion and Fragmentation

Following nearly two hundred years of conversion to agriculture, urbanization, and other uses, today, isolated prairie and savanna remnants are scattered among millions of acres of agricultural fields and developed towns and cities. These fragmented landscapes provide the last suitable habitat for many grassland-dependent species, including prairie mole crickets (*Gryllotalpa major*), Franklin's ground squirrel (*Poliocitellus franklinii*), Henslow's sparrow (*Ammodramus henslowii*), northern crawfish frog (*Lithobates areolatus circulosus*), and the Missouri state endangered greater prairie-chicken (*Tympanuchus cupido*). Habitat loss and fragmentation remain primary threats to such species.

Woody Species Encroachment and Invasive Species

Modern grassland communities face additional threats, including chronic overgrazing and encroachment by woody vegetation and invasive species. Approximately 13 million grassland acres are dominated by tall fescue (*Festuca arundinacea*). This popular, exotic forage is resilient to drought and withstands severe grazing. As a result, it is managed in a manner that seldom provides beneficial habitat for grassland-dependent species. Due primarily to the absence of fire, encroachment by woody species such as eastern redcedar (*Juniperus virginiana*), black locust (*Robinia pseudoacacia*), sumac (*Rhus copallina, R. glabra*), and Osage orange (*Maclura pomifera*), are quick to take hold and overwhelm grasses and forbs, greatly reducing plant diversity and fragmenting the landscape. An ever-growing list of invasive plant species pose an immense challenge for today's grassland managers. Species such as sericea lespedeza (*Lespedeza cuneata*), multiflora rose (*Rosa multiflora*), autumn olive (*Elaeagnus umbellate*), tall fescue (*Festuca arundinacea*), yellow sweet clover (*Melilotus officinale*) and white sweet clover (*Melilotus alba*), Johnson grass (*Sorghum halapense*), and reed canary grass (*Phalaris arundinacea*), spotted knapweed (*Centaurea stoebe*), and common teasel (*Dipsacus fullonum*) and cutleaf teasel (*Dipsacus laciniatus*) aggressively outcompete native grasses and forbs, forming dense monocultures that reduce the overall plant species richness and structural diversity of these grassland communities.

Additional Threats – Wet Prairies

Wet prairie systems face similar threats but are also negatively impacted by pollution, siltation, and altered hydrology resulting from stream channel and floodplain alterations, including channelization, impoundments, and modified drainage systems.

Management Actions and Opportunities

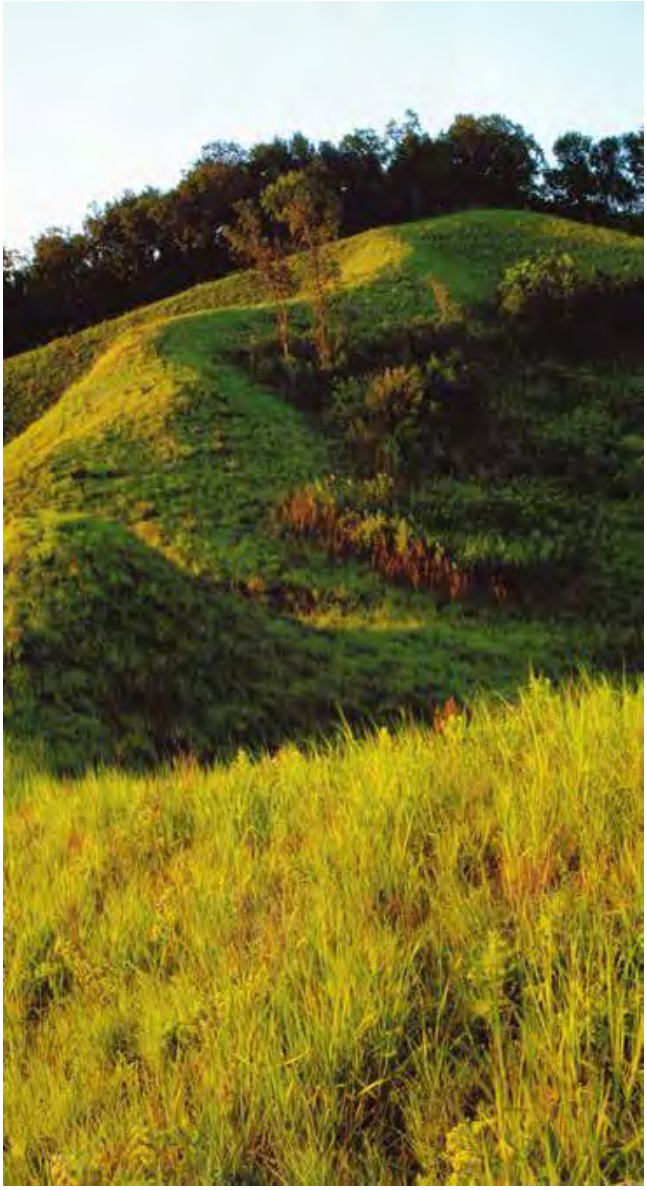
Grassland conservation actions in Missouri must focus on protecting intact, remnant habitats and maintaining sites that have been successfully restored, as well as increasing connectivity among these areas. This means proactive restoration or reconstruction of additional grasslands is also critically important. Such efforts may involve limited land acquisition but will in most instances require cooperation with private landowners. Improving these working grasslands will require providing training in regenerative production techniques and innovative approaches that address underlying economic realities faced by producers, such as the National Audubon Society's Conservation Ranching Program. MDC and other partner organizations focus substantial resources on cost-share and incentive programs aimed at improving grassland management.

The conversion of cropland and fescue pasture to diverse reconstructed grassland communities remains a guiding objective. The establishment of a broad diversity of native plants and subsequent maintenance of heterogeneous vegetative structure that benefits an equally broad diversity of grassland-dependent wildlife remain a high priority for public and privately owned grasslands. Prescribed burning, mechanical tree and brush removal, mowing, haying, and herbicide treatment will continue to be important tools to keep woody vegetation and invasive species at bay. Likewise, in some instances, a combination of prescribed burning and grazing may be needed to restore and maintain the diversity and vegetative structure of healthy grassland communities. Efforts to restore populations of species with low mobility (e.g., invertebrates, amphibians) into these reconstructed grasslands are relatively new in Missouri.

Missouri's CCS identifies COAs that represent the greatest opportunities for sustainable conservation of Missouri's habitat systems and the species they support. Of the COAs, three have been specifically selected as PGs to represent immediate grassland and savanna community conservation emphasis, including Grand River Grasslands and Spring Creek Watershed, both located within the Central Dissected Till Plains region of north Missouri, and the Upper Osage Grasslands, within the Osage Plains of southwest Missouri. Each of these includes key public and private protected lands within a matrix of privately owned working lands. Conservation actions within these geographies include working with landowners to promote BMPs; using fire, grazing, and other management tools to restore remnant and reconstructed prairies and savannas; and monitoring to assess resources present and to progress toward established objectives.

Natural Community Subtypes and Case Studies

Loess Hills Prairie and Savanna



Historically in Missouri, loess hill prairies and savannas occurred along the Missouri River from the Iowa state line to south of St. Joseph. However, these prairies are now restricted to Atchison and Holt counties in the far northwestern corner of the state. Loess hill prairies are characterized by very deep fertile soils, historically deposited as wind-blown silt and sand. Slopes are generally steep and soils are well drained. Melting glaciers deposited silty soil in river valleys, which was later blown by wind and redeposited as piles of deep loess on adjacent uplands. Today, these loess hills feature dry prairies on steep south- and west-facing bluffs with soils characterized by high levels of carbonates. Though many of the species of loess hill prairies are common to the Great Plains region, they are, in fact, rare in Missouri as their ranges only enter the northwestern part of the state. Common species found in loess prairies include thimbleweed (*Anemone cylindrica*), large beard-tongue (*Penstemon grandiflorus*), locoweed (*Oxytropis lambertii*), skeleton plant (*Lygodesmia juncea*), swift tiger beetle (*Cylindera celeripes*), mermiria grasshopper (*Mermiria picta*), and Packard's grasshopper (*Melanoplus packardii*).

Examples of this community include Star School Hill Prairie Conservation Area (CA), Brickyard Hill CA, Jamerson McCormack CA, and Loess Bluffs National Wildlife Refuge (formerly Squaw Creek).

Case Study: Loess Hills Prairie Complex
Location: Loess Hills Prairie Complex COA

The Loess Hills Prairie Complex includes lands managed by MDC and USFWS and includes land owned by TNC and MPF. Overlooking Loess Bluffs National Wildlife Refuge (formerly Squaw Creek), the prairies are actively managed to preserve the unique biodiversity of these rare communities.

Rare species found in this area include silvery psoralea, downy painted cup, soapweed, low milk vetch, and the swift tiger beetle. A combination of prescribed fire, mechanical clearing, and herbicides help maintain the open character of the landscape.

Fewer than 200 acres of this landscape remain in the state of Missouri, and working with private and public entities is important to preserve this unique piece of Missouri's heritage.

Conservation partners include Friends of Squaw Creek, Midland Empire Audubon, MDC, Missouri Natural Areas Committee, Missouri Western State College, NRCS, Northwest Missouri State University, TNC, and USFWS.

Glaciated Prairie

Missouri's glacial till prairies are primarily found in the Central Dissected Till Plains region, north of the Missouri River. These prairies are typified by deep, highly fertile soils formed by historic glacial deposits. These fertile soils were attractive to farmers at the time of widespread European immigration, thus many of these prairies were long ago converted for agricultural production. Plant communities of glacial till prairies are dominated by tallgrass species such as Indian grass (*Sorghastrum nutans*) and big bluestem (*Andropogon gerardii*), as well as forbs like compass plant (*Silphium laciniatum*) and pale purple coneflower (*Echinacea pallida*).

Animal communities in glacial till prairies are diverse, typified by a suite of species including generalists such as American badger (*Taxidea taxus*) and gartersnake (*Thamnophis* spp.) and habitat specialists such as Henslow's sparrow (*Ammodramus henslowii*). Four animal SGCNs are found mainly in this prairie type: bobolink (*Dolichonys oryzivorus*), Henslow's sparrow (*Ammodramus henslowii*), northern prairie skink (*Eumeces septentrionalis septentrionalis*), and Franklin's ground squirrel (*Poliocitellus franklinii*).

Examples of glacial till prairies include the focal landscapes Grand River Grasslands, Helton Prairie, Mystic Plains, Pony Express, Prairie Forks, and Tarkio Prairie Conservation Areas.

Case Study: Grand River Grasslands Priority Geography
Location: Grand River Grasslands COA

The Grand River Grasslands Priority Geography incorporates lands managed by MDC and TNC. It supports several SOCCs, including northern prairie skinks, regal fritillary butterflies, and Topeka shiners. Many important grassland birds (Henslow's sparrows, dickcissels, bobolinks, northern harriers) breed within this landscape, benefiting from prairie restoration projects at Dunn Ranch and Pawnee Prairie Natural Area.

The West Fork of Big Creek, Little Creek, and Big Muddy Creek flow through this landscape and are considered high priorities for prairie stream wildlife. Characteristic prairie fishes include black bullhead, bluntnose minnow, orange-spotted sunfish, and western redfin shiner. The federally listed Topeka shiner has been reintroduced into two of these PWs.

Additional conservation actions include working with landowners to promote BMPs on private lands and using fire and other management tools to restore remnant and reconstructed prairies in the region.

Conservation partners include Blank Park Zoo, Iowa DNR, MDC, TNC, MRBO, NRCS, and USFWS.

Unglaciated Prairie

Unlike the glacial till and loess hill prairies, these grasslands, found south of the Missouri River, were not formed by glacial soil deposition. Thus, soils are generally shallower than those on northern prairies, often exhibiting exposed bedrock. Historically, prairie dominated the highest, flattest areas and graded into post oak barrens and savanna on side slopes and into draws.

The Osage Plains ecoregion, which supports the clear majority of Missouri's unglaciated prairies, stretches from Texas, Oklahoma, and Kansas into the southern and western portions of Missouri. This region is characterized by a flat to gently rolling landscape underlain mainly by Pennsylvanian-age shale, sandstone, and limestone. Grasslands in the southern portion of Missouri are generally found in this Osage Plains region or near the Osage Plains border in the western Ozarks.

Plant communities in the Osage Plains and Western Ozarks may be similarly dominated by tallgrass species, but shorter grasses such as little bluestem (*Schizachyrium scoparium*), prairie dropseed (*Sporobolus heterolepis*), and sideoats grama (*Bouteloua curtipendula*) may be more prevalent. Forb species include blue false indigo (*Baptisia australis*), orange puccoon (*Lithospermum canescens*), and pale purple coneflower (*Echinacea pallida*). Plant SGCNs include Barbara's buttons (*Marshallia caespitosa var. caespitosa*) and Mead's milkweed (*Asclepias meadii*). Animal SGCNs that can be found in these prairies or associated prairie streams include the northern crawfish frog (*Lithobates areolatus circulosus*), great plains skink (*Eumeces obsoletus*), southern prairie skink (*Eumeces septentrionalis obtusirostris*), blacknose shiner (*Notropis heterolepis*), Topeka shiner (*Notropis topeka*), greater prairie-chicken (*Tympanuchus cupido*), Henslow's sparrow (*Ammodramus henslowii*), regal fritillary (*Speyeria idalia*), and prairie molecricket (*Gryllotalpa major*).

Case Study: Upper Osage Grasslands Priority Geography
Location: Upper Osage Grasslands COA

The Upper Osage Grasslands Priority Geography encompasses both Taberville and Wah'Kon-Tah Prairies, totaling 3,300 acres of native tallgrass prairie, currently owned by MDC and TNC. This landscape also contains two large-scale grassland restoration projects on both Schell-Osage and Linscomb CAs, totaling around 1,400 acres. Beyond the boundaries of public lands lie privately owned remnant prairies, such as MPF's Schwartz Prairie, that add to the existing conservation network. In addition, there are other grasslands and cropland that hold significant restoration potential.

Conservation partners lead by example with resource management on public land that includes prescribed fire; and, in some instances, grazing; hosting workshops and field days to connect the public to the prairies; continued monitoring of projects that evaluate past management and shape future actions; and providing technical assistance and cost-share funds to landowners.

Conservation partners include the USDA Farm Service Agency (FSA), MDC, MPF, NRCS, Quail Forever, St. Louis Zoo, TNC, and USFWS.

Sand Prairie

Sand prairies exist on natural levees and terraces with very little sloping on all aspects. Soils tend to be well drained, very deep, and low in nutrients and organic matter. Sand prairies have highly erodible, often arid soils. Flora and fauna in sand prairies must be adapted to these harsh conditions.

Examples of flora that flourish in this habitat are little bluestem (*Schizachyrium scoparium*), jointweed (*Polygonella articulata*), and Hall's bulrush (*Schoenoplectiella hallii*), as well as various fungi, lichens, and mosses. Several state-ranked animals occupy these communities, such as the American badger (*Taxidea taxus*), dusty hog-nosed snake (*Heterodon gloydi*), eastern spadefoot toad (*Scaphiopus holbrookii*), barn owl (*Tyto alba*), and northern harrier (*Circus hudsonius*).

Within Missouri, this habitat is restricted to areas bordering the Mississippi River in only the southeastern and northeastern regions of Missouri. Even in these areas, high quality sand prairies are rare. Therefore, in Missouri, sand prairies are listed as Critically Imperiled (S1) and remain among the rarest natural communities in the state.

Currently, examples of sand prairie opportunities identified in the state include Frost Island Sand Prairies in the Central Dissected Till Plains and Southeast Sand Ridge Grasslands in the Mississippi Alluvial Basin.

Case Study: Sand Ridge Grasslands
Location: Mississippi/Scott Sand Prairie COA

Fewer than 2,000 acres of sand prairies remain in southeast Missouri, all of which have been altered for agricultural purposes. Landowners are essential to sand prairie recovery efforts. Partnerships that promote the conservation of sand prairies through cooperative habitat management, landowner technical support, and programs tailored to recover SOCCs are ongoing.

Rare species include snoutbean, sand hickory, Hall's bulrush, jointweed, dusty hog-nosed snake, Illinois chorus frogs, eastern spadefoot toad, and northern harriers, as well as many native bees, sand cicadas, and other insects that we have just begun to learn about.

Conservation actions include land acquisition and private land partnerships, such as incentive programs to protect and enhance small remnants of sand prairies. Restoration and management of these habitats include prescribed burning, seed collection, planting, and invasive species control. Continued monitoring of species that occupy these habitats is critical.

Conservation partners include Cape Girardeau Conservation Campus Nature Center, Charleston Baptist Association, Eastern Illinois University, Missouri Botanical Garden, MDC, MDNR, MPF, NRCS, Quail Forever, Southeast Missouri State University, Southern Illinois University at Edwardsville, and USFWS.

Savanna

Savanna is a grassland natural community dominated by native grasses and forbs differentiated by widely spaced trees, usually with no more than 30 percent canopy cover. Missouri savanna communities most frequently occur in the Osage Plains and Central Dissected Till Plains ecoregions on mostly level to dissected plains terrain. The geologic substrate most frequently associated with savannas is Pennsylvanian limestone and sandstone; however, savannas can exist on any upland topography with level to gently rolling contours, regardless of the underlying substrate.

Savannas are easily identified and differentiated from woodlands by their characteristic canopy cover of less than 30 percent; whereas woodlands typically have 30–80 percent. The open canopy is composed of either assorted groupings of various-aged trees or stand-alone trees and allows for sun-loving prairie grasses, forbs, and shrubs to dominate the landscape. Typical flora and fauna found in savannas are adapted to full sun, as well as frequent, low to moderate intensity fires. Historically, low-intensity fire forged these natural communities by repressing establishment of seedling trees, while doing little harm to mature trees. Without natural or anthropogenic fires, savanna natural communities are easily overtaken by trees and succeed into woodland communities.

Previously, six savanna ecosystems were designated based on soil moisture and substrate material in Missouri. Today, only fragmented samples of these former savannas exist within Missouri. Many savannas today are masked by dense stands of trees that have invaded them in the absence of fire, or their herbaceous layers have been converted to exotic pasture grasses.

Because savannas are a blend of grassland and woodland habitat structure, their species composition reflects an ecotone between these dominant community types; and species inhabiting savannas tend to be habitat generalists or edge species that are able to exploit both grassland and woodland characteristics. The precise composition often fluctuates as the dominance of grasses and forbs versus shrubs shifts in the understory spatially and temporally due to fire and successional stage. Species inhabiting savannas include white-tailed deer (*Odocoileus virginianus*), coyote (*Canis latrans*), eastern cottontail rabbit (*Sylvilagus floridanus*), red-headed woodpecker (*Melanerpes erythrocephalus*), loggerhead shrike (*Lanius ludovicianus*), red-tailed hawk (*Buteo jamaicensis*), and eastern bluebird (*Sialia sialis*). Many grasses, shrubs, and trees also thrive in the savanna landscapes including little bluestem (*Schizachyrium scoparium*), American hazelnut (*Corylus americana*), and bur oak (*Quercus macrocarpa*).

Example locations exhibiting savanna habitat in Missouri include Union Ridge CA (Spring Creek Watershed Priority Geography) and Long Branch State Park.

Case Study: Missouri-Iowa Woodland/Savanna Geography

The Missouri-Iowa Woodland/Savanna Geography is a landscape of natural community management that includes portions of five Missouri counties and continues into Iowa. This geography encompasses both Spring Creek Watershed and Thousand Hills COAs. This aggressive and sweeping effort is designed to capture previously overlooked tracts of degraded woodland, savanna, and prairie communities – the majority of which are contained on private land. Historically, fire shaped the composition of these savanna communities. The variable geography of this region afforded diverse fire behavior and less-intense pressure from row crop production; which in turn, offers more restorable savanna remnants than other nearby landscapes.

Restoration efforts have focused on removal of undesirable woody species, reintroduction of prescribed fire, chemical treatment of exotic species, and conversion of exotic grasses to native grasses and forbs. An example of success is the Roeslein property in southern Putnam County, a 1,600-acre complex on which the Roesleins have employed all the mentioned practices, with superb results. Although their savanna restoration is ongoing, past efforts have enhanced hundreds of acres of savanna and prairie natural communities. The result of these efforts has been extremely rich, post-oak savanna habitats containing plant species such as rough blazing star, showy goldenrod, and New Jersey tea.

Conservation partners include Iowa DNR, MoBCI, MDC, MPF, NRCS, NWTF, PFQF, Southern Iowa Oak Savanna Alliance, and USFWS.

Wet Prairie

Wet prairies are a critically imperiled community type in Missouri with an estimated acreage loss of 99.6 percent. Wet prairies are defined by a dense cover of perennial grasses mixed with forbs and sedges; they typically occur on floodplains of narrow and large rivers and occasionally in upland prairie depressions or swales. Soils are often saturated due to high clay content, with seasonally high water tables and standing water present during the spring and winter or after heavy rains.

Wet prairies support a variety of species, such as American bitterns (*Botaurus lentiginosus*), yellow rails (*Coturnicops noveboracensis*), sedge wrens (*Cistothorus platensis*), meadow voles (*Microtus pennsylvanicus*), meadow jumping mice (*Zapus hudsonius*), plains leopard frogs (*Lithobates blairi*), and many species of snakes, including foxsnakes (*Pantherophis vulpinus*), ribbonsnakes (*Thamnophis proximus proximus*), gartersnakes (*Thamnophis* spp.), watersnakes (*Nerodia* spp.), and the state-endangered prairie massasauga rattlesnake (*Sistrurus tergeminus tergeminus*).

Representative wet prairie habitats include Loess Bluffs National Wildlife Refuge (formerly Squaw Creek), Lower Grand Conservation Opportunity Area, Marmaton River Bottoms Preserve, Douglas Branch CA, Ripgut Prairie Natural Area, Four Rivers CA, and Flight Lake CA.

Case Study: Flight Lake, Douglas Branch, and Ripgut Prairie
Location: Four River Wetland and Prairie Complex COA

The unprecedented decline of wet prairie habitat across Missouri is a major concern to the Missouri conservation partners. During 2013 and 2014, MDC staff restored a total of 86 acres of remnant wet bottomland prairie on three CAs in Vernon and Bates counties, including Flight Lake (46 acres), Douglas Branch (32 acres), and Ripgut Prairie Natural Area (18 acres). Portions of these wet prairies had become degraded due to altered hydrologic regimes and limited management abilities, including the use of prescribed fire. As a result, these areas experienced encroachment by early successional woody species, including buttonbush, willow, silver maple, green ash, and cottonwood.

To restore the remnant wet bottomland prairie, area managers used prescribed fire and mechanical equipment to remove woody cover. Post tree and shrub removal, natural grass and forb recruitment was allowed to occur from an existing viable seed bank within the soils on the areas.

Continued management of Missouri's wet prairie systems will involve a combination of treatments, including the use of burning, herbicide, and haying to maintain the openness of these areas. In addition, there is a need to evaluate wet prairie restoration potential and expand this natural community type on other public and private lands

Forest and Woodland Conservation and Case Studies

Overview

Wooded lands comprise just over one-third of the land area in Missouri, totaling 15.4 million acres. It's not hard to see why they are among Missouri's most valuable resources. Financially, the forest products industry provides jobs to thousands of Missourians and contributes billions of dollars to the state's economy annually. Our forests and woodlands provide excellent recreational opportunities, ranging from walking and sightseeing to birding, fishing, floating, and hunting, all of which encourage people to engage with nature and serve to improve the quality of life for Missouri citizens and visitors. Large tracts of forest and woodland also provide tremendous ecological benefits in the form of clean air and water and extremely diverse natural communities for wildlife.

While the titles "forest" and "woodland" are often used interchangeably for all wooded lands, "woodlands" have been treated as a unique community type since the early 2000s, each having its own management prescriptions. While forest structure can vary by age and management practices, mature forests are generally dominated by trees forming a closed canopy, often comprised of multiple overlapping layers. The mid-story and understory contain a variety of shade-tolerant woody species, and a sparse herbaceous vegetative layer will likely be present in the understory. Mature woodlands are characterized by areas with a 30–100 percent canopy closure. They have a sparse woody understory or mid-story that allows more sunlight to penetrate to the ground. This in turn produces a dense ground cover containing a variety of forbs, grasses, and sedges. Fire plays a valuable role in the restoration and maintenance of woodland habitat systems.

Forests and woodlands are rich in floral and faunal diversity. An incredible amount of plant diversity can be observed within any given tract of wooded land. This variety of plant species and structure is dependent upon factors such as soil substrate, temperature, topography, aspect, and availability of moisture. The independent way in which any of these elements combine creates a broad spectrum of circumstances that support different plant species and create a mosaic of habitats across the landscape. This plant diversity, in turn, supports a tremendous number of terrestrial and aquatic faunal species.

Healthy forest and woodland systems provide this variability of habitat, which supports both generalist and specialized animal species. These natural communities have abundant nesting, cover, and foraging sites to attract many generalists: the black bear (*Ursus americanus*),

sharp-shinned hawk (*Accipiter striatus*), and Diana fritillary (*Speyeria diana*) are species that can be found throughout the matrix of forest and woodland systems. Other species, such as the Indiana bat (*Myotis sodalis*), Ozark zigzag salamander (*Plethodon angusticlavius*), and Swainson's warbler (*Limnothlypis swainsonii*) are very specialized in their needs and have particular nesting or foraging requirements, only offered by specific elements of forests or woodlands. Another important and often overlooked aspect of forests and woodlands is their role in protecting and enhancing water quality. Healthy forests and woodlands retain soil, absorb nutrients, slow runoff, and allow for water infiltration, so it can also be said that many of Missouri's fish and other aquatic species are dependent upon forests and woodlands as well.

Example characteristic forest wildlife species include the wood frog (*Lithobates sylvaticus*), Acadian flycatcher (*Empidonax virescens*), western slimy salamander (*Plethodon albagula*), and southeastern bat (*Myotis austroriparius*).

Example characteristic woodland wildlife species include red-headed woodpecker (*Melanerpes erythrocephalus*), prairie lizard (*Sceloporus consobrinus*), three-toed box turtle (*Terrapene carolina triunguis*), and timber rattlesnake (*Crotalus horridus*).

Figure 4.3.1 – Missouri Forest/Woodland COAs

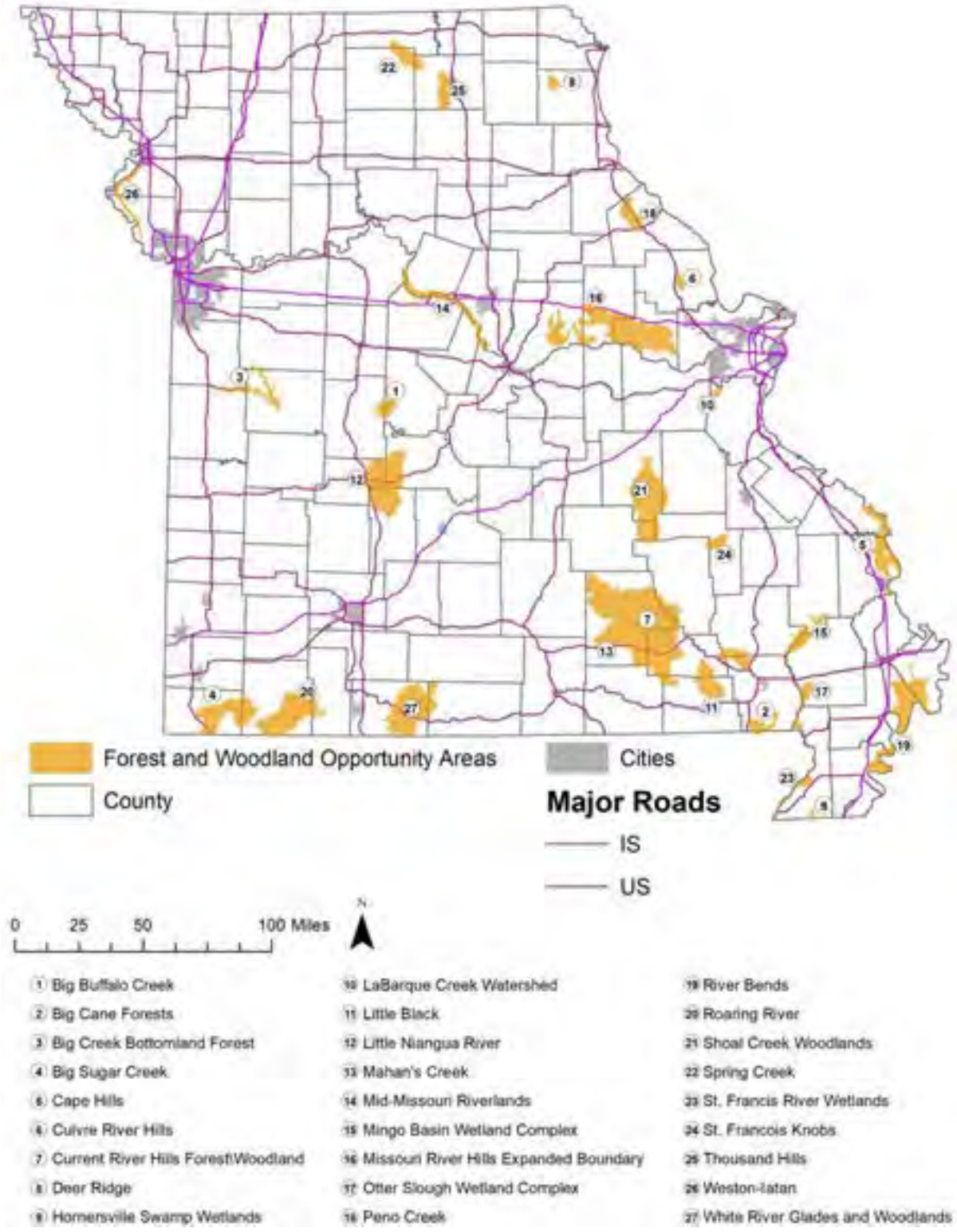
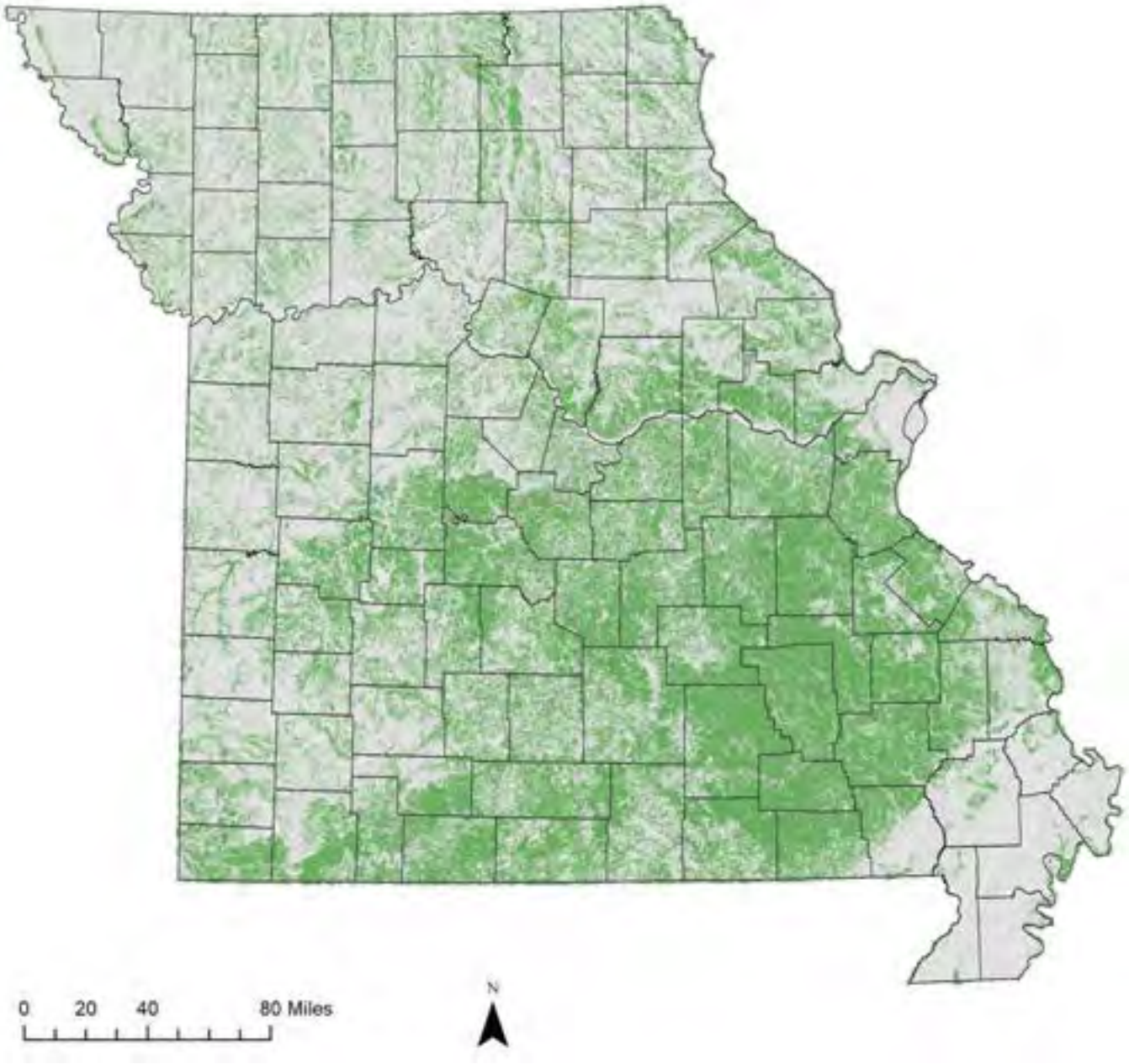


Figure 4.3.2 – Estimated Extent of Tree Cover in Missouri (NLCD 2016)



This map shows the extent of tree cover in Missouri based on NLCD 2016 data. The forest and woodland COAs were selected based on MDC's Forest/Woodland model, the current treed land cover from the NLCD, and MDC's Heritage Database of forest and woodland community and species records.

Scoring Criteria

8. HUC 16 has >50 acres of woodland/forest potential, AND at least one of the following: ≥ 80% cropland/pasture, OR ≥ 30% developed, OR <75% of woodland/forest potential is still treed
9. HUC 16 has >50 acres of woodland forest potential AND all of the following: has <80% cropland/pasture, AND <30% developed, AND 75–90% of woodland forest potential still treed
10. HUC 16 has >50 acres of woodland forest potential, AND ≥ 90% forest woodland potential is still treed, AND <80% cropland/pasture, AND <30% developed
11. One or more recent* Heritage records for forest or woodland species or communities
12. Greater than 1 recent heritage records for forest or woodland species or communities
13. HUC 16 has >50 acres of woodland forest potential, AND ≥ 90% forest woodland potential is still treed, AND <10% cropland/pasture, AND <10% developed
14. HUC 16 intersects SFAP OR intersects TNC portfolio sites
15. HUC 16 intersects PFLs, OR intersects CFLRP landscape, OR intersects the Elk Restoration Zone, OR intersects high PG for forest or woodland habitat
16. Those areas scoring an 8 AND intersecting the conservation network
17. **Those areas scoring a 9 AND containing >1 recent heritage record**

{ Decisive selection criteria for COAs }

* Recent Heritage Database records are considered since 1981 for community records and after 1989 for species record

Species of Greatest Conservation Need

Plants

Southern monkshood (*Aconitum uncinatum*) * Purple giant hyssop (*Agastache scrophulariifolia*) * Slough sedge (*Carex atherodes*) * Cumberland sedge (*Carex cumberlandensis*) * Graceful sedge (*Carex gracillima*) * Drooping sedge (*Carex prasina*) * Tony's sedge (*Carex reznicekii*) * Long-beaked sedge (*Carex sprengelii*) * Willdenow's sedge (*Carex willdenowii*) * Pretty sedge (*Carex woodii*) * Ozark chinquapin (*Castanea pumila var. ozarkensis*) * Vase vine (*Clematis viorna*) * Littlehip hawthorn (*Crataegus spathulata*) * Showy lady's slipper (*Cypripedium reginae*) * Tall larkspur (*Delphinium exaltatum*) * American beak grass (*Diarrhena americana*) * Leatherwood (*Dirca decipiens*) * Spinulose shield fern (*Dryopteris carthusiana*)* Beech drops (*Epifagus virginiana*) * Forked aster (*Eurybia furcata*) * Big-leaved aster (*Eurybia macrophylla*) * Pale sunflower (*Helianthus decapetalus*) * Great St. John's wort (*Hypericum ascyron ssp. pyramidatum*) * Bushy St. John's wort (*Hypericum lobocarpum*) * Large whorled pogonia (*Isotria verticillata*) * Prairie lily (*Lilium philadelphicum var. andinum*) * Pondberry (*Lindera melissifolia*) * Southern twayblade (*Listera australis*) * Basil bee balm (*Monarda clinopodia*) * Pennywort (*Obolaria virginica*) * Black-seeded rice grass (*Patis racemosa*) * Coville's phacelia (*Phacelia covillei*) * Broadleaf phlox (*Phlox amplifolia*) * Short-toothed mountain mint (*Pycnanthemum muticum*) * Water oak (*Quercus nigra*) * Nuttall's oak (*Quercus texana*) * Red-berried elder (*Sambucus pubens*) * Soapberry (*Sapindus saponaria var. drummondii*) * Wolfberry (*Symphoricarpos occidentalis*) * Crane-fly orchid (*Tipularia discolor*) * Ozark spiderwort (*Tradescantia ozarkana*) * Running buffalo clover (*Trifolium stoloniferum*) * Snow trillium (*Trillium nivale*) * Ozark wake robin (*Trillium pusillum var. ozarkanum*) * Cedar elm (*Ulmus crassifolia*) * Southern arrowwood (*Viburnum dentatum*) * Sand violet (*Viola affinis*)

Characteristic:

Kidney-fruited sedge (*Carex reniformis*) * Cespitose sedge (*Carex socialis*) * Rose turtlehead (*Chelone obliqua*) * Parsley hawthorn (*Crataegus marshallii*) * Stiff gentian (*Gentianella quinquefolia* ssp. *occidentalis*) * Pale green orchid (*Platanthera flava var. flava*) * Tubercled orchid (*Platanthera flava var. herbiola*)

Mollusks

Capital vertigo (*Vertigo oscariana*)

Insects

Linda's roadside skipper (*Amblyscirtes linda*) * A solitary bee (*Andrena [Scrapteropsis] rubi*) * Golden banded skipper (*Autocthon cellus*) * Half-black bumblebee (*Bombus [Pyrobombus] vagans*) * Northern metalmark (*Calephelis borealis*) A cellophane bee (*Colletes aestivalis*) * Creighton's slavemaking ant (*Formica creightoni*) * Bessy's cuckoo nomad bee (*Nomada besseyi*) * A mason bee (*Osmia [Melanosmia] sandhouseae*) * Similar mason bee (*Osmia [Melanosmia] simillima*) * Ozark woodland swallowtail (*Papilio joanae*) * Long-horned shining amazon ant (*Polyergus longicornis*) * Appalachian eyed brown (*Satyrodes appalachia leeuwi*) * A long-horned bee (*Svastra [Epimelissodes] texana*)

Amphibians

Characteristic:

Ringed salamander (*Ambystoma annulatum*) * Mole salamander (*Ambystoma talpoideum*) * Long-tailed salamander (*Eurycea longicauda longicauda*) * Dark-sided salamander (*Eurycea longicauda melanopleura*) * Four-toed salamander (*Hemidactylium scutatum*) * Pickerel frog (*Lithobates palustris*) * Wood frog (*Lithobates sylvaticus*) * Western slimy salamander (*Plethodon albagula*) * Ozark zigzag salamander (*Plethodon angusticlavius*) * Southern red-backed salamander (*Plethodon serratus*)

Reptiles

Characteristic:

Timber rattlesnake (*Crotalus horridus*) * Rough green snake (*Opheodrys aestivus*) * Five-lined skink (*Plestiodon fasciatus*) * Prairie lizard (*Sceloporus consobrinus*) * Little brown skink (*Scinella lateralis*) * Northern red-bellied snake (*Storeria occiptomaculata occipitomaculata*) * Three-toed box turtle (*Terrapene carolina triunguis*)

Birds

Sharp-shinned hawk (*Accipiter striatus*)

Characteristic:

Chuck-will's-widow (*Caprimulgus carolinensis*) * Eastern whip-poor-will (*Caprimulgus vociferus*) * Chimney swift (*Chaetura pelagica*) * Yellow-billed cuckoo (*Coccyzus americanus*) * Eastern wood-pewee (*Contopus virens*) * Blue jay (*Cyanocitta cristata*) *Yellow-throated warbler (*Dendroica dominica*) * Acadian flycatcher (*Empidonax virescens*) * Kentucky warbler (*Geothlypis formosa*) * Worm-eating warbler (*Helmitheros vermivorus*) * Wood thrush (*Hylocichla mustelina*) * Swainson's warbler (*Limnothlypis swainsonii*) * Red-headed woodpecker (*Melanerpes erythrocephalus*) * Eastern towhee (*Pipilo erythrophthalmus*) * Summer tanager (*Piranga rubra*) * Prothonotary warbler (*Protonotaria citrea*) * Common grackle (*Quiscalus quiscula*) * Louisiana waterthrush (*Seiurus motacilla*) * Cerulean warbler (*Setophaga cerulea*) * Bewick's wren (*Thryomanes bewickii*)

Mammals

Silver-haired bat (*Lasionycteris noctivagans*) * Hoary bat (*Lasiurus cinereus*) * Northern myotis (N. long eared bat) (*Myotis septentrionalis*) * Tri-colored bat (*Perimyotis subflavus*) * Plains spotted skunk (*Spilogale putorius interrupta*)

Characteristic

Little brown myotis (*Myotis lucifugus*) * Indiana bat (*Myotis sodalis*) * Golden mouse (*Ochrotomys nuttalli*) * Black bear (*Ursus americanus*)

Threats and Challenges

Many natural and human-caused disturbances threaten Missouri's forested ecosystems. Destructive pests, changing weather patterns and extreme weather events, invasive species, and human and animal actions are all stressors that can affect the health of our wooded communities and lead to a decline in the countless benefits that our forest and woodland habitats provide.

Habitat Loss and Degradation

Fragmentation, conversion, and degradation of habitat are among the greatest threats to forest and woodland ecosystems. Every year, wooded acres are lost to the creation of fields, roads, and urban structures. The conversion of these acres from a forest or woodland disrupts the continuity of habitat. This fragmentation creates more forest edge, changing the composition and structure, which eventually leads to a change in the species that utilize that area.

Unsustainable harvest practices that do not utilize best management practices place significant pressure on the health and productivity of forests and woodlands and can cause erosion and sediment loading in streams.

A change in the use of fire and intensive grazing are the primary causes of woodland habitat degradation. The application of fire is what maintained many areas in a woodland state. The absence of fire has allowed some of these dry woodlands to lose components of their plant cover and diversity and to gradually progress to a more forested system. One of the most noticeable changes of this conversion is the lack of pine regeneration in the Ozarks as woodland overstories become more closed.

Between 1890 and 1920 the extensive shortleaf pine woodlands of the Missouri Ozarks were unsustainably harvested with pine stands decimated. This was then followed by years of severe wildfires in the former pineries, which killed many of the remaining pine seed trees. Scarlet oak (*Quercus coccinea*) and black oak (*Quercus velutina*) were the winners in this scenario and readily resprouted following the cutover and the big burns. With fire suppression beginning in the 1930s, many former pine stands shifted to scarlet and black oak dominated stands. Today many of these red oak group dominated stands are mature, overstocked, and declining in growth. Unfortunately, many of these sites lack adequate pine stocking to restore a pine woodland.

However, in certain geographies, due to a mix of natural and artificial past pine regeneration, the opportunity for large-scale pine woodland restoration is possible. The best example of this is the CFLRP project of the MTNF and partner organizations, agencies, and landowners, centered on restoring pine woodlands that occur in a zone north and south of US 60 from approximately Birch Tree to Poplar Bluff, Missouri.

Invasive Pests and Diseases

There are several insects and diseases that are of particular concern in Missouri. Most problems are caused by exotic species like EAB, but some of the threats, like red oak decline, are native and pose a serious threat to the oak community. There is no single cause for red oak decline; rather, it is believed to be a complex interaction of environmental stresses and pests to which the red oak group is more susceptible due to age and where they grow. Oak wilt is a serious disease that affects many species of oak trees in forests, woodlots, and urban landscapes. This aggressive disease is caused by a fungus that is easily transported as fungal mats under the bark of infected wood such as firewood. The EAB is an exotic pest that primarily attacks ash trees. While ash is a relatively small component of Missouri's upland forested ecosystems, EAB poses a significant threat to our urban landscapes where ash trees can be found in greater numbers and in bottomland and riparian forests where ash is often a significant component of the overstory.

Due to the potential for devastating ecological and economic effects, Missouri is diligent in monitoring for new and potential threats. The gypsy moth (*Lymantria dispar*), for

example, targets oak species. Individual gypsy moths have been found in Missouri in the past, so yearly surveys are conducted with pheromone-scented traps to continually monitor gypsy moth occurrences and distribution. Currently Missouri does not have an established gypsy moth population. Other forest pests and diseases that are not known to be established in Missouri include the Asian longhorned beetle (*Anoplophora glabripennis*), which attacks a variety of hardwood species, and thousand cankers disease, which can be found on any of the walnut species (*Juglans* spp.) but primarily affects black walnut (*Juglans nigra*). These and other existing and potential pests have significant potential to negatively impact Missouri's forests and woodlands.

Unfortunately, introductions of invasive forest pests continue through global trade, despite international policies intended to limit the movement of destructive species. Education, awareness, early detection, and rapid response are key to limiting the impact of these and other invasive pests.

Invasive Plant Species

There are several exotic plant species that threaten the biodiversity and productivity of Missouri's wooded communities. Whether purposely introduced like autumn-olive (*Elaeagnus umbellata*) for a windbreak and wildlife food and cover or sericea lespedeza (*Lespedeza cuneata*) for forage and erosion control, or accidentally, these invasive species cause tremendous problems for native flora and fauna. Without the predators, parasites, or environmental factors that kept these plants in check in their native environment, they often thrive and outcompete native species, seldom provide a quality food source to wildlife, and choke out native habitat. Other invasive plants that affect our forested systems include bush honeysuckles (*Lonicera morrowii, L. maackii*), garlic mustard (*Alliaria petiolata*), round-leaved bittersweet (*Celastrus orbiculatus*), and wintercreeper (*Euonymus fortunei*), just to name a few.

Native Insects and Diseases

Native insect and disease species are a common and important part of Missouri's forest and woodland communities. Some of these species cause little harm to trees while others act as stressors or even contribute to tree death.

High populations of native insects and diseases are periodically observed on Missouri's trees. In stressed forest and woodland communities, several native wood-boring insects and tree diseases act as secondary antagonists of mature trees, particularly those stressed by periodic extreme weather events such as drought (i.e., red oak borer, Armillaria root rot, Hypoxylon canker).

Ultimately, some native insects and diseases do work in concert to kill stressed trees; however, this is part of the natural cycle of succession in oak-dominated forests in Missouri. Many Missouri wildlife species depend on the dead trees and patches of forest disturbance caused by native insects and diseases.

Invasive and Large Animal Impacts

Feral hogs, domestic livestock, and even white-tailed deer can impact tree and forest health. Overgrazing by cattle or deer can lead to compacted soils and loss of herbaceous vegetation and seedling regeneration. Longterm overgrazing can also shift tree and plant composition from desirable species to species that cattle won't eat.

Feral hogs are extremely destructive; their rooting destroys the ground flora, causes erosion, and can damage trees. The disturbance they cause in natural communities also allows invasive plants to gain a foothold in some locations. Feral hogs compete directly with the native wildlife for food, and they eat native wildlife species. The Missouri Feral Hog Elimination Partnership is working to eradicate feral hogs from Missouri's landscape.

Weather Events and Climate Change

The weather can have significant impacts on the health of our wooded ecosystems. Changes in global climate and conditions, and the frequency of extreme weather events (i.e., tornadoes, droughts, ice storms, etc.) can have direct impacts like tree mortality and damage, but they can also affect forests indirectly by increasing a system's vulnerability to diseases and insects.

Management Actions and Opportunities

The Missouri Ozark Forest Ecosystem Project

Initiated in 1991, The Missouri Ozark Forest Ecosystem Project (MOFEP) is one of the most comprehensive ecological investigations of forest response undertaken in upland oak ecosystems. Great attention has been given to the design of the MOFEP experiment and to coordination of numerous associated research studies examining response of vegetation, downed wood, fungi, birds, small mammals, herpetofauna, invertebrates, and genetics to forest management including even-age, uneven-age, and shelterwood management. Soil, geolandforms, ecological land types, and climate are also studied. This project offers valuable data in a long-term, top-to-bottom study of the Ozark forest resource and provides the foundation to decide the best ways to satisfy demands for wood products while ensuring the survival of healthy forest ecosystems (MDC 1994). In the twenty-five years since its inception, MOFEP has grown from a cooperative research effort between MDC and the University of Missouri to a platform that includes and supports studies conducted by multiple universities and USFS.

Integrated Pest Management and Missouri Invasive Forest Pest Council

The most effective defense against natural and human caused disturbances is a resilient ecosystem. IPM is a sustainable approach to managing pest problems that supports plant/ecosystem health and minimizes negative nontarget impacts. This process encourages managers to use all available tools in a proactive and preventative manner, so that potentially destructive elements are kept from reaching the threshold of economic or biological damage. One of the goals of IPM is to monitor and assess potential pest impacts and to manage for those pests, not necessarily work to eradicate them. Each threat has a cycle or pattern that it follows. IPM requires that we understand those cycles and are aware of the point that is most advantageous for interrupting the cycle to keep that pest manageable.

The Missouri Invasive Forest Pest Council (MIFPC) is a cooperative group of public agencies that plans and coordinates readiness and response activities in Missouri for invasive forest insect and disease pests. It is composed of state, federal, and university partners with responsibilities to provide public land management, plant regulatory activities, and natural resource management information to the public. The Missouri Invasive Forest Pest Plan, developed by MIFPC, presents a framework for consistent, coordinated responses to invasive forest insects and diseases. MIFPC coordinates the annual detection surveys for the gypsy moth, EAB, thousand cankers disease, and other invasive forest pests; it coordinates outreach, regulatory, and management activities to reduce introductions and to respond to detections of invasive forest pests in Missouri.

Major partners in MIFPC to date have included the Missouri Department of Agriculture, USDA – Animal and Plant Health Inspection Service; USFS, MTNF; MDC; MDNR, the University of Missouri Extension; NRCS; and State and Private Forestry, Forest Health Protection.

Forest and Woodland Management Plans

Forest and woodland management plans are developed for wooded ecosystems to incorporate the use of IPM, prescribed burns, and a multitude of silvicultural prescriptions geared toward the conservation of forest and woodland biodiversity. Reforestation efforts of bottomland species in riparian areas and the reintroduction and management of shortleaf pine in the woodland systems of the Ozark Highlands are slowly increasing those native communities. Some silvicultural treatments are used to regenerate forested stands, others (e.g., uneven-aged management, prescribed fire) are used to manage the structure and/or composition in existing stands, but all of them dictate the

resulting habitat. The biodiversity of each stage of a stand's succession plays a vital role in wildlife management. Removal of timber, whether by mechanical methods of thinning or harvesting, use of fire, or chemical application, works to influence stand structure, whether the goal is to have a closed forest or an open woodland. The differentiating factor between these two systems is the intensity of the management tool used. Land managers use a combination of these methods to create and maintain a spectrum of habitats across the landscape.

While most of the state and federally owned forests in Missouri are managed for long-term health and sustainability, creating wildlife habitat is also a major goal of forest management. Within Missouri, conservation partners are constantly working to build relationships with private landowners and to develop management goals and prescriptions to increase the level of private land management, ensuring that forested land conservation doesn't stop at the borders of public lands. Through these partnerships, management plans are written and assistance is provided in completing on-the-ground activities intended to best meet the landowner's conservation objectives and to achieve public benefits of private forestland – such as clean water, diverse wildlife habitat, carbon sequestration, and sustainable production of forest products.

There are many examples of collaborative conservation efforts being conducted in Missouri's forest and woodland PGs. Big Buffalo Creek Watershed, Little Niangua River, Mahan's Creek Watershed, and Huzzah and SCWW are all PGs that are being managed to restore and maintain healthy, functioning forest-woodland watersheds and stream systems around the Ozark Highlands. Missouri River Hills is another PG that encompasses a subset of the largest contiguous tract of forests and woodlands in Missouri north of the Missouri River. This area is being managed to improve woodlands, bottomland forests, and glades that support fish and wildlife.

Another example of cooperative conservation is the Current River Watershed Freshwater and Sustainable Forestry Program that TNC is spearheading through funding they received from a USFS grant. TNC is using the grant to help Ozarks landowners change land management practices by funding technical assistance, planning resources, and field demonstrations on Ozark woodland management.

Natural Community Subtypes and Case Studies

Glaciated Hardwood Forest

Glaciated hardwood forests are found in the Central Dissected Till Plains of northern Missouri. They are strongly associated with loess and limestone/dolomite soils and tend to be found on upper to mid-slopes up to the ridges and summits. Typically found on north and east aspects, the glaciated hardwood forest prefers deep, moderately well-drained soils that are slightly acidic. These forested stands are commonly of mixed hardwoods with multiple vertical layers. White oak (*Quercus alba*), northern red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), and an assortment of hickories (*Carya* spp.) dominate the overstory of these upland forests. A tremendous variety of shade-tolerant trees and shrubs combine to create the mid-canopy layer, including Ohio buckeye (*Aesculus glabra*), eastern hop hornbean (*Ostrya virginiana*), slippery elm (*Ulmus rubra*), eastern redbud (*Cercis canadensis*), and spice bush (*Lindera benzoin*).

Typically, a rich layer of ground flora expresses in the spring but becomes increasingly patchy as summer progresses. May apple (*Podophyllum peltatum*), white bear sedge (*Carex albursina*), Virginia creeper (*Parthenocisssus virginiana*), trilliums (*Trillium* spp.), and red honeysuckle (*Lonicera dioica*) are just a few of the species that can be found scattered across the forest floor.

Case Study: Dark Hollow Natural Area
Location: Spring Creek Watershed COA

Dark Hollow Natural Area falls along the dividing line of the Unionville Upland Prairie Plain and the Upper Chariton River Woodland/Forest Hills. Historically the rugged, dissected hills in northern Missouri consisted of narrow ridgetop prairies that graded into woodlands, forested slopes, and valleys. This public area within the Spring Creek Watershed PG is managed for savanna, woodland, and forest. Forest types include dry-mesic loess/glacial till forest and mesic loess/glacial till forest. There are less than 1,300 acres of high integrity dry–mesic loess/glacial till forest in the state and approximately 34 percent is found in northeastern Missouri. Encroachment of invasive plant species, lack of prescribed fire, grazing, and excessive logging are threats to glaciated forests and their associated species.

Several conservative forest plants occur here including false hellebore, blue cohosh, lady fern, and spikenard. The federally endangered Indiana bat and the federally threatened northern long-eared bat use the forest for foraging and maternity roosts. Updated Indiana bat and northern long-eared bat management guidelines are in place to ensure that management on public lands benefits these two species. The USFS's Northern Research Station has a long-term study titled "Composition and Structure of Old-Growth Hardwood Forests in the Midwest" that shows an increase in ironwood and decrease in desirable oak species at Dark Hollow. MDC used these data in the Forest Management Plan.

Current management includes reducing the ironwood understory and sugar maple on ridgetops down to mid-slope. Select harvesting and prescribed burning, to encourage oak regeneration and groundcover diversity, are planned management activities. Forest management on private lands is another important component of forest conservation in the Spring Creek Watershed PG.

Conservation partners include MDC, NWTF, and USFWS.

Ozark Oak-Pine Forest

Mixed stands of oak and pine can be found in the Ozark Highlands ecoregion of the state. They perform best in chert soils that are well drained, moderately deep, and strongly acidic. These forests are most often located on moderately steep north- and east-facing slopes. On occasion, the oak/pine mixed stands will be found in igneous soil types.

These natural communities are generally comprised of an overstory with a variety of oaks (*Quercus*, spp.), hickories (*Carya,* spp.), and shortleaf pine (*Pinus echinata*), which is the only pine native in Missouri. The understory consists of shade-tolerant trees and shrubs over an irregular layer of herbaceous ground cover. Flowering dogwood (*Cornus florida*), red maple (*Acer rubrum*), serviceberry (*Amelanchier arborea*), black cohosh (*Cimicufuga racemose*), Christmas fern (*Polystichum acrostichodies*), and blue phlox (*Phlox divaracata*) are among the species that can commonly be found here.

Case Study: Sunklands Conservation Area
Location: Current River Hills Forest/Woodland COA

Few regions today preserve the wild and natural beauty of the Ozarks as well as Sunklands Conservation Area. Sunklands is the largest CA in the state at 40,589 acres owned and managed by MDC. Sunklands contains a diversity of natural communities including glades, woodlands, sinkhole ponds, and forests. Oak-pine forest natural communities are found along lower slopes of exposed aspects and upper slopes of the protected aspects near the upper Current River in northern Shannon County. These communities provide a variety of important habitat for several bird species including whip-poor-will, ovenbird, Chuck-will's-widow, Carolina chickadee, pine warbler, white-breasted nuthatch, Cooper's hawk, yellow-throated warbler, and worm-eating warbler. Reptiles and amphibians associated with mature oak-pine forests include long-tailed salamander, dark-sided salamander, southern red-backed salamander, three-toed box turtle, ground skink, western worm snake, western earth snake, and American toad.

Sunklands' oak-pine forest communities are managed through sustainable forest management practices, which include thinning and regeneration type harvests. The forest management prescriptions are determined through a detailed stand-level forest inventory that is repeated every 20 years. This scientific-based inventory system helps determine which silvicultural management techniques will be used. This ensures that the forest natural communities are sustainable over the long term and that they will continue to provide a diverse forest structure that can be used by an array of forest-dependent wildlife.

Forest management field days have been held on Sunklands CA throughout the years. Field day participants have included local landowners, area users, and NGOs such as Pioneer Forest and TNC. These field days help aid communication with stakeholders regarding the importance of regenerative and sustainable forest management in the area.

Ozark Hardwood Forest

The hardwood forests of the Ozarks are generally associated with the limestone/ dolomite, chert, and sandstone soil types. While these forested stands can be found in soils that range in depth from shallow to very deep, they are consistent in their preference of acidic, north-facing or east-facing slopes that are well drained. These hardwood forests typically have very distinct vertical layers. The tall overstory usually provides 75–100 percent canopy cover and often contains a mixture of white oak (*Quercus alba*), northern red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), American basswood (*Tilia americana*), and a variety of hickories like pignut hickory (*Carya glabra*), shagbark hickory (*Carya ovata*), and mockernut hickory (*Carya tomentosa*). A subcanopy of shorter stature trees is often present, as well as an understory of shade-tolerant small trees, shrubs, and canopy saplings. The very diverse herbaceous ground cover consists of shrubs, sedges, ferns, and vernal forbs.

Case Study: Meramec River Hills Priority Forest Landscape
Location: Shoal Creek Woodlands COA

The Meramec River Hills Priority Forest Landscape is located in east-central Missouri, 50 miles southwest of St. Louis. These forests are on the northern fringe of the Missouri Ozarks. Clear, spring-fed creeks and streams dissect the area, creating a rugged terrain consisting of steep slopes and narrow valley bottoms. The landscape is home to many species of wildlife, including the Cerulean warbler, Kentucky warbler, Acadian flycatcher, and wood thrush.

Management efforts in this landscape focus on mitigating a handful of stressors. Much of the forest in this landscape is even-aged, resulting in a less diverse canopy structure for wildlife. Forest health concerns are also in the spotlight. Some are due to red oaks maturing to the point of natural mortality and others are still a mystery, such as the recent onset of RWOM. In the absence of wildfire, these forests face an increased abundance of shade-tolerant species in the understory and subsequent reduction of oak recruitment. They are also experiencing more frequent occurrences of invasive plant species such as bush honeysuckle.

MDC owns and manages several large tracts within this landscape, including Huzzah, Pea Ridge, Meramec, and Little Indian Creek CAs. Forest management on these areas is aimed at improving the structure and composition of these mostly even-aged forests through management that mimics natural disturbances. Current practices include controlling invasive species, thinning, harvesting with a greater emphasis on uneven-aged management, and using low-intensity prescribed fire to establish oak regeneration. Also, research is underway to ascertain the nature of forest health threats and how to best manage them.

Conservation partners include MDC, MDNR, NWTF, Ozark Land Trust, TNC, USFS, and USFWS.

Bottomland Forest

The term "bottomland forests" can be used to cover a variety of wooded systems. True bottomland forests occur in seasonally wet sites associated with alluvial soils that are generally more productive than upland soils. These areas typically have very deep well-drained soils that tend to have moderately acidic to neutral pH levels. Bottomlands are commonly found along intermittent or perennial streams and rivers that are seasonally flooded and/or saturated in fall, winter, or spring with a high water table. Flooding is normally shallow and can last more than a month. In areas with higher clay content, the poorly drained soils can remain saturated and wet for significant periods of the year. Several species can be found in the overstory of these wet wooded areas such as bur oak (*Quercus macrocarpa*), pin oak (*Quercus palustris*), sycamore (*Platanus occidentalis*), silver maple (*Acer saccharinum*), and cottonwood (*Populus deltoides*). The understory is more open and will contain a variety of vines and shrubs as well as sparse herbaceous ground cover. Spicebush (*Lindera benzoin*), blue beech (*Carpinus caroliniana*), poison ivy (*Toxicodendron radicans*), and an assortment of sedges (*Carex* spp.) are just a few of the species found here.

Riverfront bottomland forests or riparian forests can be found in floodplains along major river systems and streams. These communities have many of the same species listed above but can have a poorly structured canopy with variable heights and age classes depending on their relationship to recently deposited sediments and organic materials. The understory is usually sparse and open due to flooding and inundation, and high velocity overflow creates a scouring effect that can lead to unevenly developed patches of ground flora.

Case Study: Shaw Nature Reserve

Bottomland forest at Shaw Nature Reserve is best represented by the floodplain of the Meramec River. Characteristic trees in this area include sycamore, cottonwood, silver maple, elm, and box elder. Shaw Bottomland Forest State Natural Area is an area of old-growth forest within this younger forest, which has never been farmed and is dominated by large specimens of bur oak, northern red oak, and shellbark hickory. In spring, wildflowers abound, including several violet species, blue phlox, and large swaths of Virginia bluebells. During the spring migration, many neotropical migrant birds use the forest to forage as they continue their northward migration. Bird species such as the indigo bunting, northern parula, and prothonotary warbler use the forest for breeding and rearing young. The Cerulean warbler, a SOCC and greatest conservation need, has been noted in this area. Winter creeper and garlic mustard are invasive species of concern in Shaw Nature Reserve.

Conservation management within Shaw Nature Reserve consists of an array of native flora plantings and natural community reconstruction and restoration projects including tallgrass prairie, dolomite glades, woodlands, savannas, forests, and a variety of wetlands.

Conservation partners include GrowNative!, MDC, MDNR, Ozark Land Trust, Missouri Botanical Garden, and many other

Glaciated Hardwood Woodland

Glaciated hardwood woodland communities, much like the glaciated hardwood forests, are found throughout the Central Dissected Till Plains. They are common on south- and west-facing upper slopes, ridgetops, bluffs, and knobs. The loess and limestone/dolomite soil complexes where they are found are deep and fairly well drained and range from moderately acidic to slightly alkaline in nature. The tree canopy is extremely variable, ranging from a very open canopy at 30 percent coverage to a fuller 80 percent closure and usually has a moderate height that can fluctuate from 30 to 90 feet. Post oak (*Quercus stellata*), white oak (*Quercus alba*), bur oak (*Quercus macrocarpa*), black oak (*Quercus veluntina*), and shagbark hickory (*Carya ovata*) are all common components of the overstory.

The understory can be sparse and is often even-aged depending on the frequency and intensity of fire. While the ground flora is generally rich and abundant, it can be patchy, depending on the fire regime. Fragrant sumac (*Rhus aromatica*), a variety of sedges (*Carex* spp.), and many asters, goldenrods, and sunflowers are common to this habitat.

Case Study: Spring Creek Watershed Priority Geography
Location: Spring Creek Watershed COA

Located in Adair, Putnam, and Sullivan counties, Spring Creek Watershed PG is the best example of prairie-savanna-woodland habitat systems in North Missouri. Woodland types include dry-mesic loess/glacial till woodland and dry loess/glacial till woodland. Both types of woodlands are found predominantly in the northern and eastern portions of the state.

Dry loess woodlands typically have a sparse to moderate understory (depending on fire frequency) that is dominated by oaks and shrubs. This woodland type is often found in dissected plains and hills on mid- and upper slopes. Dry-mesic loess woodlands have a fairly open understory depending on fire frequency/coverage and can be found in dissected plains on mid- to upper backslopes and ridges.

Glaciated hardwood woodlands are threatened due to excessive logging, lack of prescribed fire, urban development, and invasive species. Current management at Union Ridge CA, located within the Spring Creek Watershed PG, includes thinning the canopy and understory where it is necessary and using prescribed fire to encourage oak regeneration and increase ground cover diversity.

Conservation partners within Spring Creek Watershed PG include the FSA, Missouri Conservation Heritage Foundation, MDC, MDNR, MPF, NWTF, NRCS, PFQF, SWCDs (Adair, Putnam, and Sullivan counties), Truman State University, and USFWS.

Ozark Oak-Pine and Pine Woodlands

The oak-pine woodlands of the Ozark Highlands are found on ridges and backslopes, escarpments and knolls up to the mountain tops. These mixed oak-pine stands are common in the well-drained and shallow chert, sandstone, and igneous soil types. These soils tend to be extremely to moderately acidic and have a lower fertility. Though this habitat is most often found on south- and west-facing slopes, they can occur on all aspects.

The structure of this community is largely influenced by the presence of fire, but the positioning of these habitats on the upper reaches of slopes and ridges and the dry nature of the sites makes them more susceptible to the effects of drought, wind, and lightning. Shortleaf pine (*Pinus echinata*), post oak (*Quercus stellata*), black oak (*Quercus veluntina*), white oak (*Quercus alba*), scarlet oak (*Quercus coccinea*), and shagback hickory (*Carya ovata*) dominate the open-canopied overstory. The understory consists of small trees like sassafras (*Sassafras albidum*) and oak shrubs that occur in gaps and patches depending on the frequency of fire and rocky outcroppings in the landscape. The herbaceous flora can vary from a sparse layer to a rich ground cover of little bluestem (*Schizachyrium scoparium*), tick trefoil (*Desmodium marilandicum*), and many more species.

Pine woodlands were once a major natural community in the Missouri Ozarks, but extensive logging during the late 1800s and early 1900s devastated those vast communities. This, coupled with altered disturbance regimes, allowed oaks to then spread into most of the former pinelands. However, today, some scattered pine woodland communities, mostly on public lands, are being managed to preserve this important natural community.

Case Study: Pioneer Forest – Pine-Oak Woodland Ecological Management
Location: Current River Hills Forest/Woodland COA

Pioneer Forest, owned by the L-A-D Foundation, is the largest private landholding in Missouri. Although the land is private, the Foundation allows for public use and recreation. This includes the Virgin Pine Area along Highway 19 with its old-growth shortleaf pine, some of which are about 240 years old. This was the last known location in Missouri for the federally endangered red-cockaded woodpecker. L-A-D/Pioneer Forest staff recognized that the old trees were gradually dying, and few new pines were replacing them. Pine needs open woodland conditions and bare mineral soil, created with regular prescribed fire, to regenerate.

Seven hundred acres of pine-oak woodland are currently under fire management at this site. Commercial timber harvests are conducted to remove the fire sensitive scarlet oak and favor pine, white oak, and post oak. Timber stand improvement techniques are used to manage the smaller diameter trees. Prescribed fire is used in the dormant season about every three years to drive the restoration. Care is taken with fire to reduce scarring of valuable timber, avoid burning the accumulated organic duff layer under old-growth pines, and maintain public safety while also getting the essential positive effects of fire. Exotic invasive species are systematically treated, and vegetation monitoring is in place to track management effects.

After ten years of management the shortleaf pine-oak woodland community is returning. Seed has fallen from cones to regenerate shortleaf in canopy openings. The herbaceous ground layer is blooming strong with over 500 plant species documented, supporting rich insect populations and eight priority bird species such as prairie warbler, blue-winged warbler, and red-headed woodpecker. Wild turkeys are reproducing well.

The Foundation hires a seasonal crew to implement this work along with Pioneer Forest staff. Conservation partners include AmeriCorps St. Louis, MDC, NPS, Oak Woodlands and Forests Fire Consortium, TNC, University of Missouri Student Association for Fire Ecology, and individual volunteers.

Ozark Hardwood Woodland

The hardwood woodlands of the Ozarks are found on the upper portions of escarpments, knolls, and the ridges of terraces, on well-drained rocky soils, typically on south- and west-facing aspects and ridgetops. The soils are usually fairly acidic and low in fertility. These woodlands are also associated with the cherty limestone/dolomite soils that occur throughout most of Missouri.

The overstory of this community type ranges from open grown to a closed canopy but has an open understory and diverse and abundant herbaceous layer, consisting of grasses, sedges, forbs, and legumes. Oaks and hickories dominate this landscape from the small statured post oak (*Quercus stellata*), black oak (*Quercus veluntina*), blackjack oak (*Quercus marilandica*), and pignut hickory (*Carya glabra*) to the taller white oak (*Quercus alba*), southern red oak (*Quercus falcata*), and mockernut hickory (*Carya tomentosa*). The understory includes small trees and shrubs like American hazelnut (*Corylus americana*) and lowbush blueberry (*Vacciinium pallica*).

Case Study: Huzzah and Shoal Creek Woodlands Priority Geography
Location: Huzzah and Shoal Creek Woodlands COA

Huzzah and Shoal Creek Woodlands PG consists of 193,000 acres nestled within the scenic Ozark hills and consisting primarily of woodlands, glades, forests, pasture fields, and hundreds of miles of streams. The landscape is rugged, with narrow ridges and valley bottoms, steep slopes, cliffs, springs, and caves. The PG supports a rich community of species including gray bats, blue-winged warblers, and running buffalo clover and is worthy of conserving for future generations.

Public and private landownership is almost evenly split within this landscape. Landowners are actively adopting BMPs such as alternative watering systems, the fencing of woodlands and riparian areas, planned grazing systems, streambank stabilization, tree planting, and woodland thinning. Monitoring the PG's amphibians, bats, birds, fish, and plant communities is being conducted to detect landscape-scale responses to BMPs.

Recognizing the significance of natural resources in the area, the SCWW was formed. This group is a citizen-led conservation partnership that includes agricultural producers, local business owners, and recreational landowners who support efforts to implement BMPs to enhance landscape health.

Conservation partners include the Fishers and Farmers Partnership, MDC, MDNR, The National Fish and Wildlife Foundation, TNC, Ozark Land Trust, Public Broadcasting System, SCWW, SWCDs, University of Missouri Extension, USFS, and USFWS.

Glade Conservation and Case Studies

Overview

Glades are typically open, rocky, barren areas usually within woodland dominated terrain. Soils are shallow to bedrock. Here occur drought-adapted forbs, warm-season grasses, and a specialized fauna. Much of the growing season is characterized by high temperatures, intense solar radiation, and dry conditions; however, during spring, winter, and fall, the soils can become saturated. Trees and shrubs do occur on glades but are not dominant unless overgrazing and/or disruption of fire cycles have allowed for invasion by woody species.

Glades are best categorized by associated bedrock type: limestone, dolomite, sandstone, igneous, and chert. Igneous, sandstone, and chert glades support plant, lichen, and moss species that prefer acidic substrates, while plant communities on limestone and dolomite glades are more adapted to alkaline soils. In Missouri, the most abundant glade habitat is found in the Ozark Highlands ecoregion of the state; however, a handful of glades are located in both the Osage Plains and Central Dissected Till Plains ecoregions. In general, within Missouri, dolomite glades can be found across most of the Ozark Highlands; limestone glades are along the west and north borders of the Ozark Highlands; sandstone glades are scattered across the northern half of the Ozark Highlands, with more dense communities on the west and north Ozark border; igneous glades are limited to southeast Missouri; and only an estimated 60 acres of chert glades remain in extreme southwest Missouri.

A few Missouri animals are well adapted to living on glades. These species, like the greater roadrunner (*Geococcyx californianus*) and eastern collared lizard (*Crotaphytus collaris*), are frequently found in the arid southwest of the United States but find similar, suitable conditions in glade systems within Missouri. Invertebrate species strongly associated with glades include Missouri tarantula (*Aphonopelma hentzi*), striped bark scorpion (*Centruroides vittatus*), and multiple grasshopper species, such as *Pardalophora saussurei* and *Amblytropidia mysteca*. Though not restricted to glades, many bird species are also commonly associated with glades, including Bachman's sparrow (*Aimophila aestivalis*), yellow-breasted chat (*Icteria virens*), and painted bunting (*Passerina ciris*).

Figure 4.4.1 – Missouri Glade COAs

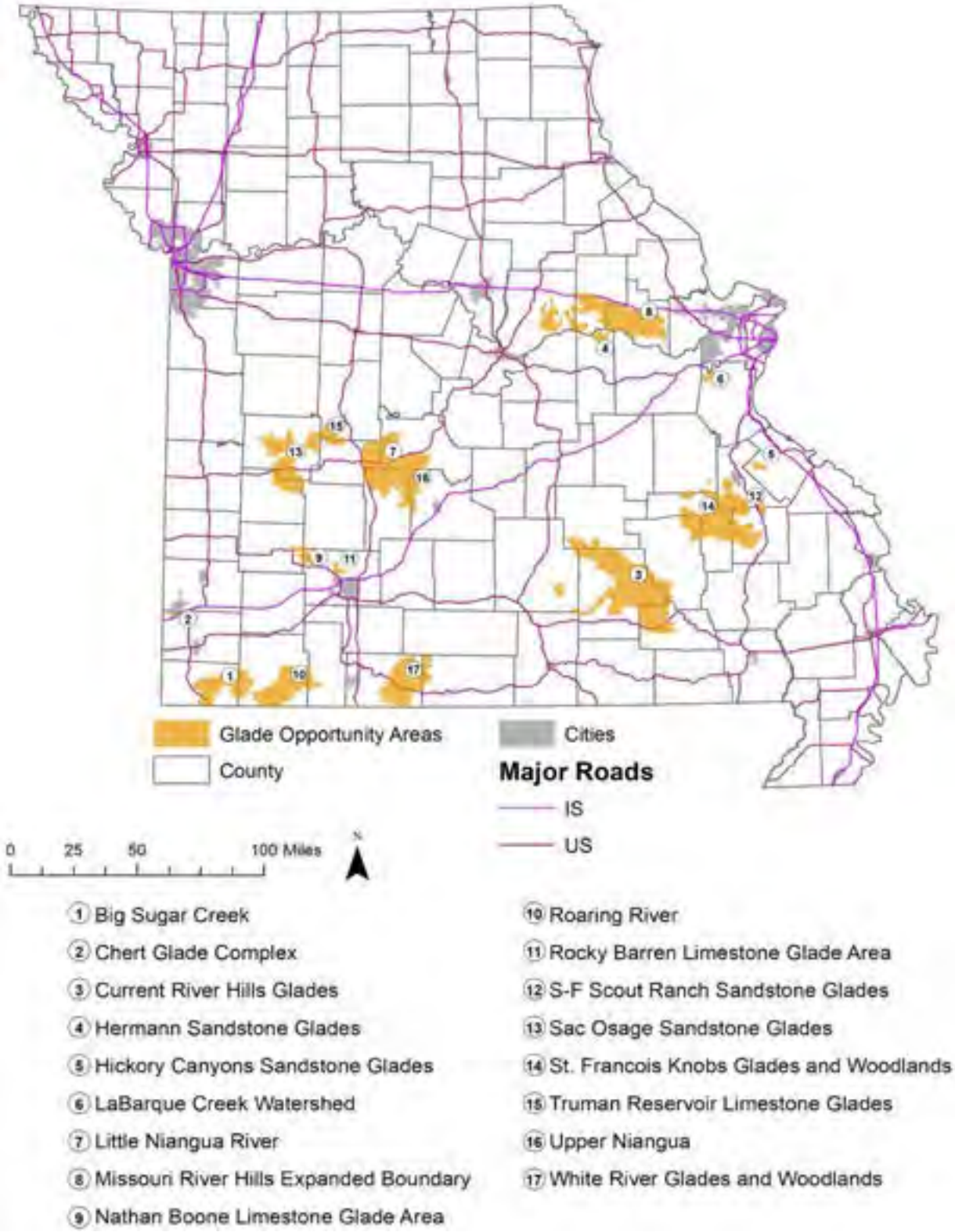
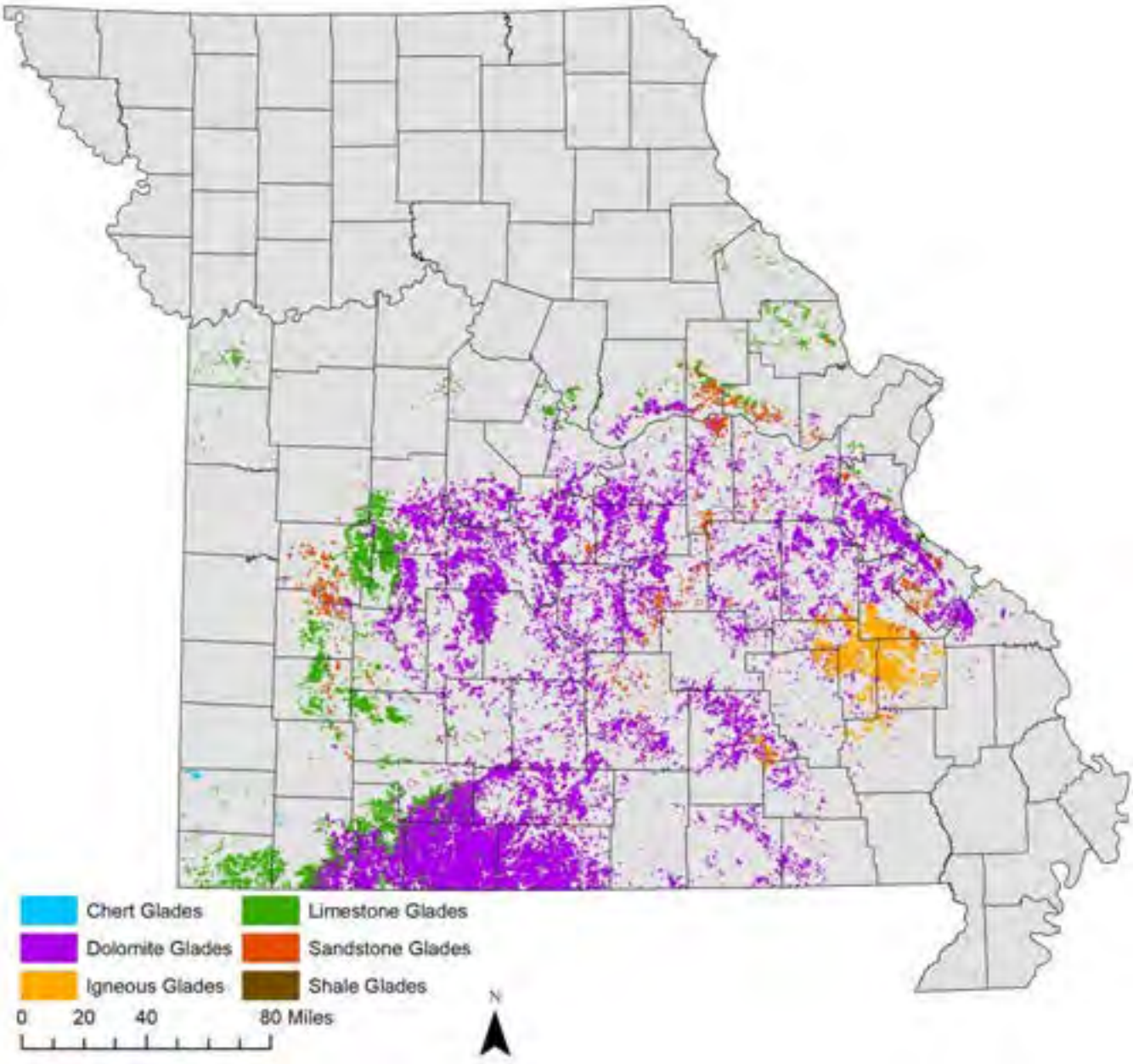


Figure 4.4.2 – Estimated Extent of Glade Areas in Missouri
(Exaggerated Boundaries for Visualization)



This map shows the extent of potential glade areas within Missouri. Known glade locations, mapped by Paul Nelson and partners, and Heritage Database information on glade community and species records were used to select the designated COAs containing glade communities. (Note: Glade location boundaries have been greatly exaggerated to illustrate type and relative concentration of glades at this statewide scale.)

Scoring Criteria

1. Glade density based on natural data breaks: >0 and <0.00175 *
2. Glade density based on natural data breaks: >0.00175 and <0.00487 *
3. Glade density based on natural data breaks: >0.00487 and <0.0127 *
4. Glade density based on natural data breaks: >0.0127 and <0.0426 *
5. Glade density based on natural data breaks: >0.0426 *
6. Glades in the existing conservation network
7. Glades within selected high priority forest/woodland landscape or high priority glade area
8. Glades within selected high priority forest/woodland landscape or high priority glade area, AND ≥ 1 glade heritage record
9. Glades within selected high priority forest/woodland landscape or high priority glade area, AND intersect conservation network land
10. Glades within selected high priority forest/woodland landscape or high priority glade area, AND intersect conservation network land, AND ≥ 1 glade heritage record

Decisive selection criteria for COAs

Glade area is acreage-based, taken from the Central Hardwoods Joint Venture Glade Conservation Assessment for the Interior Highlands and Interior Low Plateaus of the Central Hardwoods Region, developed by Nelson et al. (2013).

* Glade density = total area of glades divided by the total area of the HUC 16 they fall within

Species of Greatest Conservation Need

Plants

Ciliate blue star (*Amsonia ciliata var. filifolia*) * Bush's poppy mallow (*Callirhoe bushii*) * Little tooth sedge (*Carex microdonta*) * Narrow-leaved Barbara's buttons (*Marshallia caespitosa var. signata*) * Stemless evening primrose (*Oenothera triloba*) * Harvey's beak rush (*Rhynchospora harveyi*) * Thelesperma (*Thelesperma filifolium*) * Ozark corn salad (*Valerianella ozarkana*) * Soft soapweed (*Yucca arkansana*) * Death camas (*Zigadenus nuttallii*)

Characteristic:

Crawe's sedge (*Carex crawei*) * Fremont's leather flower (*Clematis fremontii*) * Gattinger's prairie clover (*Dalea gattingeri*) * Trelease's larkspur (*Delphinium treleasei*) * Yellow coneflower (*Echinacea paradoxa*) * Umbrella plant (*Eriogonum longifolium var. longifolium*) * Geocarpon (*Geocarpon minimum*)* Stiff sandwort (*Minuartia michauxii*) * Celestial lily (*Nemastylis geminiflora*) * A beard-tongue (*Penstemon cobaea*) * Missouri bladderpod (*Physaria filiformis*) * Bush's skullcap (*Scutellaria bushii*) * Gattinger's goldenrod (*Solidago gattingeri*)

Arachnids

Characteristic:

Missouri tarantula (*Aphonopelma hentzi*) *Striped bark scorpion (*Centruroides vittatus*)

Insects

Purple small-headed fly (*Lasia pururata*) * Truculent camel cricket (*Phrixocnemis truculentus*)

Characteristic:

A glade grasshopper (*Amblytropidia mysteca*) * A glade grasshopper (*Pardalophora saussurei*)

Reptiles

Characteristic:

Eastern collared lizard (*Crotaphytus collaris*) * Great plains ratsnake (*Pantherophis emoryi*) * Southern coal skink (*Plestiodon anthracinus pluvialis*) * Eastern coachwhip (*Masticophis flagellum flagellum*) * Western pygmy rattlesnake (*Sistrurus miliarius streckeri*) * Variable groundsnake (*Sonora semiannulata semiannulata*) * Flat-headed snake (*Tantilla gracilis*)

Birds

Characteristic:

Greater roadrunner (*Geococcyx californianus*) * Yellow-breasted chat (*Icteria virens*) * Painted bunting (*Passerina ciris*) * Bachman's sparrow (*Peucaea aestivalis*)

Mammals

Eastern small-footed myotis (*Myotis leibii*)

Threats and Challenges

The largest threats to glade systems today include erosion of already shallow glade soils, invasion by both native and exotic species, development, and exploitation of glade flora and fauna.

Overgrazing, Woody Species, and Fragmentation

Historic and continued overgrazing of glades within Missouri has led to substantial erosion of delicate glade soils and lowered species diversity. In many of Missouri's glades, overgrazing combined with the absence of fire has aided in significant encroachment by woody species, predominantly eastern redcedar (*Juniperus virginiana*) and winged sumac (*Rhus copallina*). These native woody species are quick to take hold and overwhelm native grasses and forbs, greatly reducing plant diversity and creating physical barriers, further fragmenting the landscape. These physical barriers of woody vegetation limit movements of glade fauna between glade openings, resulting in loss of genetic diversity among populations.

Invasive Species

Like most of Missouri's other habitat systems, an ever-growing list of invasive plant species continuously threaten glades. Species such as sericea lespedeza (*Lespedeza cuneata*), spotted knapweed (*Centaurea maculosa*), tall fescue (*Festuca arundinacea*), yellow sweet clover (*Melilotus officinale*), teasel (*Dipsacus* spp.), and crown vetch (*Securigera varia*) aggressively outcompete native grasses and forbs, forming dense monocultures that reduce the overall plant species richness and structural diversity of these glade communities.

Feral hogs have caused extensive damage to Missouri glade communities. Glade characteristics including thin soils and flippable surface rocks makes feral hog rooting extremely impactful to the delicate soils and ground flora and fauna. The disturbance they cause also allows invasive plants to gain a foothold in some locations. The Missouri Feral Hog Elimination Partnership is working to eradicate feral hogs from Missouri's landscape.

Development and Exploitation

Commercial and residential development remains a threat to glades as these open areas are developed due to their ridgetop locations and the open scenic views they provide. In addition, due to proximity to development, some glade systems are also threatened by quarrying of the valuable bedrock beneath them. Soil disturbance resulting from these activities leads to further erosion and soil loss. Digging of glade plants and collection of animal species are also common in these systems and result in further erosion as well as loss of species richness and genetic diversity.

Management Actions and Opportunities

Glade conservation actions in Missouri must focus on protecting intact, remnant habitats, proactive restoration of additional sites, and maintenance of those glade communities that have been successfully restored. Depending on their size, many glade systems are restored and managed in combination with surrounding natural community management, especially woodlands, which are highly associated with glades. Glade management may involve limited land acquisition but, in most instances, requires restoration practices on existing public lands and/or cooperation with private landowners.

Conversion of rank monoculture stands of eastern redcedar or other woody species to open connected landscapes remains a guiding objective in glade restoration. The removal of grazing livestock, feral hogs, aggressive native and invasive vegetation, as well as the reintroduction of fire are key to meeting that objective. The protection of existing soils and establishment of a broad diversity of native plants and subsequent maintenance of heterogeneous vegetative structure that benefits an equally broad diversity of glade-dependent wildlife remains a high priority for public and privately owned glades. Prescribed burning, mechanical tree and brush removal, and herbicide treatment will continue to be important tools to keep woody vegetation and invasive species at bay.

To mitigate the cost associated with glade restoration and management activities, cost-share and incentive programs aimed at improving glade communities on private property are available for private landowners. The majority of the available resources are associated with the removal of woody and invasive species. One such program, focused primarily on glade and woodland restoration, is a five-year USDA Regional Conservation Partnership Program (RCPP), administered through the NRCS. RCPP encourages partners to join in efforts with producers to increase the restoration and regenerative use of soil, water, wildlife, and related natural resources on regional or watershed scales. This project involves a collaborative effort among the NRCS, MDC, and multiple MDNR SWCDs in southeast Missouri. The objectives of this project include the management and/or restoration of 4,000 acres of glades and associated woodlands, forest management activities on 500 acres of forestland, and applied conservation practices on 500 acres of pasture and cropland all on private property.

Natural Community Subtypes and Case Studies

Chert Glade

Chert glades are globally restricted, terrestrial habitats found in southwest Missouri, northwest Arkansas, southeast Kansas, and northeast Oklahoma regions. Missouri's chert glades are located along Shoal Creek and its tributaries near the Joplin area. With scarcely 60 acres remaining in Missouri, they are the most limited type of glade in the state and therefore are considered highly imperiled.

Chert glades are found on ridges, slopes, and valleys along streams with 3–15 percent sloping on all aspects. The soil depths range from shallow to very shallow (0–20 inches) and are well drained and strongly acidic, with low soil fertility. Because chert bedrock is impervious, this glade type is very susceptible to drought. Vegetation height remains relatively low (maximum 2–3 feet), and the ground layer is composed of forbs, grasses, sedges, lichens, and mosses. Due to much slower weathering, fewer woody species tend to invade chert glades.

Case Study: Shoal Creek Conservation Education Center
Location: Chert Glade Complex COA

Twenty-seven acres of chert glades have been safeguarded in a collaborative partnership between the City of Joplin, MDC, and the National Audubon Society. Individuals in the local Ozark Gateway Audubon chapter inspired this project.

Wildcat Glades Conservation and Audubon Center opened in 2007 as product of this partnership. In July 2018, a new collaborative partnership was established between the City of Joplin, MDC, and the Wildcat Glades Friends Group. Shoal Creek Conservation Education Center opened in September of 2020.

Local MDC staff operate the distinctive chert-inspired building with its green technologies and provide outreach throughout the community and interpretive center programs. Wildcat Glades Friends Group shares office space, operates the Nature Store, and provides outreach programs to the community. Leasing 34 of Wildcat Park's 120 acres, the Center provides access and education to the public that include exhibits on local natural history, interpretive programs, and a trail system with outdoor learning stations linked to the city's biking and hiking trails. In addition to educational programs, the Center involves partners and the public in invasive species removal and planting of appropriate native species. The Missouri Master Naturalist Chert Glades Chapter and local Master Gardeners currently maintain demonstration, education, and pollinator gardens. The adjacent Wildcat Glade Natural Area, owned by MDC and the City of Joplin, represents the best remaining example of a chert glade ecosystem in Missouri. It is managed by MDC primarily with prescribed fire to protect the unique species found there. When necessary, mechanical means are used to remove aggressive woody species, such as eastern redcedar. The city portion of Wildcat Park has benefited from greater park usage and scrutiny resulting in less littering and vandalism.

The unique assemblage of species here includes widow's cross and Nuttall's sedum, rock pink, prickly pear, selenia, hairy lip fern, and Barbara's buttons, along with abundant lichens and mosses. Some post oaks on the glade were determined to be over 150 years old but, restrained by almost solid rock, are less than 20 feet tall. Few animals make chert glades their home, but lichen grasshoppers and Missouri tarantulas are often seen.

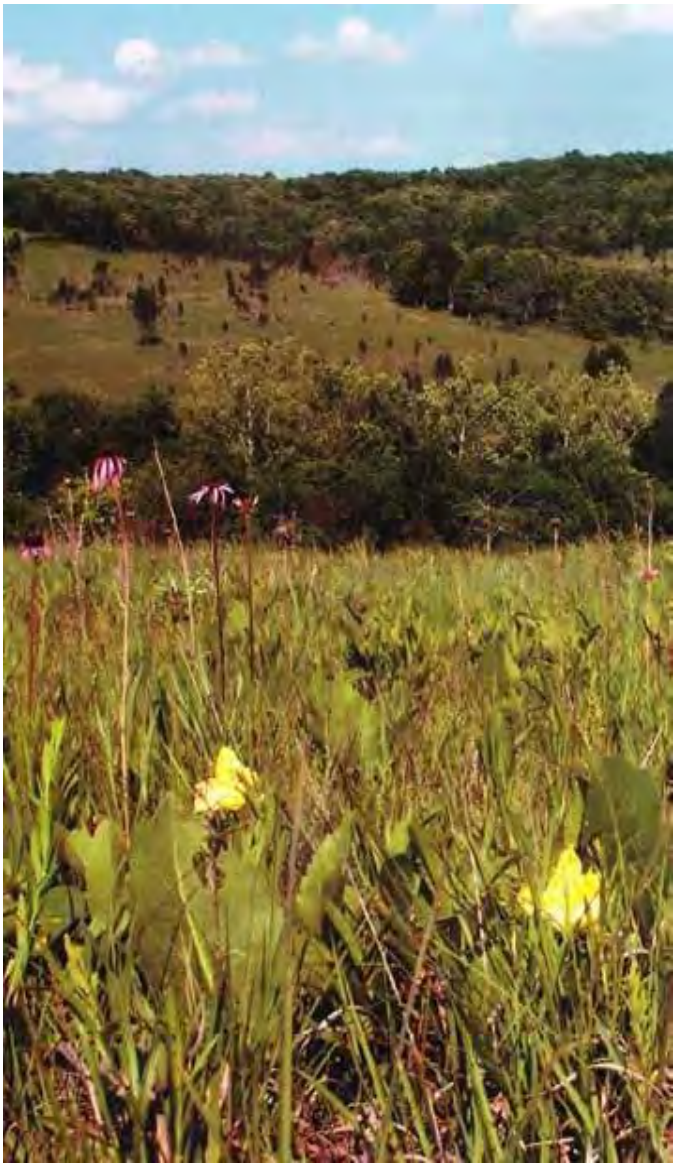
Conservation partners include the City of Joplin, MDC, Missouri Master Naturalists, Wildcat Glades Friends Group, Ozark Gateway Audubon Chapter, Master Gardeners, numerous local universities, area schools, and area businesses.

Dolomite Glade

Dolomite glades are Missouri's most abundant glade habitat system. Dolomite glades are open rocky areas with very shallow soils, dominated by drought-adapted herbaceous flora, generally occurring on south- and west-facing slopes of otherwise wooded sites. While glade plants, in general, are well adapted to surviving harsh environments, dolomite glades have further unique and characteristic flora, such as Missouri coneflower (*Rudbeckia missouriensis*) and calamint (*Calamintha arkansana*).

This natural community type tends to be exposed to intense solar radiation due to their southern or western exposure and have moderate to steep slopes in deeply dissected drainages or hilly to mountainous topography. The soil layer is extremely thin with ample rock fragments and outcrops scattered throughout. Due to the thin soil layers, dolomite glades tend to have extremely dry conditions throughout most of the growing season; however, soil saturation can occur during spring, winter, and fall. As with many glade types, dolomite glades can consist of stunted and gnarled trees and shrubs. Natural disturbances such as fire, drought, and native grazers helped form the characteristics of dolomite glades through limiting the growth of trees and preventing their dominance.

Dolomite glades sustain a wide diversity of plants and animals. Dominant plants such as little bluestem (*Schizachyrium scoparium*) and sideoats grama (*Bouteloua curtipendula*) can be found in the deeper soil areas of dolomite glades; lichens are abundant throughout.



Case Study: Angeline Conservation Area
Location: Current River Hills Glades COA

Located in the heart of the Ozarks, the Angeline CA consists of approximately 40,000 acres of public land. The natural communities on this area include upland and bottomland forests, woodlands, sinkholes, caves, Ozark fens, igneous glades, and 111 acres of dolomite glades. Glade restoration management activities since the early 2000s have included removal of invasive eastern redcedar (utilizing commercial timber sales, contractors, and AmeriCorps St. Louis crews) and prescribed fire.

The Bay Branch prescribed burn unit is particularly rich, featuring 24 acres of dolomite glade. This glade/woodland burn unit was recently expanded to 500 acres (including a portion of adjacent NPS land) to increase efficiency and safety when burning.

Coppermine Hollow Glade was a diamond in the rough in 2006, covered in cedars and showing just a few stems of the uncommon silver plume grass. After removal of the cedars, an explosion ensued of the very showy grass and rough blazing star.

Other species that have benefited from restoration include six-lined racerunners, prairie warblers, and the Ozark endemic Bush's skullcap.

Limestone Glade

Limestone glades are natural communities generally found in the western and southern portions of Missouri, occurring in dissected hills on slopes that are typically south- or west-facing and quite steep. Soils are very well-drained and shallow (0–20 cm) and are dominated by forbs, grasses, and sedges. However, interspersed clumps of stunted trees and shrubs, usually allowing for no more than 10–25 percent tree coverage, is common. Like all glades, exposed bedrock is a characteristic feature of a limestone glade, which serves as suitable habitat for mosses, lichens, and algae.

Some limestone glades in southwest Missouri are home to the federally threatened, state endangered, and SGCNs Missouri bladderpod (*Physaria filiformis*). In the herbaceous layer of the deeper soil areas of limestone glades are flora such as little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), and Mead's sedge (*Carex meadii*); whereas the herbaceous layer of the more shallow soil areas is dominated by prairie tea (*Croton monanthogynus*), rushfoil (*Croton wildenowii*), and heliotrope (*Heliotropium tenellum*).

Case Study: Danville Conservation Area
Location: Missouri River Hills COA

Located in central Missouri, Danville Conservation Area lies within the Missouri River Hills Priority Geography. This public area is comprised of a diverse mix of natural communities including upland forests, woodlands, and limestone glades. Since the early 2000s, management on Danville CA has been focused on restoring these natural communities. Glade restoration has included removal of invasive redcedar, hardwood thinning, and periodic prescribed fire. Glade management on Danville CA today includes continuing maintenance practices such as periodic prescribed fire, monitoring for and controlling invasive species, small-scale cedar removal, and hardwood thinning projects.

Limestone glades on Danville CA harbor many glade species such as prairie dandelion, striped bark scorpion, six-lined racerunner, and prairie warblers.

The ongoing glade and woodland management on Danville CA is used to showcase restoration and management of these communities to partners, including neighboring private landowners within the Missouri River Hills PG.

Conservation partners within Missouri River Hills PG include MoBCI, Missouri Conservation Heritage Foundation, MDC, NRCS, NWTF, PFQF, Quail and Upland Wildlife Federation (QUWF)— Ruffed Grouse Chapter, and USFWS.

Sandstone Glade

Sandstone glades can be associated with open woodland, cliff, and prairie natural communities. They are found in dissected hills and plains on backslopes, knobs, and short bluffs bordering valleys or canyons. Soils are well drained and shallow and moderately to strongly acidic. The ground layer is composed of forbs, grasses, mosses, and lichens, the latter two being highly abundant on undisturbed bare rock.

The shallow acidic soil tends to limit the growth of trees, yet it supports the native grasses and forbs that dominate these systems. Trees found on and near glades are often stunted and express poor development due to the shallow droughty soils and poor growing conditions. Therefore, sandstone glades frequently exhibit patches of stunted shrub and tree species in areas with slightly deeper soils.

As on the adjacent prairies, periodic fire also played an important role in the maintenance of these systems. These systems typically burned at least once every three years. These periodic fires removed the litter and stimulated the growth and flowering of the grasses and forbs. They also further limited the growth and dominance of trees.

Dominant plants include little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), broomsedge (*Andropogon virginicus*), blazing star (*Liatris squarrosa*), and false foxglove (*Agalinis gattingeri*). Some sandstone glades are also home to Missouri state-endangered geocarpon (*Geocarpon minmum*), an SGCN, and also a federally threatened species.

Case Study: Bona Glade Natural Area

Many sandstone glades in the Ozark Highlands have been degraded by redcedar encroachment due to lack of fire or by overgrazing. However, the Bona Glade Natural Area, located on lands owned by the USACE, is a sandstone glade that is still thriving. Bona Glade is located within a sandstone woodland/sandstone cliff complex overlooking Stockton Lake. Other sandstone glades in the vicinity include Kova Glade and Corry Flatrocks Glade.

A number of unique plant species are associated with sandstone glades, including succulents like Nuttall's sedum, purslane, and the federally threatened geocarpon. Bona Glade Natural Area provides habitat for all of these species.

Conservation actions have included redcedar and woody plant removal, as well as prescribed fire. Long-term glade vegetation monitoring data indicates increased numbers of geocarpon as a result of these management activities.

Conservation partners include the Missouri Botanical Garden, MDC, Missouri Master Naturalists, USACE, and USFWS.

Igneous Glade

Igneous glades are found on shoulders and backslopes of knobs and mountain domes, with the best developed sites on the south- and west-facing slopes. The Precambrian bedrock is comprised of numerous rock types, such as rhyolite, rhyodacite (delenite), and granite (Nelson 2010). Soils are exessively drained, shallow to very shallow, with acidity levels between 4.5 and 6.0. These very gravelly, silty soils exhibit low fertility. However, some of the deeper soil areas allow for a diversity of grasses and wildflowers.

The overall plant community is dominated by both annual and perennial forbs and perennial grasses, with lichens found on bare undisturbed rock. The ground layer of vegetation can reach four feet in height and is sometimes intermixed with a patchwork of dwarfed, often deformed or crooked trees and shrubs. Historically, fire and grazing by elk helped shape the landscape for these glades. The droughty conditions that exist during autumn and summer also helped limit woody plant invasion.

A few dominant plant species for igneous glades in the deeper soils include little bluestem (*Schizachyrium scoparium*) and tickseed coreopsis (*Coreopsis lanceolata*). In the more shallow soils, a few inhabitants are rushfoil (*Croton wildenowii*) and rough buttonweed (*Diodia teres*). One plant SGCN that can inhabit these glades is Mead's milkweed (*Asclepias meadii*), a Missouri state-endangered species and also a federally threatened species.

Case Study: St. Francois County – Kossman Property
Location: St. Francois Knobs Glade and Woodlands COA

Within the St. Francois Knobs Glades and Woodlands COA, in southeast Missouri, lies the Kossman brothers' property. This private property is comprised of igneous flatwoods, woodland, and glade natural communities. Starting in 2007 and continuing today, the Kossman brothers have partnered with MDC and the NRCS to focus on management and restoration of these natural communities. Since that time, the Kossman brothers have been actively managing the property, implementing prescribed burns and conducting a total of 54 acres of eastern redcedar and hardwood thinning and brush management.

Glade and woodland restoration on the Kossman property has been made possible by using financial assistance provided through successful application to the USDA's Environmental Quality Incentives Program (EQIP), with matching funds from MDC. Funding through EQIP helped the landowners offset the cost of hiring contractors to complete the prescribed burns and the glade/woodland thinning.

The Kossman brothers' property is an excellent example of landowners partnering with conservation agencies to help reach land management goals.

Case Study: Shannon County – Jerktail Mountain Restoration Project
Location: Current River Hills COA

In the Current River Hills ecological subsection, the Eminence Igneous Glade/Oak Forest Knobs LTA is an outlier of Precambrian rock 30–40 miles southwest of the more extensive igneous natural communities of the St. Francois Mountains. There are about 20 prominent Precambrian igneous knobs (including Thorny, Wildcat, Stegall, and Jerktail mountains) and dolomite basins above and below Two Rivers Campground in the Current River watershed, including the lower half of Rocky Creek CA.

Investigations followed by baseline monitoring began in 2011 on Jerktail Mountain to begin glade and woodland restoration. This has been a collaborative effort led by Ozark National Scenic Riverways and L-A-D Foundation with support from the Wildlife Conservation Society, USFS, MDC, and a host of seasonal crew members from across the country. An 1,800-acre management area was established, and management using thinning and periodic prescribed fire has been underway since 2015. Conservative igneous plants found here are American aloe (*Manfreda virginica*) and cream wild indigo (*Baptisia bracteata*).

Cave and Karst Conservation and Case Studies

Overview

Karst Systems

Areas of Missouri with soluble limestone or dolomite geology are known as karst. Acidic rainwater dissolves rock in karst areas over time to create voids and caverns below the surface. Karst features include caves, sinkholes, underground streams, springs, and losing or sinking streams, which are surface streams that lose all or part of their surface flow to groundwater systems. Missouri has five primary karst regions: Hannibal Karst, St. Louis Karst, Perryville Karst, Salem Plateau, and Springfield Plateau. The Hannibal and St. Louis karsts, which are located in the northeastern and eastern part of the state, respectively, generally exhibit low biodiversity. Perryville Karst, which follows the Mississippi in the southern half of the state, contains some of the highest densities of cave and karst features in the state, some of which exhibit high biodiversity. The Salem Plateau is located in south-central Missouri and is the largest continuous karst region in the state. Caves in this region are the oldest in the state and are home to federally listed gray bats (*Myotis grisescens*) and Indiana bats (*Myotis sodalis*). Caves in the Springfield Plateau, which run from central Missouri into northern Arkansas, are relatively young and contain species like the bristly cave crayfish (*Cambarus setosus*) and endangered Ozark cavefish (*Troglichthys rosae*).

Caves

With more than 7,000 identified and spanning more than 500 linear miles combined, caves are certainly a key natural community in Missouri. Most Missouri caves occur in the Ozark Highlands ecoregion, typically in karst topography formed by the dissolution of rock, and primarily in soluble dolomite or limestone rocks.

Cave communities are closely related to, and frequently overlap, surface and groundwater communities. Cave communities may be classified as terrestrial or aquatic, but these communities are interdependent and most caves support both types of communities. Sinkholes are formed from the collapse of a cave ceiling and may support unique subcommunities as well. Species not typically associated with caves may use them as shelter from drought, cold, and predators or seek prey within them.

Cave communities are affected by environmental conditions including size and shape of the cave entrance, number of entrances, size and shape of cave passages, water conditions, and the availability of organic matter. These conditions influence temperature and humidity within the cave, which affect species' use. For example, maternity colonies of gray bats prefer warm-air traps or high domes that accumulate warm air from air movements and the body heat of bat clusters; while hibernating gray and Indiana bats prefer cold-air traps where cold air sinks into larger or deeper entrances maintaining lower temperatures year-round.

Terrestrial communities include springtail insects, millipedes, beetles, cave crickets, and their predators such as spiders, cave webworms, and salamanders. Amphipods, isopods, cave snails, grotto salamanders, cave fishes, and cave crayfishes characterize aquatic communities. Many of these are endemic to Missouri, including the grotto sculpin and Tumbling Creek cave snail.

Figure 4.5.1 – Missouri Cave and Karst COAs

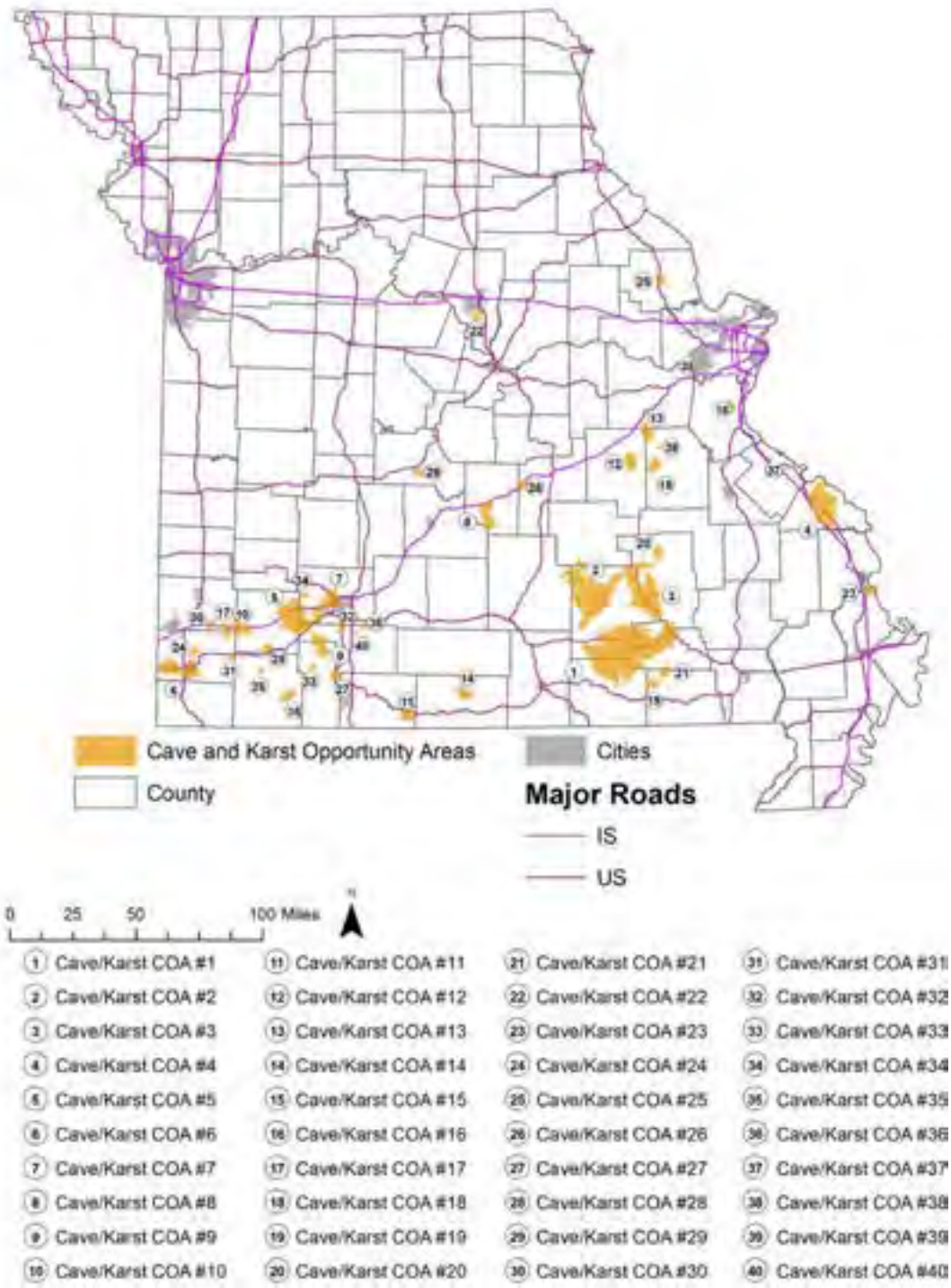
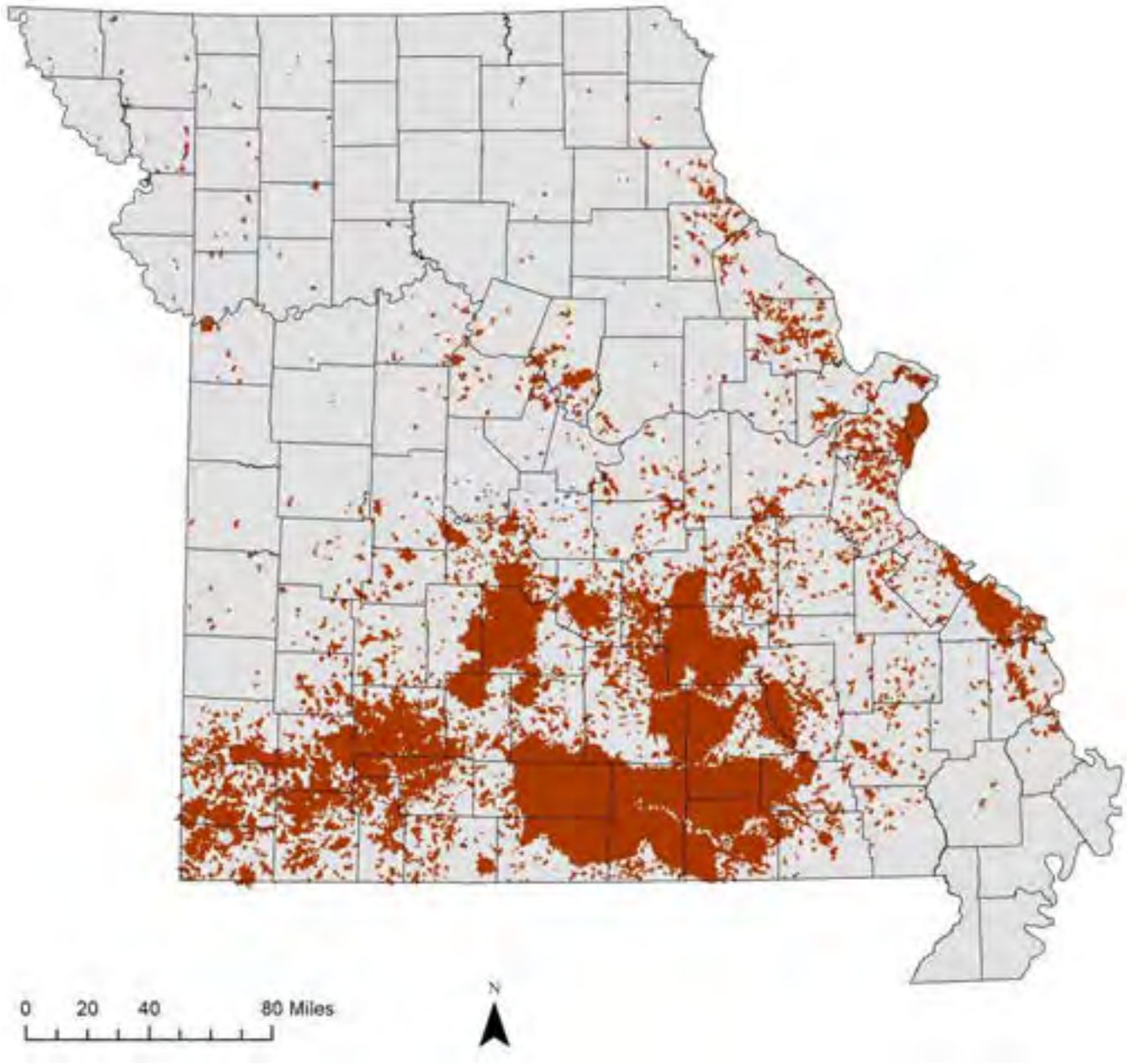


Figure 4.5.2 – Estimated Extent of Cave/Karst Land Cover in Missouri



This map shows the potential extent of cave and karst land cover in Missouri. This data includes Heritage Database information on cave community and species records, the locations of sinkholes and springs, losing stream locations, and delineated cave recharge areas, which was used to select the COAs that contained cave/karst habitat systems.

Scoring Criteria

1. One or more of the following karst features within a HUC 16: sinkhole, losing stream, spring, and heritage cave/heritage spp.
2. Two or more types of karst feature (e.g., sinkhole, losing stream, etc.)
3. Caves less than 2 miles in length
4. Caves greater than 2 miles in length, OR ≥ 1 cave heritage species (historic OR current)
5. All "focal" recharge areas,* OR ≥ 1 cave heritage species (current only)
6. HUC 16s scoring 5 on conservation network lands, OR medium biodiversity biocaves (B<200; Elliott 2007), OR TNC "subterranean portfolio" sites
7. Recharge areas affecting a federally listed aquatic species (currently: Spring Cavefish, Ozark Cavefish, Tumbling Creek Cave Snail, Grotto Sculpin)
8. Federally listed species location, OR medium biodiversity biocaves on conservation network
9. High biodiversity biocaves (B>200; Elliott 2007)
10. High biodiversity biocaves, AND federally listed spp. in conservation network

{ Decisive selection criteria for COAs }

* Largest mapped spring systems, pink planarian recharge area, plus federally listed species

Species of Greatest Conservation Need

Plants

Straw sedge (*Carex straminea*) * Log fern (*Dryopteris celsa*) * Crested shield fern (*Dryopteris cristata*) * Goldie fern (*Dryopteris goldiana*) * Hedge hyssop (*Gratiola viscidula*) * Whorled water pennywort (*Hydrocotyle verticillata*) * Forked duckweed (*Lemna trisulca*) * Horned rush (*Rhynchospora macrostachya var. macrostachya*) * Hall's bulrush (*Schoenoplectiella hallii*) * Canby's bulrush (*Schoenoplectus etuberculatus*) * Swaying bulrush (*Schoenoplectus subterminalis*)

Characteristic:

Epiphytic sedge (*Carex decomposita*) * Engelmann's quillwort (*Isoetes engelmannii var. engelmannii*)

Flatworms

Pink planarian (*Macrocotyla glandulosa*) * Lewis' cave planarian (*Macrocotyla lewisi*) * Perryville cave planarian (*Sphalloplana evaginata*) * Hubricht's cave planarian (*Sphalloplana hubrichti*)

Mollusks

Stygian amnicola (*Amnicola stygius*) * Missouri cave snail (*Fontigens antroecetes*) * Proserpine cave snail (*Fontigens proserpina*)

Characteristic:

Tumbling Creek cave snail (*Antrobia culveri*)

Arachnids

Mystery cave pseudoscorpion (*Apochthonius mysterius*) * Stone County cave pseudoscorpion (*Apochthonius typhlus*) * Cavernicolous pseudoscorpion (*Mundochthonius caves/karstrnicolus*) * Subterranean cave spider (*Phanetta subterranea*) * Cavernicolous porrhomma spider (*Porrhomma canernicola*)

Crustaceans

Hubricht's long-tailed amphipod (*Allocrangonyx hubrichti*) * Sword-tail cave amphipod (*Bactrurus hubrichti*) * False sword-tail cave amphipod (*Bactrurus pseudodomucronatus*) * Ashley's isopod (*Brackenridgia ashleyi*) * An isopod (*Caecidotea dimorpha*) * Fustis cave isopod (*Caecidotea fustis*) * Salem cave isopod (*Caecidotea salemensis*) * Serrated cave isopod (*Caecidotea serrata*) * Slender-fingered cave isopod (*Caecidotea stiladactyla*) * Stygian cave isopod (*Caecidotea stygia*) * Benton County cave crayfish (*Cambarus aculabrum*) * Bristly cave crayfish (*Cambarus setosus*) * Yeatman's groundwater copepod (*Diacyclops yeatmani*) * Caney Mountain cave crayfish (*Orconectes stygocaneyi*) * Barr's groundwater amphipod (*Stygobromus barri*) * Clanton's groundwater amphipod (*Stygobromus clantoni*) * Onondaga Cave amphipod (*Stygobromus onondagaensis*) * Subtle groundwater amphipod (*Stygobromus subtilis*)

Millipedes

Causeyvella cave millipede (*Causeyella dendropus*) * Aley's cave millipede (*Chaetaspis aleyorum*) * Zosteractis cave millipede (*Zosteractis interminata*)

Insects

Ozark stonefly (*Acroneuria ozarkensis*) * Artesian agapetus caddisfly (*Agapetus artesus*) * Marbled underwing moth (*Catocala marmorata*) * Missouri glyphopsyche caddisfly (*Glyphopsyche missouri*) * Hoff's Cave springtail (*Oncopodura hoffi*) * Espana Cave springtail (*Pseudosinella espana*) * Avita Cave springtail (*Sinella avita*) * Barr's Cave springtail (*Sinella barri*) * Missus Cave springtail (*Tomocerus missus*) * Northern xenotrechus cave beetle (*Xenotrechus condei*) * Southern xenotrechus cave beetle (*Xenotrechus denticollis*)

Fishes

Grotto sculpin (*Cottus specus*) * Spring cavefish (*Forbesichthys agassizii*) * Ozark cavefish (*Troglichthys rosae*) * Southern cavefish (*Typhlichthys eigenmanni*)

Amphibians

Characteristic:

Cave salamander (*Eurycea lucifuga*) * Grotto salamander (*Eurycea spelaea*) *

Mammals

Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)

Characteristic:

Gray bat (*Myotis grisescens*)

Threats and Challenges

Groundwater Quality

Especially in karst regions, there is a strong connection between surface and groundwater. As a result, pollutants from surface sources have multiple points of entry (e.g., sinkholes, losing streams) directly into groundwater systems. Many aquatic cave organisms are highly sensitive to water quality. Caves are naturally nutrient poor, so an influx of nutrients from agricultural or urban runoff or sewage can greatly impact cave-adapted species.

Sedimentation and chemical contamination may occur through activities such as development, agriculture, pipeline spills, and pesticide contamination. Because many caves, particularly aquatic systems, are difficult or impossible to access, degradation of water quality is often difficult to detect. Compounding this threat is the difficulty in tracing degraded water quality to sources of contamination, as few cave recharge areas have been delineated. Cave hydrology may also be affected by over-pumping of the aquifer, which may reduce or eliminate standing water within caves. With input from conservation partners, MDC policy is to maintain a 20-acre buffer of vegetative cover around any cave or sinkhole opening to protect water quality within caves.

Human Disturbance

Human visitation to caves may, intentionally or unintentionally, damage cave features. Frequent disturbance of hibernating bats causes more rapid depletion of fat reserves, threatening overwinter survival. This is compounded by the disease WNS, which affects bats during hibernation and also causes more rapid depletion of fat reserves. WNS was first detected in Missouri in 2010, and recent surveys indicate that it is found throughout the state and is causing bat mortality. To minimize disturbance of these sensitive species, many caves supporting significant populations of bats are now closed to public access except for specific research, survey, monitoring, and mapping.

To address the threat of human disturbance to both cave species and cave features, MDC partnered with MDNR, the Missouri Speleological Survey, the Missouri Caves Association, and others to support the Cave Resources Act, which was passed by the Missouri Legislature in 1980. This act prohibits vandalism and protects both the surface of a cave and the natural materials it contains, including cave life. The act also maintains the right of private cave owners to manage or use their caves as they see fit and gives cave owners legal authority to protect their caves from trespassers. The law helps protect the quality of Missouri's groundwater supplies by establishing specific legal protection to anyone whose well supply or spring has been polluted by someone using a cave for sewage disposal or other pollution-causing purposes.

Invasive Species

Cave ecosystems do not escape the threat of invasive species. For example, changes in hydrology, due to the impoundment of water from Bull Shoals Lake in times of excessive rain, have allowed predatory ringed crayfish to invade Tumbling Creek Cave, the most biodiverse cave documented in Missouri. Ringed crayfish are a native species, but the altered hydrology is believed to have allowed this species to expand its range to include Tumbling Creek Cave. Crayfish predation is one of the primary threats to the state and federally endangered Tumbling Creek cave snail (*Antrobia culveri*).

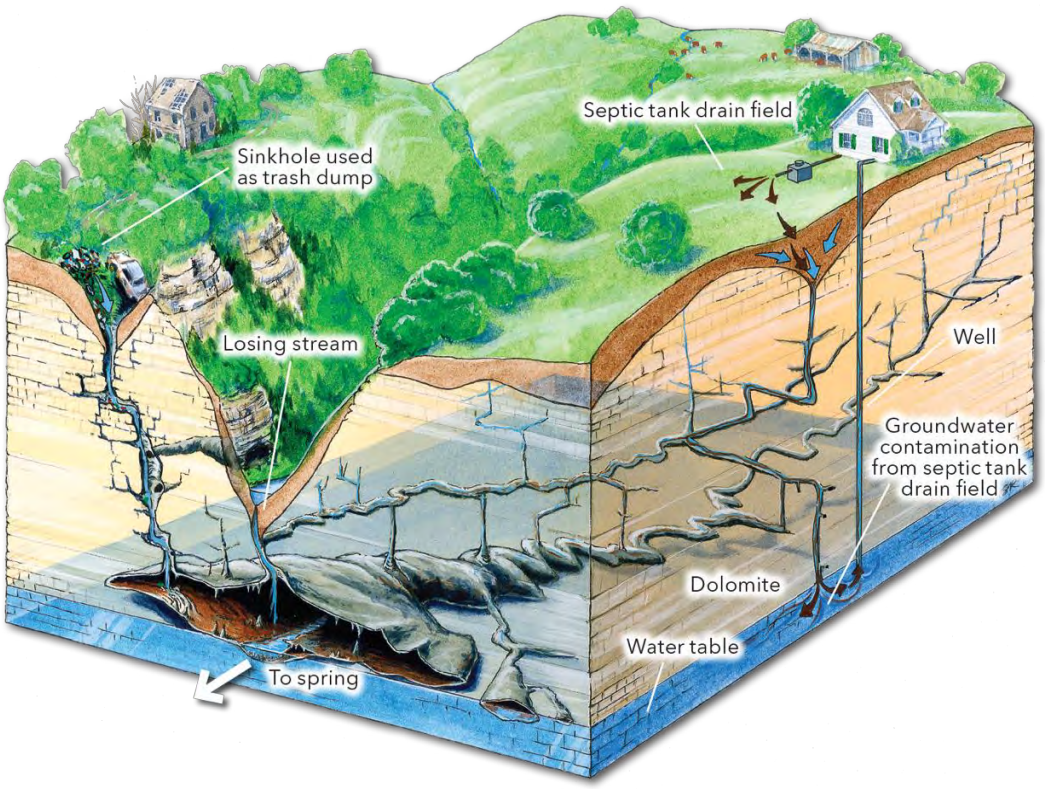


Figure 4.5.3 – Depiction of the interconnectivity of karst landscapes and potential vectors of pollution and degradation.

Management Actions and Opportunities

Cave Recharge Area Management

Within karst regions, groundwater is replenished when stormwater enters into karst systems through sinkholes, losing streams, and caves. This is known as recharge. Within the recharge areas for karst features, it is important to remove sources of pollutants and maintain appropriate BMPs, such as native vegetation, to protect groundwater quality.

MDC policy is to maintain or establish appropriate vegetative cover with a 100-ft minimum radius around the opening of a cave or sinkhole and a corridor of appropriate vegetation between a cave entrance and permanent stream. Around priority caves for federally listed bats, a minimum of 20 acres of appropriate forest/woodland communities is maintained, incorporating topography and watershed considerations into the design, size, and configuration to protect the integrity of the cave system.

Prevent Human Disturbance

Prior to WNS, caves with high biodiversity, unique features (including endangered species), or safety concerns were closed to public entry throughout the year. Caves with fewer unique features were classified as permit-only access caves. Special-use permits were required for legal access. At the lowest priority caves, signs were posted that allowed open access and listed rules for safety and conduct. Special-use permits are granted for specific research, survey, monitoring, and mapping visits. Most of the highest priority caves for bats have now been gated, or soon will be, to prevent trespassing.

Survey and Monitoring

Conservation partners regularly conduct cave surveys and inventories. These include hibernacula surveys to track bat abundance and distribution, with a focus on federally listed species. Each gray bat hibernaculum has been surveyed every 5–10 winters since the mid-1970s. Major Indiana bat hibernacula are surveyed every other winter. More effort has been expended searching for northern long-eared bats during hibernacula surveys since 2009, when the threat of WNS became truly apparent. In conjunction with hibernacula surveys, MDC has participated in major studies related to WNS, including investigating the distribution and prevalence of *Psuedogymnoascus destructans* (*Pd*), the fungal pathogen that causes WNS, detectability of *Pd*, and potential treatment of WNS.

Many cave and karst invertebrates are adapted to a nutrient-poor environment and, therefore, decline quickly when water quality is degraded. Trends in populations of aquatic cave invertebrates can be indicative of the overall health of the cave or spring system. Federally listed species, including Benton County cave crayfish (*Cambarus aculabrum*) and Tumbling Creek cave snail (*Antrobia culveri*), are monitored regularly.

Water Quality Monitoring

Water quality monitoring is used to evaluate the effectiveness of various management actions designed to improve groundwater quality in karst regions, such as well caps, sinkhole cleanouts, spring exclusions, restoration of riparian buffers, and sedimentation reduction. Cave and spring recharge area delineation is necessary to evaluate the benefits of improved water quality to specific cave/karst systems of interest. Water quality monitoring has been used or is being planned to evaluate the effectiveness of many current and planned projects, which will benefit grotto sculpin (*Cottus specus*) and spring cavefish (*Forbesichthys agassizii*) in southeast Missouri, and Ozark cavefish (*Troglichthys rosae*) in southwest Missouri.

Natural Community Subtypes and Case Studies

Terrestrial Cave

Caves are the only terrestrial natural community dominated by animals rather than plants. In the absence of light, decomposer communities form the base of the food chain. Nutrient sources include organic detritus, corpses of cave animals, and dung. Bat guano in particular is often the foundation of diverse communities in those caves inhabited by bats, especially gray bats (*Myotis grisescens*), which roost in caves year-round and therefore provide more guano to the cave system than do bat species that use caves primarily during hibernation.

Case Study: Shannon County Bat Cave

Bat Cave in Shannon County is the third-largest gray bat hibernaculum in Missouri with up to 60,000 hibernating. It is also listed as critical habitat for the Indiana bat (while only approximately 500 Indiana bats hibernate there currently, over 30,000 used to be found). Other species known to hibernate in this cave are little brown bat, eastern small-footed bat, tri-colored bat, big brown bat, and the now federally threatened northern long-eared bat. TNC owned the property at the time of this project and subsequently donated it to MDC, and it is now part of Sunklands Conservation Area.

The property is located within the scenic easement of the NPS Ozark National Scenic Riverways. Not only does this area contain a significantly important cave (in addition to bats there are grotto salamander records and prehistoric artifacts), but this area contains glade habitat with important plant species and riparian habitat along the Current River.

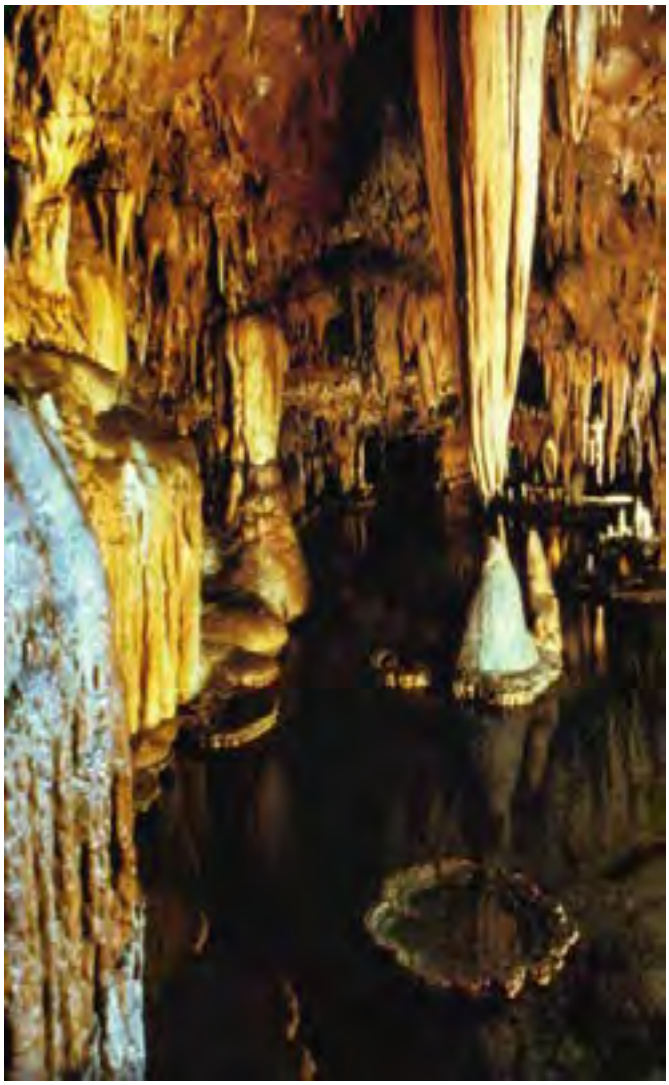
Due to the large opening above the Current River, vandalism occasionally occurred. The cave was originally protected with a chain-link fence that had been breached several times. To protect the cave resources and important bat hibernaculum, in 2012 partners from several organizations constructed a proper, bat-friendly cave gate, which is now the largest standing cave gate in the United States. MDC was the lead with support from USFWS White-nose Syndrome Grants to States award.

Conservation partners include AmeriCorps, Karst Solutions (Jerry Fant and crew), MDC, MDNR State Parks Division, TNC, NPS Ozark National Scenic Riverways, and USFWS.

Aquatic Cave

Groundwater habitats in karst geology are fascinatingly unique but potentially fragile and still poorly understood. Our knowledge of karst groundwaters and the species communities that inhabit them is limited by the tiny windows accessible to us for study. These generally include portions of wetted caves, springs, and artificial constructions such as unlined wells and mines.

A diversity of rare and vulnerable aquatic organisms call these dark, energy-limited environs home. Most lack body pigments, are sightless or nearly so, and are adapted to economize energy expenditures given the uncertainties of encountering their next meal.



Case Study: Springfield Plateau Aquatic Caves

Ozark cavefish is federally listed as threatened and found in groundwater of the Springfield Plateau of southwest Missouri. The species is known in fewer than 25 locations in the state. It is threatened by declining water quality related to poor erosion control practices and urban development, dewatering, and habitat destruction in caves and groundwater recharge areas, which alter hydrology and delivery of sediment and nutrients. The sparse, isolated populations of Ozark cavefish are highly vulnerable to chance catastrophe.

Conservation to benefit Ozark cavefish and other co-occurring species of concern, such as bristly cave crayfish, has targeted protecting cave and well openings through gating; capping unused wells; cooperative projects with landowners, such as sinkhole buffers and livestock watering systems to deter cattle away from springs and streams to promote regenerative use of land and water resources; and monitoring populations of groundwater organisms to gage conservation status and response to recovery activities.

Conservation partners include MDC, Missouri Speleological Survey, Cave Research Foundation, Ozark Land Trust, TNC, USFWS, local caving groups, and numerous private landowners.

Sinkhole Pond

When a cavern's ceiling collapses, a sinkhole is formed. The sinkhole sometimes becomes blocked with surface materials and fills with water, creating a pond. Sinkhole pond communities vary a great deal—some are dominated by trees while others may have mainly herbaceous or shrubby vegetation. Upland sinkhole ponds are important sources of water for wildlife. Species like deer, turkey, and wood ducks will often be found at the ponds. Amphibians use them both for feeding and breeding.

Case Study: Partnering to Recover Threatened Sneezeweed

In the Missouri Ozarks, Virginia sneezeweed (*Helenium virginicum*), a federally threatened plant known only from Missouri and Virginia, is associated with sinkhole ponds as well as low wet meadows and swales occurring in karst areas.

Conservation actions have included seed collection and greenhouse studies, genetics research, two reintroductions on public land (Tingler Prairie Natural Area and Cover Prairie CA), extensive survey work, and habitat management to protect and maintain sinkhole pond natural communities. Thanks to these actions, USFWS is now considering removing Virginia sneezeweed from the threatened species list.

Conservation partners include the Center for Plant Conservation, Missouri Botanical Garden, MDC, USFWS, Washington and Lee University in Virginia, numerous volunteers, and over 100 private landowners.

Springs

Springs are simply locations where water discharges from the ground by means of gravity or hydrostatic pressure. Missouri springs are either freshwater (which are often associated with aquatic caves) or mineral/salt springs. Because of the connection to aquatic caves and cool, clear, constant water conditions, many cave organisms such as aquatic snails, amphipods, isopods, crawfish, salamanders, and sculpin are often found in springs (Schaper 2007). In fact, because aquatic cave communities are largely inaccessible, much of what we know of these communities is learned through studies within cave springs, sinkholes, and similar small windows into this community. Management of groundwater quality through their recharge watershed is critical to the conservation of the aquatic cave community.

Case Study: Perry County – Spring Development

Perry County is a sinkhole plain heavily laden with many karst features existing across its landscape. It is also home to the only known populations of grotto sculpin, a federally endangered fish. Protecting these sensitive karst resources, combined with improving the water quality in this geography, is vital in protecting this cave-dwelling fish.

Much of the Perry County karst region is privately owned; therefore, conservation partners work closely with landowners, providing technical assistance and cost-share funds, hosting workshops, and monitoring the area's valuable karst resources.

Recently, conservation partners took part in a landowner-assistance project focused on improving spring health and increasing efficiency and cleanliness of livestock watering. The objective of the project was to divert spring water through a gravity-fed system and into a livestock watering tank, which, when full, overflowed back into the spring branch. In addition, the spring and its subsequent spring branch were fenced to exclude livestock access, further protecting this karst feature. This project was a win-win for both conservation and the landowner. The spring has been protected from increased nutrient loads from the livestock, and the livestock now have a clean, reliable drinking water supply.

Conservation Partners include the FSA, MDC, NRCS, and USFWS.

Case Study: Perry County (Continued) – Sinkhole Cleanup

In addition to spring conservation (discussed on the previous page), sinkhole cleanup and protection is also important in the Perry County karst region. Many of the sinkholes located in Perry County have historically been used as trash dumps. This refuse can break down and leach into the underground water supply and subsurface streams causing degradation in the water quality in this geography. Landowners have been very receptive to cleaning these unsightly sinkholes and restoring them to their natural state. Cost-share funds have also aided landowners to offset the cost of these cleanups. Most of the refuse is household trash, tires, metals, and even old discarded herbicide containers.

Pictured is an example of a cost-share project in which conservation partners assisted a private landowner in Perry County with a sinkhole cleanup. Refuse from this cleanup was excavated and taken to a permitted landfill facility for proper disposal.

Conservation partners include the FSA, MDC, L-A-D Foundation, NRCS, and USFWS, as well as multiple caver groups, including Cave Research Foundation, Meramec Valley Grotto, Middle Missouri Valley Grotto, Missouri Caves and Karst Conservancy, Missouri Speleological Survey, and Southeast Missouri Grotto.

Case Study: Perry County – Blue Spring Branch Conservation Area

Ball Mill Resurgence, purchased by Leo Drey in 1978, was recognized as a Missouri Natural Area in 1979. Since 2007, the L-A-D Foundation completed a series of buffering acquisitions, and in 2019 adjacent lands were acquired by MDC. This area today comprises the 500+ acre Blue Spring Branch CA. Here, this piece of the "Perry County Barrens," a nationally important karst landscape, is being restored by seeding native plants, using prescribed fire to restore prairie and woodland, and cleaning out sinkholes. In addition to MDC and L-A-D, the neighboring community (City of Perryville and Perry County) members have taken an interest in improving their quality of water for human consumption by better land use practices, which in turn improves conditions underground for the grotto sculpin, a federally endangered species. The collaborative effort also includes the Perry County Economic Development Authority, USFWS, Missouri Cave and Karst Conservancy, and Cave Research Foundation.

Wetland Conservation and Case Studies

Overview

Wetlands are natural communities resulting from saturation by surface or groundwater that create hydric soil conditions favoring the development of hydrophytic vegetation. Plants and animals living in wetland natural communities have evolved specific physiological and behavioral adaptations to deal with fluctuating water levels and flooded conditions. The timing, duration, and extent of flooding and/or soil saturation are key factors influencing wetland type and function along with soils and water chemistry.

Of more than 400 bird species recorded in Missouri, 110 species that regularly nest or migrate through the state depend on wetlands for part of their life cycle. Over 200 Missouri SOCCs use wetlands as their primary habitat. Wetlands are vital habitats that have been mostly eliminated or altered in Missouri. Missouri has experienced some of the highest rates of wetland loss in the nation, with only an estimated 13–15 percent of the state's original 4.8 million acres of wetland habitat remaining.

Wetlands are categorized by hydrologic regime, soils, and dominant and characteristic plant and animal species. The following types of wetlands are found in Missouri: seasonal wetlands, emergent marsh, forested swamp, shrub swamp, and fens. Although technically wetlands by strict definition, bottomland forests and wet prairies are considered in the forest and prairie sections, respectively. In the Ozarks, sinkhole ponds can act as ephemeral wetlands or support subtype communities of emergent marsh, forested swamp, and shrub swamp.

Wetland plant, fish, and wildlife species help improve and sustain other ecological functions of stream-floodplain-watershed systems. Wetland habitats produce leaves, stems, branches, and roots that are sources of organic matter available for transport to other parts of a watershed. Wetlands produce a variety of food resources that help support plant and animal populations living in streams and adjoining floodplains and uplands. Wetlands also help support many birds, bats, and insects that play important roles in pollinating and providing pest control for native plants and crops on surrounding lands.

Even though approximately 87 percent of Missouri's wetlands have been destroyed, wetland conservation partners have made great strides in restoring and improving the functionality of those that remain. State and federal agencies, conservation organizations, agricultural producers, and private landowners have worked together to restore thousands of acres of wetlands on public and private land. At the same time, partners have worked to ensure that wetland restoration efforts provide many social benefits such as improved water quality, less flood damage, and great places to recreate.

Wetland-dependent species have responded positively to previous wetland restoration efforts in Missouri. Today, wetland complexes along the Mississippi and Missouri rivers and their tributaries are recognized for their continental significance to waterfowl, waterbirds, and land birds. Recent research has shown that efforts to restore connectivity to floodplains have also been beneficial to specific riverine fish species (MDC 2015). Other research shows that certain amphibian species are using and successfully recruiting young on newly created wetlands (MDC 2015).

Successful conservation of wetlands will require acquisition, protection, restoration, and management actions. These conservation actions should integrate wetlands into appropriate stream-floodplain-watershed system settings,

sustain and restore ecosystem functions, and provide connectivity among adjacent uplands and aquatic habitats. Water stewardship, scientific research and monitoring, advocacy, and information sharing with professionals and the public will all be necessary to ensure continued support, understanding, and protection of wetland systems and their values.

Figure 4.6.1 – Missouri Wetland COAs

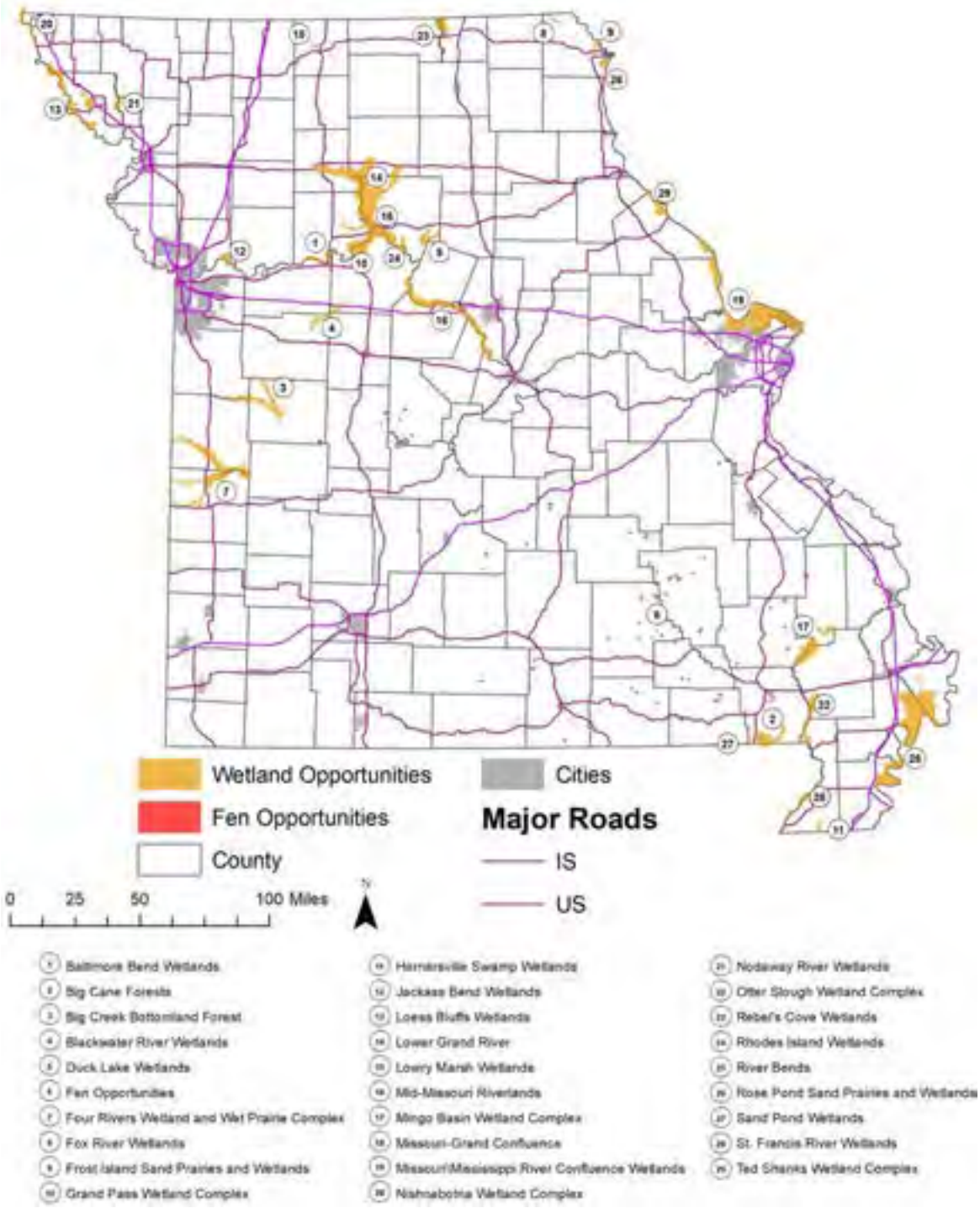


Figure 4.6.2 – Estimated Extent of Partially Hydric and Hydric Soils Within Missouri Floodplains

This map identifies the extent of mapped partially hydric and hydric soils within Missouri floodplains. This base information, as well as Heritage Database records for wetland communities and species, was used to determine the potential extent of wetland COAs throughout the state.

Scoring Criteria

1. HUC 16s within the floodplain (alluvial soils layer)
2. HUC 16s within the floodplain, AND contain ≥ 50% partially hydric soils
3. HUC 16s within the floodplain, AND contain ≥ 50% hydric soils
4. Medium to large public lands (≥ 100 acres) identified as wetlands outside a wetland COA, OR medium to large complexes of WRE lands. If priority in rivers and streams bumps 4s up to 5s
5. Within wetland opportunity area (COAs or areas identified as having active wetland work) within the floodplain
6. Within wetland opportunity area, AND contains medium to large (≥ 100 AND <1000 acres) public lands and/or WRE lands within wetland opportunity areas
7. Within wetland opportunity area, AND contains large (≥ 1000) public lands and/or WRE lands
8. Intensively managed wetland MDC areas (e.g., Grand Pass CA) or USFWS waterfowl refuge (e.g., Swan Lake National Wildlife Refuge)
9. HUC 16s that score a 6, AND support ≥ 3 AND <5 wetland heritage spp.
10. HUC 16s that score a 6, AND contain ≥ 6 wetland heritage spp.

{ Decisive selection criteria for COAs }

Species of Greatest Conservation Need

Plants

Tufted foxtail (*Alopecurus aequalis*) * Shining false indigo (*Amorpha nitens*) * Cut-leaved water-parsnip (*Berula erecta var. incisa*) * Marsh marigold (*Caltha palustris*) * Marsh bellflower (*Campanula aparinoides*) * Thicket sedge (*Carex abscondita*) * A sedge (*Carex atlantica ssp atlantica*) * A sedge (*Carex bromoides ssp bromoides*) * Bristly sedge (*Carex comosa*) * Large sedge (*Carex gigantea*) * A sedge (*Carex molestiformis*) * Dioecious sedge (*Carex sterilis*) * Swamp loosestrife (*Decodon verticillatus*) * Purple spike rush (*Eleocharis atropurpurea*) * Lance-like spike rush (*Eleocharis lanceolata*) * Fen willow herb (*Epilobium leptophyllum*) * Strawberry bush (*Euonymus americanus*) * Virginia sneezeweed (*Helenium virginicum*) * Blue waterleaf (*Hydrolea ovata*) * Creeping St. John's wort (*Hypericum adpressum*) * American frogbit (*Limnobium spongia ssp. spongia*) * A lipocarpha (*Lipocarpha drummondii*) * Hairy primrose willow (*Ludwigia leptocarpa*) * Small-fruited false loosestrife (*Ludwigia microcarpa*) * Swamp candles (*Lysimachia terrestris*) * Tufted loosestrife (*Lysimachia thyrsiflora*) * Bracted water hyssop (*Mecardonia acuminata*) * Buckbean (*Menyanthes trifoliata*) * Miterwort (*Mitreola petiolata*) * Orange fringed orchid (*Platanthera ciliaris*) * Small green fringed orchid (*Platanthera clavellata*) * Snakemouth orchid (*Pogonia ophioglossoides*) * Wild black current (*Ribes americanum*) * Lake cress (*Rorippa aquatica*) * Weakstalk bulrush (*Schoenoplectiella purshiana*) * Rocky mountain bulrush (*Schoenoplectiella saximontana*) * Cloaked bulrush (*Scirpus pallidus*) * Marsh skullcap (*Scutellaria galericulata*) * Steeple bush (*Spiraea tomentosa*) * Water canna (*Thalia dealbata*) * Marsh St. John's wort (*Triadenum tubulosum*) * Lesser bladderwort (*Utricularia minor*) * Hair bladderwort (*Utricularia subulata*) * Northern arrowwood (*Viburnum recognitum*) * Mud midget (*Wolffiella gladiata*) * Netted chain fern (*Woodwardia areolata*) * Tall yellow-eyed grass (*Xyris jupicai*)

Characteristic:

Decurrent false aster (*Boltonia decurrens*) * Grass pink (*Calopogon tuberosus*) * Hairy-fruited sedge (*Carex trichocarpa*) * Finger dog-shade (*Cynosciadium digitatum*) * Water violet (*Hottonia inflata*) * Corkwood (*Leitneria pilosa spp. ozarkana*) * Green twayblade (*Liparis loeselii*) * Water tupelo (*Nyssa aquatica*) * Riddell's goldenrod (*Oligoneuron riddellii*) * Grass-of-Parnassus (*Parnassia grandifolia*) * Swamp lousewort (*Pedicularis lanceolata*) * Mock bishop's weed (*Ptilimnium capillaceum*) * Swamp goldenrod (*Solidago patula*)

Crustaceans

Digger crayfish (*Creaserinus fodiens*) * Shrimp crayfish (*Faxonius lancifer*) * Longtail tadpole shrimp (*Triops longicaudatus*)

Insects

Eastern red damsel (*Amphiagrion saucium*) * Paiute dancer (*Argia alberta*) * Bayou clubtail (*Arigomphus maxwelli*) * Duke's skipper (*Euphyes dukesi dukesi*) * Saline spring tiger beetle (*Habroscelimorpha circumpicta johnsonii*) * Sedge sprite (*Nehalennia irene*) * Slightly musical conehead katydid (*Neoconocephalus exiliscanorus*) * Bog conehead katydid (*Neoconocephalus lyristes*) * Hoosier

grasshopper (*Paroxya hoosieri*) * A shore bug (*Pentacora signoreti*) * Spined grouse locust (*Tettigidea armata*)

Characteristic:

Swamp metalmark (*Calephelis muticum*) * Bald cypress katydid (*Inscudderia taxodii*) * Sphagnum sprite (*Nehalennia gracilis*) * Hine's emerald (*Somatochlora hineana*)

Fishes

Central mudminnow (*Umbra limi*)

Characteristic:

Ghost shiner (*Notropis buchanani*)

Amphibians

Great Plains toad (*Anaxyrus cognatus*)

Characteristic:

Blanchard's cricket frog (*Acris blanchardi*) * Three-toed amphiuma (*Amphiuma tridactylum*) * Green treefrog (*Hyla cinerea*) * Plains leopard frog (*Lithobates blairi*) * Southern leopard frog (*Lithobates sphenocephalus*) * Plains spadefoot (*Spea bombifrons*)

Reptiles

Yellow mud turtle (*Kinosternon flavescens*)

Characteristic:

Southern painted turtle (*Chrysemys doralis*) * Western chicken turtle (*Deirochelys reticularia miaria*) * Blanding's turtle (*Emydoidea blandingii*) * Western mudsnake (*Farancia abacura reinwardtii*) * Graham's crawfish snake (*Regina grahamii*)

Birds

Sandhill crane (*Antigone canadensis*) * Great egret (*Ardea alba*) * Green heron (*Butorides virescens*) * Marsh wren (*Cistothorus palustris*) * Little blue heron (*Egretta caerulea*) * Snowy egret (*Egretta thula*) * Common gallinule (*Gallinula galeata*) * Interior least tern (*Sterna antillarum athalassos*)

Characteristic:

American bittern (*Botaurus lentiginosus*) * Yellow rail (*Coturnicops noveboracensis*) * Rusty blackbird (*Euphagus carolinus*) * Least bittern (*Ixobrychus exilis*) * Black-crowned night-heron (*Nycticorax nycticorax*) * Sora (*Porzana carolina*) * King rail (*Rallus elegans*) * Virginia rail (*Rallus limicola*)

Mammals

Southeastern bat (*Myotis austroriparius*)

Characteristic:

Marsh rice rat (*Oryzomys palustris*) * Cotton mouse (*Peromyscus gossypinus*) * Swamp rabbit (*Sylvilagus aquaticus*)

Threats and Challenges

Missouri has lost over 87 percent of its wetland communities mainly due to conversion to agriculture and to a lesser extent urbanization and reservoir construction. Beyond outright destruction and conversion to a different land use, alterations of Missouri's landscape and natural hydrology have led to extensive loss and degradation of remaining Missouri wetlands.

System Alterations

System alterations, including channelization, ditching, levees, waterway navigation infrastructure (e.g., wing dikes), and reservoirs have altered the magnitude, duration, and timing of wetland inundation, resulting in altered hydrology for riverine wetlands. Landscape alterations have changed how stream channels shape the floodplain and how flooding occurs in terms of timing, flood level, and flood duration. Because of negative landscape alterations, shifting stream channels, and flood levels, which were once beneficial to wetlands, can now result in extensive scouring, head-cutting, and excessive sediment deposition that seriously degrade remnant wetlands. Changing climate patterns including extreme rain events are also altering hydrologic cycles. Increased nutrients have reduced native species richness of wetland habitats and increased the extent and persistence of invasive species. Also, mercury deposition and contamination in the Mingo Basin, and other heavy metal contaminants from mining activities in some river systems (e.g., Big River), negatively impact some wetland communities.

Land Conversion

Conversion of the landscape to row crops, intensively grazed pasture, and/or urbanization and elimination of adequate riparian buffers have resulted in subsequent increases in stream sediment loads, altered flooding regimes, and eutrophication of aquatic habitats.

Invasive Species

Invasive species have degraded many wetland communities. Currently in Missouri, the most problematic invasive species for wetlands include reed canary grass (*Phalaris arundinacea*) and Japanese stilt grass (*Microstegium vimineum*). Purple loosestrife (*Lythrum salicaria*) is a threat but is currently of spotty distribution and has been the target of intense control efforts. Japanese knotweed (*Polygonum cuspidatum*), common reed (*Phragmites australis*), and Japanese chaff flower (*Achyranthes japonica*) are increasing in abundance in the state and will likely become new serious wetland invasives. Moneywort (*Lysimachia nummularia*) and Japanese hops (*Humulus japonicas*) are firmly established in many larger waterways in riparian areas. The presence of feral hogs in the Ozarks is threatening unique fen, seep, and sinkhole pond natural communities.

Management Actions and Opportunities

Wetland conservation activities in Missouri must continue to protect intact habitats, maintain those that have been restored, restore and/or reconstruct new wetlands, and take advantage of the opportunities to enhance and improve upon the efforts of previous conservationists. Since its inception in 1989, NAWCA has contributed to the conservation of nearly 30 million acres of wetland habitat across North America. In Missouri, NAWCA projects have conserved 137,139 acres of wetland habitat. This was made possible through NAWCA funding of more than $20.7 million, matched by partner contributions of over $105.4 million. Through partnerships, NRCS, MDC, and private landowners have worked together to restore over 184,000 acres of Missouri wetlands through the USDA's WRE Program. Despite these successes the threats to wetlands and their dependent species continue. MDC's Wetland Planning Initiative has identified the following objectives, which will help abate the threats to wetland habitats:

1. Where practical, promoting the restoration of more natural stream flow variations and hydrologic connections between streams and floodplains.
2. Managing wetlands to enhance processes that input, transport, assimilate, and output organic matter, sediments, nutrients, and food within stream-floodplain-watershed systems.
3. Supportig partner efforts to restore stream-floodplain-watershed system functions that lessen localized flood damage to communities, homes, farms, and other infrastructure.
4. Providing a wide variety of wetland habitats throughout Missouri, including wet prairies and bottomland hardwood forests.
5. Managing multiple wetland areas as complexes to provide the mosaic and connectivity of habitats that are necessary to benefit wetland-dependent plants and animals and to improve stream-floodplain-watershed systems.
6. Establishing population objectives for key wetland-dependent species.
7. Providing a sufficient distribution, quantity, and quality of wetland habitat types to enable key wetland-dependent species to fulfill life history needs.
8. Identifying opportunities for collaboration to achieve stream-floodplain-watershed conservation and restoration in Missouri by establishing an interdisciplinary statewide task force with participation from agencies and partners directly involved with stream-floodplain-watershed management.
9. Improving management of wetland complexes to benefit wetland-dependent plants and animals by establishing interdisciplinary teams comprised of staff from MDC and other agencies and private landowners involved with wetland management.
10. Building capacity of conservation organizations and partnerships that promote wetland conservation.
11. Developing new approaches to strengthen partnerships with private landowners, communities, and managers.

Natural Community Subtypes and Case Studies

Ephemeral and Seasonal

Ephemeral and seasonal wetlands typically hold water in the fall through spring while drying up in summer. These wetlands can range from open mud flats to dense herbaceous vegetation. Seasonal wetlands in the main floodplain of river systems were historically created by river scour and channel migration. Annual wetland plants such as beggar ticks (*Bidens* spp.), smartweeds (*Persicaria* spp.), wild millet (*Echinochloa muricata*), and flatsedges (*Cyperus* spp.) often dominate. These dynamic "moist soil" wetlands can provide important food sources in spring and fall for migrating waterfowl and shorebirds.

Isolated ephemeral wetlands occur in depressions and sinkholes in the uplands and on floodplain terraces, and because they are typically fishless they are important larval nurseries for many amphibian species, including frogs, toads, and salamanders. This includes a number of SGCNs, such as the Illinois chorus frog (*Pseudacris illinoensis*), wood frog (*Lithobates sylvaticus*), and ringed salamander (*Ambystoma annulatum*).

Case Study: Prairie Fork and Danville Conservation Areas
Location: Prairie Fork and Missouri River Hills COAs

Seasonal and ephemeral wetlands provide important habitat to many wildlife species, particularly amphibians. In east-central Missouri, MDC staff manage and monitor many temporary wetlands in associated prairie and woodland habitats. At the Prairie Fork CA in Callaway County, a large prairie reconstruction project also includes the development and management of several ephemeral wetlands. Managers have plugged old terrace drainage tiles, installed water control structures, and renovated several old livestock watering sites to create small wetlands scattered throughout the prairie reconstructions. These improvements have resulted in wetland systems that provide habitat to species such as migrating soras, yellow rails, mallards, as well as digger crayfish and small-mouthed salamanders. As the prairie reconstruction continues, these grassland wetlands may also provide future breeding habitat to species such as northern crawfish frogs and several species of dragonflies and damselflies.

Seasonal and ephemeral wetlands are also managed nearby on Danville CA in Montgomery County. Most of these wetlands are constructed wildlife watering holes and are characterized by shallow temporary wetlands that often dry in the summer. These pools provide needed breeding habitat to many forest amphibians, such as central newts, wood frogs, spring peepers, and ringed salamanders. MDC staff monitor these ponds to ensure they remain fishless and do not become invaded by invasive species.

Emergent Marsh

Emergent marsh wetlands are characterized by herbaceous vegetation growing in soils that are semi-permanently inundated. Different vegetation zones relate to different patterns of water depths and soils. Soils are very poorly drained to poorly drained. Water depths range 0.5–3 feet in depth in a typical cycle of flooding. The vegetation consists of hydrophytic plants (typically rooted perennials). Examples of common plants found in emergent marshes include river bulrush (*Bolboschoenus fluviatilis*), giant bur-reed (*Sparganium eurycarpum*), narrow-leaved cattail (*Typha angustifolia*), water smartweed (*Persicaria amphibium*), and river sedge (*Carex hyalinolepis*). Emergent marshes provide important habitat for a variety of amphibians and reptiles, dragonflies and damselflies, muskrats (*Ondatra zibethicus*), wading birds (e.g., bitterns, rails, herons), red-winged blackbirds (*Agelaius phoeniceus*), and other wildlife.

Case Study: Ted Shanks Conservation Area
Location: Ted Shanks Wetland Complex COA

Ted Shanks CA is an intensively managed wetland area that contains excellent examples of emergent marsh. The area is one of five included in MDC's Golden Anniversary Wetlands Initiative. Landscape-scale alterations, aging infrastructure, and invasive species have all created the need for aggressive wetland restoration work.

Bur-Reed Slough is a 20-acre emergent marsh on Ted Shanks, and as its namesake suggests, it is dominated by bur-reed. Bitterns and rails use this in migration and for breeding habitat.

Conservation actions have included removal of woody invaders, treatment of reed canary grass, prescribed fire, and infrastructure improvements to improve water management capabilities.

Conservation partners include DU, MDC, USACE, and USFWS.

Shrub Swamp

Shrub swamp wetlands occur in basin-like depressions with poorly drained to very poorly drained soils. Inundation from flooding is a regular feature of shrub-scrub ecology. Shrub-scrub wetlands are dominated by shrubs and small trees; these include buttonbush (*Cephalanthus occidentalis*), black willow (*Salix nigra*), and swamp privet (*Forestiera acuminata*). Shrub swamps provide important habitat for a variety of amphibians and reptiles such as green treefrogs (*Hyla cinerea*), bitterns, prothonotary warblers (*Protonotaria citrea*), yellow warblers (*Setophaga petechia*), and other wildlife.

Case Study: August A. Busch, Jr. Memorial Wetlands
Location: Four Rivers Wetland and Wet Prairie Complex COA

August A. Busch, Jr. Memorial Wetlands is an area in Four Rivers CA in which wetland development and enhancements have helped to partially restore the floodplain features and natural processes affecting the Horton Bottoms Natural Area and the Unit 4 WRE complex. Portions of these tracts contain shrub-scrub wetlands, which would have historically been found in the Osage Plains of west-central Missouri.

A wide range of wetland vegetation including perennial smartweeds, rice cutgrass, beggar ticks, and sedges can be found, along with scattered groupings of willows and buttonbush. A host of waterbirds seasonally utilize these habitats along with numerous wetland fishes. An array of aquatic and terrestrial invertebrates drives the diversity and abundance of these larger fauna.

There have been a number of restoration and management projects in Four Rivers CA over the years. In the Horton Bottoms Natural Area, log structures were installed in the man-made ditch to stop complete drainage and restore a more natural hydrology. More recently, a large section of flood-protection levee was removed in Unit 4, and a low floodway was installed to partially restore stream-floodplain connectivity during high water events.

Conservation partners include MDC, NRCS, and DU.

Forested Swamp

Forested swamp wetlands are characterized by trees and shrubs that are adapted to long periods of flooding and soil saturation. Mature swamps can have tall canopies, with some trees reaching 100 feet in height. Bald cypress (*Taxodium distichum*), water tupelo (*Nyssa aquatica*), swamp red maple (*Acer rubrum* var. *drummondii*), swamp cottonwood (*Populus heterophylla*), and water hickory (*Carya aquatica*) are typically the dominant tree species. Swamps need occasional dry periods for tree regeneration. Swamps provide important habitat for a variety of amphibians and reptiles such as green treefrogs (*Hyla cinerea*) and western mud snakes (*Farancia abacura*), herons, prothonotary warblers (*Protonotaria citrea*), barred owls (*Strix varia*), and other wildlife.

Case Study: Mingo Basin and Big Cane Conservation Area
Location: Mingo Basin Complex and Big Cane Forested COAs

Less than 100,000 acres of lowland forest (wet-mesic bottomland forest, wet bottomland forest, swamp forest) remain in the Mississippi Alluvial Basin of southeast Missouri. Most of this basin (2.3 million acres) was historically forest but is now dominated by intensive agricultural production. The remaining forests are currently providing habitat for a host of wildlife including both nesting and migrant waterfowl and forest birds. Mingo National Wildlife Refuge, Big Cane, Coon Island, and Duck Creek CAs are examples of this lowland forest system that are actively managed to improve wildlife habitat.

Managers have begun implementing forest management plans that include selective timber harvests that provide a more diverse forest canopy structure. These conditions provide better foraging, nesting, vegetation diversity, and mast production for wildlife. These harvests are also part of two active research projects that will help determine which forest overstory conditions are best for enhancing and sustaining the valuable red oak component of Missouri's lowland forests. MDC has completed a forest-breeding-bird monitoring project that will provide baseline information and post-treatment results. Management efforts are designed to help sustain a more diverse forest structure, provide better wildlife habitat, and also help recruit and maintain the red oak forest component that has become increasingly difficult to sustain throughout the Lower Mississippi Alluvial Basin.

Conservation partners include MDC and USFWS (Mingo National Wildlife Refuge managers).

Fen

Fens are hydrologically and biologically unique wetlands found in the Ozark Highlands and Central Dissected Till Plains ecoregions, created by constant, mineralized groundwater. Most remaining fens occur in the Ozarks where groundwater percolates through porous carbonate rocks and then flows downward and laterally across an impervious geologic formation. The groundwater then flows out onto the land's surface. The water is cool and high in calcium and magnesium. Fens are typically small patch communities (often only an acre or less in size) but their plant diversity is quite high for their small size and is composed of many plants with restricted distributions in Missouri. The same is true of invertebrates. Fen-restricted plant species include swamp wood betony (*Pedicularis lanceolata*) and a number of sedge and rush species. Fens are the primary habitat type for a number of invertebrates such as the gray petaltail dragonfly (*Tachopteryx thoreyi*) and the federally endangered Hine's emerald dragonfly (*Somatochlora hineana*).

Case Study: Grasshopper Hollow Natural Area

Missouri's landowners are a keystone component to fen conservation. In the Ozarks, the heart of fen country, the majority of fens are located on private lands. Partnerships that promote the conservation of fens through cooperative habitat management, landowner technical support, and programs tailored to recover SOCCs are crucial and ongoing.

Rare fen species in need of conservation action include wild sweet William, queen of the prairie, rose pogonia, false loosestrife, Hine's emerald dragonfly, sphagnum sprite, and the glass lizard.

Conservation actions consist of land acquisition, conservation easements, and private land partnerships, including incentive programs to protect and enhance fens. Restoration and management of these systems include prescribed burning, woody species removal, and invasive species control. Additional critical concerns for fen systems include protection from draining and feral hogs.

These management tools have been employed on Grasshopper Hollow Fen Natural Area, located in Reynolds County. Grasshopper Hollow contains the largest known fen complex in unglaciated North America, and management work here directly benefits the federal and state endangered Hine's emerald dragonfly.

Conservation partners for Hine's emerald dragonfly management, associated with fens, include Doe Run Company, Illinois State Museum, MTNF, Missouri Botanical Garden, MDC, MDNR, NRCS, TNC, USFWS, and Washington University.

River and Stream Conservation and Case Studies

Overview

With more than 110,000 miles of running water, Missouri is rich with rivers and streams. These streams are the product of their watersheds. Watersheds are the total land area contributing runoff to a stream or river and consist of uplands, floodplains, stream corridors, stream channels, and groundwater. Uplands slope downward forming headwater streams that account for more than 80 percent of the channels in a watershed. These small streams are the capillaries of a river, connecting the land to streams, and play an important role in healthy stream systems, even though they may not carry water all year. They provide several biological, physical, and chemical functions such as being the beginning of the food web; retaining and transporting sediment; and processing, retaining, and transforming excess nutrients and organic matter to the stream network. As headwater streams converge, enlarge, and move down through their floodplains, they often change in flow from ephemeral to intermittent and eventually into larger perennial streams, which flow year-round due to their connection with groundwater. Each of these offer unique characteristics, habitats, and biota critical to the food chain and connectivity of the river system as a whole.

There are several stream types in Missouri that can be broadly categorized into grassland/prairie, Ozark, Mississippi lowland, and big river. Grassland/prairie streams generally occupy the northern half and a portion of the western side of the state and in an unaltered state were historically very sinuous (winding), low-gradient (relatively flat) streams with fine substrates. Ozark streams are found in the middle of the state down to its southern border. Karst topography influences the character of these streams and they have steeper gradients and coarse rocky substrates. Where these grassland/prairie and Ozark landscapes meet, streams can contain a mixture of physical and biotic characters of both stream types. Mississippi lowland streams occupy the southeastern corner along the Mississippi River through the Bootheel region of Missouri. These streams are very flat and have sandy alluvial substrates. Two of America's greatest rivers have their confluence in Missouri. They are known as the big rivers. The Missouri River dissects the state into north and south, and the Mississippi River runs along the state's eastern border.

Figure 4.7.1 – Missouri Stream Regions and Stream Reach COAs

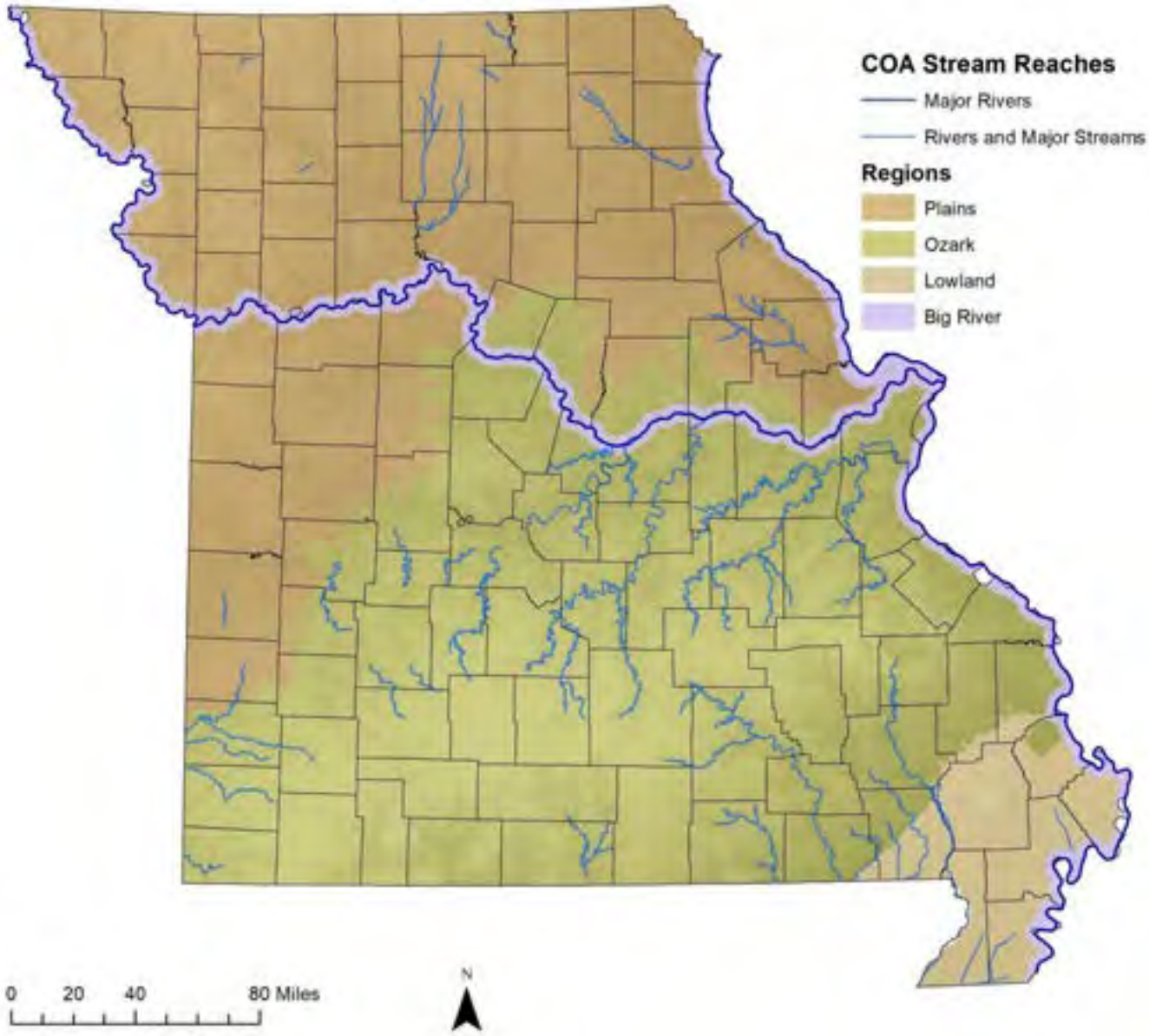


Figure 4.7.2 – Missouri Stream Reach COAs

Figure 4.7.3 – Missouri Stream Reach COAs with Watersheds for Reference

Figure 4.7.4 – Extent of Missouri Stream Networks (2nd Order Streams and Higher)

To

Scoring Criteria

1. Existing priority areas/plans (e.g., aquatic COAs, priority mussel reaches, priority crayfish reaches, etc.)
2. Missouri Integrated Aquatic Database (MIAD through 2014) stream reaches with poor index of biotic integrity (IBI) scoring, OR poor invertebrate stream condition
3. HUC 16s containing 1 aquatic heritage record, OR MIAD stream reaches with fair IBI scoring, OR medium invertebrate stream condition
4. MIAD stream reaches with good IBI scoring, OR good invertebrate stream condition
5. HUC 16s containing >1 aquatic heritage record, OR MIAD stream reaches with good IBI scoring, AND good invertebrate stream condition.
6. 4s and 5s that overlap with an existing priority area or plan
7. HUC 16s that score 4s or 5s, AND contain conservation network lands
8. HUC 16 containing ≥ 1 state/federal T/E spp.
9. HUC 16 containing ≥ 1 state/federal T/E spp., AND containing or adjacent to HUC 16 with conservation network lands (e.g., MDC, partner, easements, etc.)
10. Stream reaches within PWs and selected HUC10s resulting from overlapping 6s–9s for Plains and 8s–9s for Ozarks

Decisive selection criteria for COAs

Species of Greatest Conservation Need

Plants

Weak rush (*Juncus debilis*)

Mollusks

Elktoe (*Alasmidonta marginata*) * Slippershell mussel (*Alasmidonta viridis*) * Cylindrical papershell (*Anodontoides ferussacianus*) * Ponderous campeloma (*Campeloma crassulum*) * Western fanshell (*Cyprogenia aberti*) * Elephantear (*Elliptio crassidens*) * Curtis pearlymussel (*Epioblasma curtisii*) * Snuffbox (*Epioblasma triquetra*) * Pink mucket (*Lampsilis abrupta*) * Higgins eye (*Lampsilis higginsii*) * Neosho mucket (*Lampsilis rafinesqueana*) * Scaleshell (*Leptodea leptodon*) * Arkansas mudalia (*Leptoxis arkansensis*) * Black sandshell (*Ligumia recta*) * Spectaclecase (*Margaritifera monodonta*) * Sampson sprite (*Micromenetus sampsoni*) * Southern hickorynut (*Obovaria arkansasensis*) * Sheepnose (*Plethobasus cyphyus*) * Fat pocketbook (*Potamilus capax*) * Ouachita kidneyshell (*Ptychobranchus occidentalis*) * Winged mapleleaf (*Quadrula fragosa*) * Ebonyshell (*Reginaia ebenus*) * Salamander mussel (*Simpsonaias ambigua*) * Elk pebblesnail (*Somatogyrus rosewateri*) * Marsh pondsnail (*Stagnicola elodes*) * Rabbitsfoot (*Theliderma cylindrica*) * Purple Lilliput (*Toxolasma lividum*) * Flat floater (*Utterbackiana suborbiculata*) * Little spectaclecase (*Villosa lienosa*)

Crustaceans

Freckled crayfish (*Cambarus maculatus*) * Shield crayfish (*Faxonella clypeata*) * Coldwater crayfish (*Faxonius eupunctus*) * Belted crayfish (*Faxonius harrisonii*) * Mammoth Spring crayfish (*Faxonius marchandi*) * Saddleback crayfish (*Faxonius medius*) * Meek's crayfish (*Faxonius meeki meeki*) * Big Creek crayfish (*Faxonius peruncus*) * St. Francis River crayfish (*Faxonius quadruncus*) * Spring River crayfish (*Faxonius roberti*) * Eleven Point River crayfish (*Faxonius wagneri*) * Williams' crayfish (*Faxonius williamsi*) * Painted devil crayfish (*Lacunicambarus ludovicianus*) * Paintedhand mudbug (*Lacunicambarus polychromatus*) * Ohio shrimp (*Macrobrachium ohione*)

Insects

Midland clubtail (*Gomphus fraternus*) * Skillet clubtail (*Gomphus ventricosus*) * Austin springfly (*Hydroperla fugitans*) * A heptageniid mayfly (*Maccaffertium bednariki*) * Larger pygmy mole grasshopper (*Neotridactylus apicialis*) * Contorted ochrotrichian micro caddisfly (*Ochrotrichia contorta*) * Frison's seratellan mayfly (*Serratella frisoni*) * Ozark emerald (*Somatochlora ozarkensis*) * Treetop emerald (*Somatochlora provocans*) * Elusive clubtail (*Stylurus notatus*)

Fishes

Brown bullhead (*Ameiurus nebulosus*) * Highfin carpsucker (*Carpiodes velifer*) * Bluntface shiner (*Cyprinella camura*) * Lake chubsucker (*Erimyzon sucetta*) * Arkansas darter (*Etheostoma cragini*) * Current saddled darter (*Etheostoma euzonum erizonum*) * Arkansas saddled darter (*Etheostoma euzonum euzonum*) * Swamp darter (*Etheostoma fusiforme*) * Least darter (*Etheostoma microperca*) * Niangua darter (*Etheostoma nianguae*) * Goldstripe darter (*Etheostoma parvipinne*) * Redfin darter (*Etheostoma whipplei*) * Golden topminnow (*Fundulus chrysotus*) * Northern plains killifish (*Fundulus kansae*) *

Southern brook lamprey (*Ichthyomyzon gagei*) * Dollar sunfish (*Lepomis marginatus*) * Bantam sunfish (*Lepomis symmetricus*) * American brook lamprey (*Lethenteron appendix*) * Blacknose shiner (*Notropis heterolepis*) * Ozark shiner (*Notropis ozarcanus*) * Sabine shiner (*Notropis sabinae*) * Topeka shiner (*Notropis topeka*) * Mountain madtom (*Noturus eleutherus*) * Neosho madtom (*Noturus placidus*) * Channel darter (*Percina copelandi*) * Bluestripe darter (*Percina cymatotaenia*) * Longnose darter (*Percina nasuta*) * Stargazing darter (*Percina uranidea*) * Trout-perch (*Percopsis omiscomaycus*) * Eastern slim minnow (*Pimephales tenellus parviceps*) * Western slim minnow (*Pimephales tenellus tenellus*)

Characteristic:

Lake sturgeon (*Acipenser fulvescens*) * Alabama shad (*Alosa alabamae*) * Skipjack herring (*Alosa chrysochloris*) * Western sand darter (*Ammocrypta clara*) * Scaly sand darter (*Ammocrypta vivax*) * American eel (*Anguilla rostrata*) * Alligator gar (*Atractosteus spatula*) * Flier (*Centrarchus macropterus*) * Crystal darter (*Crystallaria asprella*) * Blue sucker (*Cycleptus elongatus*) * Whitetail shiner (*Cyprinella galactura*) * Steelcolor shiner (*Cyprinella whipplei*) * Banded pygmy sunfish (*Elassoma zonatum*) * Ozark chub (*Erimystax harryi*) * Gravel chub (*Erimystax x-punctatus*) * Harlequin darter (*Etheostoma histrio*) * Starhead topminnow (*Fundulus dispar*) * Plains topminnow (*Fundulus sciadicus*) * Mooneye (*Hiodon tergisus*) * Western silvery minnow (*Hybognathus argyritis*) * Brassy minnow (*Hybognathus hankinsoni*) * Cypress minnow (*Hybognathus hayi*) * Mississippi silvery minnow (*Hybognathus nuchalis*) * Plains minnow (*Hybognathus placitus*) * Northern brook lamprey (*Ichthyomyzon fossor*) * Least brook lamprey (*Lampetra aepyptera*) * Cardinal shiner (*Luxilus cardinalis*) * Common shiner (*Luxilus cornutus*) * Duskystripe shiner (*Luxilus pilsbryi*) * Bleeding shiner (*Luxilus zonatus*) * Ribbon shiner (*Lythrurus fumeus*) * Sturgeon chub (*Macrhybopsis gelida*) * Sicklefin chub (*Macrhybopsis meeki*) * Silver chub (*Macrhybopsis storeriana*) * Silver redhorse (*Moxostoma anisurum*) * River redhorse (*Moxostoma carinatum*) * Ironcolor shiner (*Notropis chalybaeus*) * Wedgespot shiner (*Notropis greenei*) * Taillight shiner (*Notropis maculatus*) * Silverband shiner (*Notropis shumardi*) * Weed shiner (*Notropis texanus*) * Checkered madtom (*Noturus flavater*) * Blackside darter (*Percina maculata*) * River darter (*Percina shumardi*) * Flathead chub (*Platygobio gracilis*) * Paddlefish (*Polyodon spathula*) * Pallid sturgeon (*Scaphirhynchus albus*) * Shovelnose sturgeon (*Scaphirhynchus platorynchus*)

Amphibians

Characteristic:

Fowler's toad (*Anaxyrus fowleri*) * Eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*) * Ozark hellbender (*Cryptobranchus alleganiensis bishopi*) * Oklahoma salamander (*Eurycea tynerensis*)

Reptiles

Characteristic:

Western cottonmouth (*Agkistrodon piscivorous leucostoma*) * Midland smooth softshell turtle (*Apalone mutica mutica*) * Alligator snapping turtle (*Macrochelys temminckii*) * Northern water snake (*Nerodia sipedon*)

Birds

Characteristic:

Bald eagle (*Haliaeetus leucocephalus*) * Bell's vireo (*Vireo bellii*)

Threats and Challenges

Because streams and rivers are so fundamentally linked to the watersheds that surround them, most of the threats to terrestrial habitat systems also threaten streams. A stream is a reflection of its watershed. So, if the watershed and habitat systems within them are fully functioning and intact, the stream is more likely to be healthy. Of course, in-stream alterations such as channel dredging, channelization, and damming also have direct and severe impacts on aquatic systems.

Urbanization/Suburbanization

Construction activities without effective erosion control can cause increased sedimentation in streams. In developed urban and suburban areas, impervious surfaces like roads, buildings, rooftops, etc. can have the opposite effect by not allowing enough sediment into streams, especially when the channels themselves are put through pipes or culverts or are lined in concrete. This can result in excessive velocities that erode the stream channel and degrade stream habitat. Frequent urban water quality problems include increased stream temperatures from impervious surfaces, lack of riparian buffers, and pollutants from vehicles, yards, and municipal sewage overflows, etc.

Agriculture

Overgrazing can increase erosion and runoff into stream channels, which can increase sedimentation, creating turbid water and filling interstitial spaces (spaces between stream bottom substrate, typically rocks) that are critical habitat to benthic (stream bottom dwelling) organisms. Excess eutrophication (excessive nutrient loading) from manure that enters streams can result in algae blooms and decrease water quality. Certain row cropping practices can also be detrimental to streams by allowing exposed soil to erode off fields, causing stream sedimentation. Fertilizer and chemical runoff can also negatively affect water quality. Tiling practices change the delivery rate of water to streams by constricting water into underground tubes that are often piped directly to a stream. This water enters the stream at high velocities and can erode the stream channel. Cumulatively, these and other practices can have a substantial effect on habitat, water quality, and biota in a stream system throughout a watershed.

Connectivity Loss

Streams rely on their watershed connections that run laterally into the riparian area and floodplains, longitudinally up and down channels, and vertically between the channel bed and the water table. Common causes of lateral connectivity loss occur in floodplains and riparian areas when development or levees encroach on floodplains and side channels and oxbows are filled in or cut off, or riparian vegetation is removed or altered. Alterations of natural ecological flow regimes from industrial, municipal, or agricultural uses, large dams, and other sources can also contribute to this loss of connectivity.

Longitudinal connectivity is critical for fulfilling migration requirements, genetic dispersal, and habitat utilization of many aquatic organisms. Longitudinal barriers are created by limiting the movement of organisms physically or behaviorally; dams, poorly designed road crossings (e.g., elevated slab concrete crossings without adequate conveyance for water and sediment), and culverts are common examples. Large reservoirs and the cumulative effects of small ponds have also altered hydrology, habitat, and aquatic species throughout the state.

Stream Habitat Destruction

In-channel activities, such as channelization, improper mining activities, channel reaming, filling, burying or excessive armoring, improper recreational activities, and others can cause localized and system-wide losses to stream habitat.

Deforestation and the loss of an adequate riparian corridor throughout much of the state,

ongoing since the 1800s, have altered stream hydrology and habitat and energy cycles. In addition, the loss and lack of wooded stream corridors deprive stream channels of large woody debris. This woody debris is important for creating and maintaining various habitat types throughout the channel network and is a critical component of the food chain for invertebrate and vertebrate species.

Aquatic Invasive Species

Beyond ecological concerns, aquatic invasive species have tremendous impact on local, state, and federal economies, affecting aquatic industries like water treatment, commercial and sport fisheries, recreational boating, etc. Terrestrial invasives are no different; when combined, these invasive species cost hundreds of billions of dollars per year to control and manage in the United States alone.

Like terrestrial habitat systems, aquatic systems are vulnerable to the effects of invasive species, especially due to the high connectivity of most aquatic systems. Connectivity can be both a benefit and a detriment to a system. Connectivity benefits native species by minimizing habitat fragmentation and allowing species and genetic diversity and distribution, but it also allows for the rapid population expansion and distribution of invasive species. Some of the most well-known aquatic invasive species in Missouri include zebra mussels (*Dreissena polymorpha*), quagga mussels (*Dreissena bugensis*), invasive carp such as bighead (*Hypophthalmichthys nobilis*), silver (*Hypophthalmichthys molitrix*), and black carp (*Mylopharyngodon piceus*), hydrilla (*Hydrilla verticillata*), and didymo (*Didymosphenia geminata*), also known as rock snot. These invasives are highly competitive with native species, with impacts that can include direct competition for food, predation, displacement, smothering or shading, disease introduction, and (potentially) interbreeding. Any one or combination of these factors can lead to upsetting the delicate balance of native aquatic ecosystems.

Management Actions and Opportunities

When considering river and stream management actions, it is critical that a watershed-based approach is taken (**Figure 4.7.3**). Rivers and streams are fundamentally linked to the watersheds that surround them. Most of the threats to terrestrial habitat systems also threaten the streams and groundwater resources to which those terrestrial systems supply runoff. Typically, by the time a river or stream shows degradation, there have been numerous cumulative alterations in the watershed that contributed to that condition.

Streams work with very large lag times since they mostly depend on numerous and appreciable precipitation events before damage is apparent in the channel. There is rarely an immediate or obvious cause and effect, with the exception of some in-channel activities. Much of the degradation of rivers and streams today began with actions that occurred over a century ago and continues with current alterations. For this reason, managing and restoring river and stream ecosystems is typically not as easy as simply restoring a woodland or replanting a stretch of riparian corridor, though these are important actions that also benefit the aquatic resources.

Because of the interconnection between the aquatic and terrestrial systems within a watershed, managers must first study the entire watershed and analyze what factors have, or are likely contributing to, stream system degradation and what BMPs could most effectively protect the current condition, enhance stream health and function, and begin the process of long-term watershed recovery. There are many examples and combinations of BMPs that can be employed, which include removing aquatic organism passage barriers to improve connectivity; levee notching or removal; and ensuring gravel mining operations are properly permitted by regulatory agencies and removal follows applicable rules and guidelines. These include mining only on large, unconsolidated, unvegetated gravel bars; leaving an undisturbed buffer of at least 10 feet between the stream and the harvest area and between the harvest area and the bank; no excavation below the elevation of the water line; no gravel stockpiled within the stream channel; no channel reshaping or modifications; and, after mining, disturbed streambanks should be revegetated.

There are also a variety of streamside landscape practices that can help to restore or enhance watersheds. These include riparian corridor improvement; livestock exclusions, hardened livestock channel crossings; conversion of nonnative tall fescue (*Festuca arundiancea*) pastures to deep-rooted native grasses and forbs; crop field vegetated swales and vegetated stream buffers; and grassland, forest, woodland, glade, and wetland restorations.

The most effective BMP, however, is preventing further degradation through education, awareness, advocacy, and working with landowners to meet their goals while at the same time protecting the resources.

Continuing to protect, enhance, restore, and maintain riparian corridors appropriate to the landscape type is an essential piece of managing a stream's resilience to altered landscapes and climate stressors. A minimum 50–100 feet buffer is recommended, but benefits can continue to be attained as far out as 500 feet and beyond. As buffers increase in width, they can provide more aquatic food availability, stream stability, habitat diversity, as well as improve water temperature and chemistry. They also enhance habitat connectivity within the floodplain, acting as important travel corridors for a diversity of wildlife species. The wider the corridors, the more ecosystem and wildlife services they can provide for many aquatic and terrestrial wildlife species and to people.

Urban stream improvements may include many of the BMPs described above but may also include replacing impervious surfaces with porous surfaces, installing rain gardens and bioswales, and improving sewage treatment systems and infrastructure.

Some forms of recreation may have unintentional adverse effects, and it is important to keep ATVs/UTVs out of stream beds, streambanks, steep slopes, and riparian areas where and when possible. It is also important to properly dispose of trash and human waste, and to be cautious to not create potential streambank erosion from large wakes created by boating.

Perhaps one of the most difficult management actions for aquatic systems is managing infestations of aquatic invasive (nuisance) species. Due to the highly connected network of Missouri's rivers, streams, and reservoirs and the degree of difficulty to make observations of distribution within a body of water, it is extremely difficult to control or manage (let alone eradicate) aquatic invasive species from the affected waters once introduced. Though challenging, some infestations have been managed and even eradicated when identified early enough.

Due to the degree of difficulty in managing some aquatic invasives, numerous resources are put toward preventing further introduction and dispersal of these species. The most effective vector to accomplish this goal is, again, education and awareness. Conservation partners continually campaign to heighten awareness of the effects, potential effects, and costs associated with invasive species and their management. Precautionary measures taken by the partners and the general public can greatly reduce the risk of further infestations. A coordinated statewide invasive species reporting system could facilitate the eradication of a population before it expands and flourishes.

Natural Community Subtypes and Case Studies

Grassland/Prairie Streams

These streams run along flat to rolling plains and were historically surrounded by thick glacial soils with deeply rooted perennial grasses and forbs. Steep headwater draws and larger valleys were sometimes noted to be brushy and woody, or containing "Bottom Prairie grass" according to Schroeder (1981). The dense deep-rooted vegetation of prairies allowed for precipitation to infiltrate and moderate flows to stream channels gradually through groundwater connectivity. These highly sinuous streams meandered through floodplains with many oxbows and off-channel habitats. Most of our prairie streams have been affected by widespread channelization, which has disconnected streams from their floodplains through incision since the 19th century. Channelization has also caused habitat homogenization with losses of pools, riffles, and runs. Land-use conversions of the prairie have changed runoff patterns, depleted soils, and caused erosion and sedimentation in streams. Many of the species remaining in these streams tend to be tolerant species with wider distributions than most, such as green sunfish (*Lepomis cyanellus*) and black bullheads (*Ameriurus melas*) (Pflieger 1997).

Case Study: Spring Creek Watershed Priority Geography
Location: Spring Creek Watershed COA

Spring Creek Watershed PG is the best example in northern Missouri where savanna-woodland habitats sustain a healthy prairie stream system. Union Ridge Conservation Area plays a central role in this watershed, protecting nearly 32 miles of prairie stream within the managed area. The Spring Creek Watershed contains 29 species of fish, including the federally endangered Topeka shiner, and seven species of mussels; it is a testament to the importance of high-quality prairies, savannas, and woodlands in improving and sustaining the diversity of aquatic plants and animals.

Conservation partners continue to help build a much larger conservation landscape through a public-private land partnership that reaches well beyond Union Ridge CA. Implementing BMPS for livestock and enhancing riparian corridor form a primary focus of this geography.

Conservation partners include MDC, MPF, NWTF, NRCS, Pheasants Forever, SWCDs, and Truman State University.

Ozark Highland Streams

The karst topography of the Ozark Highlands ecoregion is filled with springs, caves, clear water, and granite, dolomite, or limestone bluffs. Steep cobble bottom headwater streams run through narrow slopes converging with larger valley streams predominately lined with chert and bedrock channel beds (Pflieger 1997). Fallen trees, boulders, and large root wads within stream channels create complex habitat diversity. Beginning in the early 19th century, agricultural cultivation of bottomland forest and associated timber harvest for railroad ties led to extensive deforestation of the region and resulted in increased erosion. Prior to this, early explorers and surveyors rarely noted the abundance of gravel in streams (Jacobson and Primm 1997). The steep terrain and thin rocky soils of the Ozark Highlands Region have limited the amount of land alteration for agriculture except in the floodplains, which were once deep bottomland forests. These floodplains are still often used for grazing or haying. The Ozark Highlands Region contains almost one-third of all Missouri fishes, twenty of which are unique to this region, among them the Missouri saddled darter (*Etheostoma tetrazonum*) and the Niangua darter (*Etheostoma nianguae*) (Pflieger 1997). Other Ozark aquatic species include the rainbow mussel (*Villosa iris;* Oesch 1984), Ozark pigtoe (*Fusconaia ozarkensis*), Ozark hellbender (*Cryptobranchus alleganiensis bishopi*), and eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*;).

Case Study: Little Niangua River Priority Geography
Location: Little Niangua River COA

The Little Niangua River PG is the best example of a diverse Ozark border stream system within the Upper Ozark portion of the Ozark Highlands in Missouri. The Little Niangua River contains 61 species of fish and 15 species of mussels. A prime example of the high quality natural communities that exist within the watershed is the 240-acre Little Niangua River Natural Area, featuring more than a half mile of river, its associated riparian corridor and adjacent bluffs, woodlands, and glades.

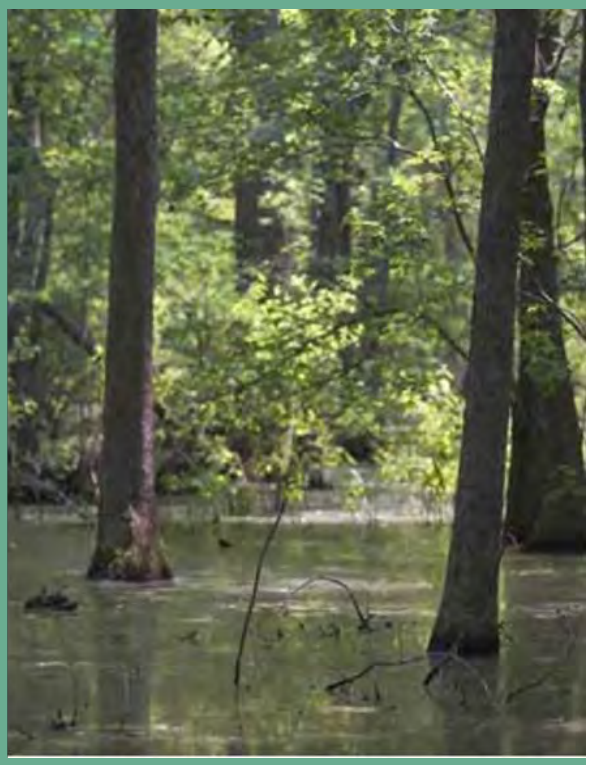
The Niangua Darter Recovery Team identified the potential for low-water road crossings to be a threat to this species because they prevent fish movement and fragment populations. From 2004 to 2014, an initiative was undertaken to replace ten low-water crossings within the Little Niangua River PG.

Completion of the low-water crossing replacement projects allows the fragmented meta-populations of Niangua darters to mix with each other and have free movement in more than 55 miles of stream. As a result, not only is genetic diversity protected but spawning and other suitable habitat is now accessible.

Conservation partners include County Commissions, Missouri Conservation Heritage Foundation, MDC, Missouri Department of Transportation, Federal Emergency Management Agency, State Emergency Management Agency, and USFWS.

Mississippi Lowland

The low-lying alluvial plains bordering the Mississippi River in southeast Missouri were once covered in cypress swamps. Streams from the bordering Ozark region drained through this area on their way to the Mississippi. The flat gradient creates streams that are mostly pools with little to no current and sandy silt beds. Decaying organic matter stains the water brown with tannins in these slow swampy streams. In the late 19th and early 20th centuries, these swamps were cleared, ditched, or drained for agricultural use. In Missouri's Bootheel there are now about 1,200 miles of ditches with little riparian corridor or vegetation around them. Some of these channels are still inhabited by distinct fishes that are at the northern end of their range, like the cypress darter (*Etheostoma proeliare*) and pygmy sunfish (*Elassomatidae* spp.) (Pflieger 1997).



Case Study: River Bends Priority Geography
Location: River Bends COA

The River Bends PG falls within the Lower Mississippi Alluvial Valley. The landscape is an agricultural-forest large river system containing a systematic array of remnant oxbow wetlands, scours, riverine wetlands, riverfront forest, early successional habitats, moist soil communities, bottomland hardwood forest, cypress-tupelo swamp, and crops interspersed with ephemeral floodplains within the lowland portion of the Missouri Bootheel.

The species diversity within the River Bends PG is extremely high and dependent on the hydrological variations that exist within the geography. Various SOCCs are accounted for in this landscape, including the mole salamander, three-toed amphiuma, eastern spadefoot, Illinois chorus frog, Mississippi kite, Swainson's warbler, black-necked stilt, loggerhead shrike, interior least tern, alligator gar, banded pygmy sunfish, bantam sunfish, cypress minnow, ironcolor shiner, harlequin darter, pugnose minnow, taillight shiner, swamp darter, Rafinesque's big-eared bat, southern short-tailed shrew, cotton mouse, rice rat, swamp rabbit, Cajun dwarf crayfish, shrimp crayfish, western chicken turtle, and the alligator snapping turtle.

Conservation actions include additional land acquisition of publicly owned land interspersed with cooperating private landowners whose properties provide comparable conservation benefit in the landscape (e.g., USDA WRE) integrated with a highly productive agricultural community.

Conservation partners include the Lower Mississippi River Conservation Committee, MoBCI, MDC, MDNR, NRCS, National Fish and Wildlife Foundation, NWTF, U.S Army Corp of Engineers, and USFWS.

Big River

The Missouri and Mississippi rivers support large and unique fauna and habitats in Missouri. The Missouri River, in Missouri, was once a turbid, braided, and unruly river. Its unpredictable flows and channel shifts created islands, ox-bows, and backwaters throughout its bottomland forests. In the early 20th century, however, large upstream reservoirs were built, modifying flows; many flood control levees were built disconnecting essential floodplain hydrologic and habitat functions; and the channel was narrowed and deepened to a single navigation channel. This greatly reduced in-stream and off-channel habitats. Similarly, the Mississippi River has also been altered with hydroelectric dams, levees, and navigation channels; however, the character of the Mississippi was originally quite different from that of the Missouri. The Mississippi River drains a larger watershed and had clearer water and more stable flows. The confluence of these two great rivers is halfway down the eastern border of the state. Because of their size, these rivers support large fish species, among them catfish, gar, sturgeon, and paddlefish (Pflieger 1997). Freshwater mussels were an impressive part of these systems and their tributaries, but their numbers have diminished greatly. Historically, bargeloads of mussels were plucked daily from these rivers for the button industry. Now, habitat loss through sedimentation and invasive species threaten many populations (Bruenderman 1999).

Case Study: Pallid Sturgeon Restoration
Location: Missouri River and Mississippi River COAs

The pallid sturgeon was listed as federally endangered in 1990 due to habitat loss and fragmentation along the Missouri and Mississippi river basins. Each spring since 2008, MDC Missouri River Field Station (MORFS) crews have used trot lines to target adult wild pallid sturgeon to send to Blind Pony State Fish Hatchery in Sweet Springs, Missouri, with hope that these adults will spawn and reproduce to help supplement the dwindling population until it can once again become self-sustaining. Typically, MORFS crews solicit help from MDC staff, universities, other government agencies, and the general public. Generally, 50–80 volunteers work during the three-week effort from the end of March through mid- April. This is an excellent opportunity to educate Missourians on the current plight of this native species, as well as that of the Missouri River.

Each year around 12,000 hooks are set and an average of 65 pallid sturgeon are captured, of which, on average, 10 are adults large enough for sexual maturity (>750 mm), and display no current markings or tags indicating a hatchery origin. These fish are assessed at Blind Pony State Fish Hatchery to determine gender and reproductive status. Since pallid sturgeons do not reach sexual maturity until at least seven years of age, and only spawn every two or three years, there are usually only a handful of fish that end up being used in the spawning efforts each year. However, each fish produces thousands of eggs, which produce larval fish that are stocked in the river. To date, there have been around 140,000 pallid sturgeon stocked into the Missouri River below Gavin's Point Dam. Many of these are recaptured years later and are reproductively ready themselves. This is all part of an effort by the USACE' funded Missouri River Recovery Program, which is working to reestablish the population of this endangered species.

Other crews, including USFWS, Nebraska Game and Parks Commission, and MDC Fisheries Biologists, also collect broodstock pallids. All pallid sturgeon used in the spawning efforts were genetically verified by Southern Illinois University and USFWS to make sure they are not related to previous hatchery fish, and not related to each other, prior to the spawn. Fish deemed not reproductively ready or of hatchery relatedness are released back to the river near where they were sampled.

Overview

Shaped and molded by the flow of water or weathering such as wind erosion and freeze and thaw cycles, cliff and talus communities are unique. Both communities are characterized by exposed rock and are associated with escarpments, river floodplains and streams, and karst features. These highly variable communities are influenced by the slope and aspect of the rocky features as well as the degree of shading, type of bedrock, and groundwater seepage. Plant and animal community composition can differ greatly across the spectrum of different slopes, aspects, bedrock type, etc.

Cliffs are steep or upright exposures of bedrock or loess soil generally greater than 10 feet high. These communities vary in type depending on the bedrock exposed, which could include chert, limestone-dolomite, sandstone, and igneous. Soft-stemmed plants are scarce in these communities, but they do exist, often growing in the crevices where soil may be present. Mosses and liverworts (small, flowerless green plants) and lichens are often plentiful on the exposed rock surfaces. Many species will use cliffs to raise young and forage as this natural community represents an "enemy-free" space for many mammals. Talus is the rubble of weathered bedrock that collects at the cliff base. Limestone-dolomite and igneous talus communities are most common in Missouri.

Bird, amphibian, and reptile species use cliffs and talus slopes as a part of their life history. For example, many bird species have historically used cliff faces for nesting, although many of these same species can be found nesting in most any human structure. Similarly, cliff and talus provide shelter, overwintering hibernacula, and places to thermoregulate for amphibians and reptiles.

Cliff and talus communities are not typically actively managed but, rather, are managed through the preservation and management of the natural communities surrounding them. As such, there are no COAs identified for this community type and no "Management Actions" included in this cliff and talus chapter.

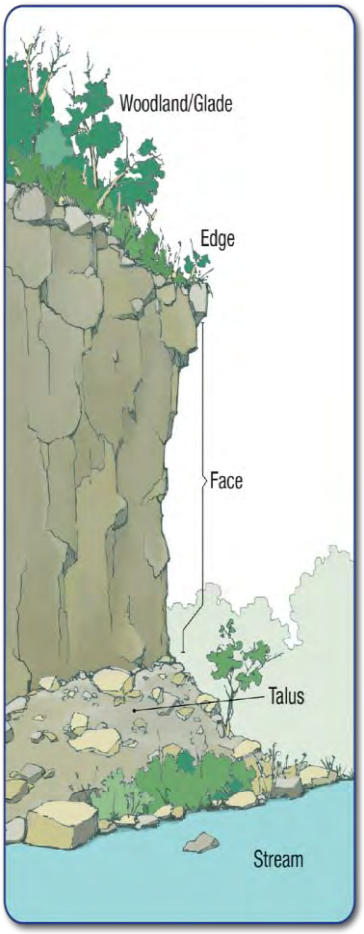


Figure 4.8.1 – Illustration of a cliff and talus community, depicting key landform features.

Species of Greatest Conservation Need

Plants

Wild sarsaparilla (*Aralia nudicaulis*) * Bradley's spleenwort (*Asplenium bradleyi*) * Mountain spleenwort (*Asplenium montanum*) * Lobed spleenwort (*Asplenium pinnatifidum*) * Maidenhair spleenwort (*Asplenium trichomanes ssp. trichomanes*) * Yellow screwstem (*Bartonia virginica*) * American barberry (*Berberis canadensis*) * Oferhollow reed grass (*Calamagrostis porteri ssp. insperata*) * A leafy liverwort (*Calypogeia sullivantii*) * Harebell (*Campanula rotundifolia*) * Alabama lip fern (*Cheilanthes alabamensis*) * Wooly lip fern (*Cheilanthes tomentosa*) * Marine vine (*Cissus trifoliata*) * Golden corydalis (*Corydalis aurea ssp. aurea*) * Fragile fern (*Cystopteris tenuis*) * Intermediate shield fern (*Dryopteris intermedia*) * Woodland strawberry (*Fragaria vesca*) * Northern bedstraw (*Galium boreale*) * A rockrose (*Helianthemum canadense*) * Cherrystone snail (*Hendersonia occulta*) * Small-flowered alum root (*Heuchera parviflora var. parviflora*) * A liverwort (*Jungermannia leiantha*) * A liverwort (*Kurzia pauciflora*) * A liverwort (*Kurzia sylvatica*) * Round-branched clubmoss (*Lycopodium dendroideum*)* Ground cedar (*Lycopodium tristachyum*) * A liverwort (*Marsupella sullivantii*) * A liverwort (*Metzgeria furcata*) * A liverwort (*Nardia lescurii*) * A liverwort (*Odontoschisma denudatus*) * Broom whitlow-wort (*Paronychia virginica*) * Missouri cliffbrake (*Pellaea glabella var. missouriensis*) * Hoary mock orange (*Philadelphus pubescens var. verrucosus*) * Amethyst shooting star (*Primula fassettii*) * French's shooting star (*Primula frenchii*) * False bugbane (*Trautvetteria caroliniensis*) * Ozark arrowwood (*Viburnum bracteatum*) * Smooth white violet (*Viola pallens*) * Blunt-lobed woodsia (*Woodsia obtusa ssp. occidentalis*) * White camas (*Zigadenus elegans glaucus*)

Characteristic:

Goat's beard (*Aruncus dioicus*) * Cedar sedge (*Carex eburnea*) * Small leather flower (*Clematis versicolor*) * Hay-scented fern (*Dennstaedtia punctilobula*) * Small-flowered alum root (*Heuchera parviflora var. puberula*) * Fir clubmoss (*Huperzia porophila*) * Ashe's juniper (*Juniperus ashei*) * Partridgeberry (*Mitchella repens*) * Common polypody (*Polypodium virginianum*) * Forbe's saxifrage (*Saxifraga pensylvanica var. forbesii*) * Sullivantia (*Sullivantia sullivantii*)

Mollusks

Cherrystone snail (*Hendersonia occulta*)

Insects

Characteristic:

A paper wasp (*Polistes annularis*)

Birds

Peregrine falcon (*Falco peregrinus*)

Characteristic:

Turkey vulture (*Cathartes aura*) * Barn swallow (*Hirundo rustica*) * Cliff swallow (*Petrochelidon pyrrhonota*) * Eastern phoebe (*Sayornis phoebe*) * Northern rough-winged swallow (*Stelgidopteryx serripennis*)

Threats and Challenges

Cliff and talus communities in Missouri face similar threats and challenges as most other natural communities. Development, disturbance, and invasive species pose the greatest threats to cliff and talus systems, many of which have endemic rare species and relic communities.

Development and Sensitivity to Disturbance

Commercial and residential development pose a threat to cliff and talus communities. Industries such as quarrying or reservoir development can completely destroy or transform cliff and talus habitat. Furthermore, destruction of wooded buffers below and above cliff face or talus slopes can significantly disturb community composition and hydrology. Finally, while recreation can be a great way to enjoy Missouri's natural communities, special care should be taken when choosing sites for rock climbing as this activity can reduce lichens, mosses, and ferns on high integrity cliffs and can even cause the extirpation of endemic cliff species. Rock climbing should be reserved for less biologically significant areas.

Invasive Species

Many cliff and talus species can be endemic to the natural community or restricted geographically within the community. Vascular plant, bryophytes, and lichens in these natural communities have adapted to living in areas where most species cannot. As such, invasive plants pose a particular threat to these species because they can take over what little area these endemic species can persist in.

Reptiles that use talus for hibernation and thermoregulation lose critical habitat when invasive species shade out areas previously containing exposed rock. Invasive encroachment in cliff and talus natural communities can restrict the availability of structures needed for reptiles and amphibians and alter the microclimate. Bush honeysuckle (*Lonicera maackii*), Japanese hops (*Humulus japonicus*), garlic mustard (*Alliaria officinalis*), and downy chess (*Bromus tectorum*) can outcompete and shade out these rare cliff and talus endemics.

Management Actions and Opportunities

Cliff and talus communities are not typically actively managed given the difficulty and logistics associated with their physical structure. Their management is heavily dependent on the preservation and management of the natural communities surrounding them. Fortunately, their physical structure also helps protect them from some environmental threats. Regardless, these are key communities across Missouri that must be conserved and monitored.

Dolomite Cliff and Talus

Case Study: Grand Bluffs Natural Area
Location: Missouri River Hills COA

The 177-acre Grand Bluffs Natural Area is recognized as the best quality occurrence of a dolomite cliff and talus community north of the Missouri River. The bluffs tower 300 feet above the Missouri River floodplain, carved by the historic meandering of the river over thousands of years. The vertical slopes of the bluffs are devoid of vegetation, but a variety of species live in the harsh conditions of the small cliff edges and shelves, where small amounts of soil have accumulated. Eastern redcedar is the dominant tree species in these locations, and herbaceous vegetation like little bluestem, side oats grama, bristle-leaved sedge, and purple cliffbrake are also present. Below the bluffs is a steeply sloped, forested dolomite talus made up of rock fragments that have broken from the bluff face over time. Sugar maple, chinkapin oak, basswood, red oak, and bladdernut are all present here; ground flora is sparse but Virginia creeper and wild grape vines are common.

To preserve the cliff natural community, area users are prohibited from rock climbing or rappelling. Recreation such as hiking is discouraged on the talus, since very little disturbance is needed to cause rockslides and tree falls. Even the use of prescribed fire is limited due to the tenuous nature of the rubble of the talus. The Katy Trail State Park runs adjacent to the boundary of the talus portion of the natural area and MDNR is responsible for keeping the trail clear of debris and clear of users when management occurs that may cause concern for safety.

Active management of the dolomite woodlands and glades above the bluffs supports a continuum of healthy natural communities. Periodic prescribed burns have been implemented above the bluffs, but the steep topography and erratic wind conditions make for unpredictable fire behavior, which has allowed undesirable species to grow into the woodlands and glades. Sugar maple and redcedar removals were recently completed. These fire intolerant trees have been able to grow large enough that the periodic prescribed burns will not carry well under their shade or kill them. By removing these trees, more sunlight reaches the ground, stimulating the diverse woodland and glade vegetation, and allowing for better burning conditions in the future.

Sandstone Cliff and Talus

Case Study: Hickory Canyons Natural Area
Location: Hickory Canyons Sandstone Glades COA

Hickory Canyons Natural Area conserves 1,134 acres of rugged sandstone cliff-lined valleys that span 350 feet of relief from sand-bottomed perennial creeks to dry rocky outcrops with old-growth shortleaf pines. Both dry and moist sandstone cliffs occur here and support distinct assemblages of lichens, mosses, liverworts, ferns, and flowering plants. The area's sandstone features are formed from LaMotte Sandstone, which originated 500 million years ago.

The area has long been known as a botanical hot spot and boasts over 500 native species of vascular plants, 47 liverwort species, and 119 moss species. The area's cliffs and sandstone forests support over 25 plant SOCCs and two salamander species too. The area is rich in ferns with over a dozen species, like royal fern, found here. A number of these species are considered glacial relicts. Glacial relicts are species that were more common in Missouri 12,000 years ago during the last Ice Age. Since then, the climate has warmed, forcing some species to inhabit micro-climates that mimic the cool, moist conditions of glacial times. Glacial relicts at Hickory Canyons include hay-scented fern, fir clubmoss, and winterberry.

This area is owned by the L-A-D Foundation but has long been managed in partnership with MDC. Incorporated in 1962, the L-A-D Foundation is a Missouri private operating foundation dedicated to the responsible management of Pioneer Forest as a working demonstration of renewable resource use compatible with the long-term carrying capacity and health of the land and water. The Foundation also acquires and preserves in the public interest outstanding areas of natural, geologic, cultural, or historic interest and provides support to various projects consistent with its conservation goals, with a particular focus on the Missouri Ozark region.

The area has 1.5 miles of hiking trails to allow for area users to appreciate the area without causing excessive damage to the highly erodible sandstone exposures. To preserve the cliff communities, area users are prohibited from rock climbing or rappelling. After a rain event, wet-weather waterfalls can be enjoyed from viewpoints on the hiking trails, and in the spring

the headwater creeks here are a good place to spot a Louisiana waterthrush.

In stark contrast to the damp sandstone cliffs and valley floor dominated by mesic woody species such as northern red oak, blue beech, paw paw, and spicebush, the ridge tops and bluff ledges are xeric in nature and dominated by fire-adapted vegetation, including shortleaf pine, farkleberry, little bluestem, and goat's rue. Recently MDC and the Foundation have begun restoring the dry sandstone woodlands and glades with select understory thinning and prescribed fire. Prescribed fires are allowed to back down off the dry ridges into the moist valleys as much as possible to emulate historical fire patterns that would not have damaged the mesic vegetation on the valley bottom.

Missouri's Natural Areas

The mission of the Missouri Natural Areas Program is to conserve and sustain the best remaining examples of Missouri's natural communities and geological features as designated Missouri Natural Areas (NAs). Designated Missouri NAs are recognized by an inter-agency committee, the Missouri Natural Areas Committee, which was created by MDC and MDNR in 1977. Today, the committee consists of these agencies as well as MTNF, the Ozark National Scenic Riverways, USFWS, and TNC. Designated Missouri NAs are natural communities and/or geologic features recognized for their natural qualities deserving of special recognition, protection, and management.

There are 192 Missouri NAs on 98,435 acres that conserve an array of natural communities from springs and fens to glades and prairies. Populations of over 300 plant and animal SOCCs including many federally listed species such as the Hine's emerald dragonfly and Niangua darter find appropriate habitat on Missouri NAs. Two-thirds of all Missouri NAs and over three-quarters of the total NAs acreage occur in a COA.

Missouri NAs have multiple values, including conserving reference sites of high-quality natural communities, providing habitat for specialist species, and allowing for appropriate public recreational uses. Missouri NAs are an important facet of an overall effort to conserve Missouri's natural heritage. Typically, Missouri NAs provide scientific benchmarks and restoration models and sources of restoration materials (e.g., native seed) for conservation actions occurring in the surrounding landscape of COAs. Many of the earliest efforts at natural community restoration (e.g., redcedar removal and prescribed fire on glades) began on Missouri NAs. The inter-agency Missouri Natural Areas Committee has been a leader in the development of Missouri's terrestrial natural community classification, including publishing the book *The Terrestrial Natural Communities of Missouri* (Nelson 2010).

Designated NAs are owned by local, state, and federal agencies; private conservation organizations, other entities, and private landowners. The MDC owns 96 designated NAs totaling 43,663 acres. MDC also manages an additional 2,952 acres of designated NAs owned by other entities. After MDC, MDNR is the second- largest designated natural area owner, with 24,294 acres on 35 sites. Nearly all Missouri NAs are open to public visitation. For more information on these, please consult the online directory of Missouri NAs at **nature.mdc.mo.gov/discover-nature/places/natural-areas**.

Figure 4.9.1 – Missouri Natural Area Locations

Developing and Implementing Community and Landscape Health Indices.

Efficient and effective monitoring programs are essential tools for assessing management and achieving conservation goals. Unfortunately, the large number of SGCNs and the resources that must be devoted to monitoring these species often make monitoring a limiting factor for conservation agencies and partners. An adaptive management approach to the restoration and management of natural communities requires that we define what we are monitoring, why we are monitoring, and how we are monitoring with specific objectives.

Conservation partners utilize monitoring of both species-specific and ecological or natural community level scales. Monitoring attributes of natural communities provides for a "pulse-check" of the health of an ecosystem. We monitor natural communities based on attributes of vegetation structure and composition, and for characteristic, easily observable plant and animal species. This serves as a "coarse-filter" for representing larger groups of native plants and animals, especially invertebrates (Panzer et al. 2010), for which we have little information and cannot practically monitor on a species-specific level.

MDC has developed models of different natural community types based on attributes of ecological integrity (Faber-Langendoen et al. 2016; Faber-Langendoen et al. 2019) including landscape context, vegetation composition and structure, characteristic and remnant-dependent species such ashabitat specialists or conservative species (*sensu* Matthews et al. 2015), and negative disturbance factors (e.g., invasive exotic species infestations). These CHI models take a more quantifiable approach to methods of evaluating the natural "quality" of natural communities than are often used during assessments of habitat by ecologists in state natural heritage programs.

The CHI models for terrestrial natural communities (see **Appendix I** for a list of available and planned CHI models and an example) evaluate and score the following metrics:

- Landscape context and site size
- Vegetation structure (both horizontal and vertical and by physiognomoic group)
- Characteristic plant species and their relative abundance
- Habitat specialist animal species presence/absence
- Negative disturbance factors (e.g., invasive species)

Different factors of the natural community are weighted more heavily than others such that the total CHI score for a site consists of 75 percent vegetation metrics, 10 percent animal metrics, and 15 percent landscape metrics. Vegetation is the most easily observed and readily changeable component of a natural community that in turn directly influences the animal species composition. Hence, it is weighted more heavily.

Evaluating the response of a management unit to, say, a prescribed burn regime can range from observational notes to a full-blown replicated experimental design. Only the latter type of study can fully establish cause-effect results. Wildlife biologists and foresters need something less costly and time intensive than research projects but that still yield useful data to track changes in management units through time to assess success toward management goals.

To date, MDC has developed (and MDC and partners have field-tested) CHI models for the following natural community types (Nelson 2010): glades (dolomite, igneous, limestone,

sandstone), upland tallgrass prairie (glaciated and unglaciated regions), hardpan/claypan tallgrass prairie (glaciated and unglaciated regions), loess hill prairie, Ozark woodland, glaciated plains savanna, and glaciated plains woodland. Field staff and taxa experts as well as ecologists have been involved in the process of refining and vetting the CHI models. Initial focus has been on developing CHI models for upland, fire-adapted natural communities. Thus far, MDC, along with the MPF and Missouri Western State University, have evaluated 8,080 acres of natural community sites with CHI models (see **CHI Case Study** below).

In addition to the CHI models, MDC is working with partners to develop LHI models that will characterize the health of habitats and species at broader scales (e.g., at the COAs' level, which have a mean acreage of approximately 59,000 acres). Rooted in adaptive management and structured decision making, the LHI models have three key features that will contribute to the planning and monitoring goals of the CCS:

- LHI models integrate key elements of landscape health, including biotic integrity, ecological stressors, and landscape condition while also addressing societal elements.
- This summary is based on a value function with weightings reflecting conservation priorities.
- LHI models provide a flexible, modular framework for selecting suitable data and analyses to quantify indicators of health across landscapes.

For example, current LHI models include factors such as:

- Associations between stream nutrient dynamics and land use
- Community-level measures of metapopulation capacity based on habitat mapping
- Occupancy, abundance, and trend modeling for multiple animal and plant taxa
- Human dimensions research

These indices are also structured by habitat systems to directly communicate with the CCS and reflect the prioritization of different natural communities among landscapes. The LHI models will therefore be useful for identifying:

- Key drivers of landscape health
- Focus areas for preservation or restoration
- An approach for selecting among conservation actions based on indices and the common currency of stakeholder value
- Tracking success and assessing when priority should shift to another landscape

Current LHI models use many sources of data including field sampling as well as citizen science efforts. Biotic integrity incorporates the abundance of birds and herpetofauna from roadside counts, diversity indices of fish species from stream sampling, and occupancy of plant species from the CHIs. Terrestrial landscape and stream condition are quantified based on (1) habitat amounts and conditions from remote sensing and forestry plot data, and (2) data on stream habitat and water quality from sampling and hydrologic modeling, respectively. The long-term nature of the LHI program allows the flexibility to continually explore new data that could inform landscape health.

It should be noted that CHI and LHI models are not meant to replace existing monitoring protocols for SGCN. Established monitoring programs for SGCN will continue, and new programs will be initiated as funding allows. These models provide coarse-level data on the ecological integrity of various natural communities and landscapes and serve as "coarse-filter" approaches to monitoring as

opposed to the "fine-filter" approach of species-specific monitoring. Both types of monitoring are necessary and are complementary for assessing conservation action effectiveness.

It is important to understand that both the CHI and LHI models are not meant to compare one natural community/landscape to another, but, rather, to compare a natural community/landscape to itself over time as an evaluation of "health" in response to changes resulting from conservation outreach, effort, investments, and actions.

Figure 4.10.1 – Example of Potential LHI Dashboard Scoring Display

Case Study: Missouri Western State University Glade CHI Project

Between 2016 and 2018, faculty and students with the Missouri Western State University contracted with MDC to conduct CHIs at 51 limestone, dolomite, or igneous glade sites (totaling 866 acres) on nine MDC CAs, including seven designated Missouri NAs. These sites were located within glade and/or woodland COAs in the Ozarks. Vegetation, herptiles, and birds were surveyed at each site as per CHI protocols. These data provided area managers with baseline data for future management planning and were used to update community records in the Missouri Natural Heritage Database.

The mean CHI score was 82.9 ± 1.2 standard error of the mean (SEM) with the lowest score being 52.8 and the highest 97.6. Three herptile species total and two target herptile species were encountered, on average, per glade site. Overall avian richness did not vary strongly based on bedrock substrate or burn history. Most glade sites had between seven and ten bird species present (during the breeding season). The SOCC and SGCN eastern collared Lizard (*Crotaphytus collaris*) was documented from seven glade sites. Other SOCCs documented included purple beard-tongue (*Penstemon cobaea*) and painted bunting. Unfortunately, Bachman's sparrow, a SOCC on the target bird list was not encountered in either year. There was a strong correlation between CHI scores and the number of prescribed fires a glade site received between 2006 and 2018 ($r^2 = 0.288$, $p = <0.001$). The total CHI score was positively correlated with target herptile species richness ($r^2 = 0.319$, $p = 0.001$).

Section Five: Community Conservation

In a nutshell: The term "community conservation" refers to the incorporation of nature into community landscapes and infrastructure for the benefit of people and the natural resources. The process of incorporating nature into communities involves engaging local governments, citizens, and private organizations to connect people with nature, raise awareness of the benefits provided by healthy ecosystems, promote conservation of these resources through technical assistance, and encourage development practices that protect natural diversity.

Communities and conservation may seem incompatible, even divergent, at first glance. But in Missouri, these are viewed as symbiotic. Communities need conservation practices and improved and sustainable natural resources to thrive; our shared natural resources need continuous and enthusiastic investment of stewardship by communities, both locally and throughout the state. Community conservation in Missouri's CCS is expanded to include all community entities across the entire state of Missouri, both urban and rural, and including private and public lands. Here, Missouri itself is a community of conservationists working together to maintain, preserve, and enhance Missouri's natural resources.

Community conservation in urban and suburban landscapes provides residents with a connection to nature and nurtures support and appreciation for conservation actions taking place outside the urban environment. Community conservation provides citizens with opportunities to manage native plants and ecosystems in a comfortable, accessible environment. Community gardens, greenways, greenspaces, and city parks provide residents a way to bring nature inside their community. Networking community partners work together to simultaneously eliminate invasive species and plant native species, providing food and habitat for native birds, pollinators, and other urban wildlife.

Missouri's conservation partners act as stewards to facilitate conservation action and maintain progress in building healthy urban ecosystems. MDC prioritizes community conservation specifically as part of the *Design for the Future* strategy 1.2: Implement a community conservation strategy. Several programs support partner conservation efforts in communities, including: Tree Resource, Improvement, and Maintenance (TRIM) grant, the Community Conservation Grant (CCG), and the Urban Cost-Share Assistance Program. Each of these programs offers opportunities for funding and technical assistance to partner entities who want to implement conservation practices. Partners include (but are not limited to) municipal and county parks departments, not-for-profit organizations, neighborhood organizations, school districts, watershed management associations, and land trusts.

Missouri communities have an abundance of partners who share common goals to improve the quality of life for all residents. Successfully implemented, community conservation works in a cyclical nature to benefit both communities and natural resources.

Desired Future Conditions

1. Healthy, enhanced, and sustainable urban/community natural spaces such as forests, prairies, riparian areas, and wetlands, which support desirable and environmentally healthy places of residence for Missouri citizens.
2. Urban and community natural spaces contribute significantly to minimizing stormwater runoff, improving air quality, reducing heat islands, reducing energy consumption, and more.
3. Trees, forests, streams, riparian areas, prairies, and wetlands are viewed as important components of city and community infrastructure needing to be maintained, included in planning efforts, and supported with public and private funds.

Conservation Pays Dividends to Missouri Communities

Developed and developing areas face numerous challenges that are exacerbated by increased infrastructure and impervious surface, density of population, and air quality issues. Implementing conservation strategies can mitigate some of the negative impacts of increased development on communities. These ecosystem services help to solve community-wide problems and thereby improve quality of life for residents, with the most notable: stormwater mitigation, carbon sequestration, public health, and pollinator services.

Conservation in Communities Mitigates Flooding and Improves Air Quality

Trees, forests, streams, riparian areas, prairies, and wetlands not only make cities cool, green, and beautiful, they also perform vital services that would otherwise cost cities money. Trees clean the air by reducing carbon monoxide and dioxide, ozone, and other pollutants. Trees, prairies, and wetlands reduce stormwater runoff volumes and associated problems through filtration, interception, and evapo-transpiration. Trees in communities lower energy demands by shading buildings and cooling the air. Faced with the costs of engineering clean air, handling stormwater, and cooling buildings, many cities are discovering that planting, protecting, and maintaining trees, prairies, and wetlands is a real bargain.

In 2011 an Urban Tree Canopyassessment was conducted by the Wisconsin DNR for the town of Ashwaubenon, using i-Tree Streets. Ashwaubenon has an overall tree canopy of 19 percent. This tree canopy provided Ashwaubenon with the following benefits:

- 5.3 million gallons of stormwater intercepted for a savings of $143,746 in stormwater treatment costs
- 721 tons of atmospheric CO2 captured for a savings of $19,280
- 7,322 tons of atmospheric carbon stored for a savings of $109,830
- 404 pounds of particulate matter, 757 pounds of ozone, 34 pounds pounds of sulfur dioxide, and 129 lbs of nitrogen removed from the air annually for a savings of $24,561.
- A single large tree can provide approximately $76 in average annual benefits, and $3,000 in benefits over a 40-year period
- Property values increased annually by $154,686

Prairie habitats are effective tools for community stormwater mitigation and carbon sequestration as well. Researchers at University of Missouri and MPF have found the dense and deep root structures of prairies can absorb 6–8″ of rainfall in a 24-hour period. In addition, mature undisturbed prairies store more carbon below ground than forests can store above ground. Prairie reconstruction and restoration, both large and small, can make a big difference to communities facing frequent flooding and air quality issues.

In St. Louis, MDC partnered with the Archdiocese of St. Louis to restore the last remaining prairie remnant in the city. The 24-acre prairie remnant is located in the Archdiocese's Calvary Cemetery. Following

Prescribed fire at Calvary Cemetery in northern St. Louis City. Photo by David Carson. Photo courtesy of *St. Louis Post-Dispatch*

extensive outreach to the local community, MDC conducted several prescribed fires at the site between 2010 and 2020. The prairie has become a valued asset to the larger community, which demonstrates support and enthusiasm for the project and management strategies such as use of prescribed fire.

The prairie at Calvary Cemetery is adjacent to the Baden neighborhood, one of four neighborhoods in the City of St. Louis that has experienced extensive flooding and high vacancy levels over recent decades. As a result, Green City Coalition was formed to plan and implement solutions to these widespread neighborhood problems in areas of St. Louis. This coalition is a formal partnership between MDC, the City of St. Louis, St. Louis Development Corporation, and Metropolitan St. Louis Sewer District. These entities work collaboratively with neighbors to convert vacant and abandoned properties to new community-owned green spaces that promote healthy, biodiverse, and resilient neighborhoods.

The Blue River partnership in Kansas City, MO, led by The Heartland Alliance, brings together organizations and citizens to protect and restore the Blue River and its surrounding watershed. From tree planting programs, trash cleanups, and stewardship education to land conservation in the headwaters, communities collectively aim to "Renew the Blue." The Blue River Watershed drains approximately two-thirds of the Kansas City metropolitan area. This partnership is a powerful tool to improve water quality, riparian corridors, and recreational access to the Blue River along a 41-mile stretch.

Just as streets, sidewalks, and sewers are parts of a community's crucial infrastructure, so are community trees, prairies, streams, and wetlands. Like all other components of a community's infrastructure, urban and community natural spaces require care and maintenance to function properly in the future.

Healthy Natural Communities, Healthy Lives

Natural communities and functional habitat for native flora and fauna are scarce in most urban centers. Where present, these small islands of the natural world possess significance out of proportion to their size because of what they

As part of the Blue River partnership, volunteers work to clean up debris and control invasive species at Blue Valley Park in Kansas City, MO. Photo by Jill Erickson, Heartland Conservation Alliance

represent: the promise and presence of nature, however limited, in the midst of turf, concrete, and millions of people. This significance is increasingly recognized as research continues to inform understanding, identifying that, individually and collectively, these areas have intrinsic value and contribution to human health. Nature's connection to public health is a new and quickly emerging field. Many physicians across the country are prescribing "time in nature" for certain types of illness. Communities, schools, and neighbors are designing wellness gardens to promote time in nature and well-being. Arbor Day Foundation is even looking at a recognition program for health care facilities that promote healing from the outdoors and trees.

A USFS report from 2018 looked at multiple studies concerning trees and human health. The report was broken into five categories: (1) pollution and physical health, (2) active living, (3) mental health, (4) stress reduction, and (5) social health, cohesion, and resilience. Below is a quick summary of each category:

Pollution and Physical Health

- Increase in tree canopy can have a direct effect on air quality and the urban heat island effect by filtering out pollutants and reducing temperatures, both of which contribute to smog.

Active Living

- Research points to the fact that more trees and green space in a community may promote increased outdoor activity. Increased physical activity can reduce many common health problems such as heart disease, high blood pressure, and obesity.

Mental Health

- Exposure to trees and nature have been shown to decrease depression, anxiety, and mood disorders. Short exposures to nature can increase cognitive functioning.
- Studies have shown that views and exposure to nature can increase child test scores and improve ADHD in some children.

Stress Reduction

- Views of nature and being outside have been shown to effectively reduce stress.

Social Health, Cohesion, and Resilience

- Living memorials, such as trees, help people cope with loss
- Green space and trees greatly improve cohesion and interaction between neighbors
- Equal access to nature seems to remedy some health disparities between low- and high-income neighborhoods.

The Value of Nature in a Time of Crisis

At the time of drafting the Missouri CCS, the nation and the world are engulfed in the COVID-19 pandemic. Through this difficult time, the importance of conservation and nature-related activities has been proven to be important to human health in a manner that we may not have realized otherwise.

Although this is a very difficult time, the COVID-19 pandemic has truly demonstrated the relevance of conservation and nature to human health. Visitation to public lands in Missouri and across the nation has drastically increased. Families are searching for ways to get out of the house, exercise, and relieve stress. While unfortunately certain local parks in the highly populated areas of Missouri had to close due to the density of visitors and the difficulties of social distancing, the message is clear: residents in Missouri cherish their outdoor spaces. Conservation isn't optional; it's essential to human well-being in times of crises.

Pollinator Services Support Healthy Food Production in Urban Areas

Many wild bee species across the United States and around the world are in decline, and many of Missouri's wild bee species may be imperiled more than we realize. In Missouri's cities, the value of bees and pollination is no less important but often underappreciated, under-studied, and even unrecognized. Gardening in urban areas, from the community garden down to the backyard and up to the rooftops, is becoming increasingly popular and important on a self-subsistence as well as an economic level. Our knowledge of native bees in cities and their importance to wildlife conservation and urban agriculture indicates that cities are playing a crucial role as a refuge for a diversity of native bees.

Beginning in 2013, MDC partnered with researchers at Saint Louis University to survey native bee diversity in the City of St. Louis. After surveying methodically at 28 locations over the course of 4 years, the research team discovered that St. Louis City (which represents only 0.09 percent of the state's landmass) hosts nearly 45 percent of Missouri's bee diversity, or 201 species out of 450 native bees found in the state (Camilo et al. 2017).

Particular areas of St. Louis revealed greater diversity and abundance of bees because those areas provide higher quality habitat. Neighborhoods with blocks of manicured lawns had significantly less bee diversity than neighborhoods with varied landscape. In other words, when homeowners grow native flowering plants and vegetables in their yard and allow their lawn to grow "a little more wild," bees, as well as other wildlife, benefit.

In addition to the exciting abundance of species, St. Louis is also home to some rarely occurring bees, including *Bombus fraternus*, or the Southern Plains bumblebee, whose population has declined 85 percent from historic levels. Realizing the diversity and potential for bee conservation in St. Louis motivated partners at Saint Louis University, with support from MDC, to conduct workshops with city residents on native bees and how to help support bee diversity. City residents were receptive and enthusiastic about planting with bee diversity as a goal. Most native bees are small and solitary, with a small foraging range; many can live their entire lives in an area the size of an average city yard, provided there is a diversity of flowers. This fact makes bee conservation a global issue where one person can indeed make a difference.

Similar native bee monitoring efforts in Independence and Kansas City, MO, are leading to better informed management of natural spaces. MDC partnered with Kansas City Parks and Kansas City Wildlands/ Bridging The Gap to monitor bees at several locations, including Jerry Smith Park. During the 2016 survey of Kansas City area bees, researchers noted a relative absence of stem nesters, particularly *Ceratina* spp. (Apidae) and *Hylaeus* spp. (Colletidae) in the park, despite the presence of a managed prairie. The partnership hypothesizes that burning, an essential tool for prairie management, might damage this group of bees

Gerardo Camilo, PhD, led the team of researchers studying native bee abundance and diversity in St. Louis, MO. Photos by Douglas Garfield and Noppadol Paothong

whose larvae overwinter in dry stems when the entire prairie is burned at once. In response to this, KC Parks and KC Wildlands, in conjunction with MDC, have developed a management technique aimed at facilitating the survival of more stem nesting species. During the winter of 2019/2020, management personnel set aside six small patches of the prairie as stem nester refugia. These patches were left intact while the rest of the prairie remnant was burned according to traditional management protocol. Another section of the prairie was burned without the designation of stem nester refugia. The partnership effort will help better inform management of prairies for the benefit of pollinators throughout their ranges (Arduser 2016).

Researchers have observed that a fundamental concern over pollinator health was a significant motivator for city residents to plant more flowers to support native bee diversity. Also, residents noticed that companion planting of native flowers helped them grow more and better homegrown vegetables. Improved tomato harvest from backyard gardens was a big motivator to home gardeners to plant native flowers. Ultimately, the consistent predictor of urban bee health is floral resources; bees need an abundance and diversity of flowers suitable for forage – emphasizing the need for the inclusion of a diversity of native flowers in urban and suburban landscapes. With this in mind, the potential for bee conservation in the city is real and significant: a diversity of people, with a diversity of flower preferences support a diversity of insect pollinators.

Missouri Communities Invest in Conservation

Missouri communities are fortunate to have varied and numerous community organizations that value conservation. From educational institutions to charitable organizations, from large to small, and from statewide to local, partner efforts drive conservation efforts in communities. In addition, MDC administers community conservation assistance programs as a tool to bolster partner conservation efforts in Missouri's communities. Among partners, missions may vary, but all partner entities can agree on the common goal of building quality communities for everyone. The long-term work of community conservation depends heavily on increasing partnerships. In time, partnership investments in conservation grow as community members take ownership of conservation projects and build capacity to expand their efforts.

Benchmarks for Measuring Success

While there remains much work to be done to develop proactive conservation programs in Missouri communities, great progress has been made. The number of communities certified in the Tree City USA Program has grown from 66 in 2003 to 110 in 2020. Collectively, approximately 45 percent of Missouri's population resides within these 110 communities.

The Tree City USA program is sponsored by The Arbor Day Foundation in cooperation with USFS and the National Association of State Foresters. It provides direction, technical assistance, public attention, and national recognition for community forestry programs. To qualify as a Tree City USA, a community must meet four standards:

1. Designate by ordinance a tree board or forestry department to be legally responsible for care of public trees.
2. Adopt a tree-care ordinance that determines public tree care policies for planting, maintenance, and removals. The ordinance also designates the board or department responsible for writing and implementing an annual community-forestry work plan.
3. Show an annual expense of at least $2 per capita for tree management.
4. Hold an Arbor Day event, complete with an Arbor Day proclamation.

These four standards set the framework for a sustained community forestry program that proactively manages its tree infrastructure.

Figure 5.1 – Missouri Tree City USA Community Locations.

USFS uses a similar, but different benchmark system for categorizing communities based on the following performance items:

1. Community has a **tree ordinance and/or policies** that are codified and followed. The intent is that the ordinance and/or policies guide the community in the proper care, establishment, and protection of community trees and forests.
2. Community uses **professional staff** that has education, training, and experience in the fields of urban forestry, arboriculture, and/or horticulture. Professional staff is defined as someone with a degree in urban forestry or a closely related field (e.g., forestry, horticulture, arboriculture, etc.), and/or who is an International Society of Arboriculture Certified Arborist, or who has equivalent professional certification.
3. Community has a **current tree inventory or management plan** that outlines the future management of the community's trees and forest.
4. Community has an **advocacy or advisor organization,** which ensures that community residents and program stakeholders are informed, educated, and engaged in the development and implementation of a sound community forestry program at the local level.

In federal Fiscal Year 2018, 86 Missouri communities were meeting all four elements and were considered to be "managing" their urban forest resources. Thirty-seven communities were meeting from one to three elements and were considered to be "developing" their urban forestry program.

Finally, the impact of the utility industry on the urban forest cannot be overlooked. Interest and growth in the Tree Line USA program have been slow and steady in Missouri, with 12 companies certified in 2018. These 12 certified Tree Lines provide service to 2.5 million residents in Missouri. Tree Line USA is sponsored by The Arbor Day Foundation in cooperation with the National Association of State Foresters. It provides direction, public attention, and national recognition to utility providers who strive to meet the dual goals of dependable utility service and abundant healthy trees along streets and highways. To qualify for Tree Line USA certification, a utility provider must meet five standards:

1. Provide quality tree care by formally adopting work practices that are in compliance with American National Standards Institute (ANSI) A300 Standards for Woody Plant Maintenance
2. Annually train workers to ensure that the work undertaken is carried out in accordance with ANSI A300
3. Have a tree planting and public education program
4. A formal tree-based energy conservation program is in place, putting special consideration on the value of trees in conserving energy
5. Sponsorship of or participation in annual Arbor Day events at the community level are documented, including collaboration with community groups whenever possible

On the ground, these standards lead to improved public resources for community members. The Springfield–Greene County Park System (Parks) recently completed their second TRIM grant. The extensive park system now has 5,000 trees inventoried in their system. With this information kept electronically, park staff can generate work orders (e.g., public complaint about fallen limbs and/or blocked trails or parking areas) within minutes. Prior to completing the inventory, this process took days to weeks. This has allowed park staff to act quickly, saving time and money as well as improving safety to the public and staff.

Community conservation funding opportunities offered by MDC have led to

expanded partner efforts. In 2017, MDC awarded a CCG to the City of Cool Valley, located in northern St. Louis County. The funds supported removal of invasive species and revegetation of a riparian area in a city park. Following completion of the initial project, the adjacent Ferguson-Florissant School, Innovation High School, got involved. Students, staff, and Cool Valley officials completed a planting of native forbs and shrubs to further enhance the habitat while incorporating themes of Missouri ecology into the high school science curriculum.

Students at Innovation School of Cool Valley plant native shrubs and forbs along Ball Creek. The school principal, mayor of Cool Valley, and MDC staff cooperated on the effort. Photos courtesy of Ferguson-Florissant School District.

In 2011, MDC expanded existing partnerships in the LaBarque Creek watershed of Jefferson County, MO, providing assistance to The College School, which had recently purchased property in the area. A grant from MDC allowed The College School to complete glade restoration and invasive species removal along LaBarque Creek. By 2018, the school community had built an outdoor learning center at the site, where all students and their families participate in conservation efforts in the watershed.

The College School students and their mother explore aquatic invertebrates in LaBarque Creek. Photo by Noppadol Paothong.

The Missouri citizenry is a powerful force in urban areas. For example, the cities of Columbia, St. Louis, and Kansas City support citizen tree education programs called the TreeKeepers. In Columbia during the calendar year 2009 this volunteer workforce donated 1,403 hours. As partnerships grow, more communities tap into the powerful resource of their own citizenry to assure healthy, enhanced, and sustainably managed resources in their community.

The City of Springfield has begun the process of classifying green spaces that may be managed in a more cost-effective and beneficial way. Areas that have minimal recreational use will be classified as “urban meadows” and managed as native grass and wildflower areas with minimal mowing. MDC has assisted with CCG funding to help remove nonnative vegetation and replant with natives, emphasizing the planting of

wildflowers for pollinator forage and native grasses for stormwater control.

Surveys and Inventories Inform Approach and Action

MDC conducted surveys in 2004 and 2012 of randomly selected Missourians. The survey, "Urban Forestry in Missouri Communities: Attitudes and Knowledge of Missouri Citizens," showed that the following issues were important to them (Treiman 2015):

- Quality of natural resources
- Having trees lining streets and in parks
- Protecting trees and replacing lost trees during development
- Managing stormwater runoff
- Caring for new trees after planting
- Removing trees that might break and cause injury or property damage
- Planting trees and assisting residents with private trees
- Willingness to pay a tree fund tax with the highest percentage of response being in the $1–5 range, but some respondents in the St. Louis area were willing to pay over $60.
  - When deciding whether to vote for more taxes to pay for tree care, about 80 percent of respondents say the fact that trees help with property values is an important factor.

Three urban tree inventories were conducted by MDC in 44 Missouri towns in 1989, 1999, and 2010. A comparison of results shows significant changes in Missouri's community forests. While some of these changes are positive, it is clear that Missouri's community tree infrastructure needs help:

- Communities have more street trees.
  - In 1989, there were 46.2 trees per mile, in 1999 there were 62.9 trees per mile, and in 2010 64.3 trees per mile. This is an increase, but very slight.
- Missouri's community forests declined slightly in diversity but not a significant amount.

The top six tree species constituted 39 percent of those trees surveyed in 2010, as compared to 37 percent found in 1999 and 46 percent found in 1989. Utilizing a good diversity of tree species is important for reducing the vulnerability of an urban forest to serious insect and disease threats that target specific tree species such as EAB.

Empowering communities to improve and sustainably manage their natural resources is a task that can only be achieved in partnership with others. Success is possible through the effective use of collaborative and synergistic partnerships – working with statewide organizations (i.e., Missouri Community Forestry Council, American Planning Association, Missouri Green Industry Alliance), local partnerships, not-for-profit organizations (i.e., Forest ReLeaf of Missouri, Bridging The Gap, St. Louis Audubon Society, and local municipal governments) and Missouri citizens. Building relationships with individuals in partner organizations leads to trust among partner entities, which leads to greater capacity, which leads to greater shared outcomes.

Conservation and Communities Are Interdependent

Relevancy will define the future of conservation. From MDC's *Design for the Future* strategic plan to the AWFA Relevancy Roadmap, conservation professionals are framing questions about the natural resource management through the lens of relevancy. Work in community conservation pushes the quest for relevancy further; it's not enough to simply be relevant. Conservation needs something in return: support from the people who benefit from it.

To be sure, communicating the relevance of conservation to citizens is critical. Individuals must understand "what's in it for me?" in order to understand the significance of and care about the future of our shared natural resources. Finding the intersection of citizens' wants and nature's needs is an imperative for conservation professionals to continue our work. However, we all need carbon sequestration for clean air. We all need flood control measures and clean water. We all need pollinator services for agriculture, and sustainable fish and game. Recognized or not, conservation is already relevant and significant to all our lives, and we cannot afford to lose these benefits and neglect investment in them.

Conservation needs people to invest – in whatever capacity they can – in regenerative and sustainable resource management. Perhaps this means planting native flowers in an urban yard or lending support for a local park's efforts to plant native trees or reconstruct a prairie. Perhaps this means donating a valuable natural area to a land trust, or purchasing conservation-friendly products at the grocery store. Once citizens realize the relevance of conservation to their quality of life, they are more likely to devote time, effort, dollars, and voter support to the mission.

In turn, conservation partners work with and invest in communities to offer a broader opportunity, beyond the tangible natural resource management objectives. Across the state, conservation partners are working to cultivate a coalition of citizens who actively engage in conservation in their own communities.

Community Conservation Is Exemplified Statewide

Missouri is made up of a diverse collection of ecoregions, landscapes, watersheds, and natural communities. A single watershed, for example, can span many hundreds of square miles, crossing a multitude of properties and jurisdictions. As a result, meaningful long-term benefit to conservation cannot occur in isolation by any single landowner or agency/organization. Fortunately, equally diverse is Missouri's network of private landowners, private businesses, volunteers, NGOs, educational institutions, state agencies, federal agencies, military installations, cities, counties, and others who, collectively, are the very foundation of Missouri conservation success.

Higher order community conservation in Missouri's CCS means constituents across the entire state work together to achieve conservation success. Conservation partners are part of this community and serve as catalysts to incorporate strategic vision and help connect community networks to collaborate on common conservation priorities. In unique ways, these groups partner to facilitate action on conservation projects of varying scale in both urban and rural landscapes. Statewide, the greater community of the state of Missouri is working together in unprecedented ways to improve and sustain Missouri's natural communities and resources, but there remains much progress to be made.

Missouri's landscape is approximately 93 percent privately owned. Approximately 97 percent of the state is classified as rural; however, only around 30 percent of the state's population resides in rural areas. This means the land management activities of a clear minority of Missouri's population have incredible influence over the majority of the landscape, and therefore on the future of natural resource sustainability for all Missouri citizens. As a result, just as important as the support and engagement of urban/suburban citizens, rural citizens must be engaged and supportive of conservation as well. This concept has been discussed in **Section Three: Assessment Theme Three**; however, it is important to recognize the contributions of rural landowners here as a crucial part of community conservation.

Though rural conservation actions may differ in application and implementation, their success or failure is similar to that of urban/suburban areas in that they revolve around important social networks – communities. In these networks, conservation is accomplished by collaborating within a community of large and small landowning neighbors comprised of farmers, ranchers, recreational users, conservation organizations, and others.

There are a variety of tools and actions, some previously described in **Section Three: Assessment Theme Three**, which can be employed in the context of a community network to meet rural landowner objectives while also benefiting conservation. An effective tool gaining popularity is the formation of landowner cooperatives and committees, such as those centered around improving land use practices for the benefit of watershed health (e.g., SCWW – see **Case Study**), or those focused on white-tailed deer, bobwhite quail, or wild turkey management. Landowners also band together through prescribed burn associations and pool their knowledge, personal power, and equipment to help others in their association and community conduct prescribed burns.

These types of committees, cooperatives, and associations are often facilitated and supported by nonprofit conservation organizations that have membership representation in the area, such as PFQF, Quality Deer Management Association (QDMA), NWTF, TNC, MPF, QUWF, DU, Whitetails Unlimited (WTU), and others.

Resulting conservation actions from cooperatives and proactive individuals across the state coalesce into the greater strategy of landscape scale conservation, conserving natural communities and/or increasing connectivity among them, ultimately feeding back into and informing the CCS. By strategically improving

and sustaining landscapes with healthy working lands, watersheds, and natural communities, the community of partnerships across the state aids in ensuring that common species remain common, and rare and declining species and ecosystems recover and persist. Together, the efforts of urban/suburban and rural citizens, supported by conservation organizations and partnerships, increase capacity for Missouri conservation success.

Case Study: City of Columbia, Missouri, Roadside Pollinator Program

The City of Columbia, MO, maintains thousands of acres of public land ranging from restored prairie lands to soccer fields. Specifically, the Public Works Department mows 88 acres of nonnative turf grass located in medians, roundabouts, and along roadsides. Mowing to maintain a lawn is a resource intensive management technique that creates open green space that is ecologically sterile. Mowing produces carbon emissions that contribute to climate change. As the population of Columbia grows, the city anticipates a greater need for more road infrastructure including more grass to mow.

In 2016, the Columbia City Council signed the National Wildlife Federation's Mayors' Monarch Pledge stating that the City of Columbia will take action to restore native pollinator habitat. Following the city's commitment to the Mayors' Monarch Pledge, the Public Works Department decided to reduce their mowing to better service the roads. The idea of a roadside pollinator program was born from this need to decrease the city's mowing costs.

Photo Credit: Danielle Fox

A cost-benefit analysis was conducted to determine if the city would incur additional costs or save money if it was to stop mowing grass and convert roadside vegetation to native habitat. The results of this analysis showed that the annual cost of mowing grass is more expensive than installing and maintaining native vegetation. Mowing 88 acres of grass costs approximately $230,000 to $350,000 per year. These values vary due to weather, fuel costs, and vehicle replacement or maintenance costs. Converting a majority of the 88 acres into native wildflower plantings will drop the city's annual cost of maintenance to approximately $20,000 per year after the native plants have become established. Based on local restoration consultants' fees the initial cost of installing native vegetation is estimated to be $120,000.

As a result of the cost-benefit analysis the city decided to create a citywide Roadside Pollinator Program, which will convert ecologically sterile open space into native prairie strips in medians,

Photo Credit: Danielle Fox

roundabouts, and along roadsides. These sites are highly visible and are aesthetically pleasing for Columbia patrons, but also serve as powerful citizen outreach and education tools that showcase the city's conservation efforts. Public support is necessary for implementing a program such as the Roadside Pollinator Program, and the people of Columbia have been the driving force in the success of this program. To date, the city has converted 29.5 acres of the 88 acres that is mowed annually. Future roadside plantings are scheduled to begin site preparation in 2021 and will continue until the roadside turf, where appropriate, has been converted to native vegetation.

Case Study: A.L. Gustin Golf Course

A.L. Gustin Golf Course was opened by the University of Missouri–Columbia in 1959 as a public course but with the primary aim of serving students, faculty, and alumni of the University of Missouri. Since then it has racked up an astonishing conservation score card. The course was the first college golf course in the United States to be certified by Audubon International and in 1997 earned the status of Cooperative Sanctuary. The area features 29 on-course bird houses, hatching over 3,000 eastern bluebirds (*Sialia sialis*) to date.

Recently, work converting fescue rough into native pollinator plantings has helped earn the University of Missouri–Columbia the designation of Bee Campus USA. It all started when Isaac Breuer, course superintendent, had an idea to cut the cost of maintaining the "rough." Costs add up, between equipment, hours, fertilizer, and gasoline, and Breuer realized that returning the rough to native grass and flower species would require much less maintenance, improve the course aesthetically, and provide valuable pollinator and wildlife habitat.

A.L. Gustin Golf Course native vegetation restoration before and after photos.

Breuer makes the process sound simple. In fact, the only obstacle he sighted was educating course patrons about the transition from fescue to native wildflowers. To aid with communication, signs were posted during the transition period explaining the dead fescue and the coming bloom of native wildflowers. The University of Missouri, Mid Mo Uplanders, MDC, and PFQF chipped in funding for the native seeds; Breuer and his crew already had the herbicide and mowers. Breuer's team started out by spraying the plots in late fall with herbicide to kill the fescue. Then a native seed mix with up to 25 types of flowers was spread in January. Ideally seeding is done in the snow, the cold air helps the seeds sprout, and the seeds stand out on the snow, making it easy to ensure the whole plot is adequately covered. In the spring, remaining undesirable species and fescue sprout and grow faster than the native wildflowers – Breuer and his crew mow the plots from five to seven times each spring for the first two years in order to give the native species a handicap. Spot treatments of herbicide are used to treat remaining fescue. After the first two years, Breuer has seen the plots stabilize. He recommends brush hogging once a year or burning to mimic the natural disturbance cycle and clear dead growth.

Up to five groups of schoolchildren from the Columbia area come to the A.L. Gustin course each year to participate in youth pollinator events. Students get to visit education stations around the golf course and even seed new pollinator plots. But the golfers and students aren't the only ones enjoying the course. Breuer never turns down a tour group. Just a few of the groups coming to learn are Missouri Master Naturalist chapters, Master Gardeners, 4H groups, MDC regional supervisors, Missouri science teachers, and birding groups. Breuer is not just showcasing the work of his team at A.L. Gustin, his goal is to inspire others to convert urban spaces into native pollinator plots. Breuer sees potential for homeowners to start pollinator plantings in their yard and for grounds keepers at schools, businesses, and public agencies to save money by converting manicured lawns, or at least partially, into colorful diverse wildlife habitat.

Case Study: South Creek Streambank Naturalization Project

The South Creek project was a streambank naturalization project implemented by the City of Springfield focusing on removing the concrete channel of one mile of South Creek that flows along the South Creek Greenways Trail and Sunset Street between Campbell Avenue and Kansas Expressway. The city's goal with this project was to improve water quality and habitat. In addition to removing the concrete, log and rock weir structures, boulders, channel meanders, and pocket wetlands at stormwater pipes were installed. Portions of the project site already had native vegetation. These pockets were preserved during implementation and further expanded to the rest of the project site where mowed fescue formerly dominated.

The MDC local fisheries management

biologist, Kara Tvedt, actively worked with the city and various other partners (i.e., Ozark Greenways, Greater Ozarks Audubon Society, and a paid contracted partner, James River Basin Partnership) in the planning and design of the project. The city recognized that maintenance of this project was going to be one of the keys to its success and obtained a maintenance plan from a local habitat architect company. To successfully implement the maintenance plan, and knowing

that city staff time was limited, the city decided to contract the invasive species monitoring and removal to a native landscaping company for the first growing season after the implementation of the project. The city applied for and were awarded CCG funds, in 2016, to support this endeavor. The city worked closely with the contractor and the MDC urban wildlife biologist, Ashley Schnake, to ensure that the project was successfully maintained, and local staff were trained on the invasive species at the site.

This project has spurred several other projects around Springfield. Two of those projects were road median conversions from mowed fescue grass to plantings of native grasses and wildflowers. These road medians are located on Sunset Street and further expanded on the work that was completed during the streambank naturalization of South Creek. The first road median project was accomplished with the assistance of MDC through the awarding of CCG funds in 2017. The city has converted the second road median within the last couple years.

Educational signage has been sprinkled along the entire project site to educate greenway trail users, local subdivision residents, and the roadway users on the section of Sunset Street between Campbell Avenue and Kansas Expressway. Education signage topics range from stormwater, water quality, pollinators, and the city's Environmental Meadow program.

Wildlife usage has increased in the area as well. Ducks are known to frequent the site as well as songbirds. Mallard ducks are known to nest in the area. The frequent sightings of ducks encouraged the city to place wood duck nesting boxes along the creek.

Funding Sources: City of Springfield, MDNR 319 Grant, and MDC CCG.

Case Study: Shoal Creek Woodlands for Wildlife Landowner Committee

The Huzzah and SCW PG encompasses portions of Huzzah and Courtois creek watersheds within the scenic Ozark hills of Crawford and Washington counties (~70 miles southwest of St. Louis, Missouri). SCWW represents some of the very best habitat in the Meramec River watershed supporting a rich diversity of plant and animal life and providing outstanding outdoor recreational opportunities such as hiking, hunting, fishing, and floating; however, the predominate land uses are timber, cattle, and hay production.

The SCWW is almost evenly split between private and public ownership, with both offering great potential for conservation success. Realizing the great potential for partnership and conservation success on private working lands, conservation organizations and local landowners employed an innovative approach, dropping conventional practices such as "participation by consultation" for an approach incorporating "interactive participation" and "local empowerment." Emphasizing the importance of local empowerment, in 2012 the SCWW Landowner Committee was created to be a truly bottom-up, self-organized team of highly engaged local landowners and natural resource professionals who work collaboratively to find practical approaches to meet the needs of the landscape and its people. Understanding the wants, needs, and values of landowners within the SCWW has been critical to the success of this project. To gain this knowledge and perspective, volunteer landowners Stephan Bass, Bob Dollard, Connie Cape, Bob Foshee, Rachel Hopkins, Gary Mullen, Tina Paris, Bob Scanlon, and Scott Utech have served on the committee.

One of the first orders of business of the SCWW Landowner Committee was to adapt a business marketing planning process to design, communicate, and deliver products and services desired by SCWW landowners while improving the habitat quality under their stewardship. Over the course of two years and nine facilitated planning meetings, the SCWW Landowner Committee and partnering conservation organizations created the 2014 SCWW Marketing Action Plan. The committee identified and prioritized their top five resource concerns and target audiences and helped identify the goals, objectives, and marketing strategies:

The Huzzah Field Partner Day was led by TNC. It was to show agencies and NGOs the use of large woody debris structures for streambank stabilization on the Yocom farm. (Steve Yocom and Rachel Hopkins)

- Improve pasture productivity
- Streambank erosion and management
- Education:
    - Landowner timber knowledge
    - About practices
- Lack of livestock watering systems
- Fish and wildlife habitat improvement

The vision of the SCWW Partnership is to improve environmental quality for people today

and for future generations by ensuring maintenance and enhancement of the outstanding natural resources of the SCWW. The committee envisions a voluntary program that complements the continued economic vitality of agriculture, timber, and outdoor recreation through cost-effective, innovative, and proven land, wildlife, and water management practices. By combining collective knowledge and experiences and sharing them with others, improvements to land and water use choices can be made in the SCWW area and enhance wildlife while balancing the need for food, fiber, and natural resource stewardship.

An extensive list of BMPs was created to address these resource concerns, and to date, the following practices have been implemented: alternative watering systems for livestock; prescribed burns; fencing of riparian corridors, woodlands, ponds, and fens; pollinator habitat; riparian corridor tree planting; wetland restoration; native grass and forb establishment; woodland and glade management; reinforced stream crossings; and streambank stabilization.

Perhaps the best way to illustrate the natural resource and social impacts the SCWW Landowner Committee has made in their community is by comparing results from before and after their creation. From FY03–11 (a nine-year span), MDC staff assisted private landowners with installing 24 BMPs. After the Landowner Committee was formed (2012) and the Marketing Action Plan was created (2014), MDC staff assisted landowners with installing 182 BMPs from FY12–20 (also a nine-year span), nearly eight times the number of BMPs installed compared to the prior nine years.

Why such an increase in landowner adoption rates of BMPs? The bottom line is the SCWW Landowner Committee and partners have tapped into the existing SCWW social network with communications from trusted sources: SCWW Landowner Committee members, participating landowners, and local contractors.

The success within the SCWW is the result of a shared investment in community-based natural resource management in which the entire community takes an active role in leading, designing, communicating, and delivering conservation on the ground. Conservation organizations such as The Nature Conservancy, Ozark Land Trust, USFWS, USFS, MDC, Fishers and Farmers Partnership, and Crawford County Soil and Water Conservation District serve as catalysts by facilitating community engagement and offering technical and strategic financial assistance. Since the creation of the SCWW Marketing Action Plan in 2014, including private landowner investment, over $590,000 has been spent to implement 174 landowner projects.

Installling a stabilized alternative livestock watering system in SCWW.

Section Six: Ecosystem Services and Natural Resource Economics

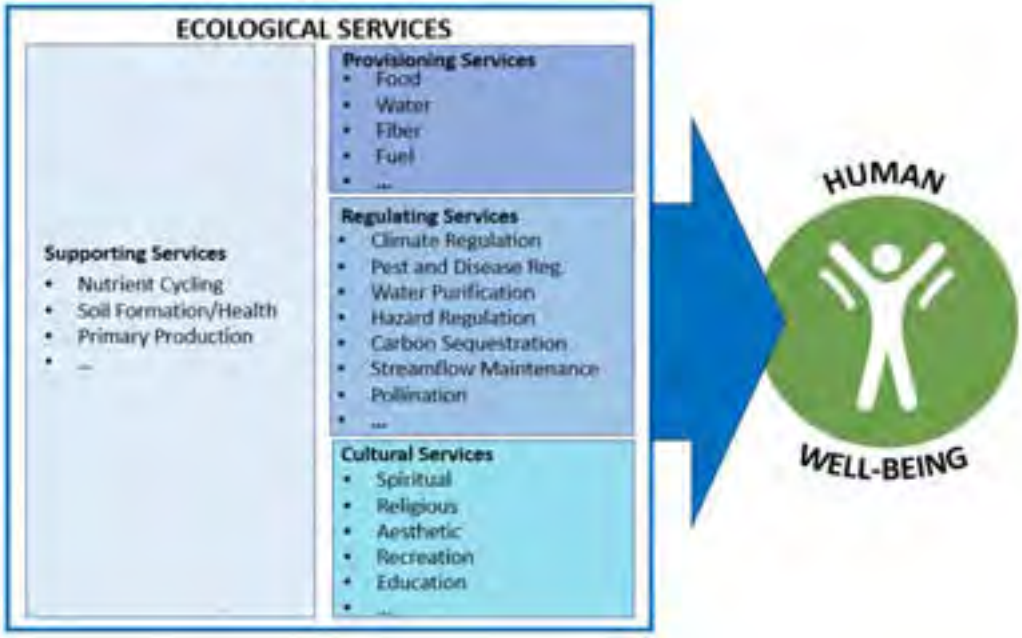
Overview

Natural resources improve our quality of life. In short, we benefit from nature. However, the connection isn't always apparent, and unfortunately, we've reduced our environment's capacity to provide clean air and water as we've historically focused on land development and food production to provide for our growing population. The idea of ecosystem services was developed to make the complex, and sometimes transparent, connections between people and our surroundings clearer (Brauman et al. 2007; Compton et al. 2011; Hodgson et al. 2007). The 2005 Millennium Ecosystem Assessment formalized four categories of ecosystem services that benefit human well-being (**Figure 6.1**). This framework has been accepted by researchers and policymakers as a good starting place to articulate our connections to nature.

Ecological Service Framework

Provisioning services are the most relatable because of their direct connection to our well-being and include food, fresh water, timber, and fiber. ***Regulating services*** are one step removed but control how our surroundings function and include the following: climate, water purification, pest and disease regulation, pollination, and natural hazards regulation (like flooding). ***Cultural services*** can be a bit more intangible and lean toward the preferences of an individual depending upon their preference for certain recreational, spiritual, educational, and cultural benefits. Although ***supporting services*** are the most abstract and furthest removed from our daily lives, they make the other services possible. This includes nutrient cycling, soil formation, and primary production.

Figure 6.1 – The Millennium Ecosystem Assessmentclassified ecosystem or ecological services into four categories that link natural resources to human well-being.



Ecological Interactions and Tradeoffs

The benefit of having an ecosystem services framework is to establish a means to evaluate interdependencies among certain land use decisions or policies. If we try to maximize one service without considering the entire picture and interdependency, we are likely to experience negative consequences elsewhere. The field of conservation in and of itself came from the realization that there are detrimental costs from ignoring the connections that we have with our surrounding landscape (Fennessy and Craft 2011; Power 2010). In a recent MDC report, The Missouri Bottomland Assessment (2019), the culmination of past alterations and current land use has led to multiple ecosystem services being reduced in their capacity to provide these services at a high level (**Figure 6.2**). For example, river and floodplain modifications focused on maximizing drainage, agricultural production, and flood protection cause a decrease in carbon sequestration, denitrification, and bottomland locations to reduce flood damages. These are not easily solved problems because they cut across different spatial scales and political jurisdictions. However, by addressing these issues with interdisciplinary groups instead of operating in isolation, we can have an open discussion about weighing the various tradeoffs and finding a balance between the ecosystem and economic costs (Hodgson et al. 2007; Jessop et al. 2015; Maltby and Acreman 2011; Remo et al. 2017). In the end, the best solution likely incorporates a patchwork of land uses spanning traditional agriculture, urban areas, and various degrees of development, alternative agricultural practices including organic farming or other eco-agricultural approaches like polyculture, and a network of conservation practices and programs allowing ecosystem services to maintain their connections and provide benefits to society. As John Muir most eloquently stated: "When we try to pick out anything by itself, we find it hitched to everything else in the Universe."

For more information regarding ecosystem services, refer to **epa.gov/enviroatlas/ecosystem-services-enviroatlas-0**.

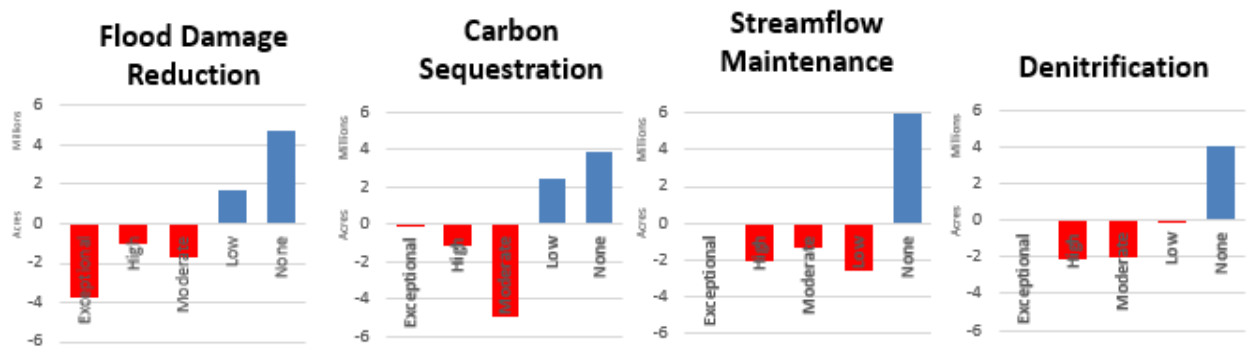


Figure 6.2 – Comparing Ecological Services From the Past and Today's Current Landscape, Multiple Ecological Services across Missouri's Bottomlands Have Decreased in Their Capacity to Function at a High Capacity.

Assigning Value to Nature, Conservation of Natural Resources, or Ecosystem Services

What does it mean to value nature, natural resources, or conservation? What role should such valuation play in decision-making? These are tough questions with varying interpretations and responses, and there is an evolving science around them. Within this subsection we take a deep dive into some of the science in the value assessment of ecosystem services. There may be unfamiliar terminology and concepts, but it is important that the conservation community and citizenry adapt an appreciation for the significance behind a greater understanding of this economic framework in consideration of our shared natural resources.

Following the National Research Council (NRC 2005), there are two principle directions that have been considered in the literature (e.g., Goulder and Kennedy 1997; Sagoff 1994; Turner 1999). One is that some values of ecosystems and their services are nonanthropocentric – that floral and faunal species have moral interests or value in themselves. The other, which includes the economic approach to value assessment, is that all values are anthropocentric – humans' moral interests only are considered. But economic values are quite broad. The term refers to more than the commercial value of something. Economic value includes many components that have no commercial or market basis (Freeman 1993; Krutilla 1967), such as the value that individuals place on the beauty of a natural landscape or the existence of a species. Economic valuation does not include all possible sources of value that have been identified or that are potentially important, but it does cover a broad range and provides a systematic way in which those values can be factored into decision making.

Environmental value assessment distinguishes between (1) instrumental vs. intrinsic values, (2) anthropocentric vs. biocentric (or ecocentric) values, and (3) utilitarian vs. deontological values (Callicott 2004). The instrumental value of an ecosystem service is a value derived from its role as a means toward an end; its value is derived from its usefulness in achieving a goal. In contrast, intrinsic value is the value that exists independently of any such contribution; it reflects the value of something for its own sake. For example, if fish provide a source of food, it has instrumental value. This value stems from its contribution to the goal of sustaining the consuming population. However, in this example, a fish can also have intrinsic value in and of itself, given its role in an ecosystem or its natural beauty. Intrinsic value can also stem from heritage or cultural sources, such as the value of culturally important burial grounds.

Anthropocentricism assumes that only humans assign value, and the value of other resources comes from their usefulness to humans. Non-anthropocentric (biocentric) values assume that certain things have value even if no human being thinks so. For example, a biocentric approach would assign a positive value to an obscure fish population even if no human being feels that it is valuable and thus worth preserving (Callicott 2004; Turner 1999).

Utilitarian values come from the provision of "welfare," overall well-being. In contrast, deontological (or duty-generating) value implies a set of rights that include a right of existence. Here, something with intrinsic value is irreplaceable, implying that a loss cannot be offset or "compensated" by having more of something else. For example, a person's own life is of intrinsic value to that person because it cannot be offset or compensated by that person having more of something else.

The economic approach to valuation is an anthropocentric approach based on utilitarian principles. It includes consideration of instrumental values, such as existence. Non-anthropocentric values, for example, are not included. Economic valuation assumes that the

potential or ability to substitute between the different goods that contribute to human welfare and values assigned by an individual reflect that individual's preferences between various goods and services, and that societal values are the combination of individual values. Preferences are influenced by a variety of factors, including culture and information, which can change over time. An individual's willingness to trade one good for another will reflect the amount of goods and services currently available to him/her, which will in turn depend at least partially on income. If income changes over time, the economic measure of value for an individual can be expected to change as well. Economic values are time and context specific.

Economic values are often categorized into use values and non-use values. Use values are further broken down as direct or indirect. Direct refers to both consumptive and nonconsumptive uses that involve some form of direct physical interaction with the resource or eco-service. Consumptive uses involve extracting a component of the ecosystem such as harvesting fish and wild resources. Nonconsumptive direct uses involve services provided directly by the ecosystem without extraction or removal of the resource, such as use of water for transportation and recreational activities. Nonconsumptive uses do not involve removal, but they can diminish the quality of ecosystems through pollution and other external effects. Non-use values are those people hold that are not associated with the use of an ecosystem good or service. Use values typically arise from a good or service provided by ecosystems that people find desirable. Non-use values need not arise from a service provided by the ecosystem; rather, people may benefit from the knowledge that an ecosystem simply exists unconstrained by human activity. Other motivations for nonuse values are inherited and cultural or heritage values. Empirical literature generally does not attempt to measure values for individual aspects of nonuse values but focuses on the estimation of nonuse values regardless of the underlying motivations people have for holding this value component. Finally, estimation of any of these economic values will always depend on how the questions are framed: How are property rights currently assigned? How is any environmental or policy change specified?

Some economic values can be assessed in the marketplace. Forest products, expenditures on hunting and fishing gear, equipment for outdoor recreation, and other market goods come at a market price that can be used to estimate the instrumental value of those opportunities and resources, and further to estimate their impact on the overall economy. But for nonmarket goods, economists have had to develop other methods of estimation. These methods can be broken down by whether the valuation method is to be based on observed economic behavior (revealed preferences) such as trips taken to a conservation area or hours spent birdwatching, from which individual preferences can be inferred, or whether the valuation method is to be based on responses to survey questions that reveal stated preferences, and whether monetary estimates of values are observed directly or inferred through some indirect method of data analysis (NRC 2005). Examples of revealed preference methods include travel cost models and random utility models, while examples of stated preference methods include contingent valuation surveys where respondents are simply asked how much they would be willing to pay for a given environmental change or policy.

Provisioning Services

Provisioning services are physical goods like food, fresh water, timber, and fiber that are provided directly from the environment. These services can be managed through various means of agriculture, forestry, and fish and wildlife management. In this subsection we focus on several provisioning services that are directly influenced by conservation actions, including wild foods, commercial fishing, aquaculture, forest products, fresh water, genetic resources/biodiversity, and biochemicals/pharmaceuticals.

Wild Foods: Fish, Game, and Native Plants

Missouri's wild foods play an important role in connecting Missourians to nature even though you can't buy wild harvested native fish, game, and plants at your local grocery store. This includes the more popular table fare like crappie, catfish, and bluegill but can also include other species like paddlefish, gar, and buffalo. The most popular field-to-fork game species in Missouri is white-tailed deer, with turkey, rabbit, squirrel, waterfowl, and quail serving as a smaller portion of wild-game diets.

As one might expect, the diverse fish and game reflect an even greater diversity in plants available for people to browse on as well. Morels are the most common mushrooms sought after in the spring. Within various times of the growing season other fruits, berries, and edible plant parts grow, ripen, and can be picked for human consumption. In the fall, oaks, black walnuts, pecans, and hickory nuts can be harvested, cracked, and enjoyed. As winter's grip starts to loosen, the sap of sugar maples can be tapped to provide another forest commodity in the making of syrup.

Quantifying the amount and economic benefits of these resources can be challenging and is often underestimated; however, a couple national studies give us an indication of the scale and economic scope of several wild-harvested goods. For example, recreational fishing in the United States contributes 16 pounds of edible fish per angler per year (Cooke et al. 2018). From the hunting side of things, the national estimate for harvested venison exceeds $1.5 billion annually (Goguen et al. 2018). When turning our gaze to plant-based foods here in Missouri, according to the USDA National Agricultural Statistics Service in 2017, our state's pecan production generated $2.4 million. Granted, these are just individual examples, so it isn't hard to imagine the total contribution of wild foods being significantly greater, and yet largely unquantified and, from an economic standpoint, undervalued.

Missourians are motivated to eat wild foods for a range of reasons. For some it is a matter of self-reliance, ease of access, and low food costs and may vary depending upon population demographics. For example, one study found that individuals in rural areas are more likely to eat fish and game than those found in more populated urban areas (Smith et al. 2018). Other studies have found that people were motivated by obtaining high quality food and by personal connections to food and place. Still others are enjoying these outdoor pursuits because of the social networks and traditions (Hendrickson and Massengale 2017; O'Hare 2019). The combination of these interests in enjoying local food, being mindful of the environment, and recreation creates links to native species. These not only encompass the traditional hunting and fishing population but also expand to those with a conservation ethic in urban centers (Tidball et al. 2013, figure 1). In recent years, this emerging demographic encompasses the "locavore movement," of individuals who are concerned about locally sourced food quality and the sustainability of natural resources (Cooke et al. 2018; Stedman et al. 2017; Tidball et al. 2013).

The focus on food also has wider ecological and social ramifications than just one individual or species. For example, the harvesting and consumption of game can keep populations, like

deer, in check. This idea has also been discussed as a way to manage nonnative invasive species like invasive carp (Varble and Secchi 2013). Second, it isn't just the individual hunters who benefit from the harvested food but the social networks that they are connected to. Many hunters and fishers share their harvest with their households, relatives, friends, and coworkers (Cooke et al. 2018; Hendrickson and Massengale 2017; Goguen et al. 2018; Smith et al. 2018; Tidball et al. 2014). The benefits don't stop there, either. For example, through the Missouri's Share the Harvest Program, hunters donated more than 259,400 pounds of venison in 2019, including 4,855 whole deer, to those in need of food. Since 1992, when Share the Harvest began, the program has provided more than 4 million pounds of venison to fortify food security for needy Missourians. Each year thousands of pounds of high quality organic wild game and fish grace the tables of homes throughout our state.

As with any ecosystem service there are tradeoffs and concerns, especially when it comes to harvesting wild foods. From the ecological standpoint, the potential for additive impacts of individuals to overharvest a population and negatively impact habitat quality exists. From a human consumption perspective, ensuring food safety is important so that people do not get sick from potential contaminants, disease, or toxicity (Goguen et al. 2018; O'Hare 2019; Smith et al. 2018; Tidball et al. 2014).

This is where government regulation attempts to provide recommendations that ensure the sustainability of wild populations and safety of the public. However, regulation isn't the only tool to reduce risk. Another option to mitigate negative impacts is the adoption by private landowners of eco-agricultural approaches such as forest-farming, agroforestry, low-density aquaculture, or other polyculture practices that encourage ecological stewardship and economic incentives, at the same time reducing pressure on wild populations (Chamberlain 2018; Svadlenak-Gomez 2010; Wurts 2004; Wurts et al. 2010).

Private land biologists help farmers integrate conservation into agriculture in a variety of ways. Eco-agricultural practices continue this integration of food and conservation for those who are interested. By cultivating a conservation ethic across overlapping interests, wider public support for the significance of wild foods can help shape future policy and markets. This could mean helping connect individuals and groups across the social landscape (rural and urban, harvester and locavore, etc.). Food is critical for human physical and social well-being, and conservation of our natural resources makes a significant contribution to this provisioning service.

Food: Commercial Fishing

Missouri was first explored by individuals motivated by commercial animal harvest, and this motive was formative to Missouri's current outdoor culture. Even in modern times, some citizens draw their livelihoods at least in part from commercial harvests. Missouri's Commercial Fishing Program promotes the continuance of this culture and its traditions while balancing them with improved and sustainable fishery management objectives.

Commercially harvested fish flesh and roe are marketed primarily as food for human consumption, while some fish is used to make products such as fertilizer, oil, and meal. In Missouri, an average of more than 600,000 pounds/year of fish were commercially harvested from the Mississippi, Missouri, and St. Francis rivers, from 2015 to 2018. The estimated value of the annual commercial fish harvest is $165,000 (live-weight, wholesale value), and the retail value is far greater.

Commercial fishing provides opportunities for people to use and enjoy Missouri's outdoor resources. Commercial fishing gear (e.g., gill, trammel, hoop, and seine nets) offers opportunities to citizens who may be less interested in sport fishing methods and provides access to underutilized fisheries. Some native fish species (e.g., buffalofish and carpsuckers)

may be unfamiliar to sport anglers because they are not commonly captured with sport fishing methods. Commercial harvest provides for public use and exposure, which may increase awareness, concern, and value associated with commercially harvested species.

Commercial fishing provides opportunities to improve and sustainably manage fish populations and can be a useful tool for reducing populations of nonnative, invasive species (e.g., common, grass, black, silver, and bighead carps). Harvest reporting provides valuable information about species that can be used to inform management and regulatory decisions. Commercial harvesters have provided information and expertise for use in research and management of many species. Consumers with access to sustainably managed, locally caught fish can decrease demand for stressed ocean fisheries and reduce carbon footprints.

Aquaculture

In the United States, aquaculture sales exceed $1.4 billion annually. While many assume that most fish farms or aquaculture facilities that supply our nation with farm-raised food are on the coast, aquaculture is growing in the nation's heartland. In the USDA 2013 Census of Aquaculture, Missouri was reported to be in the group of states that had $5.5 to $9.0 million in aquaculture sales. Aquaculture can give landowners and entrepreneurs the opportunity to produce a variety of species (e.g., catfish, yellow perch, walleye, hybrid striped bass, sunfish, salmonids, tilapia, crayfish, shrimp, etc.) for food, bait, ornamental fish, and can even provide fishing opportunities for those who don't have the means to go out on the lake or river and recreationally fish (stocking pay lakes).

The production of aquatic organisms under controlled conditions can ease demands on often overfished wild resources, but also, these farm-raised fish create an alternative market for U.S. soybeans. One fish farm in Iowa feeds over 60,000 bushels of soybeans in a year. The business of aquaculture is highly regulated by both state and federal agencies. To help navigate the regulations, the marketing, and issues involved, there are many federal and state programs that directly or indirectly encourage, support, or assist U.S. aquaculture. In many midwest states, local universities have extension offices that will make landowner visits and assist with each step of the process from setup to delivery to market. In Missouri, there is an Aquaculture Association built by many fish farms within the state to provide information and advice.

A range of opportunities exist using the aquatic conditions of ponds, rice paddies, and wetlands to cultivate an integrated cropping system or polyculture. In western Kentucky, several low-intensity options using ponds have been illustrated to promote the cultivation of channel catfish in lower density stockings, while another option is a combination of shrimp and paddlefish to create a productive polyculture (Dasgupta et al. 2007; Wurts et al. 2010; Wurts 2007 2004, 2000).

Rice is a common agricultural crop in the Lower Mississippi Alluvial Valley, which includes southeast Missouri. Over the years and in different parts of the world, various other crops have been integrated with rice production. For example, in a conventional agricultural framework, rice can be used in rotation with crayfish, and soybeans over three years (Salassi et al. 2008). A more eco-agricultural approach with smaller paddies involves the interaction of rice production with animals as part of the multi-cropping scheme. Integrating fish and ducks into rice production has the advantages of keeping weed species like azolla down and an extra boost of nitrogen from animal waste to benefit plant growth. This creates multiple cash crops of rice, duck eggs, and fish and duck meat by taking advantage of ecological interactions between crops (Kirschenmann 2002).

In a similar vein, but more hands off, crayfish production on wetlands managed for duck hunting was explored for its economic viability in providing an extra stream of income (Alford et

al. 2013). This strategy of taking advantage of naturally occurring crayfish populations that respond to the hydrodynamics of riverine wetlands is the basis of the Louisiana crayfish aquaculture tradition (McClain and Romaire 2004).

Finding a balance between a site's ecological function and landscape position can lead to regenerative aquaculture benefiting the local ecology and business. For example, a former rice farm converted its network of paddies and ditches into a restored wetland complex that produces a range of fish through extensive aquaculture practices and also serves as an important site for migratory waterbirds (Svadlenak-Gomez 2010). Elsewhere in the country, seasonal inundation of cropland within an engineered yet active floodplain can provide crucial habitats for a wide suite of fish and wildlife species as well as income for private land owners (Sommer 2001; Opperman et al. 2011; Katz et al. 2017). These possibilities exist here in Missouri, taking the right place, time, interactions, individuals, and market to make it work.

Forest Products

Missouri's forest products industry is an important contributor to Missouri's economy and supports a number of economic, social, and environmental values. Forest products are managed by balancing harvest rates with growth rates – harvest practices need to account for long-term productivity and conservation of forest benefits and services. Sustainably harvesting Missouri's forests produces many different wood products that are used in the state and around the world. Products originating in Missouri's forests include railroad ties, furniture and cabinets, flooring, barrels, tool handles, charcoal, pallets, shavings, papers, and firewood. The products from Missouri's forest industry contribute $9.7 billion to Missouri's economy, provide 41,000 jobs, and generate $103 million in sales tax. It is important forest products are generated while ensuring the long-term health, sustainability, and productivity of Missouri's forests. For more information on Missouri's forest products industry, see **Assessment Theme Eight** in **Section Three**.

Fresh Water

Fresh water is necessary for human and other animal and plant life. Surface waters are abundant in Missouri, including the nation's two largest rivers and a number of man-made ponds, lakes, and reservoirs, such that water rationing for any purpose to this point has been unnecessary. Drinking water in Missouri is drawn from both surface and groundwater sources. However, groundwater sources are ultimately fed by surface water percolating into the aquifer. In 2020 surface water was used for drinking and other needs (e.g., bathing, laundry) for approximately 3.3 million people in Missouri. Public groundwater supply was used for approximately 2 million people (MDNR 2020).

Fresh water is necessary for irrigation for crops and drinking water for livestock. In 2015 1.2 million acres were irrigated in Missouri, and 64 million gallons of water per day were used for livestock (usgs.gov). An additional 85.2 million gallons per day were used by Missouri industry in 2015. Climate change and associated changes in the timing and magnitude of precipitation events as well as aging infrastructure and demographic shifts are increasing water prices throughout the United States (Mack and Wrase 2017). Practices that decrease runoff volume and increase floodplain connectivity may help offset these costs and reduce the magnitude of flood events.

Genetic Resources (Biodiversity)

"To keep every cog and wheel is the first precaution of intelligent tinkering" (Leopold 1993).

The genetic resources of species and within populations of a species have multiple values, including both economic (e.g., in terms of food, medicine, and other products) and for conservation (e.g., maintaining species in the

face of multiple anthropogenic stressors). Therefore, conserving both species and multiple genotypes of individual species is important. Populations of species at the edge of their range often have unique genotypes more adapted to extreme conditions, including climate. With extreme climate events projected to become increasingly more common, these range-edge genotypes may be important for maintaining species viability (Booy 2000; Rehm et al. 2015).

Having a diverse portfolio of genetic and biochemical resources is critical for maintaining the global food supply in terms of increasing crop productivity in the face of new pests, diseases, and other stressors (Daily et al. 1997). For example, many thousands of varieties of rice from different locations were screened to find one with resistance to grassy stunt virus, which threatened the world's rice crop in the 1970s and 80s. Today just 20 plant species provide 90 percent of the world's food, such as corn, wheat and soybeans (NatureServe 2015). If wild relatives of these crop species are lost there would be serious implications for food security.

Just as the variability in genetic structure provides resiliency in food production, there are other ways in which we can apply or mimic the diversity of biologic architecture and function to enhance human life and facilitate economic gains. Biomimicry has grown into a diverse and profitable field for product development and emerging technologies that isn't just restricted to the medical field. A variety of materials have been developed by mining nature's diverse biological solutions and applying these answers to solve human problems. This includes light-weight strong materials, various surfaces or coatings, and adaptive or smart materials that respond to changes in the surrounding environment (Lurie-Luke 2014). Technologies focused on chemical processes, self-assembly, and organization have also been developed (Shu et al. 2011). Future pursuits have the potential to apply these lessons to anti-pollution technologies, computer and robotic development, and energy production (Lurie-Luke 2014). This opportunity exists as long as we maintain our natural diversity.

Biodiversity doesn't just occur in "wild places." Planning for biodiversity in cities has been aided by cost-benefit analyses and ecosystem service metrics that advance understanding of the value of natural assets and how they make cities more resilient and equitable. Valuating nature's services in monetary terms helps inform stakeholders and orient community investments toward cost-effective, regenerative, and sustainable projects. The city of Tacoma, WA, used ecosystem service values to earn support for and pass a $198 million bond for local parks in a city of just 200,000 people (Daily et al. 1997). In Maine, concern over protection of landscape-scale continuous habitat blocks and corridors that cross multiple government boundaries led to the development of a program called Beginning with Habitat. Through this program, relevant data was pooled from multiple agencies and distributed to all local jurisdictions for use in community planning efforts. A follow-up survey found that over 60 percent of the towns that updated their comprehensive plans after receiving the data incorporated the information into their plan. The OneSTL Regional Plan for Sustainability in the St. Louis metropolitan region also addresses landscape-scale concerns. It claims that, though landscape change today is being driven by metropolitan regions, opportunities exist to protect and connect remnants of biodiversity and to reimagine built areas to integrate living, natural systems into community design using quality data to support measurable interventions. The plan includes the following target: By 2025, 100 percent of counties in the Combined Statistical Area of St. Louis (City of St. Louis, 8 counties in Missouri, 8 counties in Illinois) are using the Regional Biodiversity Atlas to actively guide their planning, policies, and practices in ways that increase habitat connectivity, ecological functionality, and quality of life for all (OneSTL 2017).

Monitoring progress of biodiversity conservation efforts can be accomplished through a city biodiversity index, which is a self-assessment tool whereby cities benchmark and monitor efforts against their own individual baselines. When establishing a baseline, the city is profiled to understand existing conditions, including all known biodiversity features (ecosystems within the city, species within the city, quantitative data on populations of key species of local importance, and relevant qualitative biodiversity data (Chan et al. 2014). This initial inventory may lead to some surprises, because for a long time, cities have been considered through the lens of being places filled with sources of pollution, fragmented habitats, impervious surfaces, domestic pets, and introduced plant species, which lead to disrupted nutrient cycles and a loss of native biodiversity (NRC 2013). But it is hard to know what is there until you really look, especially when what you are looking for is very small. Take bees for instance. St. Louis, Missouri's largest city, is home to one of the most diverse bee populations in the Midwest with more than 200 of the 450 species of native bees found in the state, residing within the city limits (MDC 2020). Ongoing monitoring efforts can be accomplished at the local government level and some communities are even engaging citizens in the effort. In Fort Collins, CO, citizen scientists monitor 15 bird species and 10 butterfly species. The goal is to collect long-term ecological data that will help support the Nature in the City Strategic Plan to maintain "a connected open space network accessible to the entire community that provides a variety of experiences and functional habitat for people, plants, and wildlife" (Fort Collins 2020).

Increasingly, public education on the importance and associated benefits of biodiversity is driving a cultural shift in how citizens and local government view native fauna and flora. Rain gardens, butterfly gardens, and pollinator plantings incorporate native plants into urban landscapes either as green infrastructure to manage rainwater runoff or as habitat for resident and migrating species. Recently, concern over diminishing numbers of monarch butterflies motivated many people to plant milkweeds in an effort to support this beloved species. Municipalities are updating weed ordinances to remove bans on native plants used for landscaping and are investing in their community forests. Actions resulting in more variety of native plants in urban/suburban areas ultimately benefits animal biodiversity as plants are the first trophic level and the primary producers of energy (NRC 2013). Nonnative plants, however, support fewer insects; in fact, there are often five times more species and 22 times more insects in areas planted only with natives. The number and variety of insects play a significant role in supporting biodiversity because they are eaten by many animals including frogs and fish. When raising young, 96 percent of terrestrial birds eat insects (NRC 2013).

Biochemicals/Pharmaceuticals

Complex biochemical reactions are what nature has been doing over millennia as plants and animals adapt and compete for survival. With over 400,000 plant species across the globe, different combinations of organic chemicals are produced on a daily basis (Kolok 2016). Eighty thousand different plants have been used around the world for various medical uses, with over 2,100 of these from North America (Foster 1997). Animals also create a concoction of chemicals to attack or defend themselves with 100,000 animal species that are known to produce venom. Although folk remedies have long used snake and scorpion venoms, conventional medicine is just now taking a deeper dive into venomics and applying these different peptides and proteins in a host of medical treatments (Calvete et al. 2009). As long as biodiversity remains high, the depth of nature's medicine cabinet remains vast and available for advancements in modern medicine.

Unfortunately, overexploitation and certain types of wild harvesting can decimate local populations of medicinal species and threaten a

region's genetic diversity. You don't have to look any further than Missouri's Ozark Plateau to find an example. The forested hills of Missouri contain a range of medicinal herbs under its deciduous canopies that have been used as folk remedies, alternative medicines, and diet supplements for years. The more commonly known herbaceous species that occur in the Ozarks and Appalachia are ginseng (*Panax quinquefolius*), goldenseal (*Hydrastis canadensis*), black cohosh (*Actea racemosa*), and mayapple (*Podophylum peltatum*) (Trozzo et al. 2019). Unfortunately, high foreign markets demand, low naturally occurring local populations, and increasing prices have created unsustainable harvesting of certain species and devastated local populations. These actions have led to the detriment of Missouri's ginseng and goldenseal populations, which, due to unprecedented loss, are now regulated by the Convention on International Trade in Endangered Species (Robbins 2000).

Conservation in the form of protection and regulation of wild populations is only one piece of the puzzle. Regenerative and sustainable cultivation on private land through forest farming practices is an additional option to help meet the market demand yet reduce the pressure on the threatened wild populations. By applying eco-agricultural principles to forest farming, a range of medicinal herbs, including those species more at risk, can take advantage of unique ecological settings, species interactions, and provide landowners with alternative economic opportunities (Mudge and Gabriel 2014). Outside forested habitats of the Ozarks, other polyculture systems may allow for the cultivation of other medicinal species; however, research and established practices are still in their youth (Foster 1997; Kirschenmann 2010).

Another strategy for society to benefit from these beneficial biochemicals is through the study and development of synthetic replication in the lab. This line of study has blossomed into the widening field of biomimicry. Over 50 percent of modern prescription medicines were originally discovered in plants (Beattie et al. 2005; Newman and Cragg 2016). The list of important drugs originated from wild species includes aspirin (from meadowsweet), penicillin (from the penicillium fungi), digitoxin for cardiac treatment (from common foxglove), taxol for ovarian cancer (from the Pacific yew), and quinine for malaria (from yellow cinchona). While some of these materials are still naturally sourced, others can be synthesized in the lab. Science has only begun to tap untold medicinal resources from earth's incredible, albeit decreasing, biodiversity.

As previously mentioned, biomimetic advances are not restricted to just medicines but have expanded to other human health related solutions. For example, by studying the mechanics of a mosquito proboscis, a less painful hypodermic syringe has been developed (Shu et al. 2011). Another example is the application of a protein used by mussels to bind to underwater surfaces. Scientists have developed a superior surgical glue based upon these mussel-based proteins to aid in healing post-surgery and minimize scarring (Jeon et al. 2015). Applying nature's chemical library and organic architecture to human related problems is also being explored in a range of human health fields including anti-cancer agents, anti-bacterials, insect repellent, UV protection, and biomaterials for tissue repair (Lurie-Luke 2014).

Regulating Services

Regulating services include the processes that typically regulate or maintain how the world works. These services can often be overlooked and taken for granted because they seem to occur automatically in the background. However, when regulating services are diminished, the negative impacts can be severe and widespread. The example regulating services focused on in this section include pollination, pest control, carbon sequestration, flood damage reduction, streamflow maintenance, climate regulation, water purification, and disease regulation. Like all of these different ecosystem services, many of these regulating services overlap and can influence the capacity and quality of other services.

Pollination

Pollinators play a crucial role in the reproduction of approximately 75 percent of the 240,000 flowering plant species worldwide (NRC 2007). Globally, the value of pollinator-dependent crops is estimated at between $235 billion and $577 billion annually (IPBES). In the United States, 130 crop species are reliant on the services of pollinators for production of seeds and fruit (Klein et al. 2007). A few examples of these crop species include apples, cherries, squashes, watermelon, cucumbers, and peaches (NRC 2007). The value of U.S. crops dependent on native bees and honey bees alone is greater than $29 billion (Calderone 2012). Notably, bumblebees and some other native bees are capable of buzz pollination (nonnative honey bees are not) in which the rapid movement of the flight muscles causes the entire body to vibrate, dislodging pollen from the anthers of flowers (Rosenthal 2008). It has been demonstrated that buzz pollination increases the weight, length, and diameter of some fruits (Serrano et al. 2006). Furthermore, this ability of the bumblebee is advantageous when pollinating plants with tubular anthers as the pollen in these structures is more difficult to dislodge (Heinz Center 2013). Buzz pollination is necessary for maximum fruit production in crop species such as tomatoes, eggplants, strawberries, and blueberries. Animal pollinators, therefore, are an important component of food security and the generation of profits from agricultural crop sales (Heinz Center 2013).

By facilitating the reproduction of native plant species that provide food, shelter, and other important ecosystem services to wildlife, pollinators also play a vital role in habitat creation and maintenance. Game animals and charismatic wildlife such as songbirds draw people to the outdoors and generate funds for conservation, parks, the hospitality industry, and more. Many of these wildlife species rely on pollinators for some, or all, of their food requirements (Heinz Center 2013).

Agriculture isn't the only sector that benefits from pollinator species, and it is important that conservation of pollinators occurs across the entirety of Missouri's landscape. Take, for example, the previously described significance of native bee abundance in the city of St. Louis. The size, structure, plant diversity, and juxtaposition of urban gardens, green roofs, and green spaces can be an overlooked opportunity for conservation (Colla et al. 2009; Lowenstein et al. 2014; Tonietto et al. 2011). Another undervalued location for pollinators is drawing increased recognition through a new partnership with USFWS: the transportation and energy sector has been encouraged to focus on monarch and other pollinator conservation efforts along the significant miles of rights-of-way and associated lands. Unlike many ecological networks, this literal linear web links America's agricultural lands, natural refuges, and urban environments in a very real way, making the connection not only for people but also for pollinators.

Pest Control

Similar to pollinators there isn't just one group of "bugs" that contribute to controlling crop pests. There are range of invertebrates, including beetles, spiders, flies, wasps, and dragonflies, along with birds and bats, that can be beneficial for agricultural pest control. Certain crop pests, like aphids, can suppress crop yields by 40–60 percent (Robertson et al. 2007). However, these pests can be kept in check if predator populations are present (Schmidt et al. 2008). Biocontrol is often greater in more diverse landscapes that include forest and grassland habitats embedded within a diversity of different crops (Robertson et al. 2007; Gardiner et al. 2009; Ratnadass et al. 2012; Asbjornsen et al. 2014). Building from this knowledge, various research programs have begun to integrate islands or strips of non-crop habitat within agricultural fields to serve as refuge and provide supplemental food sources for these beneficial species. In England farmers created "beetle banks" by incorporating grassy islands within fields to function as overwintering refuges for predatory bugs (MacLeod et al. 2004). Back in the States, Iowa State University has rolled out a program called STRIPS, which stands for Science-based Trials of Rowcrops Integrated with Prairie Strips, to clean water, reduce erosion, and provide habitat for wildlife, including beneficial insects (Hirsh 2012). It has been estimated that natural pest control services by insects saves $13.6 billion/year in agricultural crops (Losey and Vaughan 2006).

While these actions extend horizontally and focus on insects, other strategies go vertically to enhance the presence of mammalian and avian predators. Many bats are insectivorous and through the installation of bat boxes can be effective in keeping moths and other agricultural pests in check (Puig-Montserrat et al. 2015; Riccucci and Lanza 2014). It has been estimated that a single colony of 150 big brown bats (*Eptesicus fuscus*) can eat nearly 1.3 million pest insects each year (Whitaker 1995). The benefit of bats for agricultural community and pest control across the United States has been estimated at $22.9 billion/year (Boyles et al. 2011). They aren't alone in patrolling the skies over agricultural fields, picking off pests. Birds are also known to contribute toward pest control and to benefit agriculture (Wenny et al. 2011; Whelan et al. 2008).

Incorporation of native pest control species and their habitats is an important consideration when planning a functional landscape and in consideration of decisions to promote species interactions and food production (Maas et al. 2013). If not, there will continue to be a decline in biodiversity (Rosenberg et al. 2019) and reduced resilience in our food production systems. Agriculture and natural resources conservation are not contradictory terms and can be mutually beneficial if we are mindful of the interactions among native and cultivated habitats and species.

Carbon Sequestration

Earth's surface temperature is greatly influenced by the interaction of solar radiation and the composition of gases in the atmosphere, working together to absorb and trap heat near the surface in a process called the greenhouse effect. Water vapor in the atmosphere is the most dominant GHG, and along with clouds, it is responsible for 75 percent of the total greenhouse effect. The combination of all other atmospheric GHGs (e.g., CO_2, O_3, N_2O, CH_4), aerosols, and chlorofluorocarbons contribute the remaining 25 percent, of which carbon dioxide (CO_2) alone contributes 20 percent (Lacis et al. 2010). Carbon is found all over the Earth, stored in terrestrial and marine reservoirs (e.g., vegetation, rocks, sediments, soils, and dissolved in ocean and freshwaters), frozen at the surface in permafrost layers, buried below Earth's surface in fossil fuel reserves, and floating around the atmosphere. Carbon moves around the planet by flowing in, through, and out of these reservoirs in a process called the carbon cycle. Some reservoirs store carbon briefly (e.g., annual vegetation) while others can store it for millions of years (e.g., limestone rocks).

In temperate habitats roughly 70 percent of carbon is stored in the soil and the other 30 percent is tied up in the phytomass (Scharlemann et al. 2014). Soil organic carbon (SOC) is the measure of the soluble, decomposing, and residual plant matter within the soil matrix. Phytomass is the living biomass of plants that occurs above or below ground in the form of leaves, branches, stems, and roots. Standing dead trees, coarse woody debris, and litter are other much smaller carbon pools when compared with carbon concentrations found in SOC and phytomass (Woodall et al. 2015). Forests and woodlands, as well as prairies and wetlands, play an important role in the carbon cycle by consuming atmospheric CO_2 and using it to build leaves, stems, branches, and roots where the carbon can be stored for long periods of time before it decomposes and continues the cycle. Not only does this process also create breathable oxygen, the sequestration of CO_2 reduces its concentration in the atmosphere and the capacity to trap heat, thereby lowering Earth's surface temperature.

Carbon sequestration is just part of the larger carbon cycle and is one aspect of the bio-geochemical processes that fluctuates over time (Woodwell et al. 1983; Vitousek et al. 1997; Lavelle et al. 2005). There are a range of locations and actions that can improve this ecosystem service because of the different locations, both above and below ground, that these carbon stores can accrue. The NRCS offers a helpful planning tool called COMET Planner (**comet-planner.com**), which can be used to provide general estimates of GHG emissions and reduction benefits based on conservation practice implementation scenarios. This tool was developed jointly by NRCS and Colorado State University.

Forest and Woodlands and Carbon Sequestration

Forests and woodlands account for approximately 45 percent of Earth's total terrestrial carbon storage (Bonan 2008). Across the state of Missouri, forests are estimated to sequester 4.2 million tons of carbon annually (Domke et al. 2020; Nowak and Greenfield 2010), equivalent to the annual CO_2 emissions from the energy use in 1.6 million homes (US EPA 2020). Forest carbon storage is concentrated in Missouri's rural forests and woodlands (1.04 billion tons of carbon), accounting for 99 percent of the state's total forest carbon stock (Domke et al. 2020). Forests in urban areas across Missouri, delimited using the U.S. Census Bureau's (2007) definition, store 9.7 million tons of carbon (Nowak and Greenfield 2010). Public lands in Missouri (state and federal) contain 18 percent of the state's forest carbon stock with the remaining 82 percent stored on private land (USFS FIA 2014). Given the important influence carbon has on Earth's climate and the substantial capacity of Missouri's forests and woodlands to sequester and store carbon, it is important to be aware of forest management strategies that enhance carbon sequestration and storage and the incentives available to forest owners for adopting such strategies.

As an example, the L-A-D Foundation contracted with Winrock International to study and account for carbon resources on Pioneer Forest. Winrock is a recognized leader in U.S. and international development, climate change mitigation and standards, and assessing carbon stock. The L-A-D Foundation wanted to know the amount of carbon sequestered on Pioneer Forest and to understand the impact of their uneven-aged forest management on carbon sequestration compared to other forests in the region. Winrock determined L-A-D's Continuous Forest Inventory (CFI) data from 2017, data from three previous inventories, and other GIS data could be used to estimate carbon stored in trees using allometric equations specific to merchantable biomass.

That study, completed in 2019, showed that carbon stocks in trees across Pioneer Forest had increased from an estimated 23 tons of carbon per acre as of the 2002 CFI to 26.5 tons of carbon per acre in 2017. The study also indicated that carbon

stocks on Pioneer Forest are substantially higher than common practice stocks for oak-hickory-pine forests in the geographic area by the Climate Action Resource. The Winrock study on Pioneer Forest did not include carbon stored in the ground.

The L-A-D Foundation will continue to account for carbon during each CFI measurement, and it is recommended that other Missouri forests and woodlands engage in this practice as well as additional quantitative assessment of a recognized forest benefit and as an opportunity to contribute region-specific research.

Pioneer Forest is an example of a forest carbon sink. A forest carbon sink occurs when the amount of carbon uptake from photosynthesis is greater than the amount of carbon that is released from respiration and disturbances; forests are a carbon source when the opposite is true (USGCRP 2018). Forest carbon sinks, therefore, decrease atmospheric CO_2 concentrations, reducing the greenhouse effect and lowering surface temperature. Model- and inventory-based estimates of carbon exchange between North American terrestrial ecosystems and the atmosphere provide evidence of a carbon sink leading up to the last decade (Hayes et al. 2012; King et al. 2015). Forests and woodlands are estimated to have historically contributed 40–45 percent of the United States terrestrial carbon sink capacity, with the remaining contributed by croplands and all other types of land uses (Hayes et al. 2012). It is difficult to know if forests and woodlands in the United States will continue to be a carbon sink in the future, primarily because natural disturbances (e.g., fire, insects, and pathogens) are difficult to predict and account for in carbon budgets. Model simulations suggest, however, that forests will switch to be a carbon source by the end of the 21st century because of climate influences (Gregory et al. 2009). Forest management strategies that enhance and maintain carbon sequestration will be an important tool for increasing and prolonging the forest carbon sink.

Environmental attributes have the greatest effect on short-term alterations to forest carbon sequestration and storage and tend to be those beyond our ability to manage; however, the most important attributes affecting long-term carbon dynamics (e.g., forest structure and composition) are also those that can be manipulated using conventional silviculture and management techniques (Barford et al. 2001). Although the answer to BMPs is inherently complex, the short and simple answer is to manage for maximum biomass, but this ultimately depends on the carbon management objective, e.g., maximizing rate of accumulation or total stock (Johnson et al. 2009). A BMP employs those strategies that maximize wood production while retaining and maintaining carbon stocks (Bellassen and Luyssaert 2014). Assuming no severe disturbances throughout the management period, then increasing stand densities, extending the rotation length between harvests, and reducing harvest intensity will generally result in carbon stock increases (Creutzburg et al. 2017; D'Amato et al. 2011; Harmon and Marks 2002; Perez-Garcia et al. 2005; Taylor et al. 2008; Yang et al. 2011). Afforestation, reducing deforestation, and where land conversion from forest is required, selecting lands with low carbon density can also help to increase carbon sequestration and decrease carbon emissions (Lemprière et al. 2013; Masek et al. 2011; Smith et al. 2009). General carbon management guidelines for Missouri forests are provided by Johnson et al. (2009):

- For rapid short-term C sequestration (over a few decades), even-aged management of tree species that grow rapidly sequesters carbon efficiently.
- For longer-term sequestration, managing for long-lived, shade-tolerant species may sequester more carbon.
- Managing for old-growth without harvesting accumulates large total quantities of carbon in large trees and

down wood. However, annual net increases in sequestered carbon may be small compared to younger, faster growing forests.

- Manage for mixed species to obtain maximum leaf area and maximum photosynthesis
- Manage for forest health. Minimize losses associated with insects, diseases, declines, and other sources of mortality to reduce the associated decay and carbon release.
- Use commercial thinning to reduce mortality from inter-tree competition. But also consider how alternative thinning methods and subsequent product utilization will affect net carbon sequestration.
- Produce forest products. Forest products sequester carbon during their useful life and can continue to sequester carbon when recycled or buried in a landfill. Wood construction materials generally require less fossil fuel to produce than alternatives such as steel and concrete. The growing space released by timber harvesting is then available for sequestering more carbon.
- Utilize woody biomass to produce energy. Using woody biomass to replace fossil fuels that would otherwise be used may have the greatest impact on reducing net atmospheric carbon emissions. The carbon equivalent to that released when wood is used for energy is ultimately recycled back into the next forest crop if the harvested stand is regenerated.
- Avoid wildfires that preemptively release sequestered carbon back into the atmosphere, which for a time may also reduce the subsequent rate of carbon sequestration.
- Use afforestation to increase the area of forests, which have higher rates of carbon sequestration than other land uses.
- Stay abreast of emerging markets for carbon credits. They may provide a supplemental source of revenue from forest management.

In addition to the regulating service provided by the management of forest carbon, financial incentives may be available to landowners choosing to participate in the forest carbon offset market. The forest carbon offset market exists to couple voluntary and obligated businesses with forest landowners to provide monetary returns in exchange for offsetting carbon emissions with forest carbon sequestration. Carbon sequestration projects eligible for trading in carbon marketplaces include afforestation or reforestation projects, avoided conversion projects that prevent conversion of forested land to nonforested land, and improved forest management projects that involve land management activities that maintain or increase carbon stocking.

Qualification requirements for all carbon projects include demonstration of (1) additionality, in which projects must sequester more carbon than would otherwise occur in a "business as usual" scenario; (2) permanence or long-term commitment to the maintenance of carbon sequestration for up to 100 years; and (3) non-leakage in which GHG reductions in the project area do not result in unintended increases in GHG emissions in another location.

Carbon offset projects provide opportunity to diversify revenue streams for forestland owners, but initial costs to enter the market can be prohibitively expensive for small landowners. Considering the carbon offset market is still in its infancy (having started around 2010), study data

is rare that describes the land area threshold for a single landowner to be financially viable in the market; however, preliminary results indicate 1,500 acres may be the minimum, depending on carbon stocking level, management strategies, and policy requirements (Kerchner and Keeton 2015). In the face of this challenge, cooperative groups have begun to form to provide financial and technical assistance to individual and aggregations of small landowners to support their participation in carbon markets. One such group is the RCPP, which brings together the financial support and technical expertise of the NRCS, The Pinchot Institute, the Oregon Department of Forestry, and Oregon State University, to provide small landowners in Oregon and Washington with cost-free carbon project assessments, forest inventories, and cost-sharing assistance for management planning.

There is capacity to increase carbon storage in Missouri forests and woodlands. As stated previously, 18 percent of Missouri's forest carbon stores are found on public lands, indicating the potential for private landowners to include carbon enhancement and management to their land management strategies. Development of a state cooperative carbon group, like that in the West, could provide assistance to forest and woodland landowners to manage their carbon and participate in the forest carbon offset market. Urban areas in Missouri could also be explored for opportunities to increase carbon sequestration through tree-planting programs and participation in the carbon offset market (Merry et al. 2013). There is still much to learn about forest carbon management and opportunities available to owners and managers of the state's public and private lands; however, it is clear that forest carbon management is a valuable economic and ecologic tool that should be included in forest management planning.

Native Prairie and Carbon Sequestration

Though Missouri's remaining tallgrass prairie systems are critically imperiled, these vitally important natural communities are powerhouses in carbon storage. Prairies are considered significant carbon sinks because they store a large amount of carbon in the form of SOC, which accumulates in the upper soil layers over time. Prairies can store much more carbon below ground than a forest can store above ground, according to Dr. Cynthia A. Cambardella, a soil scientist with the USDA's Agricultural Research Service National Laboratory for Agriculture and the Environment. Because two-thirds of a prairie's biomass is in roots underground, this results in a large transfer of carbon to the SOC pool in these native grasslands. Soil carbon makes up over three-quarters of the total ecosystem carbon in these systems (Janowiak et al. 2017).

Even annually burned tallgrass prairies accumulate more carbon than they release (Johnson and Matchett 2001; Wilcox et al. 2016). The widespread plowing and cultivation of the tallgrass prairie biome over the past two centuries has led to measurable increases in atmospheric CO_2 (Wilson 1978), and many former prairie soils have lost 30–50 percent of their original carbon due to conversion to row crop agriculture (Janowiak et al. 2017). In reconstructed prairies and native grassland plantings, SOC increases slowly over time (Kindscher and Tieszen 1998). But even native warm-season grass plantings can provide substantial long-term belowground carbon storage (Yang and Tilman 2020).

Protecting and conserving remnant prairies and reconstructing prairies and native grass plantings all have value in sequestering carbon (Lal et al. 2011; Hungate et al. 2017).

Organic Soils

For example, even though the amount of organic soils is limited in Missouri, certain decisions can be made to ensure that their carbon stores are protected. These soils primarily occur in the ancient abandoned channels or archaic lakebeds of the Mississippi Alluvial Plain in southeast Missouri. In the Springfield and Salem Plateau, sinkhole ponds and Ozark fens contain pockets

of histosols or inclusions of carbon accumulating soils that range from peaty to marly soils driven by groundwater discharge, have elevated water tables, and/or poor soil drainage (Amon et al. 2002; George et al. 2016; Nelson 2010; Kolka et al. 2015). Maintaining or restoring the hydrology to these sites and managing for the natural plant communities is the best strategy here.

Sedimentation

Within Missouri's bottomlands, several dynamics are in play that move carbon throughout the system. Although sedimentation rates vary within and among habitat types, the deposition and burial of carbon are among the quickest means to sequester carbon and are significant in the Midwest (Bridgham et al. 2006; Bouchard et al. 2011). Riparian corridors experience both sedimentation and erosion depending upon the levee restrictions, bank stabilization measures, and stream power during floods. For this reason, certain locations accrue more sediment than others, as demonstrated in spots along the middle Mississippi River where sedimentation has increased 60–300 percent over time (Remo et al. 2018).

As floodwaters spread out from rivers and streams, through their adjacent riparian corridors, they deposit sediment in nearby wetlands. The sediment comes from the surrounding catchment or watershed and varies across Missouri depending upon the river reach and neighboring land use (Baker et al. 2009; Alexander et al. 2013; Heimann 2016). This is a good example of tradeoffs between ecosystem services. Although sedimentation in wetlands is a great way to store carbon, it can be detrimental to the receiving plant communities (Sluis and Tandarich 2004). Managed wetlands on public land often lie in a sea of agriculture and receive high sediment inputs from the adjacent streams during flood events; therefore carbon sequestration and biodiversity is one of the tradeoff scenarios that must be weighed (van der Burg et al. 2017).

Historically, beavers were the primary river engineer that would adjust stream characteristics by damming up channels, which would then have a ripple effect on the stream's nutrient cycling, adjacent plant communities, and formation of shallow carbon sinks (Gurnell 1998; Rosell et al. 2005; Puttock et al. 2017; Polvi and Sarneel 2018). Instead of widely distributed sets of small and "slow moving bed reactors of organic carbon" inching toward the coast, today's river systems are human engineered with networks of large dams stockpiling carbon in static locations behind infrastructure of large order rivers, like the Missouri and Mississippi rivers (Maavara et al. 2017).

Recovering Soil Organic Carbon

Various programs and BMPs have attempted to restore various ecological processes as the impacts of different land use practices have been realized. Unfortunately, the processes to sequester carbon within the environment takes hundreds if not thousands of years to occur (Foster et al. 2003). Restoring the depleted pools within the soil is at a difficult timescale for humans to conceptualize and incorporate into land management and planning efforts. That being said, steps can be made to increase soil organic matter. Minimizing soil disturbance can maintain and slowly increase SOC over time. Several conservation land use practices like light or rotational grazing, rotational cropping, conservation tillage, and no-till farming are examples that benefit soil health and have been increasing in recent years (Garnett et al. 2000; Swift et al. 2004; Euliss et al. 2006; Pacala et al. 2007; Carvalho et al. 2010). Setting aside land from intensive land practices and restoring the hydrology in depressional wetlands can increase the soil organic content in wetlands (Fenstermacher et al. 2016). Granted, this process takes time and doesn't occur over night (Jenkins et al. 2010; McMillan and Noe 2017).

Recovering Carbon in Phytomass

In certain parts of the country, vegetative regrowth has been shown to be a significant contributor to regional, national, and global

carbon stocks (Houghton 1999; Aighewi et al. 2014; Yu et al. 2018). Over half of the annual carbon uptake in the United States is performed by forests (Pacala et al. 2007; Woodall et al. 2015). Many WRE have a reforestation component, which over time shows the greatest potential to sequester a large amount of carbon. Within the first hundred years of bottomland restoration, 86 percent of the carbon stores reside in the phytomass component compared to the soil (Jenkins et al. 2010). Proper management of forests, woodlands, wetlands, and grasslands on public land over time can be another significant contributor to carbon sequestration that complements sequestration on private land (Banasiak et al. 2015).

Flood Damage Reduction

Floods have become one of the most expensive natural disasters, and long-term averages have continually risen (Birkland et al. 2003; Brody et al. 2007). As populations grow so does infrastructure development. Flood control methods like levees and dams often provide a false sense of security, which increase the potential for future flood damage as economic investment, development, and population density increase behind or below these engineered flood control measures (Brody et al. 2007; Guida et al. 2016). Flood damage costs will continue to rise unless steps to reduce these risks are addressed (Pielke and Downton 2000; Changnon et al. 2000; Winsemius et al. 2016; Wing et al. 2018).

There are strategies to reduce flood damages by maintaining lateral connectivity that do not consist of cutting the river entirely off from the floodplain. Sometimes the best action is to limit activity that would increase risk and damage, such as keeping development to a minimum in flood-prone locations (Xiao et al. 2013). One way to do this is for state and federal agencies to acquire flood prone areas and set them aside for conservation to minimize the risk of flood damage. Several recent analyses of this strategy found that this was a smart and cost-effective move because in the long-run land acquisition was 5:1 cheaper than the avoided flood damages (Johnson et al. 2020; Multi-Hazard Mitigation Council 2019). In Missouri this strategy has led to a "string of pearls" of public lands dotting the length of Missouri's large river floodplains (Galat et al. 1998). Urban areas can help shape land use decisions through land development regulations, ordinances, and zoning (Burnett 2018). Maintaining natural channels and providing adequate space in and around urban areas can be the best options for communities to minimize flood damage (Juan et al. 2020).

Another option is for private landowners to enroll flood prone areas into conservation easements. They still retain rights to the property but agree that this land will provide space for water to slow down and spread out through hydrological restoration. Since 1992 the USDA's Agricultural Conservation Easement Program, which includes the formerly known Wetland Reserve Program (WRP) easements, has restored 157,870 acres on private land. The Missouri Agriculture Wetland Initiative is another program involving multiple partners (DU, FSA, NRCS, MDC, and USFWS) in an effort to integrate agriculture and wetland landscapes and minimize floodplain development. To date, the partnership has both delivered 52 projects on the Missouri landscape that have directly restored 1,765 acres of native wetland habitats and enhanced flooding opportunity on another 1,264 acres of adjacent row-crop fields.

If floodplains must be constricted because of existing infrastructure and development, then floodways are options to decrease flood stage and allow water to spread out in designated areas (Shadie et al. 2018; Lopez-Llompart and Kondolf 2016). Floodways are locations where backwater flooding occurs between a gap in mainline and setback levees during higher river stages, providing extra storage capacity and slower water velocities that are less damaging. In urban scenarios, a system of different engineered biofilters are often used in conjunction with urban waterways to slow stormwater runoff. This can include water retention basins, extended

storage ponds, basins, rain gardens, infiltration basins, wetlands, vegetated filter strips, and bioswales (Burnett 2018). Often, the capacity of grey infrastructure is undersized for extreme events. Municipalities can look to green solutions like daylighting streams to increase the resiliency of aging stormwater systems, boosting flood storage capacity, as well as providing new recreational opportunities within developed landscapes (Burnett 2018). Maintaining natural channels and providing adequate space in and around urban areas can be the best options for communities to minimize flood damage (Juan et al. 2020).

At the site level, land use decisions can help slow water down, spread it out, and encourage infiltration so that immediate and adjacent properties are less likely to experience the negative impacts of floods. Natural vegetation provides hydraulic roughness to slow down damaging water velocities and to increase infiltration. Numerous studies have shown that consistent buffer widths, larger blocks of vegetative cover, and a greater percentage of wetlands act as buffers to reduce the amount of flood damages (Weller et al. 1998; Barbier and Enchelmeyer 2014; Goodwell et al. 2014; Brody et al. 2015; Brody et al. 2017; Narayan et al. 2017).

Ongoing population growth, demand for food production, and increased frequency of extreme weather events will continue to put the risk of flood damages to the forefront. Being aware of the interplay between changing precipitation patterns, land use, and infrastructure will help stakeholders identify areas of future risk and inform decision-making (McCauley et al. 2015; Mallakpour 2016; Munoz et al. 2018). Using spatial planning to identify areas, their potential uses and risks, and to consider tradeoffs when considering future policy decisions related to reducing flood damages will be key for conservation to leverage better decisions for tomorrow (McAllister et al. 2000; Xiao et al. 2013; Kreibich et al. 2015; Winsemius et al. 2016; Wing et al. 2018).

Bundling incentive programs such as flowage easements with other nutrient cycling programs could move the needle toward more ecologically functioning landscapes as opposed to fragmented, economically vulnerable, and ecologically broken. These yearlong flowage easements could help provide more space for flooding to occur and provide private landowners and communities with more shared responsibilities for managing floods. Another potential partner could be the local drainage districts. Broader easements incorporating buffer strips and riparian corridors would help expand the amount of floodwater storage along waterways and save costs by reducing the amount of sedimentation, thereby minimizing the amount and frequency of dredging needed in ditches.

Streamflow Maintenance

Having adequate water levels (flow) in streams and rivers to improve or sustain aquatic life and provide clean drinking water is vital, and therefore maintaining streamflows in Missouri's rivers and streams is an important ecosystem service. The collective input of headwater streams, which includes small drainages from 0, 1st, and 2nd order streams, account for the majority of the flows in larger downstream reaches (Meyer et al. 2003; Alexander et al. 2007; Nadeau and Rains 2007; Morley et al. 2011). The land use and habitat adjacent to these headwater streams are extremely important even though the presence and action of water isn't always visible. Vegetative cover including deep-rooted native grasses, forbs, and trees benefit water infiltration and slow surface runoff during and after rain events. Changes in land use and modifications to stream networks have shortened the lag time, increased the peak flow, and increased the volume and energy of water coming off the landscape in these key locations (Ehrenfeld 2000; Barksdale et al. 2014; McCauley et al. 2015; Webb et al. 2017). These hydrologic alterations interact at multiple spatial scales across watersheds and their fluvial

networks create imbalances in the hydrologic power and sediment transport (Covino 2017).

Conservation efforts and BMPs in and around headwater streams and improved infiltration and groundwater recharge in urban and suburban areas are all vital to minimize future negative impacts and maintain functional stream flows. In some urban settings with altered stream networks, wastewater treatment discharge regulation is important in maintaining stream flow and can play a vital role in sustaining aquatic life.

Climate Regulation

Climate regulation occurs through a variety of mechanisms at both global and local scales. Processes related to air quality, GHG abundance, and moderation of temperature and precipitation are all connected to climate regulation. The processes involved in carbon sequestration discussed in previous sections contribute to climate regulation at the global scale. At a local scale, the services provided by temperature moderating processes are most apparent.

Urban areas generally experience increased temperatures over the surrounding landscape in an effect known as "urban heat islands." Natural cover such as forests, grasses, forbs, water features, etc., in urban areas help to control the heat island effect through temperature moderation (Hathway and Sharples 2012). Urban forests provide shade, increase evapo-transpiration, buffer wind speeds, and reduce the urban albedo (Nowak et al. 2010). Temperature reductions provided by urban forests are dependent on many factors including tree species (Ballinas and Barradas 2016) and size of forested areas, with larger contiguous blocks being more effective (Jaganmohan et al. 2016). Wetlands presence in urban areas also provide a cooling effect influenced by location and shape (Sun et al. 2012). To maximize the ecosystem services provided by natural cover in urban environments, it is important to consider how green space is structured, not just that it is available.

Aquatic systems are sensitive to water temperatures with fish, invertebrates, and amphibians all having some sensitivity to temperature. Riparian areas contribute to the infiltration and cooling of groundwater stores. Emergence of these cooler waters via springs offset ambient warming and cooling of surface water to create thermal refugia and buffer temperature over greater areas (Westhoff and Paukert 2014; Westhoff et al. 2016). They also can help maintain surface flow in drought conditions. Wooded riparian corridors, through shading, can reduce maximum water temperatures and moderate temperature increases (Bowler et al. 2012). Healthy, intact riparian forests, shrubs, and even grasses and forbs, provide important micro-climates as the cooling effects of shading and evapo-transpiration from the riparian area and stream. This provides an important thermal refuge for many species. Riparian areas are important migration corridors, which may become increasingly important as species adjust ranges under increased climate stress (Krosby et al. 2018).

Water Purification

Many processes occurring within and alongside wetlands, streams, and rivers reduce the concentration of pollutants in aquatic systems. Functional floodplains and riparian areas trap sediment, nutrients, and other pollutants before flows reach a stream. Research in Missouri has found that mixed grass-shrub-tree riparian areas can reduce concentrations of nutrients and herbicides flowing out of the buffer zone (Lin et al. 2004). Floodplains operate in the same way, as slower velocities allow particulates to settle out of the water column in large fractions (Noe and Hupp 2009). However, anthropogenic modifications to streams and rivers generally decrease river-floodplain connectivity, reducing this capacity. Aquatic and semi-aquatic plants found on streambanks or in wetlands can contribute to a similar physical effect: lowering velocity and increasing sedimentation rates.

Plants, benthic algae, and phytoplankton also remove nitrogen and phosphorus from wetlands and the water column of rivers and streams. Similar to carbon these nutrients are stored in large quantities in living or decaying tissue. Ultimately nutrients and carbon may re-mineralize from decayed material and move through the system, but the nutrient cycling process slows that movement (Ensign and Doyle 2006).

Human activities can also have large impacts on nutrient cycling rates by increasing runoff and thus in-stream velocity and volume, allowing fertilizers and other chemicals to enter aquatic systems, and reducing the amount and type of vegetation present. In 2015 the Des Moines River Water Works brought a lawsuit against upstream drainage districts on the Raccoon River due to high concentrations of nitrate in the river. The suit alleged that the nitrate pollution was in large part caused by agricultural practices and that the drainage districts should be responsible for increased costs to remove the nitrate. Iowa courts decided for the drainage districts meaning the water works, and potentially all citizens paying for water, will continue to pay to remove the increased nitrate. Resource management practices that allow for connectivity between riparian, floodplain, and other aquatic features slow the movement and reduce the amount of nutrients and other pollutants in our freshwaters. This, in turn, reduces the frequency of eutrophication events and the overall costs of processing water for human use.

Municipalities employ a range of stormwater management practices to reduce runoff of pollutants (Burnett 2018). In addition to these preemptive measures, green infrastructure involving aquatic plants and wetlands are used to treat sewage, polluted waters, and industrial and agricultural waste (Liehr et al. 2004). For example, engineered wetland impoundments at Eagle Bluffs Conservation Area have been used since the 1990s as part of the City of Columbia's wastewater treatment process. Filtering the effluent through this green infrastructure reduces fecal bacteria and dissolved nutrients before the wastewater heads downstream (Knowlton and Jones 2003). As populations grow, grey infrastructure ages, and the linkages between water and the surrounding environment become more stark, government agencies, communities, and industry must work together to maintain and improve water quality. Using green infrastructure is and will be a growing part of the solution (Wise 2008).

Disease Regulation (Zoonotic Prevention)

A perhaps little-known service of healthy, intact ecosystems is the potential regulation of disease. Emerging infectious diseases are an increasing concern for wildlife, domestic animals, and humans. In wildlife, diseases like WNS in bats, CWD in deer and elk, and chytrid fungus in amphibians are increasingly threatening the health and sustainability of wildlife populations worldwide. Diseases in wildlife can also directly impact human health. At least three out of every four new or emerging infectious diseases in humans come from animals, and many of these diseases are associated with wildlife. As the human population continues to expand, there continues to be encroachment into and conversion of natural communities and habitat and therefore increased human-wildlife interactions. Increasing evidence suggests that protecting habitat and biodiversity may lessen the impacts and burden of disease on both animals and people.

Globally, changes in land use have been identified as a top driver associated with recently emerging infectious diseases in humans. Activities such as agricultural development, urbanization, deforestation, and habitat fragmentation significantly change the composition of wildlife communities on the landscape, increasing the likelihood that disease pathogens spread to new wildlife hosts or become more abundant. Changes in wildlife abundance, distribution, and behavior also

increase the likelihood that humans are exposed to diseases from wildlife.

Maintaining biodiversity within an ecosystem may further limit the exposure and impacts of many diseases by creating a dilution or buffering effect. Researchers are finding increased evidence that biodiversity may decrease disease exposure and transmission. For example, increased mammalian diversity has been correlated with decreased Lyme disease and hanta virus exposure risks. Similarly, increased bird diversity may decrease West Nile virus. The connection between human, animal, and environmental health is increasingly apparent. Understanding the role that the environment plays in infectious disease dynamics is critical to lessening or even preventing the impacts of these events overtime.

Cultural Services

Cultural services are nonmaterial benefits that people garner from their surrounding environment. These services may be the reason people go outdoors or value conservation even if they may never visit a particular location. The experiential aspects of cultural services are often influenced by provisioning and regulating services. Cultural services include fishing-hunting/consumptive recreation, recreation/nonconsumptive, ecotourism, education, and aesthetic/spiritual/mental health.

Fishing-Hunting: Consumptive Recreation

Hunting, fishing, and trapping gear and permit purchases are the original sources of funding for conservation in the United States and the foundation of the North American Model. Without the outcry of hunters and fisherman, starting in the late 1800s, resource overexploitation would have continued to go unchecked and America's natural resources and natural communities would have been depleted and destroyed. The revenue provided by purchasing permits and equipment goes directly toward those resources that the permits and equipment were purchased for, ensuring the resources will be there to use in the future.

Across the entire United States, purchases for hunting, fishing, trapping, and their associated permits, equipment, travel, lodging, and supplies resulted in approximately $81 billion in revenue in 2016. Migratory bird hunting in 2016 raised over $2.25 billion (US DOI et al. 2018). Such funding sources, established by the Pittman-Robertson Act and the complementary Dingell-Johnson Act, provide a large portion of the revenue that can be used to manage both game and non-game species and habitats.

Hunting, fishing, and trapping resources and public access continue to be a priority in Missouri. Hunters and anglers are vital to the funding for wildlife and fisheries restoration, research, and habitat as well as funding for educational efforts such as hunter education programs and shooting ranges. The funds generated by this group not only economically benefit the state fish and wildlife agencies, they also have an impact on the local economy. According to the Hunting Works for Missouri website, hunters support over 18,000 jobs in Missouri. Hunting generates $541 million in salaries and wages annually. Yearly spending by hunters in Missouri is $985 million. Missouri hunters spend an estimated $1,600 per year on trip-related expenses and gear. Hunters annually generate $108 million in taxes for the state of Missouri. Hunters generate $126 million in federal taxes annually. The total ripple effect from hunting in Missouri is $1.6 billion (Hunting Works For Missouri [n.d.], **huntingworksformo.com**). Fishing also plays a major part in our state economy by adding $1 .2 billion a year to state and local economies and supporting 21,000 jobs (ENVIRON 2014).

Recreation, Nonconsumptive

Nonconsumptive use of natural resources is a growing segment of overall natural community use in Missouri and across the United States. Wildlife viewing, hiking, and photography are just a few examples of nonconsumptive use of natural resources. Unlike consumptive use, there is no legislation that sets aside money for nonconsumptive uses. The amount of revenue created by nonconsumptive users, however, is not insignificant. In 2016, total expenditures in the United States for wildlife watching was approximately $76 billion (US DOI et al. 2018). While this money doesn't go directly toward conservation, it contributes to a healthy national, state, and local economy. With such significant financial contributions, the desire for expanded opportunities to attract nonconsumptive users (as well as additional consumptive) is embraced by local businesses in parts of the state relying heavily on ecotourism.

As an example, NPS properties continue to be an increasingly popular destination for nonconsumptive users. Over the past five years, national parks have welcomed more than 1.5 billion visitors (**nps.gov/aboutus/index.htm**).

A further example is recreation along the Missouri River. The Missouri River is attractive to the public as a place for fishing, hunting, and other water-sports activities. People find it a place of solitude and beauty. The Missouri River also offers private businesses and local, state, and federal agencies many opportunities to develop facilities and manage the river, its valley, and its resources for attracting even more people to the river. In 2004 and 2005 exit interviews with visitors were used to estimate public use on and along 811 miles of the Missouri River from Gavins Point Dam near Yankton, SD, to the river's mouth near St. Louis, Missouri. These interviews allowed the estimation of both types and amounts of public use and the economic value of the river to the users. Economic values of recreation to the public were estimated using both the Travel Cost Method (TCM) and the Contingent Valuation Method (CVM). Resultant from the interviews, it is estimated that 2,042,980 individual visits were made to the Missouri River in 2004 and 2005.

The exit interviews study allowed estimates of the economic benefit people obtained when they value a "product," that is, the use of the Missouri River, more than what they paid for it. One challenge in estimating this "consumer surplus" (CS) generated by river recreation was that there is no "price" or market where a person could purchase a day at the Missouri River. No ticket was required. Rather, two indirect methods, zonal travel cost and discrete choice, were used to estimate the economic benefit of the river to users. In all, recreation at public accesses and areas on and along the Missouri River was a highly valued experience for users, with a benefit to users somewhere in the range of $20 million (zonal TCM) to $39 million, estimated using the discrete choice model (DCM) during the period from January 3, 2004, through January 28, 2005. If the total CS was divided by the estimated number of individual visits or party visits, the economic benefit ranged from about $15 per individual visit using the zonal TCM to $43 per party visit using DCM (Treiman et al. 2014).

Missouri's outdoor shooting ranges provide both recreation and an opportunity to hone hunting skills. These instrumental values are on display at MDC's 69 areas with unstaffed shooting ranges across the state that provide various kinds of shooting opportunities including archery, rifle, handgun, and shotgun opportunities. In 2015, MDC undertook user surveys at its ranges estimating that about 299,810 visitors, in 171,423 parties, used 39 unstaffed firearms ranges during 2015, with about 1.5 visits per visitor per year. MDC's unstaffed ranges provided over $1.8 million in economic benefits (consumer surplus) to the users. The estimated economic impact on Missouri's economy of spending associated with use at MDC ranges is $7.3 million.

Ecotourism

Communities near nonconsumptive use attractions see seasonal and even year-round boosts to their local economies from ecotourism. For example, during the federal fiscal year 2017, 53.6 million visitors to the National Wildlife Refuge System injected $3.2 billion into the local economies from trip-related spending (Caudill and Carver 2019). Missouri has nine National Wildlife Refuges in varying landscapes across the state (seven open to the public), which accounted for 322,189 visits in federal fiscal year 2017. Local communities near these refuges benefit from the economic boost derived from local management practices designed to preserve the area and attract patrons.

Missouri conservation partners, which includes private landowners, have been working collaboratively toward restoring representations of the original composition and function of the state's natural heritage. One example of a restoration effort that has benefited Missourians is the effort to reintroduce formerly extirpated elk

to southern Missouri. Reintroduction efforts have been very successful, and elk reestablishment has Missourians visiting the Ozarks to see this charismatic species. Efforts such as these increase local species richness, which provides higher nature-based tourism value (Chung et al. 2018). Tourism to view the elk is another instrumental value that can be categorized under recreation. In 2016 over 11,000 visitors toured the elk zone, with Peck Ranch CA visitors coming farther distances than Current River CA visitors. More Peck Ranch visitors came specifically to see elk (and saw them) than did Current River's, but both groups of visitors were overwhelmingly satisfied with their visits. Overall, the two new elk tour loops yielded a nearly $1.3 million dollar economic impact on the local area (counting only spending by nonlocal visitors), supporting about 13 full-time jobs. This estimate includes the direct, indirect, and induced benefits associated with visitor spending. The economic value of each elk viewing experience to visitors (the consumer surplus), as measured by willingness-to-pay analyses, was over $14 at each area.

Education

Natural resources can contribute to increased cognitive development and successful academic achievement. A study (Dadvand et al. 2015) looked at cognitive development in relation to "greenness" (trees, shrubs, flowering plants, etc.) around students' schools and homes. They found that students who had more exposure to greenness showed a beneficial increase in superior working memory, and attentiveness. This was particularly true for students who had more exposure to greenness at their schools.

Several recent studies have examined the Normalized Difference Vegetation Index (NDVI) using remote sensing technologies. The NDVI is a spectrum-based greenness index that measures and monitors plant growth, vegetation cover, and biomass production. Increasing NDVI values indicated higher levels of greenness around schools, while zero or negative values indicated non-vegetative features, i.e., barren surfaces, concrete, water, clouds, etc. A study by Leung et al. (2019) showed that trees and forests around schools can help students perform better in mathematics and English. Their nine-year study included 27,493 public school students from third to tenth grade. Their study supported the findings of Kweon et al. (2017) that trees have a positive impact on student performance, while green lawns and sporting fields do not. Most of these studies examined areas that included a buffer zone of up to 1,000 meters from school grounds. Wu et al. (2014) looked at distances of 2,000 meters from the school grounds. The expanded buffer zones were included to try to ascertain the amount of greenness students would encounter in their neighborhoods when not in school. Their findings also showed a correlation between increased greenness values and increased academic success in mathematics and English. A study by Matsuoka (2020), analyzed how nearby nature impacted student mental fatigue and stress at 101 high schools in Michigan. This study found a positive correlation between views from classrooms and the cafeteria that contained trees and shrubs with an increase in standardized test scores, graduation rates, percentages of students planning on attending a four-year college program, and fewer occurrences of criminal behavior. Large expanses of landscape lacking natural features, including campus lawns, athletic fields, and parking lots, had a negative impact on standardized test scores and college plans. Each of the studies mentioned above took measures to control for socioeconomic differences.

Student engagement is a critical component of student learning. A vital part of keeping students engaged and learning is keeping their attention. Many educators are reluctant to try nature-based learning because they fear the students will not be able to focus on returning to the classroom. Attention restoration theory suggests that natural landscapes induce a state of "soft fascination." This allows our ability to deliberately focus to rest, thus allowing our

capacity to direct attention to be refreshed and restored (Kaplan 1995). A study by Li and Sullivan (2016) demonstrated that window views of green landscapes promoted higher student attention restoration and sped up stress recovery in high school students, whereas exposure to daylight alone did not. Other studies demonstrated that walks in both forested (van den Berg and van den Berg 2011), and green urban settings (Faber Taylor and Kuo 2009) can have a rejuvenated effect on student attention. These studies indicate that doing a lesson outdoors and/or spending time walking in a green area between classes can improve focus when students return to the indoor classroom setting.

Motivation is another vital part of student engagement (Deci et al. 2011) and several studies have found a link between nature-based learning and engagement. There is some evidence that nature-based learning fosters a greater interest in school and overall learning (Ernst and Stanek 2006). Separate studies by Fägerstam and Blom (2012) and Skinner and Chi (2012) indicate that nature-based education also seems to increase students' intrinsic motivation. Each of these studies suggests that outdoor nature-based learning is more hands-on, interesting, and enjoyable. These are all positive attributes that seem to carry over to the following indoor lessons.

Stress is another important, yet negative, factor in student engagement. Studies by Grannis (1992) and Leppink et al. (2016) have shown that high levels of student stress are a predictive measure of low academic achievement. Several studies with both adults (Park et al. 2010; Kuo 2015) and children (Bell and Dyment 2008; Chawla 2015; Wiens et al. 2016) indicate that exposure to nature provides quick and powerful reductions of stress biomarkers (salivary cortisol levels, blood pressure, pulse and heart rates). Li and Sullivan (2016) also showed a decrease in heart rate and stress levels in high school students who had a view of green landscapes versus those who did not have such a view. Kuo et al. (2018) studied whether taking the students outside for a nature-based lesson would later make them unengaged and more keyed up when they returned to formal classroom instruction. Their study found that student engagement increased dramatically during formal classroom instruction when the students had previously been engaged in a nature-based lesson.

It is yet unclear why access to nature has such a profound impact on academic success. One theory is that exposure to trees and nature areas can relieve stress (Tyrväinen et al. 2014). Exposure to nature is known to decrease mortality rates, illness, and disabilities, so people become healthier (WHO 2017). Students who are healthier, both mentally and physically, are more motivated and more capable of learning, which helps them perform better academically (Basch 2011).

Time spent in or viewing nature at home can also impact not only academic success but also life success. A study by Faber Taylor et al. (2002) looked at how views of nature from the home affected self-discipline in inner-city children. Low levels of self-discipline can contribute to academic underachievement, juvenile delinquency, teenage pregnancy, and high drop-out rates. Their study had mixed results. Girls, who had a green view from their home, showed a 20 percent increase in all levels of self-discipline. Boys, however, did not show a relationship between their home view and any of the self-discipline measures.

There are several substantial ways that nature can improve mental health. Many of these, especially regarding children, can contribute not only to academic success but also to lifetime success. In 2017, the National Center for Education Statistics identified four million U.S. public school students with emotional, cognitive, and behavioral disabilities (ECBDs). As identified by the Individuals with Disabilities Act (U.S. Congress 2004) ECBDs include students with ADD, attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD) and dyslexia. These are all neurobehavioral disorders with indicators of poor

student behavior, attention span, and academic achievement. ADHD is the most common neurobehavioral disorder. Approximately 6.1 million (9.4%) children have an ADHD diagnosis. Boys are more likely to have an ADHD diagnosis than girls (12.9% compared to 6%). Additionally, 64 percent of children with an ADHD diagnosis also had other conditions (depression, ASD, anxiety, Tourette Syndrome, or other behavior or conduct disorders). The CDC has called ADHD "a serious public health problem." Some of the reasoning behind this declaration is its prevalence, how impactful it can be on overall life, the limited effectiveness of traditional medications, and severity of side effects. In 2016, approximately 90 percent of students with an ADHD diagnosis received school accommodations, while 60 percent had received some type of skills training or behavioral treatment.

Finding ways to teach students with ECBDs often requires creativity so they do not lag behind their non-ECBD peers. One creative method that is showing great potential is utilizing nature, especially with ADHD. The research team of Faber Taylor and Kuo have done considerable research looking at how greenness affects ADHD symptoms. In 2004, their nationwide study collected data from parents on how their children spent their free time. They found that play time in green spaces significantly reduced ADHD symptoms in children across all incomes, races, locations, and community types. In a similar study in 2011, they also found that if children participated in unstructured routine play for multiple days during the week, children with ADD/ADHD had improved attention spans. Unstructured routine play was also significantly better at reducing hyperactivity than playing on built outdoor environments (i.e., playgrounds) or playing inside. Kuo et al.'s 2018 research showed that students can focus and learn better inside the classroom after spending time participating in nature-based learning. It is also important to point out that nature-based symptom improvement comes without the side effects often experienced with traditional medication for ADD/ADHD.

ADD/ADHD are not the only ECBDs that have responded well to time in nature. A study by Farnham and Mutrie (2003) showed that nature-based education could help with improved trust and working within groups and significantly helped with anxiety for students with mild to moderate learning disabilities.

In 2019 Kuo et al. did an integrative mini-review of research literature asking the question "Do nature experiences promote learning and child development?" They looked for evidence within the peer-reviewed scientific journals, paying careful attention to the difference between evidence for cause-and-effect relationships and evidence for associations. During this critical review, their findings indicated that "experiences with nature do promote children's academic learning and seem to promote children's development as persons and as environmental stewards."

The academic learning outcomes include:

- increased retention of subject matter
- higher standardized scores
- better grades
- better math, reading, and writing skills
- higher graduation rates

Personal development outcomes include:

- better leadership skills
- better communication skills
- more resilience
- better critical thinking and problem solving
- better spatial skills

Positive stewardship outcomes include:

- stronger connection to nature
- stronger environmental values
- more pro-environmental behaviors

They also found there are eight reasons these results occur. Five of them are learner based, including:

- attention restoration
- stress reduction
- improved self-discipline
- enhanced motivation, enjoyment, and engagement
- higher levels of physical activity and fitness

The other three reasons involved how nature provides a better platform for learning. Nature tends to:

- be calmer, safer, and quieter
- foster warmer and more cooperative relationships
- encourage more beneficial play.

These findings are particularly important for students who struggle with traditional classroom learning.

Aesthetic/Spiritual/Mental Health

Among the other cultural services obtained from ecosystems are aesthetic experience, spiritual enrichment, and mental health benefits (Gebre and Gebremedhin 2019). Nature may provide inspiration for culture and art, but it can also be appreciated in its own right from an aesthetic point of view. Aesthetics involve an appreciation of beauty. In essence, when viewing a landscape for its aesthetic value, all other aspects of its identity and function are subordinated to its artistic qualities (Meining 1979). No longer does the eye of the beholder see nature or habitat for wildlife, nor is the landscape seen as an artifact, system, problem to be solved, wealth to be gained, ideology, history, or even place. Appreciation of the aesthetics of nature is a personal experience that rests upon the belief that there is something close to the essence, to beauty and truth, in the landscape. In this view, landscape lies utterly beyond science, holding meanings that link us as individual souls and psyches to an ineffable and infinite world.

Beyond appreciating its beauty, a desire to feel spiritual connections motivates some people to spend time in nature (Floyd et al. 2016). This may entail a visit to an outdoor space that is considered sacred. Or it may simply consist of time spent outside where a balance within nature is experienced along with a connection to it. Researchers are also finding that time spent in nature, in addition to nourishing the spirit, provides a wealth of mental benefits, from increased cognitive performance and well-being to alleviated mental health illnesses such as depression, ADDs, and Alzheimer's (USFS 2018). When a person is stressed, views of nature can within minutes reduce blood pressure, muscle tension, and pulse rate. Hospitals that maintain healing gardens for patients, visitors, and staff provide them as places for relaxation, recovery, rejuvenation, and an offset to the stress of both routine medical procedures and more complex long-term treatments. A study conducted in Wisconsin identified a strong association between better mental health among both urban and rural residents in areas with more green space. This led the researchers to suggest that "greening could be a mental health improvement strategy in the United States" (USFS 2018).

Supporting Services

Supporting services are the fundamental processes that feed into and make provisioning, regulatory, and cultural services possible. While these include photosynthesis and the water cycle, in this subsection we focus specifically on nutrient cycling and soil formation and health, because without conserving these, healthy natural communities and agriculture would not be possible.

Nutrient Cycling

Nutrient cycling refers to how basic elements are stored and how they move through the environment. Soils are the largest storage reservoir for both nitrogen and phosphorus (Bowden 1987; Kim and Geary 2001). Historically, the turnover rate for soil minerals takes hundreds of years for the chemical structure to slowly transform and move through the system. Because these nutrients weren't always biologically available, many of Missouri's native species have strategies to survive in nutrient poor settings and hold onto the nutrients they could obtain. Despite this, the nutrient processing through plants occurs at a quicker and more variable rate depending upon patterns of succession and periodic disturbance.

As portions of Missouri's natural communities were converted to agriculture, nutrient cycling changed significantly. This conversion released a pulse of mineralized nitrogen and phosphorus into the environment (Turner and Rabalais 2003; David et al. 2001; Van Meter et al. 2017; Heimann 2009). Another bump began in the 1950s and has continued to rise due to manufacturing and application of synthetic fertilizer to agriculture. Subsequent runoff has led to enriched terrestrial and aquatic environments (David and Gentry 2000; David et al. 2001; Mitsch et al. 2001; Panno et al. 2006; Alexander et al. 2007; Blevins et al. 2014; Van Meter et al. 2017). In urban areas, ongoing development, increased impervious surfaces, and greater stormwater runoff have also increased nutrient loading to adjacent streams and wetlands (Foley et al. 2005; Harrison et al. 2014; Hopfensperger et al. 2014; Palta et al. 2016; Sutton-Grier et al. 2010).

No doubt Missourians have benefited from both agriculture and urban development that has occurred, but there are tradeoffs. The tradeoff has been a series of negative ecological impacts, some of which are irreversible. Consider that over 99 percent of Missouri's native prairies have been lost to agricultural conversion or development. Over 87 percent of Missouri's wetlands have been lost due to agricultural conversion, development, and enhanced drainage systems, which undermines and reduces the landscape's capacity to cycle excess nutrients by denitrification or phosphorus retention (Nelson et al. 2019). Of the existing habitats, the excess nutrient load can shift the plant communities away from their natural states that once included a diverse composition of unique native plants to a more monoculture suite of generalist and invasive species (Morris 1991; Ehrenfeld and Schneider 1993; Foster et al. 2003; Jessop 2014). In aquatic environments, excess sediment and nutrient loads have a similar effect, as aquatic plants are replaced by algae and phytoplankton (Kemp et al. 1983; Moore et al. 2010). This change in trophic structure can decrease water quality when the conditions are ripe for blue-green algal blooms. The explosion and collapse of these ephemeral occurrences create toxins, reduce light and oxygen from the water, and negatively impact aquatic life, leading to fish kills in certain situations (Havens 2008).

The realization of these deleterious impacts and interactions has led to the development of conservation strategies and BMPs to do a better job managing nutrients. Considering agroecological solutions to site-specific nutrient cycling includes crop diversification, rotation, use of crop residues, green manures, and animal integration as options farmers can consider (Altieri and Rosset 1996; Wezel et al. 2014). Private land guidance also recommends no-till

practices, and buffer strips along field perimeters and drainageways can temporarily slow down the movement of sediment and nutrients from uplands into aquatic systems (Osborne and Kovacic 1993; Dosskey 2001; Sharpley et al. 2002; Dorioz et al. 2006; Knight et al. 2010; Kleinman et al. 2011; Dupas et al. 2015). The use of landscape position, natural vegetation, and interaction of water is why the protection of and restoration of upland natural communities, riparian corridors, and wetland habitats is also critical to the management of nutrients.

Managing nutrients has to be done across multiple scales. Because of the decreased capacity of natural communities, bioengineering alternatives must also be employed across urban and rural landscapes. At the local level, bioswales, rain gardens, and detention basins are well-established tools employed by stormwater management plans that help intercept suspended solids and excess nutrients in strategic locations (Burnett 2018). Another emerging application is plumbing sub-surface field drains to bioreactors that contain woodchip and steel byproducts to limit the release of agricultural runoff downstream (Hua et al. 2016). Incorporating wetlands into the wastewater treatment process, like the wetland cells at Eagle Bluffs Conservation Area, scales the treatment to a municipality level (Knowlton et al. 2002). Moving it beyond the site or community level requires coordination within and across watersheds. The Chesapeake Bay is one of the largest and best-known water quality trading programs in the country working to reduce nitrogen, phosphorus, and sediments across multiple states thatincludes Maryland, Pennsylvania, Virginia, and West Virginia (Molnar and Kubiszewski 2012). This program and others use cost-effective approaches to improve environmental compliance of water quality standards by allowing financial incentives and flexibility on whom and where nutrient management occurs. In addition to the environmental and economic benefits, this approach encourages communication among all the stakeholders and a shared responsibility and commitment to water quality improvement (Corrales et al. 2013; Fisher-Vanden and Olmstead 2013; Molnar and Kubiszewski 2012).

The legacy changes to nutrient availability and cycling to Missouri's land and waters will endure. This will require all stakeholders, involving members of conservation, agriculture, and surrounding communities to work together, balance tradeoffs, and design future landscapes that are more integrated in their nutrient management approaches.

Soil Formation/Health

Soils are defined as natural bodies with diverse physical, chemical, and biological processes that sustain life. Soil and water are linked foundational natural resources that support human and ecosystem health. Soil is an expression of a complex web of ecological mutualism whereby earthen materials and biological processes create mutual benefits for many forms of life, including people and natural communities. Healthy soils are long-term reservoirs of surface and groundwater. Healthy soils are long-term buffers of soil fertility for habitats and agricultural lands. Healthy soils are long-term buffers of ecological resiliency, which is especially important with changing climatic conditions. Healthy land and water support healthy people and are the foundation of all ecosystem services.

Soils form and evolve as the result of the interactions of "parent materials (earthen materials), climate, topography, the biology of the soil, and time" (Jenny 1941). The integration of soil physical conditions and environmental influences defined by these five factors revolutionized concepts of soil formation. Roy Simonson (1959) outlined a general theory of soil genesis whereby soils are a continuum across the landscape. Expression of soils across the landscape are results of the accumulation of parent materials and the differentiation of the soil profile. The soil profile is formed because of the relative influences of various physical, chemical,

and biological additions, removals, transfers, and transformations within the soil body. All these processes occur simultaneously. Different soil profiles are formed because of the relative and cumulative impacts of these four soil-forming processes (Simonson 1959). Soil properties and soil ecosystems in nature are constantly changing, albeit (seemingly) very slowly.

Cultivation drastically alters soil properties including loss of topsoil from erosion; radical changes in soil structure from compaction and loss of pore space; decline in soil fertility, soil organic matter, and soil biology; and alterations of soil physical characteristics, particularly affecting how water infiltrates into and percolates through the soil profile and how water is stored within the soil. Robert Ruhe determined that soil formation was intimately tied to geomorphology and drainage, and he refined concepts as to how soils are altered by water moving across the landscape and through the soil (Ruhe 1969, 2:55).

The current soil health movement builds on these foundational soil formation studies, including the growing awareness of the importance of how soil biology influences how nutrients are stored and made available and cycled in the ecosystem. Practices that promote soil biology mitigate the effects of cultivation by increasing soil organic matter accumulation, improving nutrient cycling and water infiltration, percolation, and storage in soils. Early and ongoing research suggests a variety of practices including minimal tillage or no-till improves soil structure and porosity. Using cover crops increases soil organic matter and improves nutrient cycling, promotes the benefits of increased soil biological populations and enhances diversity of the soil ecosystem. These practices can make steady progress in improving cultivated and managed soils. These soil health practices promote processes that sustain yields while reducing chemical use, which increases income, slows rates of erosion, and improves water quality and food nutrition. Successful soil conservation practices, often supported by incentive programs, translate into healthier land, water, and people.

Soil health is based on five principles (Miller 2014):

- Maximize the infiltration of water into the soil
- Maximize percolation of water through the soil
- Maximize soil organic matter production
- Maximize soil organism and plant populations and diversity
- Minimize soil compaction and erosion

A critical component of soil health is the biological diversity of the soil ecosystem. Plants, animals, and people depend upon the immense biomass and diversity of soil microbes, macro-invertebrates, fungi, bacteria, and actinomycetes to remain healthy and productive. Soil microbes fix atmospheric nitrogen and drive processes that decompose soil organic matter, which releases essential nutrients that are stored and cycled by a variety of soil mechanisms and processes. Interactions between plants, soil organisms, and fungi are bio-geochemical factories that create essential ecological benefits and provide high value ecosystem services and cost savings for land managers.

A good example of this process is the mutualistic relationship between plants, mycorrhizal fungi, and soil organisms. Virtually all perennial plants depend upon mycorrhizal fungi to obtain water and nutrients. Plant roots and fungal strands become interwoven and spread throughout a soil to obtain water and nutrients. The fungi gain carbohydrates from plants in return for providing water and nutrients, particularly phosphorus and micronutrients such as zinc or boron. Soil organic matter consumers and decomposers obtain nutrients from plants and fungi. Soil organisms die, and nutrients are subsequently released in forms that are available to plants and fungi. Plant growth and development are greatly impaired when

mycorrhizal fungi are not present in a soil. Many forest and prairie species depend upon specific kinds of mycorrhizal fungi to survive, affecting success in establishing native species in cropland or old fields that have a history of herbicide and fungicide use. Residual pesticides can greatly reduce beneficial soil microbes and macro-invertebrates in the soil. Healthy soils facilitate successful root and fungal strand development, which releases compounds that improve soil structure.

Recent and continually developing science suggests that the vast underground network of roots and fungal strands play a critical role in improving and sustaining ecological resiliency and benefits to wildlife and people. The greatest complexity of these webs of biological connections are found in healthy forests and native prairies.

Highly managed and drastically altered soils are ecosystems that are being utilized for the needs of people. Disturbed soils will respond positively to soil health practices. These practices are based on ecological foundations that can improve soil resiliency and ecological function of altered habitats such as old fields, pastures, and even cropland. Planting cover crops promotes root and mycorrhizal health and creates soil pore space, which in a few short years improves soil structure that facilitates water infiltration, percolation, and storage in the soil. Cover crops accumulate soil organic matter and support growing soil organism populations, thus sustaining processes that store and cycle nutrients and support habitats, crop production, and forest products. The use of buffer strips with perennial native plants in croplands, pastures, riparian zones, and waterways promotes not only pollinators but also beneficial soil organisms and fungi. Improved nutrient storage and cycling reduces the need of expensive fertilizers. Soil bio-geochemical processes can break down many pollutants. Together, these ecosystem services increase or sustain productivity while improving water quality.

As ecologist Barry Commoner wrote in *The Closing Circle* (1971): "Everything is connected to everything else." The life of the soil is the foundation of the entire terrestrial ecosystem and has enormous benefits for terrestrial and aquatic habitat and health.

The soil's rhizosphere, the area surrounding plant roots and mycorrhizal strands, has been called the underground economy by many popular writers, including geomorphologist and biologist David Montgomery in *The Hidden Half of Nature* (2016) and *Growing a Revolution* (2017). Healthy soils with diverse microbial populations improve nutrition for people and wildlife with more efficient uptake of essential micronutrients such as iron and zinc. Soil microbes, soil organic matter, and root exudates create a chemical factory in the soil that can break down some organic pollutants into less harmful compounds. A soil's biological system and clay micelles can bind hazardous materials into insoluble forms that are unavailable to plants and animals and thus reduce impairment to surface and groundwater. Soil microbes are a first line of defense in controlling many soil and water-borne diseases and pathogens that affect people and wildlife. People lived for many generations closely interacting with soil organisms, plants, and animals in the wild and on farms. Exposure to healthy lands and waters in nature generally has been a positive reinforcement of human health. Much of those human-nature benefits come from nutrient-enriched foods and from microbes that sustain soil life.

All these soil processes depend upon the presence of water. Water is a major determinant in how soils form and ecosystems develop. Water is an active, dominant determinant in all five factors of soil formation and the four processes of soil genesis. Soil bio-geochemistry is water chemistry. Water is the driver and facilitator as to how soils and ecosystems process energy and nutrients, which in turn supports habitats that animals and people depend upon. Ecosystems and ecosystem services rely on the mutualistic

benefits of terrestrial processes in the soil, which are directly and intimately linked by water throughout the web of life.

Healthy soils drive many ecosystem services that promote healthy land, healthy water, and healthy people.

Section Seven: Missouri's Strategic Actions for a Regenerative and Sustainable Conservation Future

The first six sections of the CCS have focused on explaining "why" proactive conservation actions and investments are needed, "where" such efforts should be focused to be most strategic, and that the time to take action is "now." Section Seven shifts gears to focus on "what" needs to be done, by "whom," and "how." This section serves as a strategic plan to bring together all the diverse components of CCS into a succinct *call to action* for Missouri's conservation community to ensure a bright future for conservation in Missouri. Given the diversity and complexity of conservation needs, challenges, opportunities, partners, and resources, the scale of this strategic plan (**Table 7.1**) is broad – focusing on four overarching goals with 16 underlying strategies. At this scale, these concepts and strategies are not necessarily operational. Partnerships, organizations, teams, and individuals can internalize these broad strategies and interpret their approach of how best to operationalize based on their specific interests, expertise, resources, and network. As guidance, **Table 7.2** is included to show some examples of actions and programs being utilized to help advance each strategy and is not intended to illustrate an exhaustive list of options.

A close examination of this strategic plan reveals considerable overlap between it and MDC's *Design for the Future* agency strategic plan (Table 1.1). This close alignment is not accidental. The facts that (1) MDC's mission "*to protect and manage the fish, forest, and wildlife resources of the state; to facilitate and provide opportunity for all citizens to use, enjoy, and learn about these resources*" aligns so well with the purpose of CCS, and (2) that MDC's *Design for the Future* strategic plan was just recently conservation partners made it a great foundation to build upon.

However, as has been conveyed throughout this document, MDC is not and cannot be the only face of conservation in Missouri. Conservation at the magnitude needed in Missouri can only succeed by bringing together all of Missouri's conservation partners and citizens as a united front to properly address the challenges, threats, and opportunities posed to and by Missouri's natural landscape. Each partner brings its own unique skill sets, assets, passions, and energies. It is when these assets come together that amazing things are possible in conserving Missouri's fish, forest, and wildlife resources and making these resources available for citizens to appreciate and enjoy. Because it takes us all, Missouri's Strategic Actions for a Regenerative and Sustainable Conservation Future (**Table 7.1**) is needed to show how we can all best work together to make conservation happen.

Table 7.1 – Strategies for a Regenerative and Sustainable Conservation Future

Goal 1. Missouri has healthy, productive, regenerative, and sustainable natural communities and species				
Strategy	**Resources Needed**	**USFS Priorities Supported**	**USFWS Element Supported**	**Principal Desired Future Conditions (DFCs) Addressed (Refer to DFCs on pgs. 395–398) Key: Assessment Theme:DFC**
1.1 Implement Missouri's CCS to prioritize water and land conservation management in Missouri	State; Federal (USFS, USFWS, NRCS, FSA); NGO; Private	1,2,3	1,2,3,4,5,7,8	**1:**1–4,7; **2:**3,4; **3:**1–7; **4:**1–3,5,6; **5:**1–3; **6:**1–3; **7:**3,5,6; **8:**3,4; **9:**3,4; **10:**1,2
1.2 Maintain and improve the ecological functions of Missouri's watersheds and wetland systems	State; Federal (USFS, USFWS, NRCS, FSA); Local; NGO; Private; Industry	1,2,3	1,2,3,4,5,7,8	**1:**1–7; **2:**1–4; **3:**1–8; **4:**1,5,6; **5:**1,2; **6:**1–6; **7:**1,3,6; **8:**2,3,4,5; **9:**1–4; **10**:1–3
1.3 Prevent, where possible, and control the impacts of priority invasive species and diseases	State; Federal (USFS, USFWS, NRCS); Local; NGO; Private; Industry	1,2,3	1,2,3,4,5,7,8	**1:**1–7; **2:**3,4; **3:**1,4–8; **4:**1,2,5,6; **5:**1,2; **6:**1–6; **8:**1–5; **9:**1–4; **10:**1–3
1.4 Manage, through sound science, harvestable fish and wildlife species at biologically and socially acceptable levels	State; Federal (USFWS)	1,2,3	7,8	**1:**1–4,7; **2:**3,4; **3:**1,7,8; **4:**1–3,5,6; **5:**1,2; **6:**1,5; **9:**1–3; **10:**1–3
1.5 Recover and maintain SGCN to sustainable levels	State; Federal (USFWS, USFS, NRCS); NGO; Private	1,2,3	1,2,3,4,5,7,8	**1:**1,2,4,7; **3:**8; **4:**1–3,5,6; **5:**1,2; **6:**1; **7:**5; **9:**1,3; **10:**1–3
1.6 Control and suppress wildfires and promote the appropriate use of prescribed fires	State; Federal (USFS); Local/Rural Fire Department; NGO; Private	1,2,3	1,2,3,4,5,7,8	**1:**1–7; **2:**3; **3:**1,5,8; **4:**1,2,5; **5:**1,2; **6:**1–3,5,6; **7:**1–6; **8:**1,2,4–6; **9:**1–3; **10:**1–3
1.7 Provide improved and sustainable ecosystem services such as forest products, clean water, and flood control relied upon by citizens for their economic, social, and ecological well-being.	State; Federal (USFS, USFWS, NRCS, FSA); NGO; Private; Industry	1,2,3	1,2,3,4,5,7,8	**1:**3,6,7; **2:**1–4; **3:**4–8; **4:**1–6; **5:**1–3; **6:**1–6; **7:**1–3,5; **8:**1–7; **9:**1–4; **10**:1,2

Goal 2. Missouri invests in regenerative and sustainable natural resource conservation				
Strategy	**Resources Needed**	**USFS Priorities Supported**	**USFWS Element Supported**	**Principal Desired Future Conditions Addressed**
2.1 Establish and utilize partnerships between government agencies, schools, nonprofit organizations, and the business community to build capacity to deliver conservation in Missouri	State; Federal (all); Local; NGO; Private	1,2,3	3,4,7	All
2.2 Promote citizen awareness of the need to invest in conservation and increase opportunities for citizens to contribute through voluntary service, professions, advocacy, and financial investment	State; Federal (all); Local; NGO; Private	1,2,3	3,8	All
2.3 Maintain and support conservation organizations with the expertise, resources, and mandate needed to deliver conservation in Missouri	State; Federal (all); Local; NGO; Private	1,2,3	7,8	All
2.4 Update the CCS at least every 10 years to address changing opportunities, threats, and resource and citizen needs	State; Federal (all); Local; NGO; Private	1,2,3	6,7,8	All

Goal 3. Missouri citizens have access to engage in outdoor recreation and to enjoy nature				
Strategy	**Resources Needed**	**USFS Priorities Supported**	**USFWS Element Supported**	**Principal Desired Future Conditions Addressed**
3.1 Utilize land conservation tools (e.g., voluntary land acquisition, conservation easements) strategically to protect important landscapes and habitats and to provide valuable places for people to enjoy nature	State; Federal (USFS, USFWS, NRCS, FSA); NGO; Local; Private	1,2,3	1,2,3,4,7,8	**1:**1–7; **2:**3,4; **3:**1–4,7; **4:**1–5; **5:**1,2; **6:**1–6; **7:**5; **8:**1–6; **9:**1–4; **10:**1–3
3.2 Utilize community conservation strategies effectively to incorporate nature into the places where people live	State; Federal (USFS, USFWS); Local; NGO; Private	2,3	2,3,4,7,8	**1:**2,3,5,6; **2:**1; **3:**4,8; **4:**1–6; **5:**1,2; **6:**1,2,4–6; **7:**1–4; **9:**1–4; **10:**1–3
3.3 Provide quality maintenance of public lands, other lands made available to the public, and the infrastructure they contain. Where appropriate expand public opportunities for outdoor recreation	State; Federal (USFS, USFWS, NPS, COE); Local; NGO/Volunteer	3	2,3,4,7,8	**1:**1–7; **2:**3,4; **4:**1–5; **5:**1,2; **6:**1–6; **7:**3,5,6; **8:**1–6; **9:**1,2; **10:**1–3

Goal 4. Missouri citizens value natural resource conservation				
Strategy	**Resources Needed**	**USFS Priorities Supported**	**USFWS Element Supported**	**Principal Desired Future Conditions Addressed**
4.1 Utilize information campaigns to communicate the social, economic, and ecological value of nature for sustaining and enhancing our quality of life	State; Federal (USFWS, USFS, NRCS); NGO; Local; NGO	2,3	1,2,3,4,5,7,8	**9**:1–4; **10**:3
4.2 Make educational programs and resources available to help citizens connect to nature	State; Federal (USFWS, USFS, NRCS); Local; NGO	2,3	3,7,8	**9**:1–4; **10**:3

Table 7.2 – Example Strategy Programs and Action Items

Strategy 1.1 Implement Missouri's CCS to prioritize water and land conservation management in Missouri
Identify nine PGs (Tier 1 landscapes) with teams and partners dedicated toward proactively advancing natural community management and landscape conservation. Expand or create new PGs as needs dictate and resources become available. Identify COAs (Tier 2 landscapes) for each natural community system that will serve as sites of focused investment of time, resources, and effort for conserving wildlife diversity. Evaluate annually. Identify PFLs, PWs, QRLs, and other focal landscapes for specific conservation purposes (e.g., PFLs for focusing federal forestry dollars) and for informing the development of COAs. Utilize this tiered approach for prioritizing dollars available for conservation investments such as public land habitat management; private land assistance and cost share; and land conservation (e.g., public land acquisition from willing sellers and voluntary conservation easements).
Strategy 1.2 Maintain and improve the ecological functions of Missouri's watersheds and wetland systems
Identify issues and targeted actions in PWs by continued implementation of the PW Monitoring and Assessment Plan. Evaluate and identify potential high aquatic biodiversity areas to inform the CCS. Continue to implement the Wetland Planning Initiative.
Strategy 1.3 Prevent, where possible, and control the impacts of priority invasive species and diseases
Work collaboratively with the Missouri Feral Hog Elimination Partnership to eliminate feral hogs from Missouri's landscape. Effectively monitor for CWD in deer. Utilize management programs to minimize the spread or eliminate the disease where detected. Conduct monitoring for forest pests such as gypsy moth to facilitate early detection and elimination as part of national "slow the spread" campaigns. Maintain a collaborative "Grow Native" program to promote the use of native species in landscaping and avoidance of invasive plant pests. Proactively engage in invasive species control partnerships, such as MoIP, MIFPC, and 100th Meridian to advance invasive species control techniques, research, education, and communication. Update state or federal regulations where necessary to prevent the introduction and spread or to aid in the removal of invasive species.

Strategy 1.4 Manage, through sound science, harvestable fish and wildlife species at biologically and socially acceptable levels

Update, simplify, follow, and enforce regulations where appropriate to protect and ensure proper management of fish and wildlife populations.
Regularly review and update species-specific management plans and consider their effects on both target and nontarget species.
Develop a common structure for species management plans and require their consideration in making annual work plans.
Place research importance on sustainably managing harvestable species to help inform regulations.
Use waterbody-specific species sampling data to meet management objectives.

Strategy 1.5 Recover and maintain SGCNs to sustainable levels

Develop and implement recovery work plans for priority state listed species.
Coordinate with partners including state and federal agencies, conservation NGOs, municipalities, and landowners to recover state listed species and the habitats on which they depend.
Identify and prioritize research, survey, and monitoring needs for priority SGCNs, to inform the allocation of limited resources including federal funding, state funds, and staff time.
Complete and implement Missouri's Bird Conservation Strategy to identify and prioritize opportunities for MDC and partners to work together toward the conservation of priority habitats, avian surveys and monitoring, and consistent messaging in education and outreach programs to grow citizen awareness of declining bird populations and opportunities to help.
Utilize Missouri's Natural Heritage Database to track and monitor known populations of SOCCs.
Utilize MOFEP to advance understanding of forest management impacts on sensitive wildlife species.

Strategy 1.6 Control and suppress wildfires and promote the appropriate use of prescribed fires

Through state, federal, and local rural fire department partnerships maintain the capacity to fight wildfires through ensuring fire departments are adequately staffed; firefighters are properly trained and equipped; and by facilitating good communications, coordination, and mutual aid assistance.
Build local wildfire preparedness through the collaborative development of CWPPs.
Conduct prescribed fire workshops for private landowners to improve their ability to utilize prescribed fire for natural community management purposes.

Strategy 1.7 Provide regenerative and sustainable ecosystem services such as forest products, clean water, and flood control relied upon by citizens for their economic, social, and ecological well-being

Conduct annual FIA and CFI data collection to track trends in Missouri's net annual growth of timber volume.
Conduct annual timber product output surveys of sawmills to track over time trends in Missouri's forest products harvest volume.
Conduct professional timber harvester training and maintain Missouri's Master Logger Certification Program to promote the use of BMPs in harvesting timber.
Engage in collaborative partnerships and campaigns for protecting watersheds, streams, and drinking water.
Utilize cost-share programs and information campaigns to increase the amount of suitable habitat for insect pollinators.

Strategy 2.1 Establish and utilize partnerships between government agencies, schools, nonprofit organizations, and the business community to build capacity to deliver conservation in Missouri

Increase or enhance partnerships that inform local land use decisions and promote the use of conservation-friendly development practices that conserve and protect natural resources, such as the Meramec River Tributary Alliance, KC Green, Beyond Housing, and many more.
Identify opportunities and engage in collaboration with partners to increase capacity for natural community and habitat management (e.g., MoBCI, CFLRP, and SRISP), priority professional trainings, and outreach and education events.
Identify and implement market-based initiatives and partnerships that support conservation practices to be implemented by private landowners and producers.

Strategy 2.2 Citizens understand the need to invest in conservation and contribute through voluntary service, professions, advocacy, and financial investment

Build a common language among conservation partners to deliver consistent and understandable messages to citizens.
Promote Missouri's Master Naturalist program, Missouri Stream Teams, Missouri ForestKeepers, and other programs to help facilitate awareness and volunteerism toward conservation in Missouri.
Missouri citizens continue to support the Conservation Sales Tax, the Missouri Soils and Parks Tax, and other funding mechanisms for local, state, and federal agencies.
Missouri citizens engage in conservation organizations and support delivery of their respective goals.

Strategy 2.3 Maintain and support conservation organizations with the expertise, resources, and mandate needed to deliver conservation in Missouri

- Conservation organizations regularly review their strategic plan and organizational model and adapt accordingly to ensure they are properly aligned to efficiently accomplish priority conservation work, including the shared strategies in this document.
- Conservation organizations fill unique roles with different capabilities and capacities and work together to find ways to achieve shared priorities within their strengths and roles through partnerships that build on those complementary strengths.
- Conservation organizations work to understand their constituencies and funding sources and develop actions to enhance their relevancy, increase membership, and solidify or broaden their funding sources, as appropriate, so as to ensure sufficient support and capacity for conservation actions to continue into the future.

Strategy 2.4 Update the CCS at least every 10 years to address changing opportunities, threats, resources, and citizen needs

- The CCS will be reviewed on a five-year rotation starting in 2025. Each review and subsequent revision will account for any changes or shifts in Missouri's conservation opportunities, threats, needs, and priorities.
- The first comprehensive revision of CCS is scheduled to be submitted to the USFS and USFWS in 2030.

Strategy 3.1 Utilize land conservation tools (e.g., public land acquisition from willing sellers and voluntary conservation easements) strategically to protect important landscapes and habitats, and to provide valuable places for people to enjoy nature

- Utilize an effective LCS to guide strategic acquisition from willing sellers and the strategic disposal of lands.
- Utilize the USFS FLP to make feasible the acquisition of key forest/woodland/glade habitats from willing sellers.
- Utilize MDC's Land Conservation Partnership Grant to assist NGOs and local governments with strategic acquisition of conservation easements and fee title acquisition of properties from willing sellers in important landscapes for public use, wildlife conservation, and other ecosystem services.
- Make effective use of USDA programs, such as CRP, EQIP, and WRE.

Strategy 3.2 Utilize community conservation strategies effectively to incorporate nature into the places where people live

- Utilize partnerships to develop land conservation strategies to prioritize land acquisitions and/or conservation easements from willing sellers in major metropolitan areas to increase public outdoor recreation access opportunities.
- Develop partnerships between local municipalities, state and federal agencies, and private and nonprofit entities to identify, retrofit, and manage vacant lands or "brownfields" that could provide opportunities to connect people with nature where they live.
- Create, maintain, and promote a one-stop shop of state financial assistance resources available to communities and partner organizations for incorporating and sustainably maintaining trees, forests, and other natural green infrastructure in municipalities or for providing increased public access to nature.
- Develop in partnership with community/municipal planners and civic professionals a common set of community conservation tools to be used in long-term planning and development.
- Among conservation partners, develop and implement BMPs to serve as models for regenerative and sustainable development that ensure natural resources are protected and conserved.
- Through public, private, and nonprofit partnerships utilize the Project CommuniTree program to provide free container trees for public community sites (roughly 10,000 per year) in Missouri.

Strategy 3.3 Provide quality maintenance of public lands and infrastructure and, where appropriate, expand public opportunities for outdoor recreation

- Utilize Missouri Recreational Access Program to increase opportunities for citizens to enjoy the outdoors on voluntarily participating private properties.
- Utilize programs like Land and Water Conservation Fund and Land Conservation Partnership Grant to assist local governments with acquiring and developing public outdoor recreation facilities.
- Develop Public Use COAs for strategically focusing resources toward outdoor recreation (existing and new) in places and in ways that provide the greatest opportunity and potential benefit. Include collaboration between local, state, and federal agencies.
- Ensure adequate funding and investment is made into maintaining Missouri's public lands and outdoor recreation infrastructure.

Strategy 4.1 Utilize information campaigns to communicate the social, economic, and ecological value of nature for sustaining and enhancing our quality of life

- Utilize MDC's Trees Work information campaign to promote awareness of the importance of trees and forests and to communicate a call to action for conserving and enhancing these resources.
- Employ marketing campaigns to inform citizens of the importance of protecting watersheds as a key to providing clean, affordable drinking water, outdoor water-based recreation, and aquatic habitat – and to engage citizens in such actions.
- Maintain Missouri's collaborative Call Before You Cut campaign for providing information to landowners on how to properly conduct a sustainable timber harvest in the best conservation interest of Missouri citizens.
- Utilize social media to increase awareness of important conservation issues such as feral hogs, CWD, and wildfire prevention.

Strategy 4.2 Make educational programs and resources available to help citizens connect to nature

- Maintain Missouri's collaborative Great Missouri Birding Trail program to help citizens enjoy and connect to birds and nature in Missouri.
- Maintain and enhance Missouri's MO Outdoors App to make information readily available to citizens on where and how to get out and enjoy nature.
- Implement pilot programs in urban areas that offer citizens and families the opportunity to learn about and explore the outdoors close to home.
- Maintain Discover Nature Schools and other environmental/conservation educational resources to current state curriculum standards and develop strategies to increase usage.
- Create and implement strategies to recruit new audiences to conservation programs, workshops, and events.

Desired Future Conditions for Missouri's Regenerative and Sustainable Conservation Future

This subsection provides a summary of desired future conditions from the Missouri Natural Systems Assessment themes (**Section Three**) and Community Conservation (**Section Five**).

Theme One: Species and Natural Systems Health and Conservation

1. Missouri's natural communities provide valuable habitat to native species that depend on them.
2. Missouri's native wildlife species maintain stable and resilient populations.
3. Missouri's natural communities and urban green infrastructure sustainably provide important ecosystem services.
4. Missouri's natural communities function at a landscape scale.
5. Methods for effectively preventing and managing invasive species and diseases are known and utilized.
6. The future threats of invasive species, diseases, and other environmental stressors are well understood and mitigated during management decisions.
7. Missouri's natural communities are managed to enhance health, habitat value, and resilience; and management options are not compromised by invasive species, diseases, and environmental stressors.

Theme Two: Pollution Prevention, Control, and Mitigation

1. Pollution threats in Missouri are minimized or mitigated through voluntary actions, regulatory protections, enforcement, and willing adoption.
2. Research is improved to gain better understanding of existing and potential pollution threats with adaptive BMPs employed accordingly.
3. Missouri's natural communities are maintained in a healthy, resilient manner that can assist with rebounding from pollution impacts.
4. Missouri's natural communities help buffer and mitigate the social, ecological, and economic impacts of pollution.

Theme Three: Private Lands

1. As privately owned lands change ownership, affected natural communities transition smoothly to new owners who will maintain or initiate regenerative management.
2. PGs, COAs, and other focal landscapes maintain or increase in total acreage of functional natural communities and become less vulnerable to fragmentation.
3. Privately owned tracts remain sufficiently large to maintain various management options; or such management can be achieved across multiple adjoining ownerships.
4. Future residential and commercial development is well planned to encourage green infrastructure and avoid destroying or negatively impacting important natural communities and landscapes.
5. Private landowners understand the basics of natural resource management and practice informed regenerative management.
6. Qualified foresters, biologists, contractors, and loggers are readily available who can help private landowners manage their property for healthy, regenerative, and sustainable forest and woodland natural communities.

7. Voluntary incentives and markets make it simple and cost effective for private landowners to manage healthy regenerative natural communities.
8. Societal benefits of Missouri's privately owned natural habitats (e.g., water quality, biodiversity, forest products, etc.) are recognized by private landowners and appreciated by the public.

Theme Four: Missouri's Public Lands Managed for the Greatest Public Good

1. Public lands are managed appropriately to provide multiple benefits (recreation, wildlife habitat, ecosystem services, watershed protection, timber, aesthetics, etc.).
2. Public lands are inviting and provide convenient and desirable opportunities to enjoy nature and the great outdoors.
3. Citizens are aware of public lands and their importance and availability.
4. Public lands provide sufficient infrastructure (parking lots, trails, etc.) that can be maintained efficiently and sustainably.
5. Public land management serves as a model for private landowners to view regenerative management practices and outcomes.
6. Citizens understand the need to actively manage public lands (e.g., forest thinning, invasive species control, prescribed fire) to improve and maintain their health and benefits.

Theme Five: Climate Change

1. Ecosystem services are improved and sustained as Missouri's natural communities successfully adapt to a changing climate.
2. Healthy natural communities and regenerative agricultural/working lands significantly contribute to mitigation of global climate change.
3. New scientific information, tools, and technology increase understanding of climate change impacts, adaptation and mitigation options, and risks and uncertainties.

Theme Six: Improving and Maintaining High-Quality Soil and Water Resources

1. Aquatic ecosystems, and the plants and animals they support, are maintained and enhanced by healthy soils and intact natural communities and landscapes.
2. Soil and water resources are protected and enhanced through the widespread use of native vegetated riparian buffers and many other widespread best management practices.
3. Soil productivity and water quality are maintained through regenerative agriculture and forest management practices.
4. Urban stormwater runoff is minimized by planting and maintaining native grasses and forbs, trees, forests, green infrastructure, and through use of other BMPs.
5. Intact natural communities and landscapes maintain and enhance water-related recreation opportunities (boating, fishing, wildlife viewing, aesthetics, etc.)
6. Intact natural communities and landscapes provide healthy soils that support high quality, cost-effective drinking water.

Theme Seven: The Role of Fire – Historic, Wild, and Prescribed

1. Frequency and size of wildfires is kept to a minimum to protect people, structures, and natural resources.
2. Homes, structures, and communities are "Firewise." Fire departments and communities develop CWPPs to best manage the threat of wildfire emergencies.
3. Forest resources and natural communities are not adversely affected by wildfires but benefit from appropriate prescribed fires.
4. Conservation professionals, volunteer firefighters, and other partners spend less time fighting wildfires and can direct time and financial resources to other natural resource priorities, which include use of prescribed fire.
5. Fire-adapted landscapes and natural communities are restored and/or maintained through prescribed fire and/or other management tools.
6. Prescribed fire techniques are refined and practiced that maximize the benefits of prescribed fire while minimizing potential negative impacts.

Theme Eight: Missouri's Growth, Harvest, and Consumption of Forest Products

1. Missouri's forests and woodlands and forest industry provide sustainable forest products demanded by the public and contribute significantly to Missouri's economy.
2. The harvest of forest products, including potential new markets, is improved and sustainable both statewide and regionally.
3. Best harvesting practices are utilized to maintain and enhance the health and productivity of forests and woodlands, and to ensure harvesting does not compromise other forest and woodland services and benefits, especially on privately owned lands.
4. Forests and woodlands are resilient to potential stressors (insects and disease, invasive plant species, drought, climate change) to ensure improved and sustained growth and yield over time.
5. Forest industry and communities that depend on it remain viable into the future.
6. Trees are grown and utilized to their highest value.
7. Missourians are aware of how they use wood, how much they use, and where it comes from.

Theme Nine: Recreation, Human Health, and the Relevance of Nature

1. All Missourians, including new and underserved audiences, have plentiful opportunities to learn about and connect with nature and understand the human health benefits of doing so.
2. All Missourians, including new and underserved audiences, have good access to quality outdoor recreation opportunities close to home.
3. Missouri citizens have widespread understanding and appreciation for the value and diverse public benefits (quality of life, human health, environmental) of Missouri's conservation resources and their need for proactive investment, management, and protection.
4. Missouri citizens understand the role they play in determining the future improvement and sustainability of Missouri's conservation resources and

engage through volunteerism, advocacy, and personal actions

Theme Ten: Logistical Framework for Improvement and Sustainability

1. Public agencies, NGOs, and private industry work strategically, collaboratively, efficiently, and effectively toward the regenerative conservation of Missouri's natural resources and the services they provide.
2. Conservation stakeholder organizations collaborate effectively to increase dialogue, feed off each other's strengths, advance conservation science and techniques, and increase synergistic partnerships.
3. Sufficient funding and legal backing is available and widely supported by Missouri citizens to ensure the regenerative conservation of Missouri's natural resources and the services they provide.

Community Conservation

1. Healthy, enhanced, and sustainable urban/community natural spaces such as forests, prairies, riparian areas, and wetlands that support desirable and environmentally healthy places of residence for Missouri citizens.
2. Urban and community natural spaces contribute significantly to minimizing stormwater runoff, improving air quality, reducing heat islands, reducing energy consumption, and more.
3. Trees, forests, streams, riparian areas, prairies, and wetlands are viewed as important components of city and community infrastructure needing to be maintained, included in planning efforts, and supported with public and private funds.

Section Eight: Evaluation of the CCS

MDC serves as steward for the development and maintenance of Missouri's CCS; however, its development has been greatly informed by partner and citizen input. The implementation and success of the CCS is dependent upon the collective contributions from a diversity of partners, which includes the citizens of Missouri. Evaluation of this comprehensive approach relies on numerous factors at many scales discussed throughout this document. However, in general, the question for evaluation is, "Is the implementation of the strategies outlined in the CCS improving or, at a minimum, sustaining Missouri's complete natural resources portfolio and positively contributing toward achievement of the specified desired future conditions?" This means evaluating the CCS as an overall approach and the ability of this approach to deliver regenerative conservation in Missouri, including Missouri's role in regional, national, and international conservation initiatives.

To be efficient with conservation investment, it is imperative that we monitor the effectiveness of the conservation actions and adapt these conservation actions to respond appropriately to new information or changing conditions.

CCS Review and Reporting

The CCS is a living document that promotes an adaptive approach to conserving Missouri's natural resources. It will be updated as necessary, following appropriate communication and documentation protocols with USFWS and USFS. Minor updates may address:

- Changes to the SGCN list (excluding changes to the process for identifying SGCNs)
- Changes to the COA and PG maps (excluding changes to the process used to identify and prioritize COAs)
- Elevating a COA to the level of PG
- Identification of emerging threats
- Incorporation of new partner feedback and engagement opportunities

Further, in accordance with federal requirements, the CCS will be reviewed at a minimum of every five years with a comprehensive revision at a minimum of every ten years. As a component of the five-year review, MDC will prepare a highlight report to showcase ways in which the state is advancing resource conservation. The next five-year review and highlight report will be completed in 2025. Highlight reports are intended to include the following:

- A brief summary of implementation highlights from the past five years
- These will include the three USFS National Priorities: (1) Conserve and manage working forest landscapes for multiple values and uses; (2) Protect forests from threats; and (3) Enhance public benefits from trees and forests
- A brief summary of implementation challenges discovered over the past five years
- Identification of the implementation focus for the next five years
- Identification of data needs or new issues revealed since the CCS was completed
- An informal "check-in" with stakeholders regarding plan implementation

A comprehensive review/revision of the entire CCS content and supporting materials will occur at a minimum of every ten years, which includes an up-to-date public review process. The next

comprehensive revision is currently scheduled for 2030.

Missouri conservation partners engage actively with other state and federal partners toward cooperative implementation of SWAPs, SFAPs, and other key planning at a regional and national level. In addition to identifying opportunities to partner toward common conservation goals, regional and national networks provide opportunities for agencies and partnerships to learn from one another and discuss opportunities to improve planning and implementation efforts. Regional and national forums have produced guidance documents including "Best Practices for SWAPs – Voluntary Guidance for Revision and Implementation," "Guidance for SWAP Review and Revision," "Guidance for State Forest Action Plans," and "Statewide Forest Resource Assessments and Strategies (SFAP) Requirements Checklist," which have been exceedingly helpful in improving consistency among SWAPs/SFAPs and facilitating both local and regional implementation efforts.

As steward of the CCS, MDC intends to use these updates, five-year review highlight reports, and ten-year comprehensive revisions as one of several means of monitoring and portraying progress made among partners in achieving the vision set forth in CCS.

Missouri Conservation Partners Roundtable Meetings

MDC intends to continue the Missouri Conservation Partners Roundtable Meeting as an annual engagement among a group of partners representing a great diversity of organizations and disciplines. The event is an incredible networking opportunity that encourages broad engagement. The roundtable meeting is an excellent opportunity to offer updates on past, ongoing, or upcoming conservation projects and initiatives and to receive direct feedback from a diversity of partners in one collaborative setting. Given the immense partner role in the development and implementation of the CCS, these meetings are invaluable to informing the strategy, evaluating its successes and challenges, and identifying upcoming opportunities.

In addition to these critical roundtable meetings, it is important to understand that there is constant communication occurring among Missouri conservation partners and with Missouri citizens. Feedback gained from formal and informal communications is continually analyzed and, where appropriate, incorporated into the CCS.

Tools Aiding in the Evaluation and Informing the Reviews and Revisions of the Missouri CCS

MDC Conservation Dashboard

MDC has launched a new measurement dashboard to track conservation milestones, outcomes, and successes. This tool, though parts are still under development, is also used to help manage MDC's strategic plan, budget directly to priorities, achieve results through continuous process improvement, and measure progress toward outcomes outlined in the strategic plan. This measurement tool is a resource that can be shared with partners and Missouri citizens, in addition to staff, to show how conservation dollars and work are benefiting conservation at the state, national, and international scale. Measures informing the conservation dashboard are developed or in the process of development for all outcomes of MDC's *Design for the Future* strategic plan and include important measures for natural community and species management, invasive species and disease, code compliance, realty, community conservation, public use and area maintenance, relevancy, outreach and communications, cultivating partnerships, customer service, continuous improvement, staff recruitment and retention, and supporting a quality work environment.

Landscape Health Index, Community Health Index, and Species Evaluation

The CCS approach to monitoring the effectiveness of conservation actions and applying adaptive management is designed to fit a natural community– and landscape-focused approach to implementation. To evaluate effectiveness, both outputs and outcomes must be assessed.

- Outputs: What proportion of the conservation actions planned for a given time period were actually implemented?
- Outcomes: Did the conservation actions implemented produce the anticipated response in the target natural community/landscape?

Outcomes will be assessed at two scales described in greater detail at the end of **Section Four**. At the finest scale, the CHI is designed to evaluate the condition of a specific natural community (e.g., an individual glade or grassland unit) over time. The LHI, though still under development, is designed to evaluate the condition of the overall landscape (e.g., an entire COA) that is made up of multiple natural communities. At both scales, natural communities are monitored based on attributes of vegetation structure and composition, and characteristic, easily observable plant and animal species, as well as landscape context and negative disturbance factors. Continued development of the LHI also includes social considerations in landscape-scale conservation.

To understand the relationship between conservation actions and the resulting outcomes, it is also necessary to measure outputs. To accomplish this for natural community and landscape conservation, annual work plans are developed for each PG, and annual accomplishment reports describe implementation of the work plan, assess the effectiveness of implementation efforts, and identify challenges and opportunities that can be used to inform the work plan in subsequent years as the initiative works toward its ultimate desired future condition. Currently annual work plans and accomplishment reports are required for each of the nine PGs (see **Priority Geography Annual Reports** below). Similar work planning and reporting can be and is being considered for other landscapes (e.g., COAs) and priorities following this model.

The CCS takes a habitat-based approach to conservation planning and implementation, and

this approach is expected to meet the needs of the majority of Missouri's native species, including SGCN. Monitoring of characteristic species is included in the CHI and LHI as well. However, rare and declining species, particularly those that are difficult to monitor, often require more intensive monitoring effort to evaluate the effectiveness of recovery actions and adapt management as needed. To meet this need, MDC has developed a system for tracking progress toward recovery of state-listed species, all of which are SGCNs. The recovery update forms evaluate the trajectory of the species' population within Missouri (e.g., declining, stable, recovering) as well as progress toward meeting information and planning needs (e.g., How well are threats to the species understood? and Has a species management plan been developed?). The recovery update form for each species is reviewed and updated annually, and the information provided is used to identify and prioritize future actions. Some species may not be targeted for and are simply monitored and managed with the goal of ensuring they persist. For those species that are targeted for recovery, a three-year recovery work plan is developed, and progress toward implementation of that work plan is assessed annually. This approach allows for assessment of outputs (implementation of recovery work plans) and outcomes (progress toward recovery) for state-listed species. In addition, species distribution surveys and/or monitoring occur on a regular basis with a frequency appropriate to the target species to track species population trends and changes in distribution.

Priority Geography Annual Work Plans and Accomplishment Reports

PGs have been identified in each MDC region as the current highest priority landscapes to focus conservation effort for natural community management. Resources, including funding and staff time, currently have increased focus within PGs. In accordance with this high level of support, a higher level of planning and reporting is also required for these areas. Annual work plans direct the management, monitoring, and outreach activities within each PG, and annual accomplishment reports describe which activities were accomplished and evaluate the effectiveness of those accomplishments. Each annual accomplishment report describes the primary activities and accomplishments within the PG. The goals (conservation priorities) and objectives identified in the annual work plan are listed in the annual accomplishment report, along with an evaluation of whether they were achieved and how effective they were. Objectives may include public land management, landowner contacts and private land assistance and project implementation, landowner workshops, monitoring objectives, partner engagement, educational programs, human dimensions surveys, and sound business and workplace practices. These reports enable MDC to assess the effectiveness of conservation practices (outputs) and to inform future work plans, facilitating adaptive management and promoting a culture of continuous improvement.

Ultimately, once developed, the LHI will be the evaluation assessment for PGs, COAs, and other important landscapes to determine if the resources invested, practices implemented, and communications have produced beneficial outcomes contributing to progress toward the desired future condition. However, the annual work planning and accomplishment reporting is important to set incremental objectives and to track progress over time.

Appendices

Appendix A: Roadmap to Federal Requirements

Table A.1 – Eight Elements Required for SWAPs

Element Number	Element Description	Applicable Sections/Pages
Element 1 – Species of Greatest Conservation Need	Information on the distribution and abundance of species of wildlife, including low and declining populations as the state fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the state's wildlife.	Information on the SGCN selection process can be found starting on page 181. Specific SGCN for each natural community can be found under each community subsection in **Section Four**, starting on page 185. Strategies for SGCN conservation are covered on pages 386 and 390 within **Section Seven**. The complete SGCN table can be found in **Appendix H**.
Element 2 – Habitat Systems	Description of the locations and relative condition of key habitats and community types essential to conservation of SGCNs.	Locations, relative condition, threats and challenges, and management and conservation opportunities for each of Missouri's primary natural communities are covered in **Section Four**, starting on page 185. Additional information can be found in **Section Two**, starting on page 22 and **Section Three**, starting on page 84.
Element 3 – Species and Habitat Systems Threats	Problems that may adversely affect SGCNs or their habitats.	Threats and challenges for each of Missouri's primary natural communities and associated species are covered in **Section Four**, starting on page 185; additional information can be found in **Section Three**, starting on page 84.
Element 4 – Conservation Actions	Descriptions of conservation actions determined to be necessary to conserve SGCNs and their habitats and priorities for implementing such actions.	Management actions and conservation opportunities for each of Missouri's primary natural communities are covered in **Section Four**, starting on page 185 and additional information can be found in **Section Three**, starting on page 84. Also, please refer to **Section Seven**, pages 385–398.

Element 5 – Monitoring and Evaluation	Proposed plans for monitoring SGCNs and their habitats, for monitoring the effectiveness of the conservation actions, and for adapting these conservation actions to respond appropriately to new information or changing conditions.	Monitoring and evaluation of SGCN, natural communities, and the effectiveness of conservation actions can be found in **Section Four**, on pages 181–184 and pages 326–329, and in **Section Eight**, on pages 398–401.
Element 6 – Review and Revision	Procedures to review and revise the plan at intervals not to exceed ten years.	Review and revision timeframes and procedures can be found on page 21 ("Timeframe and Revision") as well as within **Section Eight**, pages 398–401.
Element 7 – Partner Engagement	Plans for coordinating the development, implementation, review, and revision of the plan with federal, state, and local agencies that manage significant land and water areas within the state or administer programs that significantly affect the conservation of identified species and habitats.	Partner engagement and coordination is described in **Section One**, "Citizen and Partner Engagement," page 20; **Appendix D**, page 444; and **Appendix B**, page 406. Beyond these specific locations, partner engagement and coordination are described and emphasized throughout the document and are key to the development, implementation, and success of the CCS.
Element 8 – Public Participation	Plans for public participation in the development, revision, and implementation of the plan.	Public engagement and participation are described in **Section One**, "Citizen and Partner Engagement," page 20 and **Appendix D**, page 444; however, public engagement and participation are described and emphasized throughout the document and are key to the development, implementation, and success of the CCS.

Table A.2 – Crosswalk of Missouri's CCS to SFAP Required Elements

Statewide Forest and Woodland Resource Assessment	
Conditions and Trends of Forest and Woodland Resources	Forest resource conditions and trends are primarily captured in **Section Three**, via ten analysis theme chapters (pages 85–180). Since CCS covers both SFAP and SWAP, much of our assessment is written broadly enough to capture how these themes affect ALL Missouri natural communities (glades, wetlands, prairies, karst, streams, and cliff/talus in addition to forest/woodland). Forestry-specific data was provided as appropriate, and additional forest resource conditions and trends data are provided in **Appendix G** (pages 464–473) and **Section Four**, "Forest and Woodland Conservation" (pages 215–240).
Threats to Forest and Woodland Resources	Same as above for Conditions and Trends
Areas or Regions of the State that are Priority	**Section Two** (pages 30–33) provides maps and brief background on our PFLs and FLAs. This section also describes how our PFLs roll up into multi-disciplinary agency and partner COAs and PGs. All supporting maps and information for PFLs and FLAs can be found in **Appendix C** (pages 409–421) and **Appendix D** (pages 422–457).
Multi-state Areas that are Regional Priority	Multi-state areas are captured in **Section Two**, "Multi-State and International Collaboration" (pages 80–83).
Statewide Forest and Woodland Resource Strategy	
Long-term Strategies to Address Forest and Woodland Threats	Missouri's conservation strategy is captured under **Section Seven** (pages 385–397). The section includes one table of broad strategies, one table of example (not all-inclusive) programs and action items to advance each strategy, and then a list of desired future conditions that applies to the strategy table. As with the assessment, this section is intended to capture all the natural community types (not just forest/woodland).
Resources Necessary to Address Conservation Strategies	Resources needed are captured in the strategy table provided in **Section Seven** (pages 386–388).
Stakeholder Group Coordination	Stakeholder coordination is described in **Section One** (page 20), **Appendix D** (page 406–408), and **Appendix B** (pages 444–446).

Other Plans Incorporated	
CWPPs	CWPPs are addressed in **Section Three**, "Theme Seven" (pages 144-154).
SWAP	**CCS merges both our SFAP and SWAP into this one document/approach.**
Forest Legacy Program Requirements	Missouri utilized a combined approach for meeting FLP Assessment of Need (AON) requirements. When possible, elements were captured in the main CCS document body. However, items that did not naturally flow in the main document body are included in **Appendix D** (pages 422–457). This appendix covers all additional needed items; it also includes a crosswalk describing where to find all FLP AON requirements (pages 423 and 424).

Appendix B: CCS Partner Engagement List

1. Back Country Horsemen of Missouri
2. Backcountry Hunters & Anglers
3. Beyond Housing
4. Bridging The Gap
5. Burroughs Audubon of Greater Kansas City
6. Central Hardwoods Joint Venture
7. Columbia Center for Urban Agriculture
8. Conservation Federation of Missouri
9. Delta Waterfowl
10. Ducks Unlimited
11. Eastern Ozarks Forestry Council
12. Evergy
13. Forest and Woodland Association of Missouri
14. Forrest Keeling Nursery
15. Great Rivers Greenway
16. Greenbelt Land Trust of Mid-Missouri
17. Greenway Network, Inc.
18. Heartland Conservation Alliance
19. Kansas City MO Parks and Recreation
20. L-A-D Foundation
21. Land Learning Foundation
22. Lincoln University
23. Lower Mississippi Valley Joint Venture
24. Mark Twain Forest Watchers
25. Mark Twain National Forest
26. MFA, Inc.
27. Mid-America Regional Council
28. Mid-MO Regional Planning Commission
29. Midwest Association of Fish and Wildlife Agencies
30. Missouri Agribusiness Association
31. Missouri Association of Soil and Water Conservation Districts
32. Missouri Bird Conservation Initiative
33. Missouri Birding Society
34. Missouri Botanical Garden
35. Missouri Cattlemen's Association
36. Missouri Caves and Karst Conservancy
37. Missouri Chapter of the American Fisheries Society
38. Missouri Chapter of the Walnut Council and Other Fine Hardwoods
39. Missouri Chapter of the Wildlife Society
40. Missouri Coalition for the Environment
41. Missouri Community Forestry Council
42. Missouri Conservation Heritage Foundation
43. Missouri Consulting Foresters Association
44. Missouri Corn Growers Association

45. Missouri Dairy Association
46. Missouri Department of Agriculture
47. Missouri Department of Conservation
48. Missouri Department of Economic Development
49. Missouri Department of Natural Resources
50. Missouri Department of Transportation
51. Missouri Farm Bureau
52. Missouri Forest Products Association
53. Missouri Humanities Council
54. Missouri Native Plant Society
55. Missouri Nurseryman's Association
56. Missouri Parks Association
57. Missouri Park & Recreation Association
58. Missouri Prairie Foundation
59. Missouri Resource Assessment Partnership
60. Missouri River Bird Observatory
61. Missouri Smallmouth Alliance
62. Missouri Society of American Foresters
63. Missouri Soybean Association
64. Missouri State Parks
65. Missouri Stream Team Watershed Coalition
66. Missouri Trappers Association
67. Missouri Tree Farm Committee
68. Missourians for Monarchs
69. MO Bicycle and Pedestrian Federation
70. MO Conservation Heritage Foundation
71. MO Hunter Education Instructors Association
72. MO Master Naturalists – Confluence Chapter
73. MO Master Naturalists – Mississippi Hills
74. MO Rock Island Trail
75. MO Youth Shooting Sports Alliance
76. National Audubon Society
77. National Wild Turkey Federation
78. Northwest Missouri State University
79. Ozark Greenways
80. Ozark Land Trust
81. Ozark Trail Association
82. Pioneer Forest
83. Pheasants Forever, Inc. & Quail Forever
84. Platte Land Trust
85. Powell Gardens
86. Prairies Forever
87. Quail and Upland Wildlife Federation
88. Quality Deer Management Association
89. Shaw Nature Reserve – Missouri Botanical Garden

90. Sierra Club
91. Southeast Association of Fish and Wildlife Agencies
92. Southwest Missouri Council of Governments
93. St. Louis Audubon Society
94. St. Louis Zoo
95. Stantec Consulting Services Inc.
96. Stream Teams United
97. The Conservation Fund
98. The Nature Conservancy
99. Timmons Group
100. Trout Unlimited
101. University of Central Missouri
102. University of Missouri
103. University of Missouri Agriculture Experiment Station
104. University of Missouri Center for Agroforestry
105. University of Missouri Extension
106. Upper Mississippi/Great Lakes Joint Venture
107. U.S. Army Corps of Engineers
108. U.S. Army Fort Leonard Wood
109. USDA APHIS Plant Protection and Quarantine
110. USDA APHIS Wildlife Services
111. USDA Farm Service Agency
112. USDA Natural Resources Conservation Service
113. USFS Mark Twain National Forest
114. USFS Northern Research Station
115. USFS State and Private Forestry
116. USFWS–Ecological Services
117. USFWS–Fisheries
118. USFWS–Private Lands
119. U.S. Geological Survey
120. U.S. National Park Service Ozark National Scenic Riverways
121. Watershed Committee of the Ozarks
122. Whitetails Unlimited
123. Wildlife Management Institute

Appendix C: Forest Opportunity Model and Priority Forest Landscapes

To ensure the most strategic use of funds provided through the Cooperative Forestry Assistance Act, the USFS requires states to designate PFLs in which federal dollars will be focused toward the most critical places, opportunities, and threats. However, the value of establishing PFLs goes beyond just meeting a federal requirement. In Section Three we identify a broad set of desired future conditions we hope to achieve from Missouri's forestlands and other natural communities. The assessment portrays a clear need for investment to ensure the future health and improved and sustained benefits desired of these communities. Prioritizing forested landscapes helps ensure the most efficient, strategic, and effective use of limited resources (funding, staff, volunteers, etc.) for achieving these goals.

MDC first developed PFLs in 2010 as part of Missouri's 2010 SFAP. This product proved quite useful and the landscapes did a good job of showing top priorities for investing resources. However, the data utilized in this initial assessment is now out of date. As part of Missouri's CCS, MDC is updating and revising PFLs to reflect the latest data available and to ensure these landscapes truly reflect Missouri's greatest opportunities. To complete this task MDC utilized a two-step process: (1) updating Missouri's Forest Opportunity Model to include the best information available; and (2) taking the results of the Forest Opportunity Model to delineate or adjust PFLs as needed. The remainder of this appendix will be devoted to describing these two steps and products.

Missouri's Forest Opportunity Model

Missouri's Forest Opportunity Model is a geospatial assessment that evaluates all of Missouri at a one-quarter-acre scale through the lens of eight data themes (see sidebar). Data themes were carefully selected to depict the best geographic opportunities for improving and sustaining Missouri's forest resources and the benefits they provide. The model provides each one-quarter-acre cell across the state a score, with a maximum score of 10 points per data theme. Then each one-quarter-acre acre cell gets a composite score, which is the total points assigned for all eight data themes combined, with a maximum possible score of 80 points. Higher scoring cells offer the greatest "opportunity."

The eight data themes consist of five "Forest Benefits and Attributes" that indicate the importance of a given forest area, and three "Forest Vulnerabilities," which depict key stressors to forests that organizations and citizens can positively mitigate. The idea behind the model is that the places offering the greatest opportunity are those that are of great importance AND are under threat that can be proactively addressed. Conversely, places that are important but are not under threat are not in significant need

Forest Opportunity Data Themes

Forest Benefits and Attributes:

1. Biodiversity
2. Forest Productivity and Carbon Sequestration
3. Soil and Water Conservation
4. Recreation and Social Values
5. Forest Patch Size

Forest Vulnerabilities:

1. Current Harvest Pressure
2. Insect and Disease Risk
3. Land Use Change Risk

of intervention; and places that are under threat but are not as beneficial do not provide a high return for investment.

An example of how this works is Labarque Creek Watershed in Jefferson County. This watershed is of especially high importance for biodiversity, recreation, and public drinking water, but it is also under great development pressure. This development pressure could be minimized through practices such as "smart growth planning," conservation easements, public land acquisition, and working with landowners. Therefore, this landscape is a good place to invest resources. Other areas may be just as ecologically important but are less vulnerable to degradation. Therefore, it is less urgent to invest resources in these places. Some other places might be even more vulnerable than Labarque Creek watershed but less able to provide important benefits. Therefore, they pose less opportunity as well.

The following pages provide a more thorough description of each of the Forest Opportunity Model data themes, and the composite model results.

Data Theme One: Biodiversity

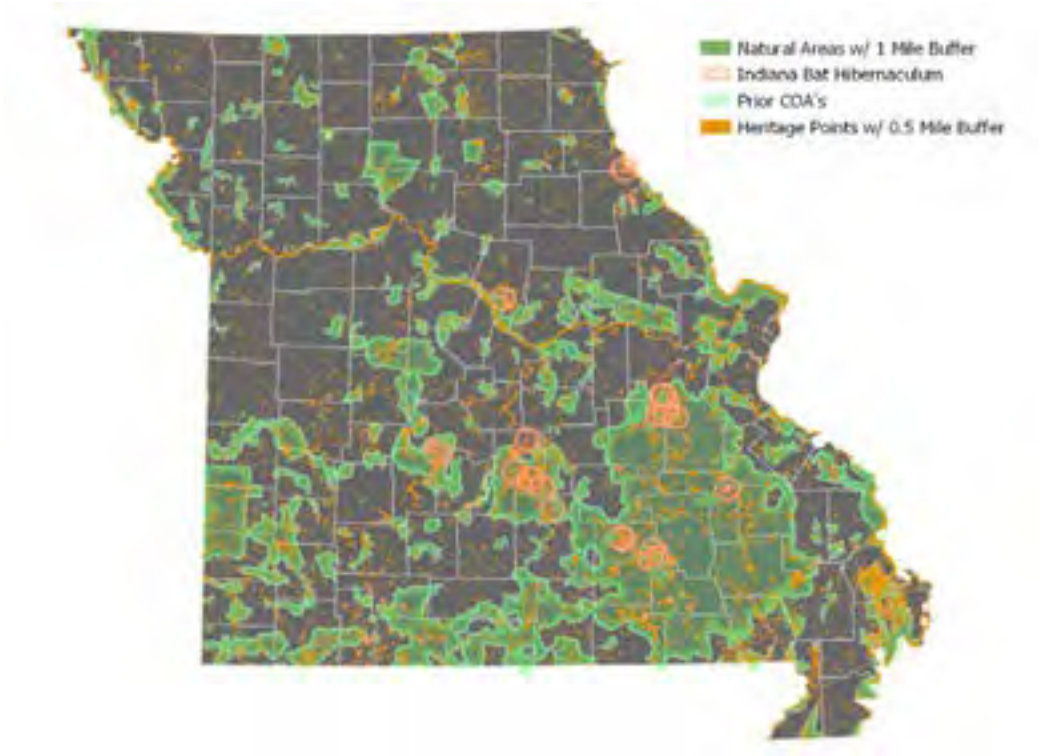
Description: This data theme includes four primary components with the following point allocations:
Designated Missouri Natural Areas with 1-mile buffers = 10 points
Heritage points (species/communities of conservation concern) with one-half-mile buffer = 10 points
2005 Comprehensive Wildlife Strategy COAs[15] = 8 points
Indiana bat priority hibernacula buffers = 8 points

When multiple layers overlap, the cell is assigned points for the highest scoring data component.

Significance: This data theme represents areas in which forest/woodland conservation and restoration has the greatest potential to conserve Missouri's rich biological diversity.

Data Sources: MDC's Natural Areas Database, Missouri Natural Heritage Database, Missouri's 2005 Comprehensive Wildlife Strategy COAs, and MDC's Indiana bat priority hibernacula buffer data

Figure C.1 – Biodiversity Data Theme



[15] Missouri's 2005 COAs were established to identify Missouri's best places to conserve wildlife diversity. Although the 2020 CCS updates COAs, the new COAs are utilized to depict conservation opportunity in general (not just for wildlife) and are informed in part by PFLs. Therefore, 2005 COAs are utilized here to maintain the wildlife focus and avoid a circular feedback loop.

Data Theme Two: Forest Productivity and Carbon Sequestration

Description: This data theme consists of forest site index (productivity) ratings for all currently forested areas of the state as depicted by the NRCS's Soil Survey. Points are assigned to cells as follows:
Forested area with site index >75 = 10 points
Forested area with site index 65–75 = 8 points
Forested area with site index <65 = 6 points

Relevance: This data theme assigns the greatest points to cells that have the greatest potential for producing high quality forest products. In addition to the fact that these sites can produce the greatest volume and value of forest products, they are also in general the most likely to be targeted for harvesting and are therefore a good place to target for working with landowners to ensure forest management activities follow BMPs. More productive sites are also capable of sequestering and storing the most carbon to help mitigate against climate change.

Data Sources: NLCD 2016 (Dewitz 2019); NRCS Soil Survey (NRCS 2020)

Figure C.2 – Forest Productivity and Carbon Sequestration Data Theme

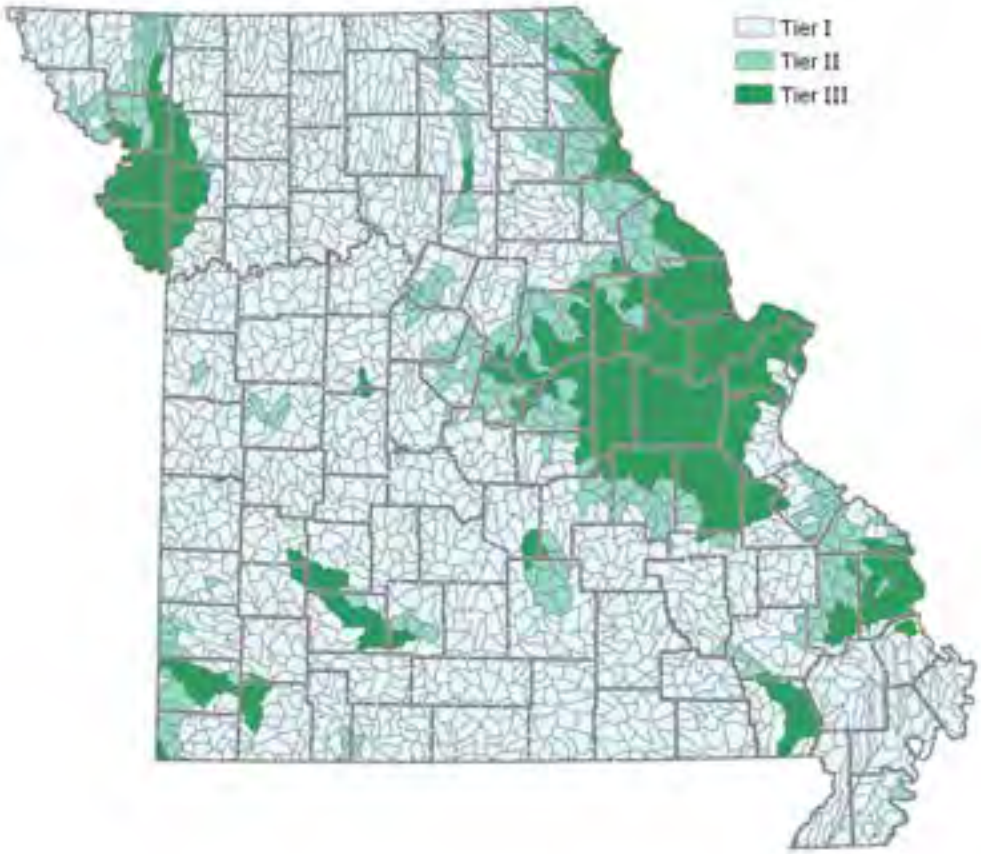
Data Theme Three: Soil and Water Conservation

Description: This data theme consists of the composite of two equally weighted data layers from the USFS's Forests to Faucets Assessment: (1) the ability of 12-digit HUC watersheds to produce clean water, and (2) the number of people who obtain surface drinking water from the watershed (adjusted for how far the watershed is from the water intake). Points are assigned as follows:
Tier One = 10 points
Tier Two = 8 points
Tier Three = 0 points

Relevance: This data theme represents areas that have the greatest ability to produce clean water AND the most people who benefit from this clean water for drinking water. Thus, these are the most important places to invest in protecting forestland for maintaining clean and affordable public drinking water supplies (along with other purposes).

Data for this layer comes from the following source: USFS Forests to Faucets Assessment (USFS 2019)

Figure C.3 – Soil and Water Conservation Data Theme



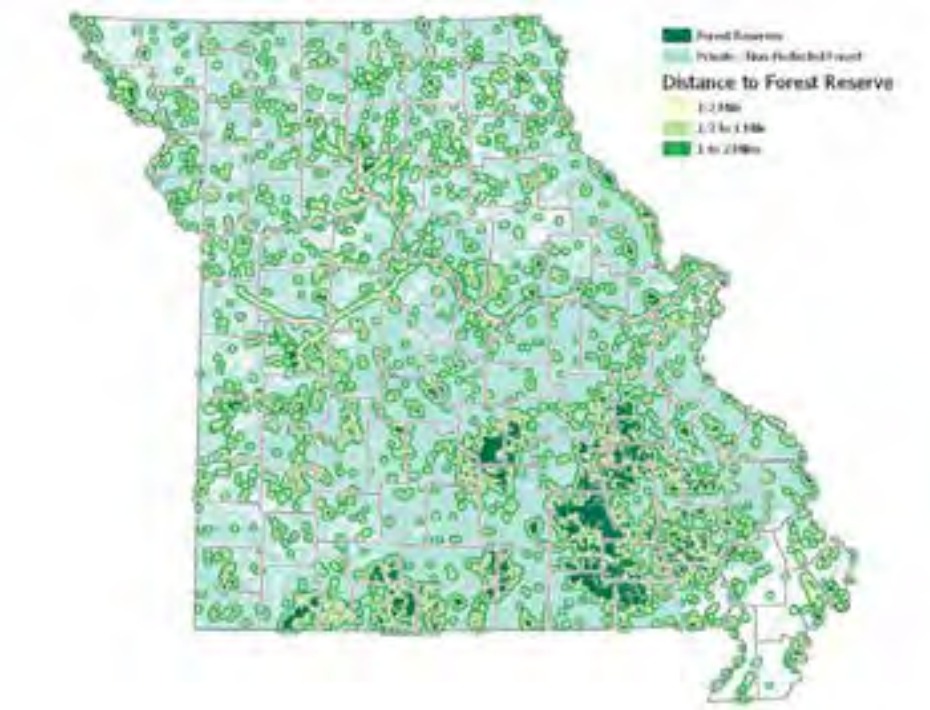
Data Theme Four: Recreation and Social Values

Description: This data theme includes publicly owned land plus known privately owned land under conservation easement or other legal protection to prohibit development. Collectively, these tracts will be referred to as protected "forest reserves." This data theme also includes buffers around reserves, and nonprotected forestland with the following point allocation:
Public and private forest reserves plus one-mile buffers = 10 points
Areas within 1–2 miles of reserves = 6 points
Unprotected privately owned forestland = 2 points

Relevance: Protected forest reserves provide vast public benefits such as wildlife habitat, watershed and drinking water protection, forest products, scenic beauty, psychological benefits, and other intrinsic values. Most of these lands also provide high quality opportunities for outdoor recreation and for people to connect to nature. These tracts are expected to remain forested indefinitely and generally have legal requirements for regenerative and sustainable forest management practices – offering reasonably high assurance that investment in these lands will be protected into the future. Buffers around forest reserves are included to help maintain the ecological and social integrity of these reserves. Privately owned, unprotected forestland is included, albeit with much less points, to recognize that privately owned forestland offers significant public benefit as well.

Data for this layer comes from the following sources: MDC's public land data plus geospatial data provided by the NRCS, Ozark Land Trust, L-A-D Foundation, and TNC on privately owned protected land.

Figure C.4 – Recreation and Social Values Data Theme



Data Theme Five: Forest Patch Size

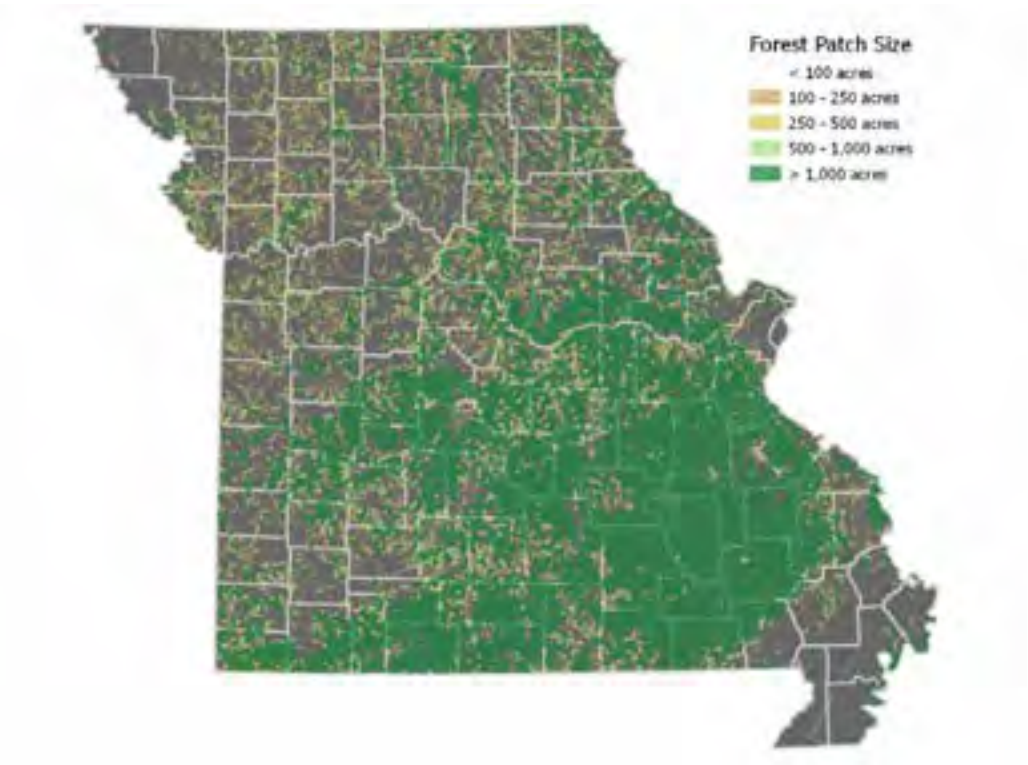
Description: This data theme focuses on contiguous forest patch size with the following point allocation:
Forest patches >1,000 acres = 10 points
Forest patches 500–1,000 acres = 8 points
Forest patches 250–499 acres = 6 points
Forest patches 100–249 acres = 4 points

Relevance: Large forest patches are better able to provide many benefits compared to smaller forest patches. Large forest patches provide unique habitat for fish and wildlife that helps to maintain Missouri's plant and animal biodiversity. Larger forest patches provide greater flexibility in forest management options – including prescribed fire, timber harvesting, and noncommercial thinning. Larger forest patches are also better able to provide environmental services such as clean water and carbon sequestration compared to more fragmented forests. An additional advantage of large forest patches is that they are less vulnerable to numerous "edge" effects associated with forest fragmentation such as exotic invasive plants, animals, and diseases.

Data for this layer comes from the following sources:

MDC analysis of data from NLCD 2016 (Dewitz 2019)

Figure C.5 – Forest Patch Size Data Theme



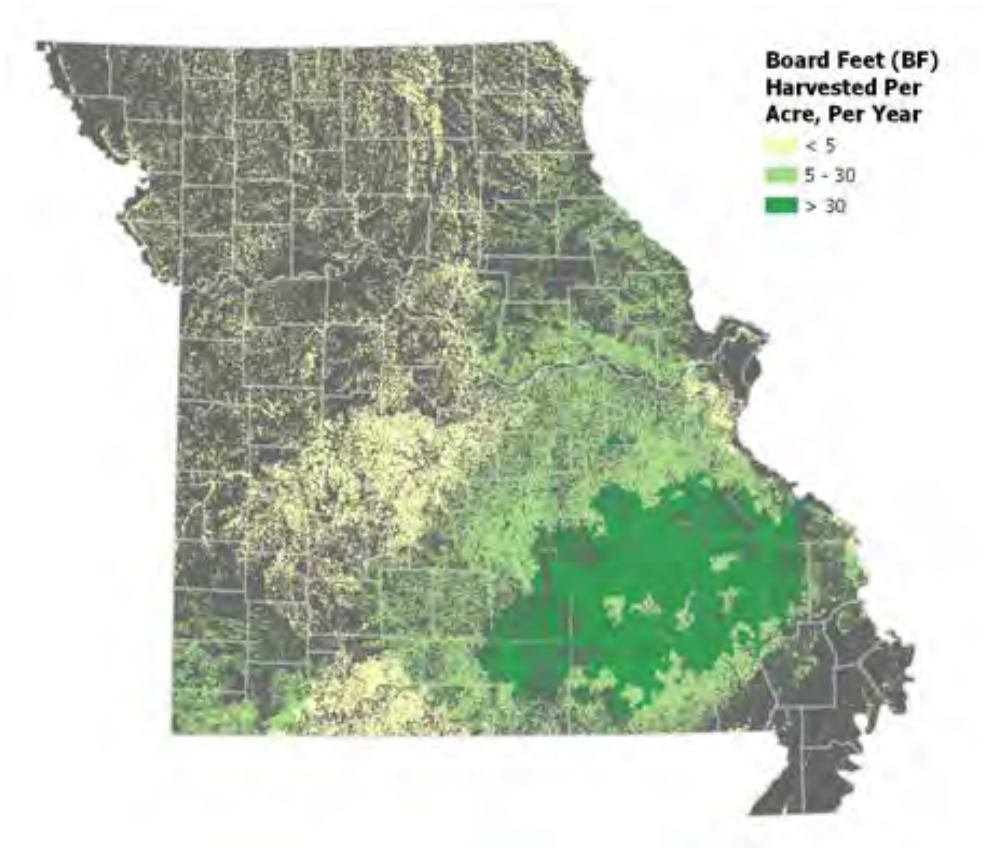
Data Theme Six: Current Harvest Pressure

Description: This data theme consists of Missouri's current forest products harvest pressure per forest acre per year. This later is restricted to currently forested acres that are assessed by the collective volume of wood utilized by mills within a reasonable driving distance (~50 miles) of that given one-quarter-acre forest cell. Volume utilized is based on data derived from Missouri's Primary Wood Processor (sawmill) Survey. Areas under the greatest pressure get the most points through the following allocation:
Tier One = 10 points
Tier Two = 7 points
Tier Three = 4 points

Relevance: Areas of greater current harvest pressure have a greater need for forester availability to ensure harvesting is conducted in a regenerative and sustainable manner. This also represents areas in which communities are especially economically dependent on the sustainable harvest and production of forest products.

Data for this layer comes from the following sources: MDC's Primary Wood Processor Survey information (Treiman and Morris 2018) and NLCD 2016 (Dewitz 2019)

Figure C.6 – Current Harvest Pressure Data Theme



Data Theme Seven: Insect and Disease Vulnerability

Description: This data theme consists of forested areas at increased risk to forest pests and pathogens from 2013 through 2027. Oak decline is the primary influencer, but oak wilt, gypsy moth, EAB, and Dutch elm disease are also incorporated into this assessment.

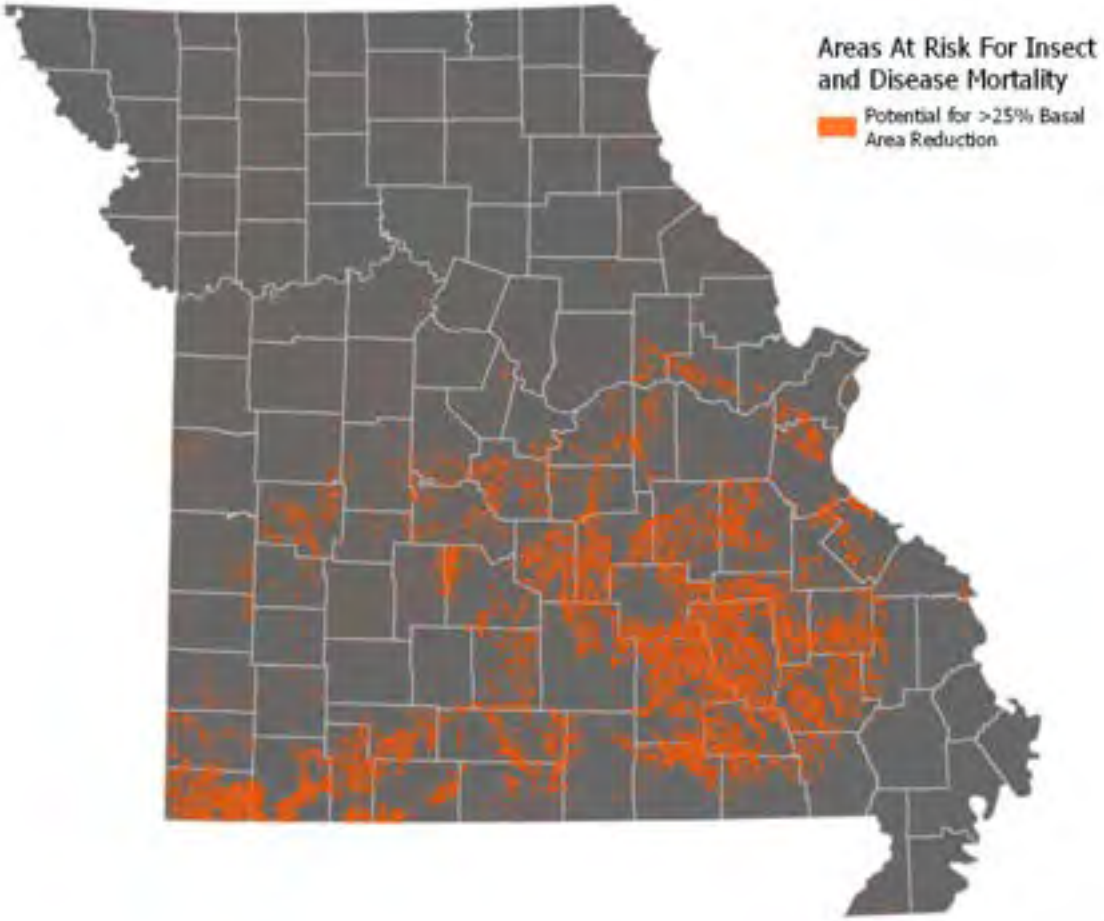
All forested areas identified as being at significant risk = 10 points

Relevance: This data theme represents areas most prone to tree mortality from insects and diseases from 2013 through 2027. These areas need increased attention to minimize mortality and/or economic losses and to ensure a healthy forest emerges following mortality.

Data for this layer comes from the following source:

USFS National Insect and Disease Risk Map (USFS 2020a)

Figure C.7 – Insect and Disease Vulnerability Data Theme



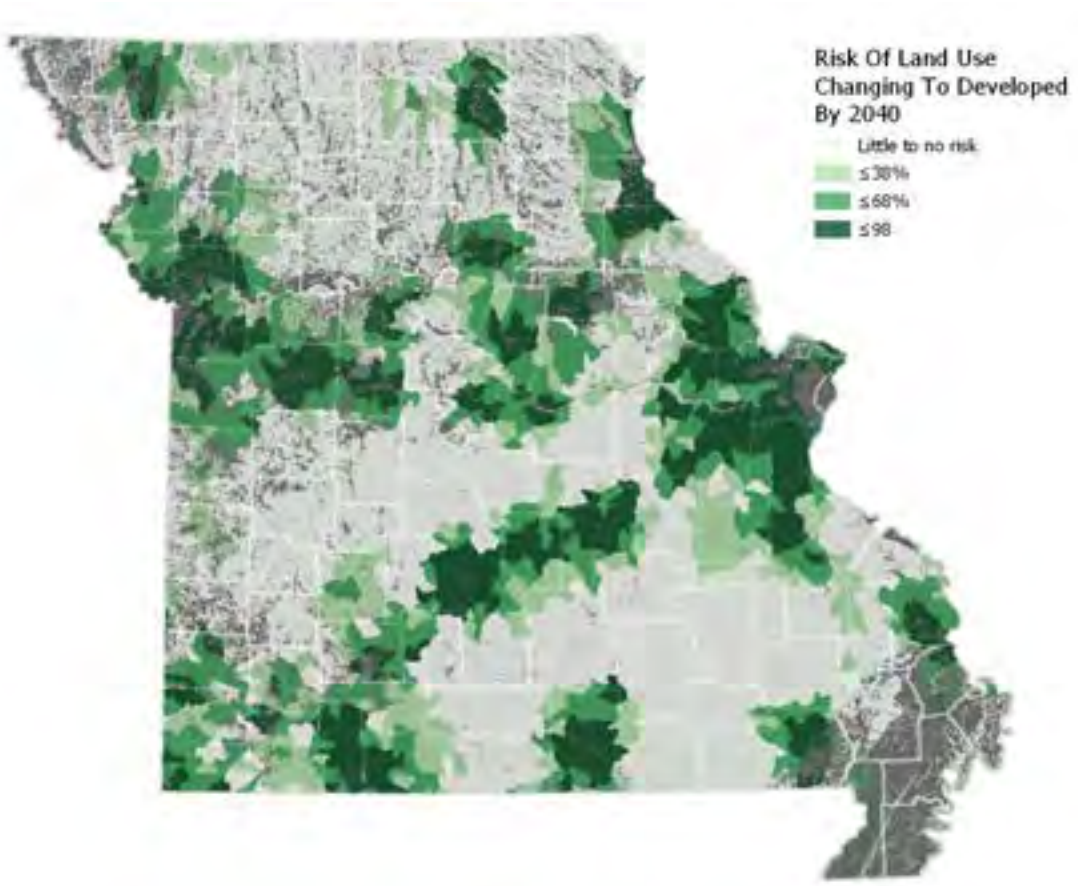
Data Theme Eight: Land Use Change Risk

Description: This data theme consists of areas identified as being most vulnerable to land-use changes through the year 2040 as a function of population growth and housing density projections using continued high carbon emissions modeling. Points are allocated as follows:
Highest land use change risk = 10 points
Moderate land use change risk = 8 points
Low land use change risk = 6 points
Negligible land use change risk = 0 points

Relevance: These areas are subject to increased threat of conversion of forest to nonforest land cover, fragmentation, and parcelization in the next 20 years. These threatened areas that overlap with highly important forestland represent high priority areas for targeting land conservation efforts (smart growth planning, conservation easements, etc.).

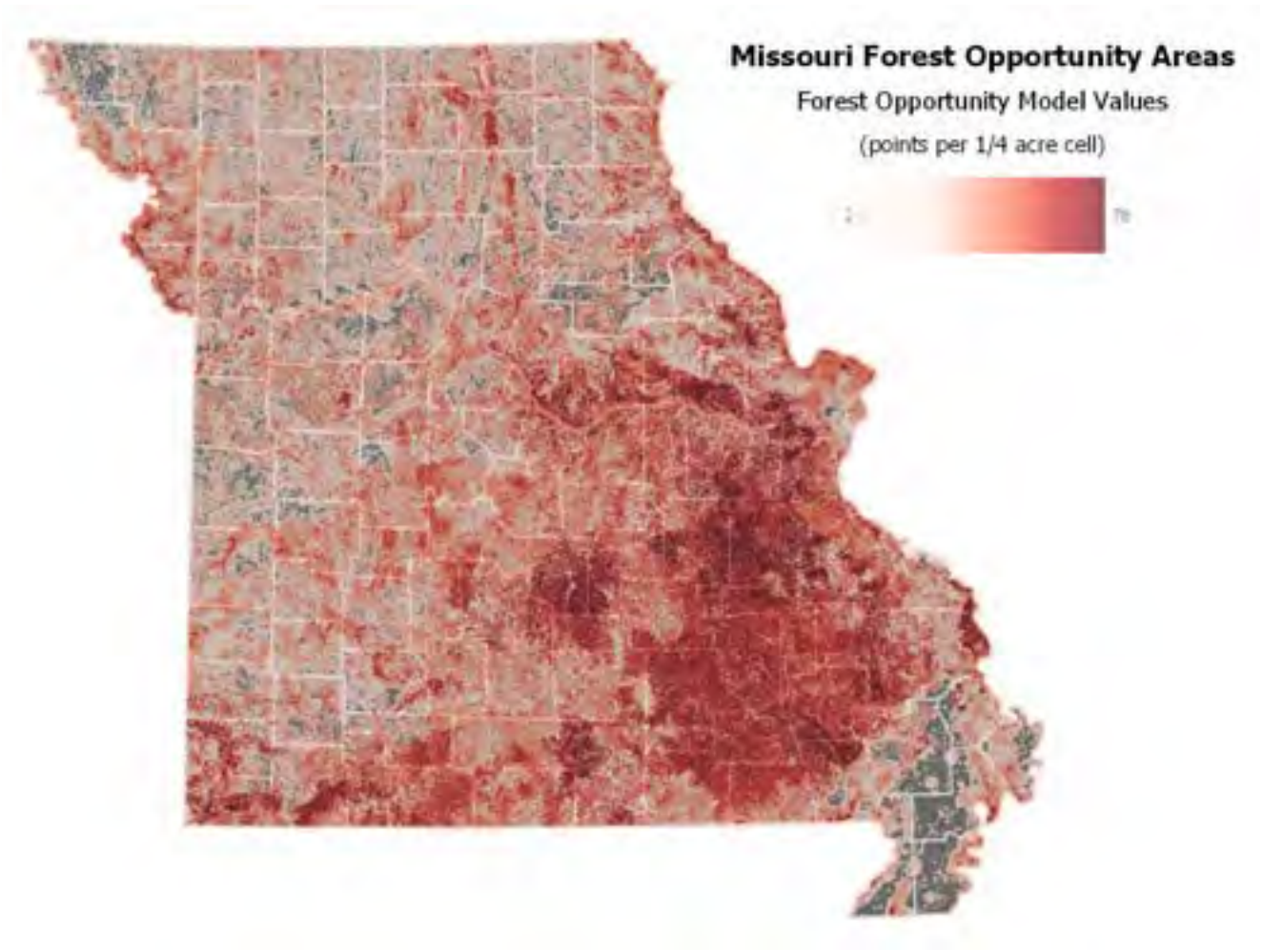
Data Source: U.S. Environmental Protection Agency – Integrated Climate and Land-Use Scenarios (U.S. Environmental Protection Agency 2017)

Figure C.8 – Land Use Change Risk Data Theme



Missouri Forest Opportunity Model – Composite Score Map (Figure C.9)

As the data set scores for each one-quarter-acre cell are added up, they result in the following composite score map. On the color spectrum shown below, the darkest areas represent the greatest opportunities for improving and sustaining forests and forest benefits.



Priority Forest Landscapes

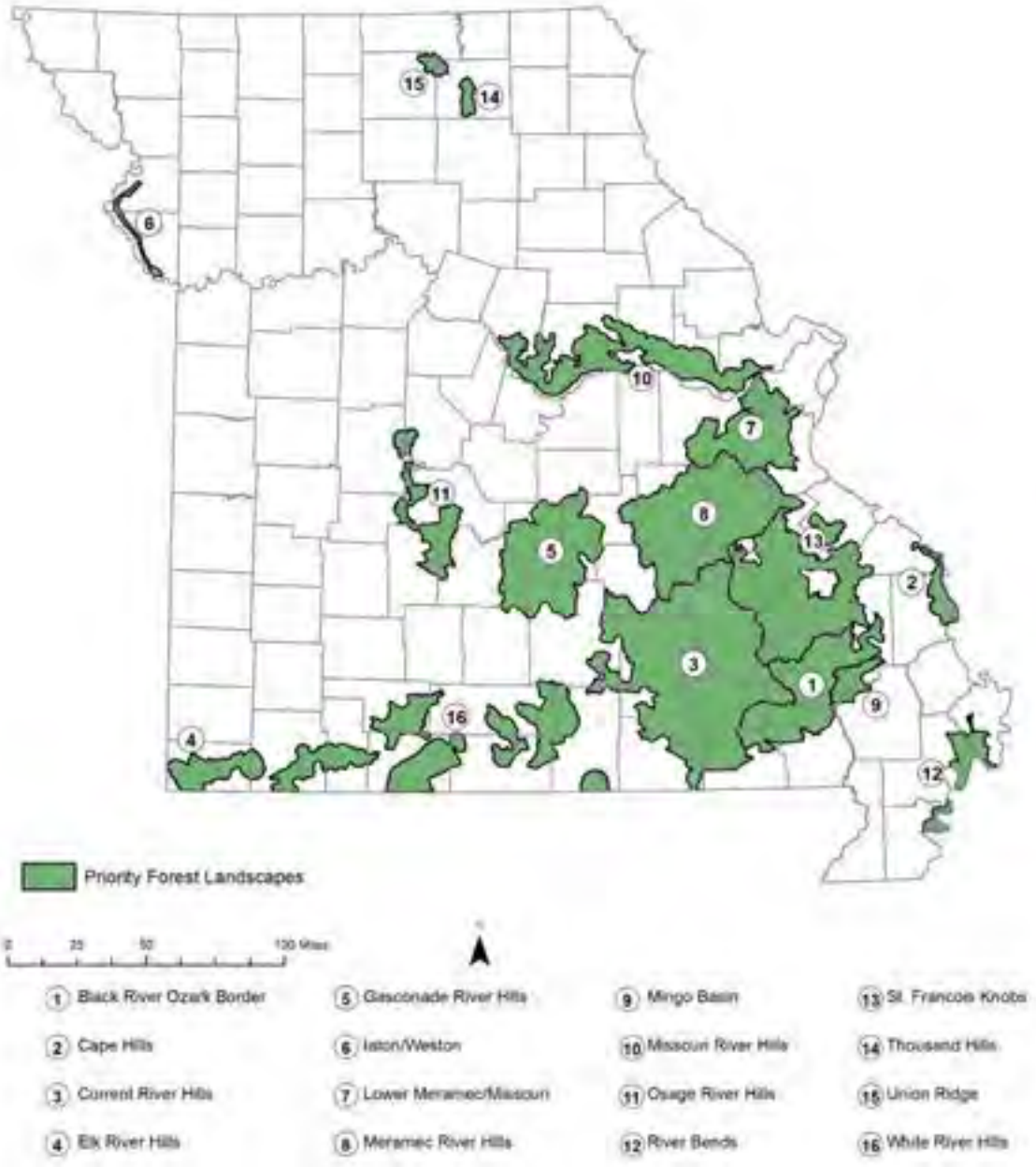
PFLs are large landscapes (>10,000 acres) offering Missouri's best opportunities for improving and sustaining forest resources and the benefits and services derived from them. They are places that offer the greatest conservation benefit but are also under significant but mitigable threat. PFLs are important places for focusing limited resources (dollars, staff, volunteers, grants, etc.) toward strategic planning, collaborating, and implementing conservation.

Besides the fact that prioritizing what work should be done where is the right thing to do, the development of PFLs is also required for states to continue receiving federal funding from the USFS. Missouri's PFLs were designed to meet the needs and requirements of all USFS funding – including Forest Legacy and Forest Stewardship Programs, which each have unique requirements for priority landscapes.

Missouri's PFLs were primarily developed by tracing the outline of the highest-scoring places in the state as depicted by the Forest Opportunity Model. In most cases, these boundaries also consist of distinct transitions between forest and nonforest cover. However, a couple of additional PFLs were identified based on criteria that they are already existing PGs for wildlife conservation with active partnerships working toward their conservation.

The following map (**Figure C.10**) shows the resulting PFLs. On this map, **approximately 42 percent of Missouri's existing forestland is recognized as** PFL.

Figure C.10 – Missouri's Priority Forest Landscapes



Appendix D: Forest Legacy Program in Missouri – The Rest of the Story

Background

The USFS's FLP is a valuable tool available to states for protecting important working forestlands that are threatened from conversion to nonforest uses in order to improve and sustain the myriad benefits and ecosystem services they provide (USFS 2017). The FLP accomplishes this purpose by providing competitive funding support to states for fee title acquisition of forestlands to be placed in public ownership and for establishing conservation easements held by public agencies to protect these conservation values. The MDC administers FLP for Missouri, but other state and local government agencies such as MDNR, county governments, and municipal governments are eligible to hold land and easements acquired through FLP as well.

Missouri's goals for utilization of the FLP include:

- Ensuring the future health of important watersheds and streams that produce clean, affordable drinking water; mitigating flooding; and providing important aquatic habitat and recreation
- Protecting habitats important to improving and sustaining populations of sensitive wildlife species
- Maintaining outstanding opportunities for outdoor recreation
- Maintaining the productivity of Missouri's forestland and improving the sustainable production of forest products
- Protecting karst features (caves, springs, fens), other unusual natural features, and cultural sites
- Protecting the scenic values of forestlands that are important to Missouri citizens where they live and play and that are important to maintaining the integrity of Missouri's tourism economy

States that participate in FLP are required to develop an AON to demonstrate eligibility. AONs were originally stand-alone documents. However, modern Farm Bill requirements stipulate that AONs must be incorporated into SFAPs (or CCS in Missouri's case) either directly and/or as an appendix (Wormstead and Neuenfeldt 2018). Missouri's first Forest Legacy AON was completed in 2005 and was incorporated into Missouri's 2010 SFAP by simple reference. However, since this original AON is now 15 years old it is necessary to update this information and more fully incorporate it into Missouri's new CCS.

To the extent possible, Missouri has addressed Forest Legacy AON requirements directly into the heart of this CCS document. However, some required AON elements do not flow smoothly into the main document and are thus included here in **Appendix D** and in **Appendix C**. **Table D.1** provides a crosswalk to explain precisely where in CCS each of the Forest Legacy AON requirements are addressed (as listed in Wormstead and Neuenfeldt 2018). Any elements not addressed earlier in the document are addressed in this appendix following the crosswalk or are captured in **Appendix C**.

Table D.1 – FLP Assessment of Need Crosswalk

FLP AON Requirement	Location Addressed in CCS
Forest resources and benefits	
• Aesthetic and scenic values	**Section Three**, Theme Nine
• Fish and wildlife habitat	**Section Four**
• Public recreation opportunities	**Section Three**, Themes Four and Nine
• Soil productivity	**Section Three**, Theme Six; **Appendix C**, "Data Theme Two: Forest Productivity"
• Forest products and timber management opportunities	**Section Three**, Theme Eight; **Section Six**; **Appendix C**, "Data Theme Two: Forest Productivity," and "Data Theme Six: Harvest Pressure"
• Watershed values including water-quality protection	**Section Three**, Theme Six; **Appendix C**, "Data Theme Three: Soil and Water Conservation"
A. Present and future threat of conversion of forest to nonforest uses	**Section Three**, Theme Three
B. Historic or traditional uses of forest areas; trends and projected future uses of forest resources	**Section Three**; **Section Four**, "An In-Depth Look at Missouri's Natural Community Conservation"; **Appendix D**, "Historic Uses of Missouri's Forests," and "Uses of Missouri's Forest Resources Today and into the Future"
C. Current ownership patterns and size of tracts; trends and projected future ownership patterns	**Section Three**, Theme Three
D. Cultural resources that can be effectively protected	**Appendix D**, "Cultural Resources"
E. Outstanding geological features	**Section Four**, "Missouri Natural Communities Background" (including linked materials); **Appendix D**, "Forest Legacy Areas"
F. T&E species	**Section Four**, "Forest and Woodland Conservation," subsection "Species of Greatest Conservation Need"
G. Other ecological values	**Section Three**; **Section Four**, "Forest and Woodland Conservation"
H. Mineral resource potential	**Appendix D**, "Mineral Resource Potential"
I. Protected land, including federal, state, municipal, and private conservation organization lands	**Section Three**, Themes Three and Four

J. Issues identified by State Forest Stewardship Coordinating Committee and through public involvement process	**Section Three**; **Section Four**, "Forest and Woodland Conservation"
K. Identification of applicable eligibility criteria	**Section Two**, "Forest Legacy;" **Appendix C**; **Appendix D**, "Identification of Applicable Eligibility Criteria and Analysis Method"
Identification of specific FLAs for designation	
• Location of each geographic area on map and written description of boundary	**Section Two**, "Forest Legacy"; **Appendix D**, "Forest Legacy Areas"
• Summary of the analysis used to identify the FLA and its consistency with eligibility criteria	**Section Two**; **Appendix C**; **Appendix D**, "Forest Legacy Areas"
• Identification of important environmental values and how they will be protected/conserved	**Appendix D**, "Forest Legacy Areas"
• The conservation goals or objectives for each FLA	**Appendix D**, "Forest Legacy Areas"
• Public benefits that will be derived from establishing each FLA	**Appendix D**, "Forest Legacy Areas"
L. Identification of government entity that may hold lands or interest in lands enrolled in FLP	**Appendix D**, "Background" and "Means of Protection"
M. Documentation of the public involvement process and analysis of the issues raised	**Section One**, "Citizen and Partner Engagement"; **Appendix D**, "Public Involvement"
N. Specific goals and objectives to be accomplished by the FLP	**Appendix D**, "Background" and "Forest Legacy Areas" (description provided for each FLA)
O. Process used by state to evaluate and prioritize projects to be considered for inclusion in the FLP	**Appendix D**, "Process Used by State to Evaluate and Prioritize FLP Proposals"

Historic Uses of Missouri's Forests

"Early explorers of the Missouri territory found a blend of landscapes rich with the essentials of frontier life – wood, water, and wildlife. Forests covered 70 percent of the state with an astonishing variety of tree species. Explorers wrote of the dark swamps of the Bootheel, the park-like pine forests of the Ozarks, the balds of Southwest Missouri, and the mix of prairie and forest in north and west Missouri.

"This diverse mix of habitat was home to many kinds of wildlife. Early journals tell of herds of buffalo, elk, and deer. Bear, wild turkey, passenger pigeon, and grouse were also common.

"Immigrants moved up the major rivers first. Until this point, they cut the timber and floated it back downstream to the larger towns. Cords of fuelwood supplied steam-driven riverboats. By the mid-1800s, European immigrants had cut the forests in the Osage and Gasconade River valleys. In the eastern Ozarks, the forests around Potosi and St. James had been logged off and made into charcoal to fire the local iron and lead smelters.

"In the post–Civil War years, a war-torn nation needed lumber to rebuild. Railroad ties were in demand to complete the transcontinental railroad. Until then the great pine forests of the Ozarks were largely untouched because of their remoteness and lack of access. But eastern businessmen saw a valuable resource waiting for exploitation. The lumbermen bought up large tracts of forestland in the Missouri Ozarks. In 1887, the Missouri Lumber and Mining Company shipped a sawmill by rail to the end of the line in Williamsville. It was then hauled by wagon to Grandin in Carter County. This mill would eventually become one of the largest sawmills in the nation at that time. Other large sawmills operated in Winona, West Eminence, Bunker, Leeper, Greenville, Poplar Bluff, Doniphan and Birch Tree. The far reaches of the hollows sheltered hundreds of other small saw-mills. At the turn of the 20th century, the Ozarks was one of the largest timber-producing regions in the nation.

"Workers laid hundreds of miles of rails for narrow-gauge railroads to pull carloads of pine logs back to the mills. The mill at Grandin needed the logs from 70 acres of forest each day to keep it running. The rivers were also used for transportation. Large log drives were made on the Current, Jacks Fork, and Black rivers. Farmers could make a little money by 'hacking' or chopping railroad ties out of logs – a lot of work for the grand sum of 10¢ for the labor to hack a tie.

"J.B. White was one of the principals of the Missouri Lumber and Mining Company in Grandin. Although White had made a fortune from logging, he was also a conservation-minded individual and recognized that logging could be compatible with forest management. In April 1910, he, along with other early forest conservationists, invited USFS Chief Gifford Pinchot to Missouri. They hosted Pinchot on a tour of the cutover forests in the Ozarks. White urged Pinchot to establish a national forest in Missouri in the interest of forest conservation.

"By 1920, the forests that no one thought would run out, did. The huge mills shut down and the mill workers were left to eke out a living in the rocky, barren hills. They cleared the ridgetops, trying to grow a few crops. Free-ranging livestock roamed the woods to forage on acorns and sprouts. European immigrants burned the cut- over woods each spring, mistakenly believing that fire killed the ticks and snakes.

"It was not until 1928 that Missouri's depleted forests received any official attention. That year, the Missouri General Assembly authorized a Department of Forestry under the Board of Agriculture. The Board appointed Frederick Dunlap as State Forester and hired Paul Dunn as a District Forester. Dunn moved to Ellington, where his primary job was fire prevention. He once reported that at least three-fourths of the land outside the state parks burned off twice each year.

"Dunn drove around his district in a Model T, hauling a trailer with a movie projector and

generator. He had one film, "Trees of Righteousness," apparently made by the USFS in Arkansas. Dunn wore out five prints of it showing it to every school district in Reynolds and adjoining counties.

"In 1931, the governor vetoed the forestry appropriation due to the Depression economy and the Forestry Department was abolished due to lack of funding. Following six years of failure and the abolition of the Forestry Department, State Forester Dunlap concluded that it was impossible to stop forest fires in the Ozarks.

"By the mid-1930s, Missouri's forest and wildlife resources were at an all-time low. The forests were burned and abused. Gravel, eroded from the hillsides, choked the once-clear streams. An estimated 2,000 deer remained in the entire state, and turkeys declined to a few thousand birds in scattered flocks.

"In 1929, the Missouri National Forest Association successfully lobbied the Legislature to permit the federal government to purchase land in Missouri for a national forest. Eight purchase units were set up in 1934–1935, and the national forests became a reality. Eventually 1.5 million acres of cutover forestland was acquired – the land that nobody else wanted.

"Conservation efforts were also underway on the state level. Voters approved the constitutional amendment creating the Missouri Conservation Commission in 1936. This new agency included a forestry division; an innovative idea at a time when most other fish and wildlife agencies were separate from forestry departments. The early Missouri conservationists recognized that a healthy forest resource was essential to healthy fish and wildlife populations.

"The commission hired former USFS employee George O. White as State Forester in 1938. Fire control was his first big job. Borrowing an idea from Paul Dunn, the "Showboat" was put into operation to educate the rural folks not to burn. This was a truck with a generator, picture screen and projector, and operator. It took forestry movies into the Ozark hills where there was no electricity. The pictures were shown outdoors, in crossroad stores, at country churches and schools. The "Showboat" brought movies to people who had never seen one in their lives. This mobile entertainment operated for 12 years, continuing even through World War II.

"Gradually, fire prevention programs began to pay off. Once fires were reduced, efforts could be turned to managing the forest. Foresters planted seedlings, harvested trees damaged by fire, and removed undesirable trees. Commission employees worked with landowners to teach them how to improve their forest and wildlife habitat.

"Tremendous progress in Missouri's forest management has been made in the last half century. The once impossible task of fire control in the Ozarks is a reality. Today less than one-tenth of one percent of Missouri burns each year. Deer and turkey are found in record numbers. Restoration programs have reintroduced ruffed grouse and river otters. The forest is again healthy, and once again, Missouri is a leader in wood products.

"Conservation, wise use, has made all this possible. The recovery has been so remarkable that some areas are now called 'wilderness.' Older foresters just smile and think back to all the years of firefighting and management that helped create that 'wilderness.'" (This excerpt is taken verbatim from Palmer 1991.)

Uses of Missouri's Forest Resources Today and Into the Future

Missouri's forest and wildlife resources have made a remarkable recovery from the ravages of the early 20th century. Forest fire control, more sustainable harvesting practices, and reforestation have all resulted in the quality forests Missourians now enjoy. Today, Missouri has 15.3 million acres of forest of which 13.8 million acres are dominated by medium to large size trees. This represents a 2.4 million acre increase in total forestland since 1972 and a 4.8 million acre increase in the abundance of woods dominated by medium to large diameter trees during this same time (Goff 2018).

This recovery of Missouri's forests has resulted in a resource that provides an abundance of benefits and services to Missouri citizens that can be reasonably sustained into the future with proper management. These benefits and services include everything from clean drinking water to wildlife habitat, outdoor recreation, forest products and much more; these are described in much greater detail throughout **Section Three** and **Section Four**.

Cultural Resources

Missouri's cultural history is rich and varied. Native Americans, most notably the Osage, Fox, Missouri, and Sauk, all inhabited Missouri prior to widespread European immigration. Cherokee and Shawnee tribes were also found in Missouri during the times of European immigration. These tribes all hunted and farmed, establishing small communities but ranging out to hunt. Native American artifacts are regularly found throughout the state, including implements, tools, and a variety of points (MDC 2005).

Missouri was originally influenced by French trappers and traders. Later, Spanish traders and German farmers immigrated to Missouri. Many Missouri communities have rich French and German heritage and many bear French and German names. Early explorers included the likes of the Lewis and Clark Expedition, Daniel Boone, Nathan Boone, and several others. Missouri also provided the setting of many historic civil war forts and battles (MDC 2005). To track these and numerous other archaeological activities of significance, the Missouri State Historic Preservation Office maintains records on more than 17,500 archaeological sites throughout the state via the Missouri Cultural Resource Inventory (MDRN 2019). Conversion of forestland may result in the loss of important cultural artifacts and resources if they are not identified and protected in the process. The presence of cultural resources and archaeological sites will be a consideration when ranking proposed tracts within FLAs.

Mineral Resource Potential

In 2015, the estimated value of non-fuel mineral production for Missouri was $2.6 billion, based upon preliminary USGS data. The state was ninth in rank among the 50 states in total non-fuel mineral production value, of which Missouri accounted for nearly 3.58 percent of the U.S. total. Portland cement, crushed stone, industrial sand, and gravel (in descending order of value) accounted for 68 percent of Missouri's total non-fuel mineral production in 2015. Lead and lime were also important contributors, along with smaller amounts of masonry cement, clay, copper, natural gemstones, silica, silver, dimension stone, and zinc (USGS 2019). Based upon USGS estimates of the quantities produced in the 50 states in 2013, Missouri was ranked first in the production of lime, fire clay, and lead, and ranked third in the production of crushed stone, portland cement, and zinc (USGS 2016).

Much mineral extraction in Missouri is accomplished through surface mining, which leads to the conversion and loss of forestland. Surface mining of crushed stone is common in most Missouri counties due to the limestone and dolomite bedrock found throughout most of the state. The threat of forest conversion for surface mining for crushed limestone increases in rural areas as populations increase in areas, bringing

the need to expand road infrastructure (MDC 2005).

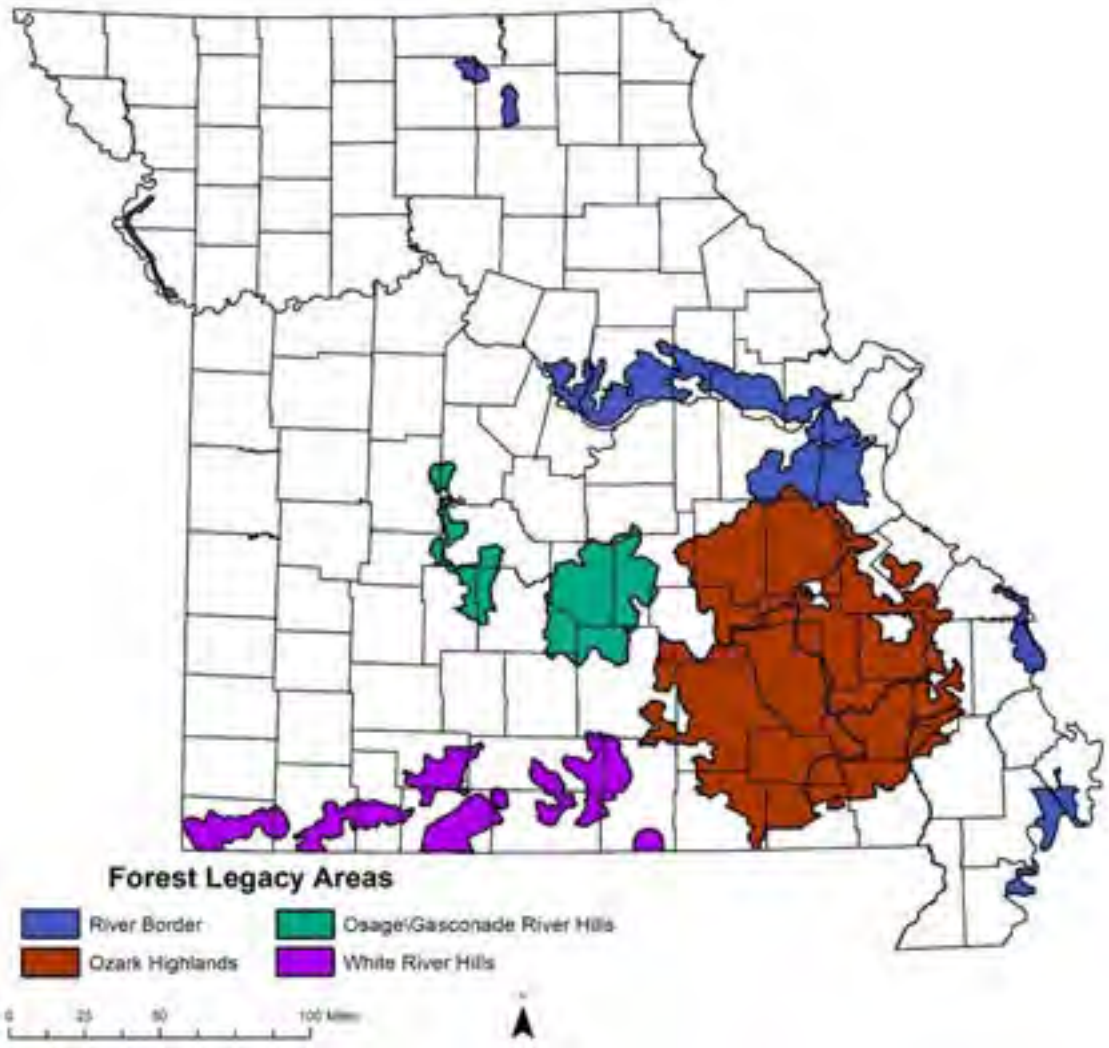
Missouri has traditionally been one of the nation's leading producers of lead, with most production centered in the heart of the St. Francois Mountains in Washington, Iron, Reynolds, Crawford, and Dent counties. Small amounts of copper, silver, and zinc are also mined in this same region of the state. Since limestone is prevalent throughout the state, crushed stone is produced in nearly every county. Clay production is most prevalent in counties bordering the Mississippi and Missouri rivers (MDC 2005).

Mineral production is an incompatible use on FLP properties – so to be eligible for consideration, tracts must be free of mineral extraction encumbrances, have any mineral rights severed, or have an official state determination that the mineral rights have in essence no chance of being exercised (USFS 2017).

Forest Legacy Areas

FLAs are geographic areas eligible to be considered for Forest Legacy projects. Only tracts within FLAs can be submitted to the USFS for competitive funding for fee title public land acquisition or conservation easement. Missouri's FLAs consist of all of Missouri's PFLs (see **Figure C.10**) grouped into four distinct FLAs – Riverborder, Ozark Highlands, White River Hills, and Gasconade/Osage River Hills (**Figure D.1**). Although the overlap is substantial, our 2020 FLAs represent a significant change from our previous 2005 FLA delineations. Our 2005 FLAs were established using county units. Most of our 2020 FLAs fall within the 2005 FLAs but represent a significant refinement by utilizing PFL units instead of county units.

Figure D.1 – Missouri's Forest Legacy Areas



Identification of FLA Eligibility Criteria and Analysis Method

The PFLs that make up Missouri's FLAs were delineated primarily using the Forest Opportunity Model described in **Section Two** and **Appendix C**. Missouri's Forest Opportunity Model is based on the following attributes of forest importance and threat: (1) biodiversity, (2) forest productivity and carbon sequestration, (3) soil and water conservation, (4) recreation and social values, (5) forest patch size, (6) current harvest pressure, (7) insect and disease vulnerability, and (8) land use change risk. These attributes align well with seven of the public values identified in the FLP Guidelines, of which all FLAs must contain at least one. One PFL (River Bends) was delineated because of its high habitat and wildlife restoration potential outside of the Forest Opportunity Model.

Description of FLAs

River Border Forest Legacy Area

Riverborder FLA Location: Riverborder FLA consists primarily of PFLs located along the Missouri and Mississippi rivers including Iatan/Weston, Missouri River Hills, Lower Meramec/Missouri, Cape Hills, and River Bends. Also included are Union Ridge and Thousand Hills PFLs, which are along the Chariton River. With one exception, the boundaries of the underlying PFLs consist of the outline of the highest scoring areas as calculated by our Forest Opportunity Model (see **Appendix C**). These boundaries also generally coincide with the boundaries of distinct forest landscapes. The one PFL that was not delineated using the Forest Opportunity Model was River Bends. Much of River Bends PFL did not score highly using our Forest Opportunity Model because most of this historically forested swamp landscape was cleared off and converted to agriculture in the early to mid-1900s. However, this area is included in the PFL/FLA system because it represents a critical bottomland hardwood restoration opportunity of great importance to wildlife. **65.7 percent of the FLA is in forest cover**, but this figure is influenced significantly by River Bends PFL, which is significantly more open than other PFLs.

Figure D.2 – River Border Forest Legacy Area

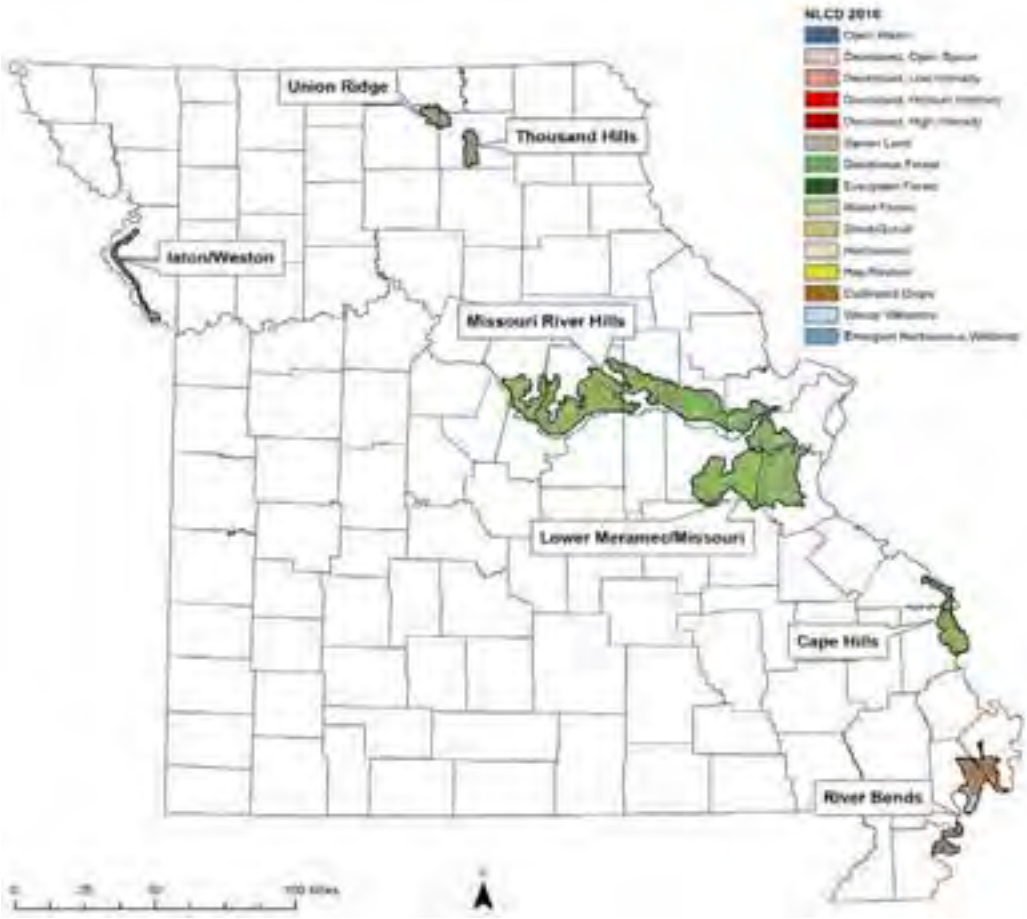


Table D.2 – River Border FLA PFLs, Counties, and Focal Public Lands

Priority Forest Landscapes	Counties	Focal Public/Protected Lands
Iatan/Weston	• Platte • Buchanan	• Weston Bend State Park[2] • Bluffwoods Conservation Area[1]
Missouri River Hills	• Boone • Callaway • Montgomery • Warren • St. Charles	• Cedar Creek Ranger District[3] • Daniel Boone Conservation Area[1] • Weldon Spring Conservation Area[1] • Rock Bridge State Park[2] • Little Lost Creek Conservation Area[1]
Lower Meramec/Missouri	• St. Louis • Jefferson • Franklin	• Rockwoods Reservation[1] • Labarque Creek Conservation Area[1] • Castlewood State Park[2] • Meramec State Park[2] • Meramec Conservation Area[1]
Cape Hills	• Cape Girardeau • Perry	• Trail of Tears State Park[2] • Apple Creek Conservation Area[1]
River Bends	• Mississippi • New Madrid • Pemiscot	• Donaldson Point Conservation Area[1] • Big Oak Tree State Park[2] • Black Island Conservation Area[1]
Union Ridge	• Sullivan • Adair • Putnam	• Union Ridge Conservation Area[1] • Dark Hollow Natural Area[1]
Thousand Hills	• Adair • Macon	• Thousand Hills State Park[2] • Big Creek Conservation Area[1] • Sugar Creek Conservation Area[1]

[1] MDC, [2] MDNR, [3] USFS

Riverborder FLA Special Values and Public Benefits:

Riverborder FLA consists of seven separate PFLs on the shoulders of the Missouri River, Mississippi River, and Chariton River. They consist of deeply dissected upland hills, bluffs, and wet bottomlands. Upland sites in these landscapes contain a significant component of loess soils, which lead them to be some of the most productive growing sites for forests in Missouri. Given the widely dispersed nature of these river border landscapes it is difficult to provide specific data on their contributions to the forest products industry. However, given the productivity of these sites, most of these landscapes produce high quality white oak, walnut, and red oak timber that is sought worldwide.

These landscapes tend to be located in important migratory travel corridors for wildlife such as the Mississippi Flyway. The FLA is mostly dominated by mixed oak-hickory forests and woodlands with scattered glades. However, these landscapes also contain several truly unique and important habitat types, including extensive bottomland swamp/forest in River Bends PFL, upland oak savanna in Union Ridge PFL, deep loess forested hills in Iatan/Weston PFL, the convergence of the northern extent of the Ozarks with north Missouri's Central Dissected Till Plains (historically tallgrass prairie growing on glacial soils) in the Missouri River Hills, and St. Peter's Sandstone communities in the Lower Meramec/Missouri PFLs. As such, these landscapes are of tremendous importance for a wide variety of sensitive wildlife species – such as neotropical migrant songbirds, amphibians, waterfowl, Indiana and Northern long-eared bats, and herbaceous plants, including many SOCCs. They also contain significant karst features in which forest cover is important for protecting groundwater.

Another common feature among these landscapes is that most of them are adjacent to significant metropolitan areas. For example, Iatan/Weston PFL is sandwiched in between Kansas City and St. Joseph, the Missouri River Hills PFL is sandwiched between St. Louis and Columbia/Jefferson City, the Lower Meramec/Missouri PFL is within St. Louis Metropolitan Area, and the other PFLs are in close proximity to moderately large cities including Kirksville, Cape Girardeau, and Sikeston. Five of the 19 counties this FLA intersects are among the ten fastest growing counties in Missouri (in terms of the number or percentage of population increase) including Warren, St. Charles, Boone, Platte, and Jefferson (MOA 2020). Four other counties are already highly developed including St. Louis, Franklin, Buchanan, and Cape Girardeau. Thus, people are a highly important component of this FLA. This is in part because these forested landscapes directly benefit a huge number of people through opportunities for outdoor recreation, pleasing natural aesthetics, clean drinking water, etc. For example, the Meramec watershed (including Lower Meramec/Missouri PFL) provides clean, affordable drinking water to approximately 840,000 citizens in St. Louis Metropolitan Area (Nature Conservancy 2014; U.S. Census 2020). The Lower Meramec/Missouri PFL also provides quality outdoor recreation opportunities within a metropolitan area of 2.8 million people (Statista 2020). However, the large numbers of people residing in these areas also place a significant impact to these landscapes in terms of development, fragmentation, subdividing, and related impacts. Given that **90.8 percent of this FLA is comprised of mostly unprotected private land**, the health and sustained production of ecosystem services is dependent upon tools like Forest Legacy to ensure these important forestlands remain intact.

Riverborder FLA Pressures and Needs:

One of the biggest threats in Riverborder FLA is conversion of forest to non-forestland use and subdividing of tracts due to the abundance of people who live in and near these mostly unprotected landscapes. Land conservation practices (public land acquisition, conservation easements) are needed in these areas for several

reasons. Given the uniqueness of the habitat types in the PFLs that make up Riverborder FLA, this FLA is of great importance to a wide variety of wildlife. Effort is needed to keep these natural communities intact and to recover and sustain the SOCCs and other sensitive wildlife that depend upon them. Such effort is also needed to help protect karst features and groundwater. Land conservation in these landscapes helps provide adequate opportunity for local citizens to engage in outdoor recreation activities and to connect to nature within a reasonable distance of where they live. Lastly, given the proximity of these landscapes to major rivers, efforts to keep forestlands intact pose significant opportunity to help promote healthy, quality water supplies and moderated river flow rates that minimize the risk of severe flooding.

Goals and Objectives for Riverborder FLA:

- Maintain bottomland forests along the Missouri, Mississippi, Meramec, and Chariton rivers
- Protect watersheds of the major rivers by maintaining and increasing forest cover
- Maintain forest cover to protect karst and groundwater supplies
- Reduce forest fragmentation and conversion; especially in the rapidly expanding St. Louis urban fringe.
- Protect species and habitats of conservation concern
- Provide adequate opportunities for outdoor recreation and people to connect to nature close to where they live
- Protect and enhance the integrity of existing public lands

Ozark Highlands Forest Legacy Area

Ozark Highlands FLA Location: Ozark Highlands FLA is located within Missouri's largest contiguous block of forestland – the heart of the Ozarks in southeast Missouri. Although this entire FLA is contiguous, it is comprised of several unique adjoining PFLs. The northern reach consists of Meramec River Hills. The southeast portion consists of Current River Hills. The eastern portion is made up of the St. Francois Knobs. The southeast consists of Black River Ozark Border and Mingo Basin. The boundaries of these PFLs consist of areas that scored the highest using our Forest Opportunity Model (see **Appendix C**) but are separated by these distinct ecological subsections.

Figure D.3 – Ozark Highlands Forest Legacy Area

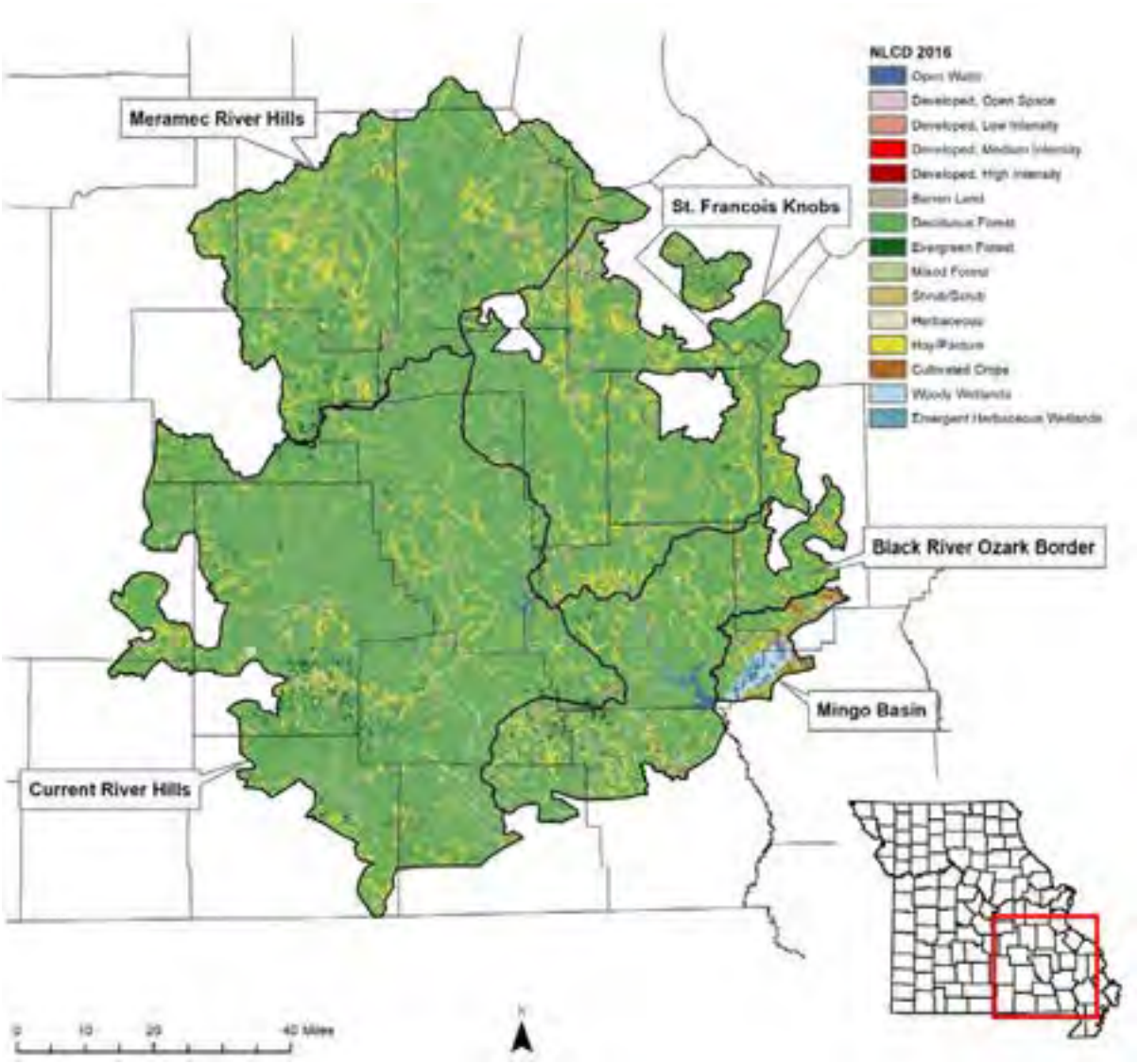


Table D.3 – Ozark Highlands FLA PFLs, Counties, and Focal Public/Protected Lands

Priority Forest Landscapes	Counties	Focal Public/Protected Lands
Meramec River Hills	Franklin Jefferson Washington Crawford Phelps Dent St. Francois Iron Reynolds	Potosi Ranger District[3] Salem Ranger District[3] Huzzah Conservation Area[1] Woodson K. Woods Conservation Area[1] Indian Trail Conservation Area[1] Washington State Park[2] Little Indian Creek Conservation Area[1]
Current River Hills	Dent Iron Reynolds Shannon Carter Wayne Texas Howell Oregon Ripley	Salem Ranger District[3] Doniphan/Eleven Point Ranger District[3] (including Eleven Point National Scenic River) Ozark National Scenic Riverways[4] Angeline Conservation Area[1] Rocky Creek Conservation Area[1] Sunklands Conservation Area[1] Current River Conservation Area[1] Peck Ranch Conservation Area[1] Pioneer Forest (L-A-D Foundation) (multiple tracts) The Nature Conservancy (multiple tracts)
St. Francois Knobs	St. Francois St. Genevieve Iron Washington Reynolds Madison Wayne Perry Bollinger	Potosi/Fredricktown Ranger District[3] Johnson Shut-Ins State Park[2] Taum Sauk Mountain State Park[2] Ketcherside Mountain Conservation Area[1] Buford Mountain Conservation Area[1] Amidon Conservation Area[1] Coldwater Conservation Area[1] Sam A. Baker State Park[2] Millstream Gardens Conservation Area[1] St. Joe State Park[2]
Black River Ozark Border	Wayne Bollinger Madison Butler Ripley Carter	Poplar Bluff Ranger District[3] Castor River Conservation Area[1] University Forest Conservation Area[1] Coldwater Conservation Area[1] Wappapello State Park[2] Pioneer Forest (L-A-D Foundation)
Mingo Basin	Wayne Bollinger Stoddard	Mingo National Wildlife Refuge[5] Duck Creek Conservation Area[1]

[1] MDC, [2] MDNR, [3] USFS, [4] NPS, [5] USFWS

Ozark Highlands FLA Special Values and Public Benefits: The Ozark Highlands FLA consists of Missouri's largest block of contiguous forestland located within the Ozark Highland Ecological Section identified in the Missouri ECS (Nigh and Schroeder 2002). The Ozark Highlands is essentially a plateau that has been undergoing weathering for a quarter of a billion years. This process has resulted in a highly diverse landscape containing over 200 endemic species (Nigh and Schroeder 2002). **82.8 percent of the landscape is in forest land cover.**

Ozark Highlands FLA contains several of Missouri's most biologically rich streams – home to impressive populations of fish, mussels, crawfish, hellbender salamanders, and many other unique species, including several SOCCs. Many of these streams are also recognized for their popularity for outdoor recreation (floating, fishing, etc.). A few highlights include the Jack's Fork and Current rivers (both National Scenic Riverways) and Eleven Point River (National Wild and Scenic River) in the Current River Hills PFL; Huzzah Creek, Courtois Creek, and the Meramec River in Meramec Hills PFL; Black River in Black River Ozark Border PFL; and Mingo Basin (National Wildlife Refuge), which contains some of the state's most diverse and abundant swamplands. What makes these streams such high quality is in large part the abundance of contiguous forestland that dominates the landscape. The key to the future of these treasured streams is keeping this forested matrix that feeds them healthy, sustainable, and intact.

Of these streams, the Meramec River and its watershed also provides special ecosystem services value by providing clean, affordable drinking water to 840,000 Missouri citizens in St. Louis Metropolitan Area (Nature Conservancy 2014; U.S. Census 2020) and by mitigating flooding in heavy population centers in and adjacent to St. Louis. This is only possible because of the high percentage of forest cover in the watershed. This watershed also provides especially high outdoor recreation value due to its proximity to 2.8 million people residing in and adjacent to it in the St. Louis Metropolitan Area (Statista 2020).

Most of the Ozark Highlands are dominated by carbonate bedrock, which has resulted in the presence of extensive karst features throughout much of the landscape – including abundant caves, springs, fens, and cliffs.

One exception to the dominance of carbonate bedrock in the Ozark Highlands is in the St. Francois Knobs PFL. The St. Francois Knobs are formed in igneous rhyolite bedrock, which was created by volcanic magma that cooled and hardened underground. This bedrock type is extremely weather resistant and has resulted in numerous unique geological and natural community features throughout the landscape such as "devil's honeycomb" rock formations on the top of Hughes Mountain Natural Area, stream shut-ins such as those of Johnson Shut-Ins and Amidon Conservation Area, and abundant glades. This is also home to Taum Sauk Mountain, Missouri's highest elevation site at 1,772 feet above sea level.

The forests of the Ozark Highlands are dominated by oak, hickory, and shortleaf pine. However, these forests are also known for the great diversity of other tree, shrub, and herbaceous species that can be found here as well. While these forests are critical to providing the impressive aquatic species diversity mentioned above, these communities are just as important to a great diversity of terrestrial species. For example, the above-mentioned karst system found here combined with vast surrounding forestland provides critical habitat for numerous sensitive bat species including but not limited to federally listed Indiana, gray, and northern long-eared bats. The landscape provides home to numerous sensitive neotropical bird species both as breeding grounds and as stopover habitat during migrations. Many rare plant species call this landscape home as well.

The Ozark Highlands are often referred to as the "wood basket" of Missouri. MDC's 12-

county Ozark Region alone contained 104 of Missouri's 374 sawmills in 2018, with 8 of these counties including some of Ozark Highlands FLA. MDC's 16-county Southeast Region contained 81 additional sawmills with the vast majority of these mills located within the FLA (Treiman and Morris 2018). For a map of MDC's regions and more information on harvest pressure, see **Section Three**, **Theme Eight**– Missouri's Growth, Harvest, and Consumption of Forest Products. This renewable economic engine is dependent on the maintenance of healthy, sustainable woods as are promoted through the FLP.

Ozark Highlands FLA Pressures and Needs: Although the proximity to so many people in the northern portions of this FLA (Meramec River Hills and St. Francois Knobs) make the FLA of especially great public value, these expanding WUI areas also place significant pressure on the landscape in the form of tract subdividing and land conversion for development. Other parts of the Ozark Highlands are not as vulnerable to urban sprawl as they are dominated by small communities with forest industry and agrarian based economies. However, these areas are susceptible to other pressures such as conversion of forestland to pasture and to "strip and flip" harvesting where all the timber on a tract is liquidated and then the property sold off.

The Ozark Highlands contain the largest percentage of public land ownership in the state. However, **68.1 percent of the landscape is privately owned**. Maintaining the connectivity of the privately owned and managed forested tracts between and surrounding the public forestlands in this area is critical to improving and sustaining the values and benefits mentioned above. Land conservation programs like Forest Legacy are key to ensuring the Ozark Highlands can continue to provide the public benefit demanded of the landscape into the future. Such programs help ensure the landscape continues to support diverse wildlife populations; tourism, outdoor recreation, and aesthetic integrity; clean and affordable drinking water supplies; and sustainable timber economies.

Goals for Ozark Highlands FLA:

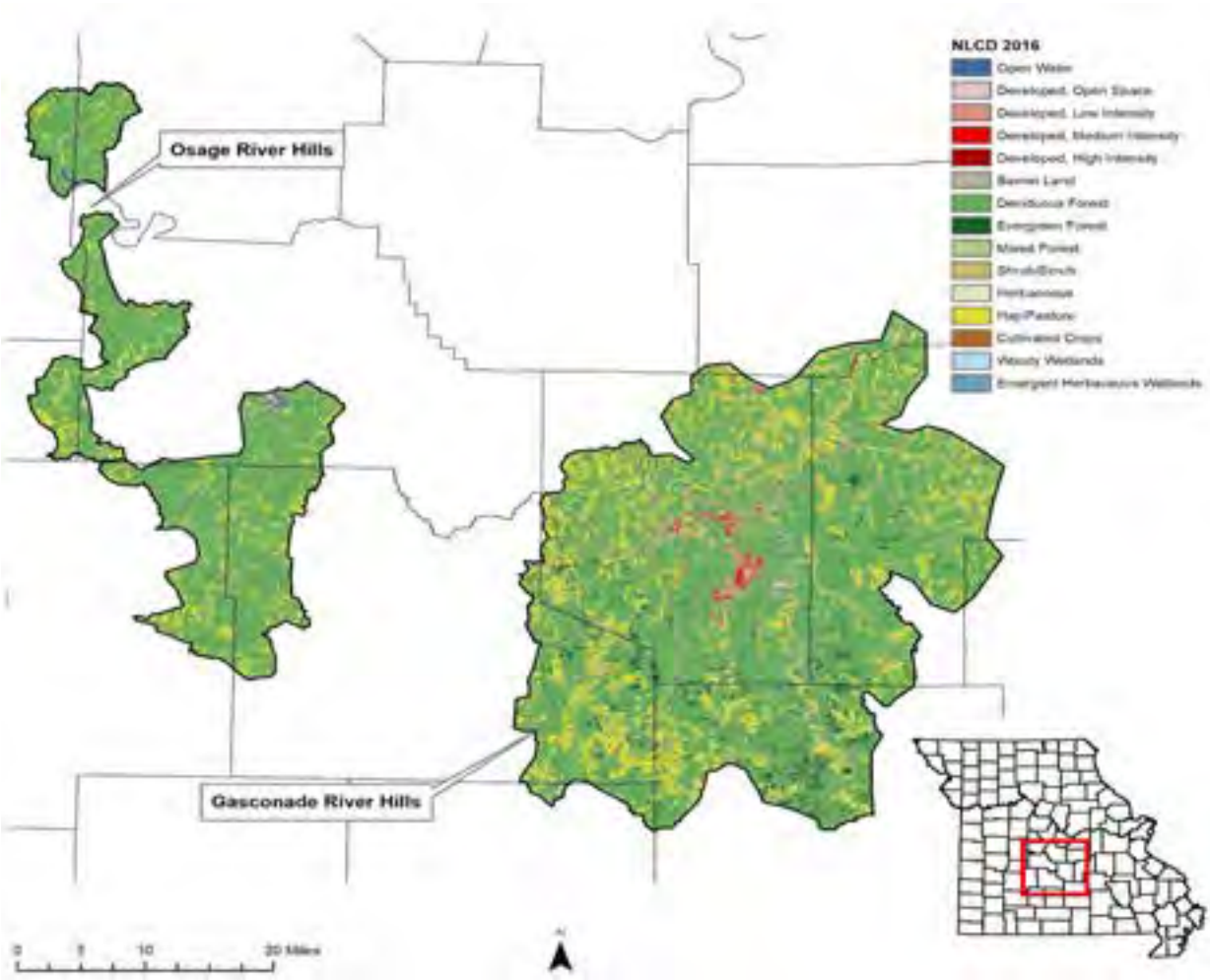
- Maintain large blocks of contiguous forest cover, particularly where linked to public or protected lands
- Protect the Jack's Fork and Current rivers (National Scenic Riverway), Eleven Point River (National Wild and Scenic River), Meramec River, and their supporting watersheds from degradation
- Protect critical habitat for aquatic and terrestrial SOCCs
- Protect karst features, groundwater supplies, and unique/sensitive natural features
- Protect the surface drinking water supply and mitigate flooding for St. Louis Metropolitan Area by maintaining important forest cover in the Meramec Basin
- Maintain important opportunities for outdoor recreation
- Maintain a sustainable timber supply to support forest industry and local economies

Osage/Gasconade River Hills Forest Legacy Area

Osage/Gasconade River Hills FLA Location: Osage/Gasconade River Hills FLA is also in the Ozark Highlands but is separated from the large contiguous landscape described above. Therefore, this area is recognized as a separate FLA in the south-central part of the state. Osage/Gasconade River Hills is comprised of two different PFLs. The largest is Gasconade River Hills, including and surrounding Fort Leonard Wood. The Osage River Hills includes parts of Laclede, Dallas, Hickory, Camden, Morgan, and Benton counties. The boundaries of these PFLs consist of areas that scored the highest using our Forest Opportunity Model (see **Appendix C**) in the south-central part of the state.

Table D.4 – Osage/Gasconade River Hills FLA PFLs, Counties, and Focal Public/Protected Lands

Figure D.4 – Osage/Gasconade River Hills Forest Legacy Area



Priority Forest Landscapes	Counties	Focal Public/Protected Lands
Gasconade River Hills	Pulaski Maries Dent Phelps Texas Wright Laclede	Houston/Rolla Ranger District[3] Fort Leonard Wood[4] Clifty Creek Conservation Area[1] Gasconade Hills Conservation Area[1] Roubidoux Creek Conservation Area[1]
Osage River Hills	Laclede Dallas Hickory Camden Morgan Benton	Ha Ha Tonka State Park[2] Bennett Spring State Park[2] Lead Mine Conservation Area[1] Big Buffalo Conservation Area[1] Mule Shoe Conservation Area[1]

[1] MDC, [2] MDNR, [3] USFS, [4] U.S. Army

Osage/Gasconade River Hills FLA Special Values and Public Benefits: The Osage/Gasconade River Hills FLA is primarily contained in Osage River Hills and Gasconade River Hills Subsections of the Ozark Highlands Section in the ECS. These subsections are composed of hilly to rugged lands associated with the Osage and Gasconade rivers. **The FLA is 77 percent forested.** The FLA's proximity to prairie-dominated ecoregions to the west and the presence of extensive areas of shallow to moderately deep and droughty soils make the influence of prairie and open woodlands stronger here than in other subsections of the Ozarks to the east. Historic vegetation ranged from prairie/savanna complexes in western portions to well-forested river breaks to the east (Nigh and Schroeder 2002).

Today parts of the FLA in the Osage River Hills are largely a focal point for recreational development associated with the Lake of the Ozarks. Only minor amounts of Lake of the Ozarks are located within the FLA. However, the FLA contains important sections of the Niangua River, Little Niangua River, and Big Buffalo Creek and their watersheds that feed directly into the lake. These streams are also important, independent of the lake, for both outdoor recreation and for the high diversity of aquatic wildlife they support.

The economy of this whole area now centers on recreation, tourism, and retirement communities around the lake. Counties included in this area were among the fastest growing in the state during the 1990s and 2000s. The pressure of this rapid growth is reflected in the common fragmentation of landownership and forest resources in this region (Nigh and Schroeder 2002).

The Gasconade River Hills PFL section of the FLA to the east of the Osage River Hills is not associated with Lake of the Ozarks. At the center of this PFL is Fort Leonard Wood Army Base, which includes about 53,000 acres of publicly owned forestland. Surrounding the base, but in a highly fragmented fashion, are about 50,000 acres of MTNF's Houston/Rolla Ranger District. Within this PFL are two streams of significant value for both wildlife diversity and outdoor recreation – the Gasconade River and the Big Piney River. The surrounding landscape has high wildlife conservation and recreation value as well.

Some forest industry exists throughout the FLA, but it is not nearly as economically significant as it is in the Ozark Highlands FLA.

Osage/Gasconade River Hills FLA Pressures and Needs: Given that **78.3 percent of the land in this FLA are privately owned**, lands

throughout the FLA are under significant pressure to be subdivided and converted into smaller acreage home sites or recreational lands. Land conservation efforts are needed to protect large forested blocks, natural features, SOCCs, important streams (Niangua, Little Niangua, Big Buffalo, Gasconade, and Big Piney), Lake of the Ozarks, scenic qualities, and outdoor recreation/tourism opportunities. Riparian forest protection is especially important throughout the FLA.

Goals and Objectives for Osage/Gasconade River Hills FLA:

- Maintain or increase large blocks of contiguous forest cover where possible
- Maintain the integrity of Niangua River, Little Niangua River, Big Buffalo Creek, Gasconade River, and Big Piney River by protecting key parts of their watersheds from degradation and forest loss associated with urban expansion and tourism development
- Protect important forested green space associated with tourism development, outdoor recreation, and scenic values
- Maintain forest cover to protect karst and groundwater supplies
- Maintain contiguous forest cover linked to public lands
- Protect unique natural features and SOCCs in this area

White River Hills Forest Legacy Area

White River Hills FLA Location: White River Hills FLA is also in the Ozark Highlands but is concentrated in the southwestern corner of the state along Missouri's southern border with Arkansas. The FLA consists of a chain of the highest-scoring forested areas within the White River and Elk River Watersheds according to Missouri's Forest Opportunity Model (see **Appendix C**). Elk River Hills Priority Forest Landscape is at the very southwest corner of the state. White River Hills PFL is comprised of six separate but nearby landscapes along Missouri's southern border.

Figure D.5 – White River Hills Forest Legacy Area

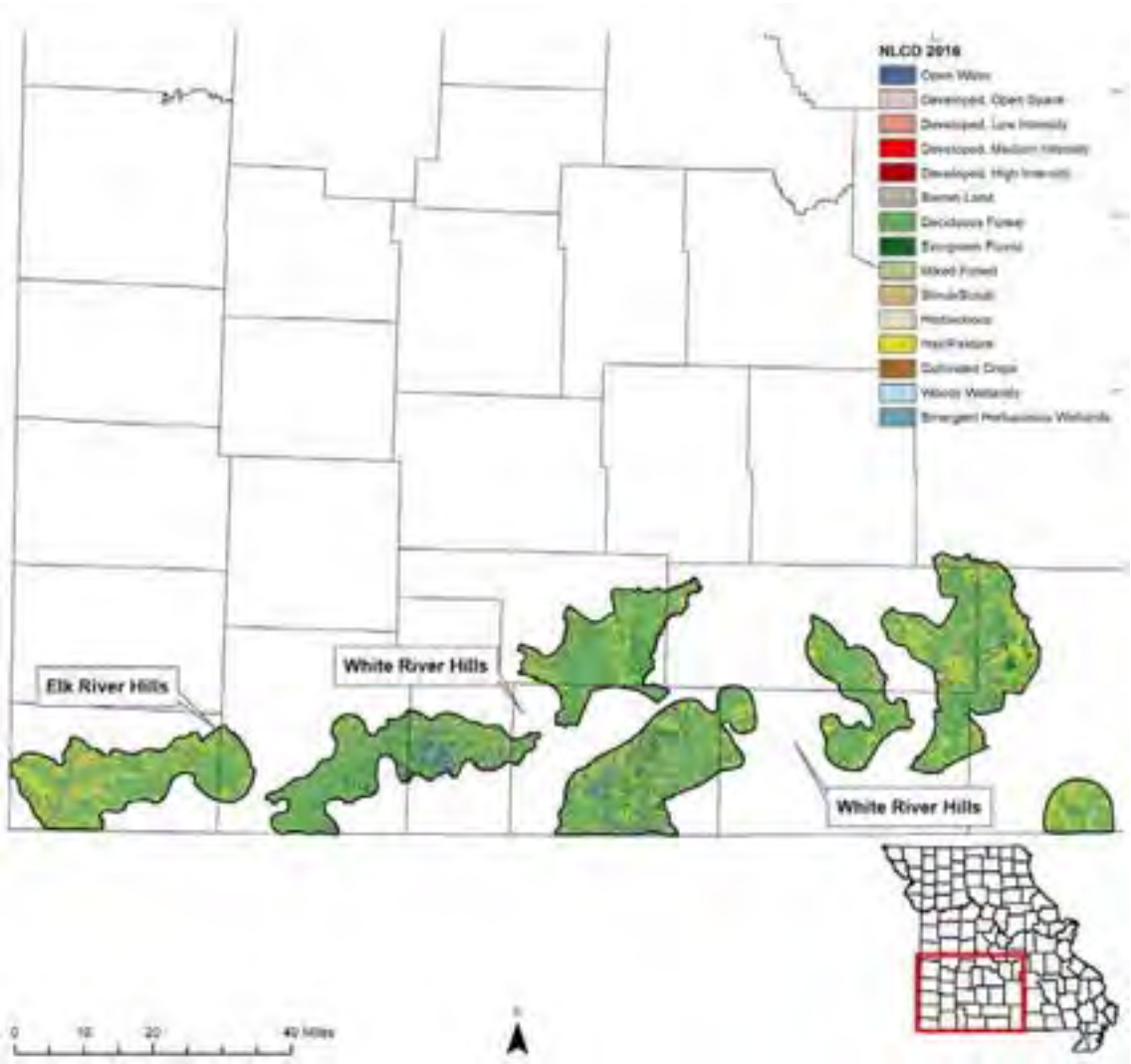


Table D.5 – White River Hills FLA PFLs, Counties, and Focal Public/Protected Lands

Priority Forest Landscapes	Counties	Focal Public/Protected Lands
Elk River Hills	McDonald Barry	Huckleberry Ridge Conservation Area[1] Flag Spring Conservation Area[1] Big Sugar Creek State Park[2]
White River Hills	Barry Stone Taney Christian Douglas Ozark Texas Howell	Ava/Cassville/Willow Spring Ranger District[3] Roaring River State Park[2] Table Rock Lake[4] Bull Shoals Lake[4] Caney Mountain Conservation Area[1] Drury-Mincy Conservation Area[1] Busiek State Forest[1] Henning Conservation Area[1]

[1] MDC, [2] MDNR, [3] USFS, [4] USACE

White River Hills FLA Special Values and Public Benefits: White River Hills FLA is located in southwestern Missouri just north of the Arkansas border. This is a heavily forested section of the Ozark Highlands Ecological Section located somewhat linearly to the southwest of the Ozark Highland FLA. This highly scenic area is one of Missouri's premier tourist destinations. The FLA includes parts of Branson and is also influenced by its close proximity to Springfield Metropolitan Area immediately to the north. Several of the state's most popular lakes intersect the FLA or are fed by the FLA including Table Rock, Bull Shoals, Taneycomo, and Norfork Lakes – all of which are known for their clean, clear water and attractive forested Ozark surroundings. This area is characterized by deeply dissected portions of the White River Watershed. Steep slopes, narrow ridges, and narrow valley bottoms prevail throughout. Soils are rocky and thin over carbonate bedrock. Areas of rugged dolomite knobs are also characteristic. Local karst, losing streams, and large springs are characteristic (Nigh and Schroeder 2002). Important streams in the FLA include the James River, Elk River, Bryant Creek, Bull Creek, and Spring Creek.

Historic vegetation in this area was dominated by extensive dolomite glades and woodland complexes, oak woodland and oak-pine woodland and forest. White River Hills dolomite glade communities, the most extensive dolomite glades in Missouri, supported a wide variety of unique and endemic plants. The glades graded into open-oak savannas and woodlands. Low slopes and bottoms were forested in oak and mixed deciduous hardwood species, and cane thickets or "breaks" were common in bottoms. Some oak-pine forest and woodland occurred on high cherty ridgetops, especially in the eastern half of this area (Nigh and Schroeder 2002). Most of these communities persist today, but with varying degrees of change resulting from expanding development pressure; decades of fire exclusion that have allowed trees to grow more densely in glades, savannas, and woodlands; and efforts to restore these communities.

The **White River Hills FLA is approximately 77.6 percent forested, with about 69 percent in private ownership**. Forest

industry is not as significant here as in the remainder of the Ozark Highlands. This is demonstrated by the fact that MDC's 17-county Southwest Region includes just 40 sawmills compared to Ozark and Southeast Regions, which contain 3.7 and 2.2 times as many per county respectively (Treiman and Morris 2018). For a map of MDC's regions and more information on harvest pressure see Section Three, Theme Eight – Missouri's Growth, Harvest, and Consumption of Forest Products. However, the forest products industry is still important here in communities; and much of the states' eastern redcedar industry is found in this area.

Tourism associated with the many lakes and the Branson area is a major contributor to the local economy. Christian County is Missouri's fourth-fastest growing county in terms of numeric population growth, with Greene County (containing the City of Springfield) immediately to the north being the third-fastest (MOA 2020). Taney County, which contains the City of Branson, is considered the sixth-fastest growing county in terms of percentage growth (MOA 2020). This growing number of people make this forested landscape of great importance – both for the ecosystem services provided and for the intrinsic value that is part of what draws people to this area in the first place. However, these abundant and growing numbers of people also place significant pressure on the landscape in terms of development, fragmentation, and subdividing. The FLP can help ensure that, while smart development continues in places where it is best suited, the most important forested tracts are protected and sustained into the future.

White River Hills FLA Pressures and Needs: Due to increasing development pressure, tourism, and people, land conservation tools including FLP are needed in White River Hills FLA to protect the integrity of important streams and watersheds (e.g., James River, Elk River, Bryant Creek, Bull Creek, and Spring Creek) and the public reservoirs they feed into (Table Rock, Bull Shoals, Taneycomo, Norfork). These water resource protections are needed for wildlife diversity values, importance for drinking water supplies (groundwater and surface), outdoor recreation value, and for maintaining high quality tourism opportunities.

Protection is also needed of karst features; sensitive natural communities (e.g., glades) and other key forested areas especially important to maintaining habitat for SOCCs; terrestrial outdoor recreation opportunities; and the scenic value of the landscape. Projects that enhance the protection and integrity of existing public lands will be considered especially important.

Goals and Objectives for White River Hills FLA:

- Protect the James River, Elk River, Bryant Creek, Bull Creek, and Spring Creek watersheds and White River basin from degradation and forest loss associated with urban expansion and tourism development
- Protect water quality and maintain stable stream flow into public reservoirs (Table Rock, Bull Shoals, Taneycomo, and Norfork)
- Maintain or enhance large blocks of contiguous forest cover where possible
- Protect forested green space and its scenic values important to local tourism
- Maintain forest cover to protect karst features, groundwater supplies, and surface drinking water
- Maintain and enhance the integrity of existing public lands
- Maintain a sustainable timber supply to support forest industry and local economies
- Protect unique natural features and SOCCs

Public Involvement

An important component of Missouri's CCS and participation in the FLP is public involvement. When Missouri's first FLP Assessment of Need was established in 2005, extensive effort was made to incorporate direct public participation through four public meetings and other meetings with individuals. These meetings and other public participation are extensively documented (MDC 2005). This 2020 update to Missouri's FLP AON/CCS does not represent the creation of a new program or drastic changes to an existing program. Therefore, MDC customized public involvement to fit the needs of this update using four forums described below:

- On October 3, 2019, MDC held a Conservation Partners Roundtable Meeting, which included a special workshop devoted to the development of CCS and PFLs. This workshop was attended by over 60 people representing 38 organizations. During this workshop, attendees were provided the opportunity to learn about the methodology MDC used to create revised PFLs/FLAs and to express any ideas regarding the approach. They also got the opportunity to review resulting draft PFLs/FLAs and provide feedback. Attendees were given the chance to share their ideas regarding the greatest threats and opportunities facing Missouri's forests and other habitat types and to provide ideas regarding how Missouri's conservation community can work together to address these ideas as effectively as possible. Input provided demonstrated good support for the revised PFLs/FLAs and underscored the importance of the FLP to advance collective conservation goals.
- On December 4, 2019, MDC met with the Missouri Forest Resources Advisory Council (MOFRAC), which is made up of 24 different partner organizations with strong interest in the protection, sustainability, and productivity of Missouri's forests. MOFRAC serves as Missouri's State Forest Stewardship Coordinating Committee (SFSCC) and is responsible for reviewing, advising upon, and prioritizing FLP proposals. During this meeting MDC presented the data and methodology used to create Missouri's Forest Opportunity Model and the draft PFLs/FLAs that resulted. Attendees were asked for feedback regarding ideas, support, or concerns regarding the approach and outcome. MDC also described the forestry issue themes being analyzed to develop CCS. Attendees were asked if there were any important conservation issues being overlooked that should be explored. As with the Partners Roundtable Meeting, participants of this meeting expressed enthusiasm and support for the effort and products created.
- On March 9, 2020, MDC sent out a map of MDC's draft revised FLAs along with other CCS documents for preliminary review by Missouri's forestry and conservation stakeholders; and on April 13, 2020, MDC sent out our complete CCS document to these same stakeholders for final review and feedback.
- While not conducted specifically for the purposes of Forest Legacy, MDC's 2013 Conservation Opinion Survey provides data that very clearly reveals public support for land conservation in Missouri made possible by the FLP:
    - 89 percent of Missouri citizens feel it is important for outdoor places to be protected even if they don't plan to visit the area
    - 71 percent of Missouri citizens feel land should be acquired in Missouri for fish, forest, and wildlife conservation

- 47 percent of Missouri citizens feel that MDC does not own enough land (28 percent stated that they don't know, 23 percent indicated that MDC owns the right amount of land, and only 2 percent indicated MDC owns too much land [Rikoon et al. 2014]).

Means of Protection

MDC intends to use the FLP primarily for fee-title acquisition of strategic forestlands to be placed in public ownership. Such lands will only be acquired from willing sellers. Although acquired lands would most often be held and managed by MDC, the opportunity exists for lands to be held by other state (MDNR) and local (county, municipal) government agencies as well.

MDC does not have immediate plans to utilize the conservation easement option offered through the FLP but may consider unique and exceptional opportunities that could arise. Such conservation easements would be used to restrict development, forest conversion, and subdivision on key forested tracts to advance the goals and objectives identified above for individual FLAs.

Process Used by State to Evaluate and Prioritize FLP Proposals

Since MDC does not participate in the conservation easement component of the FLP and does not actively solicit proposals to acquire public lands, Missouri does not utilize a formal FLP "call for proposals" or Forest Legacy Application. Instead, MDC considers tracts in which the landowners of their own initiative reach out to the agency to offer to sell their property, or in which MDC learns a key property is for sale on the open market and asks if the landowner would like to participate (either directly or in partnership with an intermediary conservation organization).

In such cases, with one exception (described below), the landowner is asked to complete and submit an MDC Land Offer Information Form (**Appendix D-1**). Submitted Land Offer Information Forms are given preliminary consideration by MDC's Realty Committee to determine if the land offer merits further consideration. If so, and the offered tract seems desirable, regional MDC staff are asked to evaluate the property and complete a Proposal for Land Acquisition (**Appendix D-2**). This proposal is submitted to a state realty coordinator who assembles a complete realty packet for the tract, including a tract scoring sheet (**Appendix D-3**) to help guide the decision as to whether MDC should pursue negotiations. In completing the tract scoring sheet and assembling the realty packet, the state realty coordinator assesses whether the tract would make a viable FLP Project Proposal. This determination would be based on the following criteria at minimum:

- The tract must be within or partially within a designated FLA
- The tract must be at least 100 acres or include multiple tracts that total at least 100 acres
- The tract must be at least 75 percent forested or will be reforested to attain this threshold
- Acquisition of the tract is consistent with the purpose of the FLP and would meet several of the established scoring criteria for the FLP
- The landowner has expressed willingness to wait long enough for MDC to go through the FLP application and award process

If the tract seems like it would be a good fit for Forest Legacy, the completed packet will be submitted to MDC's Realty Committee along with a recommendation to pursue acquiring the tract through the FLP. If agreed upon by MDC's Realty Committee, then the state realty

coordinator/Forest Legacy coordinator will bring the proposal to Missouri's SFSCC (aka MOFRAC), to seek feedback on the proposal prior to submission of a proposal to the FLP. If more than one viable proposal is brought forward for a given Call for Proposals, then the state realty coordinator/Forest Legacy coordinator will ask the SFSCC to help prioritize projects for submission. This prioritization is informed by a Missouri FLP Parcel Evaluation Scoresheet (**Appendix D-4**), completed by MDC in coordination with the SFSCC, but is not dictated by the score.

Exception: In cases in which a third party may be involved as an intermediary for the purpose of purchasing and/or holding a key property for FLP consideration and eventual transfer to public ownership, the above-mentioned forms and process may not be utilized until the property is ready for transference to public ownership. Instead, such proposals would be considered through collaborative deliberations between MDC and associated partners. Such Forest Legacy project proposals are then brought forth to the Conservation Commission for consideration and endorsement prior to proposal submission to the FLP. Such projects still have to meet the above-mentioned minimum criteria and undergo SFSCC review.

Note: If in the future MDC would decide to formally solicit proposals for Forest Legacy funding, this CCS document will be amended to include a formal request for proposal process and application.

Appendix D-1

Note: This form is not a Forest Legacy application. It will be modified as needed to best meet the needs of the Missouri Department of Conservation (MDC) without review or approval from the Forest Legacy Program. It is provided only to help explain MDC's process used to consider tracts for Forest Legacy proposals.

LAND OFFER INFORMATION FORM
For Property Offered for Sale to the Missouri Department of Conservation

For Department Use Only:

Received By: _____ ***Date:*** _____

Owner(s) Name(s)—List all Owner Names: _____

_____

Address: _____

City: _____ **State** ____ **Zip:** _____

Phone Number: _____

E-mail: _____

Is owner related to any Department of Conservation employee? ☐ Yes ☐ No

If 'Yes,' name of employee and relationship: _____

Realtor Information (Realtors please provide a copy of your listing agreement and disclosure statement)

Name: Agent: _____

Company: _____

Address: _____

City: _____ State: _____ Zip Code: _____

Phone: (Office) _____ (Cell) _____

E-mail: _____

PROPERTY INFORMATION
(Please provide a map indicating property location)

County: _____ **Nearest City:** _____

Number of Tracts: _____ **Total Number of Acres:** _____

Tract 1: *Section(s)* _____ *Township* _____ *Range* _____ Acres ____

Tract 2: *Section(s)* _____ *Township* _____ *Range* _____ Acres ____

Tract 3: *Section(s)* _____ *Township* _____ *Range* _____ Acres ____

Asking Price: $ _____

1

Cropland (acres)_____ Pasture (acres) _____ Forested (acres) _____
River/Stream (feet) _____ Lakes/Ponds (acres) _____ Caves (number) _____
Springs (number) _____
Describe buildings or structures, including estimated age:
1._____4._____
2._____5._____
3._____6._____

Describe condition of structures: Good Fair Poor
Boundary fences present: Yes No
Utilities present: Water Wells Electric Gas Sewer Septic Telephone
Deed restrictions, easements, or reservations: (Briefly describe any restrictions, easements, reservations, etc. like pipelines, power lines, roads, mineral rights, CRP, and WRE)
_____
_____
_____

Environmental hazards: (Describe any potential hazards like dumps, underground tanks, lagoons, chemicals, etc.)
_____
_____
_____
_____
Road access: (Describe any road frontage or other property access) _____
_____
_____

Other comments: _____
_____
_____
_____

Sellers urgency to sell: Urgent Not Urgent

Submitted by: _____ Date: _____Seller or Agent

Please return to: Missouri Department of Conservation, Realty Services, P.O. Box 180, Jefferson City, MO 65102 robyn.hilliard@mdc.mo.gov. Thanks for your interest in conservation! Any questions about this form should be directed to the Missouri Department of Conservation, Realty Services, 573-751-4115

Appendix D-2

Note: This form is not a Forest Legacy application. It will be modified as needed to best meet the needs of the Missouri Department of Conservation (MDC) without review or approval from the Forest Legacy Program. It is provided only to help explain MDC's process used to consider tracts for Forest Legacy proposals.

PROPOSAL FOR LAND ACQUISITION

Tract Name: **Acres:** **Date:** **County:**

Adjoining or closest conservation area:

☐ **New area? Proposed name:**

☐ **Addition to existing area? Area name:**

Lead Division: **Region:** **Regional Contact:**

Priority Criteria

1. Does the area contribute to the Urban Lands Initiative priorities?
   a. ☐ Yes ☐ No Adjacent to a Conservation Area identified in the Land Conservation Strategy. Explain:
   b. ☐ Yes ☐ No Adjacent to partner area identified in the Land Conservation Strategy. Explain:
   c. ☐ Yes ☐ No Adjacent to conservation/recreation area in St. Louis, Kansas City, Springfield, Columbia, or Joplin. Explain:
2. Is area within one of the 15 most populous counties (Boone, Cole, Buchanan, Cass, Clay, Jackson, Platte, Christian, Greene, Jasper, Cape Girardeau, Franklin, Jefferson, St. Charles, St. Louis)? ☐ Yes ☐ No
3. Does the area fall within a priority geography/other conservation opportunity area (COA)?
   a. ☐ Yes ☐ No Within one of the nine priority geographies? List:
   b. ☐ Yes ☐ No COA? List:
4. Does the area increase conservation of imperiled species or habitats?
   a. ☐ Yes ☐ No Protection of intact habitats/imperiled species. Explain:
   b. ☐ Yes ☐ No Potential restoration opportunity. Explain:
5. Does the area protect *existing* Natural Heritage Database elements?
   a. ☐ Yes ☐ No Multiple Heritage records on area. List:
   b. ☐ Yes ☐ No Single Heritage record on area. List:
   c. ☐ Yes ☐ No Area is within one mile of existing Heritage record(s). List:
6. Is area adjacent or proximate to an existing Conservation Area?
   a. ☐ Yes ☐ No Resolves management or access challenge. Describe:
   b. ☐ Yes ☐ No Adjacent to an existing Conservation Area. Name:
   c. ☐ Yes ☐ No Within one mile of an existing Conservation Area. Describe:

7. Is area adjacent to other publicly owned (non-MDC) or otherwise permanently protected conservation land(s) (e.g., private land trust holdings, conservation easements, etc.)? ☐ Yes ☐ No If yes, please describe:
8. Is area within a priority area (i.e., geography, watershed, habitat type, other) of a potential partner agency, municipality, or nonprofit organization? ☐ Yes ☐ No If yes, please describe:

Land Cover Features

☐ Stream frontage present (feet)

☐ Ponds or lakes present (list number of ponds or lakes and acreage for each:)

☐ Wetlands (estimated acres:) ☐ Prairie (estimated acres:)

☐ Savanna (estimated acres:) ☐ Glade (estimated acres:)

☐ Open land, crop or pasture land (estimated acres:)

☐ Forest (estimated acres:) ☐ Caves (number of caves:)

Describe the forest resources in terms of species composition, size, classes, and quality.

Public Use Opportunities

☐ Unique recreational benefits (describe:)

☐ Hunting ☐ Fishing ☐ Hiking ☐ Birdwatching ☐ Other (Describe):

Other Considerations

☐ Area is an in-holding. Describe:

☐ Area can be accessed by road or from adjoining public land. Describe:

☐ Area improves connectivity of habitats with MDC or other protected lands. Explain:

Describe any known restrictions or easements (including WRE, CRP, tenant farmer):

Describe buildings or structures on the property (including age) and the potential disposition of all structures if property acquired. Please ensure the Regional Construction and Maintenance Superintendent is informed and consulted:

Describe condition of structures: ☐ Good ☐ Fair ☐ Poor

Describe any environmental hazards (e.g., dumps, waste, etc.):

If a trade of MDC land might be involved, is there a federal interest associated with the MDC land (e.g., WRE, SFR, LWCF)? ☐ Yes ☐ No ☐ Unknown

Include the following:

☐Division map package, or the following individual maps:

☐ A proximity map showing location of tract relative to county landmarks, conservation areas, other public lands, etc.

☐ If appropriate, a conservation area map showing the tract relative to any expansion boundary

☐ A topographical location map showing the tract boundary relative to special features, conservation areas, other public land, etc.

☐ An aerial view showing boundary of the tract
☐ A plat map showing location of the tract

Provide pictures of significant buildings, structures, habitats, or other features that would help in evaluation of this property.

Initial Costs: Lists all costs necessary to open this property to the public.

Parking Lot(s): Description:

Roads: Description:

Trails: Description:

Removal of building(s): Description:

Securing public hazards: Description:

Other (describe): Description:

Initial habitat restoration costs

List any critical habitat restoration needs that you anticipate implementing in the next five years:

Staffing – Can this area/addition be managed and maintained with existing staff and equipment? ☐ Yes ☐ No

If no, describe staffing/equipment needs and rationale:

Fixed Costs – Estimate and describe any annual operating expenses associated with this property (e.g., utilities, structure or road maintenance, resource management costs, etc.):

Additional Justifications: List any other advantages or disadvantages to acquiring this property that have not been covered in this document.

Appendix D-3

Note: This is not a Forest Legacy form. It will be modified as needed to best meet the needs of the Missouri Department of Conservation (MDC) without review or approval from the Forest Legacy Program. It is provided only to help explain MDC's process used to consider tracts for Forest Legacy proposals.

TRACT SCORING SHEET

	Criteria	If yes *Score	Points
1	Does the land conservation opportunity contribute to the Urban Lands Initiative priorities?	Ranked, choose highest applicable weight Adjacent to LCS identified CA – 5 Adjacent to LCS identified partner area – 4 Cons/rec in City of StL, KC, Springfield, Columbia, or Joplin – 3	
2	Within one of 15 most populous counties/gap	Yes – 5	
3	Does the land conservation opportunity fall in a focal landscape?	Within one of the nine PGs – 5 Not within one of the nine PGs – 3	
4	Does the land conservation opportunity increase conservation of imperiled species or habitats?	Protection of intact habitats/imperiled species – 5 Potential restoration opportunity – 3	
5	Does the land conservation opportunity protect existing Natural Heritage Value?	Multiple Heritage records – 5 Single Heritage record – 3 Proximate (w/in 1 mi.) of Heritage record(s) – 1	
6	Is the land conservation opportunity adjacent or proximate to an existing CA (outside of the 15 most populous counties)?	Resolves long-standing management or access challenge – 5 Adjacency – 3 Proximity (w/in 1 mi.) – 2	
7	Is the land conservation opportunity adjacent to other publicly owned (not MDC) or otherwise permanently protected conservation lands (i.e., private land trust holdings, conservation easements, etc.)?	Yes – 2	
8	Does the land conservation opportunity fall within a priority area (i.e., geography, watershed, habitat type, other) of a potential partner agency, municipality or nonprofit organization?	Yes – 1	
	TOTAL POSSIBLE	100 (multiply each by ~3.03 and sum)	
	Total Tract Score		

Tract Name:_____ Completed by:_____Date:_____

*Score is NOT a ranking unless otherwise noted. Consider each criterion on its own merits. Additional criteria to be used by Realty Committee in evaluating and ranking a project.

Appendix D-4

Missouri's Forest Legacy Parcel Evaluation Criteria

These criteria and the corresponding score sheet will only be utilized if the Missouri Department of Conservation (MDC) and State Forest Stewardship Coordinating Committee (SFSCC) have more than one project they are considering for a given funding cycle.

In such cases, each parcel under consideration will be evaluated, in part, using the following criteria and point scale. The numerical score will not be the sole deciding factor used in prioritizing parcels. **Table D-4.1** shows the maximum points possible for each of the evaluation criteria. Points awarded will be based on the quality of the characteristics of the individual parcel and weighted based on the goals and objectives identified in the corresponding Forest Legacy Area.

Table D-4.1 – Parcel Criteria Evaluation Scale

Criterial	Maximum points
Forest values	70 points
Riparian and hydrologic	50 points
Fish and wildlife habitat	50 points
Threatened and endangered species	50 points
Karst resources	50 points
Cultural and historic resources	10 points
Scenic resources	10 points
Existence of potential public recreation	30 points
Provides traditional uses	30 points
Level of threat	100 points
Acquirability/manageability	50 points
Total Maximum Points	**500 points**

Description of Evaluation Criteria

The following criteria will be used to rank each proposed tract. Higher points will be assessed for tracts either meeting most of the stated criteria and/or containing higher amounts of important individual characteristics. "Maximum points" in **Table D-4.1** indicates the maximum points allowed for each criterion.

A. Forest Values (70 points): Because the protection and management of forestland is one of the main objectives of this program, the amount, character, and condition of the forested area are important criteria. Several items will be considered in determining this:

- Total size of the forested tract and percentage of forest cover
- Condition of forest (age, size, health)

- Any unique forest habitat that is critical for a SOCC
- Proximity and/or connectivity to other public forests or protected private forest areas
- Parcel provides a mix of native forest–based ecological communities
- Parcel includes forest-based ecological communities that are dwindling in Missouri
- Parcel contains unique natural features
-

B. Riparian and Hydrologic (50 points): One of the most important "products" of forest areas is water. Proper management of forestlands can increase the quality and regulate the quantity of water for the residents of Missouri. Consideration will be given to whether:

- Parcel contains stream/river, with special consideration for formally recognized priority streams and watersheds (e.g., COA, Outstanding Resource Water)
- Parcel includes 100-year floodplain or natural wetlands
- Parcel contains minimum 50-foot-wide vegetated riparian buffers on both sides of stream falling on the tract or has a formal plan in place for re-vegetating
- Parcel is within a watershed that provides a public drinking water supply to many people
- Parcel is adjacent to identified permanent watershed protection areas (e.g., WRE)

C. Fish and Wildlife Habitat (50 points): Preventing the division of forest tracts into smaller or fragmented units is crucial to maintaining viable populations of many wildlife species.

- Parcel is located within one or more COAs recognized for their wildlife habitat value
- Parcel is located within one or more priority areas formally recognized by a conservation partner organization for wildlife conservation purposes
- Parcel contains or is adjacent to a formally designated Natural Area
- Parcel contains outstanding wildlife habitat and/or provides important connective habitat corridors or buffers that reduce biological invasion

D. Known Rare, Threatened, and Endangered Species (50 points): As urbanization and subdivision of forestlands continue, the need increases to give special attention to rare, threatened, and endangered species of fish, wildlife, and plants. Parcels nominated for the Forest Legacy Program should be inventoried or reviewed for such natural habitats that may contain species appearing on federal or state lists as rare, endangered, threatened, or species of concern:

- Parcel provides habitat supporting the occurrence of rare, threatened, or endangered species
- Parcel contains or is within close proximity to a site listed on the Missouri Heritage Database
- Parcel provides suitable habitat for reoccupation by rare, threatened, or endangered species
- Parcel contains known populations or suitable habitat for a species/habitat of conservation concern

E. Known Karst Features (50 points): Missouri is a karst state with many unique and valuable karst features. Many of these features are closely tied to groundwater protection, have some historic cultural value, or provide important wildlife habitat. Forests are key to protection these features:

- Parcel has caves, sinkholes, springs, or other known karst features
- Parcel is in a known cave or spring recharge area

- Parcel has other unique or important karst or geologic features that may be protected or improved by maintaining forest cover

F. Known Cultural and Historic Resources (10 points): Material evidence of previous human occupation comprises a unique and irreplaceable resource, as do historic features and the combination of constructed and natural landscapes:

- Parcel contains forest-related cultural resources (e.g., historic forest, historic mill site, CCC camp or construction site, or other historic forest industry site).
- Other historic or archeological resources are known to be on the parcel (e.g., Native American sites or artifacts, historic structures, historic sites or landmarks)

G. Scenic Resources (10 points): The scenic aspects of a natural resource area may often be subjective, but there are several means of measuring special qualities that make a given parcel stand out:

- Parcel is adjacent to a scenic road, byway, river, or trail as listed by the state or federal government
- Parcel includes locally important panoramic views or exceptional short views
- Conversion of forest will break continuity of a landscape view from a regularly and easily accessed public location

H. Existing or Potential Public Recreation (30 points): Public recreation opportunities are defined as those having noncommercial and non-landowner users. Existing or potential recreational use (especially public access) of a proposed parcel may be an important component. Since all tracts acquired through Forest Legacy in Missouri are anticipated to provide public access, this criterion is intended to recognize tracts that provide an especially valuable recreation opportunity:

- Water-based public recreation (e.g., swimming, fishing, rafting, canoeing)
- Trail-based recreation or day use (e.g., hiking, picnicking, horseback or bicycle riding)
- Natural resource–based recreation (e.g., camping, hunting, wildlife viewing)

I. Provides Opportunities for Traditional Uses (30 points): Maintaining traditional forest uses is important. They permit owners to remain on the land without requiring high-cost services. Traditional forest uses provide raw materials for local economies and amenities for an improved quality of life:

- Parcel will remain available for high quality timber and other forest products management
- Parcel will continue to serve watershed filtration and soil stabilization functions
- Parcel will provide "forested greenspace" in predominantly developed or agricultural landscapes or provide landscape linkages
- Parcel will provide environmental education or research opportunities

J. Type and Level of Conversion Threats (100 points): There are various kinds and degrees of threat to valuable forest areas, such as encroaching housing development, improved roads, sewer and power line extension into undeveloped areas, and the dividing of landownership into small parcels with greater numbers of owners:

- Parcel may be in danger of conversion to nonforest use within 5 years
- Parcel may remain wooded but will become further subdivided within 5 years

- Parcel is currently for sale on the open market
- Parcel may remain wooded but is in danger of being harvested in a nonsustainable fashion
- Parcel contains a remnant of a diminishing forest type in Missouri
- Infrastructure extensions are imminent in the area
- Parcel is forested and zoned as commercial, industrial, or residential and is in proximity to similar developments
- Parcel is currently scheduled for conversion of existing forest to a nonforest use within two years

K. Acquirability or Manageability (50 points): Even if a forested parcel is threatened with conversion to nonforest use, protecting it under the FLP can best be accomplished if certain conditions exist:

- Some of background work is completed, and negotiation with the landowner indicates their objectives are consistent with the program, agreement on terms and conditions is likely, and acceptable timeline will work with the program
- Outside funding or donations will likely defer a significant portion of the acquisition cost
- Tract may be available at below fair market value
- Property is specifically identified as priority in local land use plans or is especially valuable for advancing MDC's Land Conservation Strategy (LCS)
- Intensity and expense of management activities needed to protect the property's values are economically feasible
- Property can accommodate proposed priority uses or management activities without endangering or degrading its natural value
- Property can be protected from future degradation caused by activities occurring on neighboring properties

Missouri FLP Parcel Evaluation Scoresheet

Landowner Name: _____

Forest Legacy Area: _____

Date Evaluated: _____ Evaluator Name(s): _____

Criteria Category (Max points possible)	Maximum FLA Goal Weighting (circle one – see note below) Low Med High	Points Awarded	Comments
Forest values (70)	25 50 70		
Riparian and hydrologic (50)	15 30 50		
Fish & wildlife habitat (50)	15 30 50		
Threatened & endangered species (50)	15 30 50		
Karst features (50)	15 30 50		
Cultural & historic resources (10)	0 5 10		
Scenic resources (10)	0 5 10		
Public recreation (10)	0 5 10		
Traditional forest uses (50)	30 40 50		
Level of conversion threat (100)	50 75 100		
Acquirability / manageability (40)	15 30 50		
Total (500)			

Note: FLA goal value weighting level (low, medium, or high) will be determined by MDC in consultation with the SFSCC for all evaluation criteria based on stated goals and objectives set forth in the corresponding FLA descriptions.

Appendix E: Layers Used in COA Development

Grassland/Prairie/Savanna Layers

- Original prairie layer created by MSDIS from Dr. Walter A. Schroeder's "Pre-settlement Prairie of Missouri" published in 1981.
- NLCD 2016 (Dewitz 2019)
- Natural Heritage Database
- Grassland Reserve Program
- Conservation network
- Prairie opportunities identified by grassland team
- National Hydrography Dataset (NHD) + catchments

Forest and Woodland Layers

- Natural Heritage Database
- PFLs
- CFLRP locations
- Elk Restoration Zone
- TNC Portfolio sites
- Forest/Woodland areas identified by Forest/Woodland team
- Conservation network
- NLCD 2016 (Dewitz 2019)
- Woodland model developed by Lee Hughes
- NHD + catchments

Glade Layers

- Paul Nelson/American Bird Conservancy/MDC/Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative Glade Layer
- PFLs
- Glade areas identified by glade team
- Natural Heritage Database
- Conservation network
- NHD + catchments

Cave/Karst Layers

- Natural Heritage Database
- Conservation network boundaries (including land boundaries for MDNR, MDC, Missouri National Guard, MPF, NPS, Natural Areas, Ozark Land Trust, TNC, USFWS, USFS, and Wetland Reserve Easements)
- Cave lengths data from within MDC
- TNC Portfolio Sites for caves and karst
- William Elliott's Top 50 Biocaves (Elliott 2007)
- Recharge area layer created specifically for the SWAP scoring
- Sinkholes
- Losing Streams
- Springs
- NHD + catchments

Wetlands Layers

- Alluvial and hydric soils
- Conservation network
- Intensively managed wetlands
- USFWS wetlands
- Natural Heritage Database
- NHD + catchments

Rivers and Streams Layers

- Fisheries PWs
- Aquatic GAP sites
- Natural Heritage Database
- Missouri Integrated Aquatic Database Invertebrate and Index of Biotic Integrity Data
- Conservation network
- Priority stream reaches for crayfish, hellbender, mussel, and Niangua darter
- NHD + catchments

Appendix F: Priority Geography Team Charter

PG Teams
MDC
(General Team Charter)
July 2019

Purpose and Scope
The purpose of this charter is to formally establish the PG team (Team) membership, structure, and delegation of authority. The Team is responsible for coordinating and leading MDC's strategic efforts to implement focused landscape conservation to preserve, enhance, restore, manage, and monitor the health, integrity, and function of Missouri's fish, forest, and wildlife resources within the designated priority geographies (PGs), identified through the Comprehensive Conservation Strategy (CCS).

Background and Justification
The CCS allows MDC to develop tools to effectively and efficiently focus finite resources toward landscapes offering the greatest potential to enhance and sustain Missouri's diverse natural communities (i.e., forests and woodlands, grasslands [including prairies and savannas], glades, caves and karst, wetlands, cliffs and talus, and rivers and streams), with the guiding principle that investing in a habitat systems approach to conservation ensures efficiency by providing for the landscapes and functions that support species rather than trying to provide for the needs of each species individually. Working with conservation partners and stakeholders, MDC challenged staff to research, analyze, and identify these significant areas throughout the state, which were aptly named conservation opportunity areas (COAs).

To initiate implementation of the CCS, nine COAs were selected by MDC for increased conservation investment. These nine COAs are referred to as PGs and represent the initial stepping stones (the starting point) in a strategic approach to investing in the implementation of landscape-scale conservation in Missouri. Each PG has a dedicated Team challenged to employ proactive methods to deliver landscape conservation through both public land management and private land assistance and management. The Team will act as a catalyst, working to establish a local conservation initiative, engaging in diverse partnerships with federal, state, and local government agencies, conservation NGOs, and private businesses and landowners to deliver conservation action.

Team Objectives

1. Identify a desired future condition for the PG. When possible, work with conservation partners, including landowners, to help identify the desired future condition.
2. Develop a local conservation initiative engaging in diverse partnerships with federal, state, and local government agencies, conservation NGOs, and private businesses and landowners to deliver conservation action toward the PG's desired future condition.
3. Develop and implement a strategic approach to accomplish on-the-ground conservation action within the PG to achieve the desired future condition.
4. Promote awareness and participation of partners (including private landowners) in implementation of conservation actions.

Team Membership Description

Central

Coordinator: Natural Resource Management Planner – leads the implementation of CCS, including coordination among the Teams, with guidance by MDC's CCS Steering Committee.

Team Leader(s): Regional field personnel selected by the Regional Coordination Team (RCT) with advisement by the Unit Chief Team (UCT) Liaison. Team Leader(s) may rotate every three years, transitioning through Team members, with approval through the RCT and UCT Liaison.

Team Members: Regional field personnel from each resource division, Outreach and Education and other division representation as appropriate. Team Members can include cooperative partner positions, partner organization members, and private business/landowner partners also focusing conservation effort within the PG. In addition, MDC statewide coordinator positions (e.g., Grasslands Ecologist, Natural Community Ecologist, etc.) and taxonomic experts (e.g., State Herpetologist, Ornithologist, Botanist, etc.) can be included or consulted as necessary.

RCT Liaison: Representative Regional Supervisor Advisor (one per team) – RCT Liaison may rotate every three years (ensuring this rotation is staggered from that of the Team Leader rotation) with approval through the RCT and UCT Liaison.

UCT Liaison: Representative Unit Chief Advisor (1 per team)

Responsibilities of the Team

1. Natural Resource Management Planner will:
    a. In coordination with MDC leadership and the CCS Steering Committee, develop and provide CCS leadership and program guidance in alignment with MDC's strategic plan.
    b. Serve as the central point of contact for all Teams, providing guidance, consistency, disseminating relevant information, and meeting with Teams as needed.
    c. Effectively communicate with Team Members, Team Leaders, RCT Liaisons, UCT Liaisons, MDC leadership, and partner organizations.
    d. Seek additional partnerships and resources to fulfill future and currently planned conservation actions.

2. Team Leader(s) will:
    a. Function as the operational leader(s) of the Team, which is an MDC interdivisional work unit.
    b. Schedule semi-annual Team meetings and track agenda and action items, as well as budget request information, throughout the year. If necessary, additional Team meetings can be scheduled on an as-needed basis.
    c. Facilitate Team participation in Team meetings, planning, and the development and implementation of Team-prioritized conservation practices, including outreach activities.
    d. Facilitate Team participation in the development of an annual work plan, focused on achieving the PG desired future condition.
    e. Facilitate Team participation in gathering and submitting annual accomplishments for objectives, goals, and action items identified in the Team's annual work plan. (*Note:*

The Team is encouraged to track accomplishments throughout the year to ease in compiling this final report.)

f. Effectively communicate with the Habitat Management Coordinator, RCT Liaison, UCT Liaison, Team Members, and Team partners.
g. Seek additional partnerships and resources to fulfill future and currently planned conservation actions.

3. Team Members, RCT Liaisons and UCT Liaisons will:
    a. Participate in all Team meetings, planning, and the development and implementation of conservation actions, including outreach activities.
    b. Participate in the development of an annual work plan, focused on achieving the PG desired future condition.
    c. Participate in gathering and submitting annual accomplishments for objectives, goals, and action items identified in the Team's annual work plan. (*Note: The Team is encouraged to track accomplishments throughout the year to ease in compiling this final report.*)
    d. Effectively communicate with the Habitat Management Coordinator, Team Leader(s), other Team Members, and Team partners.
    e. Seek additional partnerships and resources to fulfill future and currently planned conservation actions.

Team Communication and Coordination

- The Team Leader(s) will convene semi-annual meetings of the Team to increase awareness, understanding, and coordination of management efforts taking place, discuss challenges and opportunities relevant to the Team, and work on Team tasks. (*Note: Team meeting frequency may be increased dependent upon tasks and need.)*
- Each Team will develop a system for communication among the Team members and encourage and facilitate frequent communication among all Team participants.
- Each Team will develop and maintain a SharePoint site for Team products and meeting notes. (Note: Each Team has a dedicated site established on SharePoint for housing and sharing Team information.)
- Annually, the Habitat Management Coordinator will convene an inter-Team meeting of Team Leaders, RCT Liaisons, and UCT Liaisons to discuss successes, challenges, opportunities, strategies, project concepts, and resource needs. This meeting will enhance information/idea sharing and problem solving across Teams.

Team Operational Guidance

- PG teams are critical operational teams established to deliver upon MDC and Missouri conservation priorities. From a Team perspective, this means working together to identify Team objectives, goals, and implementation priorities within the PG and working as a Team to accomplish those priorities. This means Team members may be doing things for those identified Team priorities that may have historically been perceived as outside an individual's or division's focus. For example, if the priority identified by the Team is increasing private land contact and private land stewardship plans for key landowners, then all Team members

need to support that priority and find a way to incorporate their individual strengths into the effort. The next Team priority may shift focus toward accomplishing cedar clearing and prescribed fire to open up key glade/woodland complexes on a conservation area, and so all Team members engage their strengths to achieve that. And so on, in the same manner, with other Team priorities.

- Several levels of authority (i.e., Team Member, Team Leader, RCT and UCT Liaison, Habitat Management Coordinator) have been built into Team structure to help expedite processes and find resources to accomplish tasks at various operational levels. The Team Leader is the operational leader of the work team with input/guidance from the RCT and UCT Liaisons and the Natural Resource Management Planner to ensure team tasks are accomplished within identified timeframes.
- To aid in project delivery, in addition to the Team Leader position, teams may establish specific group or branch leaders that coordinate specific branches of the duties. For example, a PG may have leaders for the following duties: Private Land Contacts, Public Land Management, Communications and Marketing, and Monitoring and Accomplishments. Other team members then are assigned to each group. Teams will need to determine the best organization of these branches and what specific branches are needed.
- Team Leaders and RCT Liaisons may rotate on a staggered three-year rotation and these positions must be approved by the RCT and the UCT Liaison.

Reporting Requirements

1. Develop an annual operational work plan, focused on achieving the PG desired future condition.
    - Final annual operational work plans must be submitted to the Natural Resource Management Planner by June 30 every year for distribution to MDC leadership.

2. Submit an annual accomplishment report for objectives, goals, and action items identified in the Team's annual operational work plan.
    - Final annual accomplishment reports must be submitted to the Natural Resource Management Planner by August 31 every year for distribution to MDC
    - leadership. (Note: The Team is encouraged to track accomplishments throughout the year to ease in compiling this final report.)

Appendix G: Forestry Analysis Theme Case Studies

Background: Given that **Section Three** covers Missouri's complete suite of natural communities (i.e., not just forests and woodlands), that section was not the place to delve too deeply into issues and case studies specific to forests and woodlands. However, proper assessment of forests and woodlands requires taking a closer look at a few issues. Appendix G provides a summary of these forestry-centric issues and related case studies.

G.1 Missouri's Aging Forest

Large portions of Missouri's forests and woodlands are roughly the same age, due to significant timber harvesting and land conversion activities that began in the late 1800s and ended in the mid 1900s. **Figure G.1.1** shows data from the USFS's FIA program. The data shows the proportion of Missouri's forest in 10-year age classes in 1989 and 2018. The blue bars from 1989 show an overall forest still recovering from large-scale timber liquidation and European immigration activities. A significant portion of the 1989 forest is less than 50 years old. Fast forward to 2018 and note how the age class distribution has changed, shifting significantly toward the older end of the spectrum.

(Source: USFS 2019)

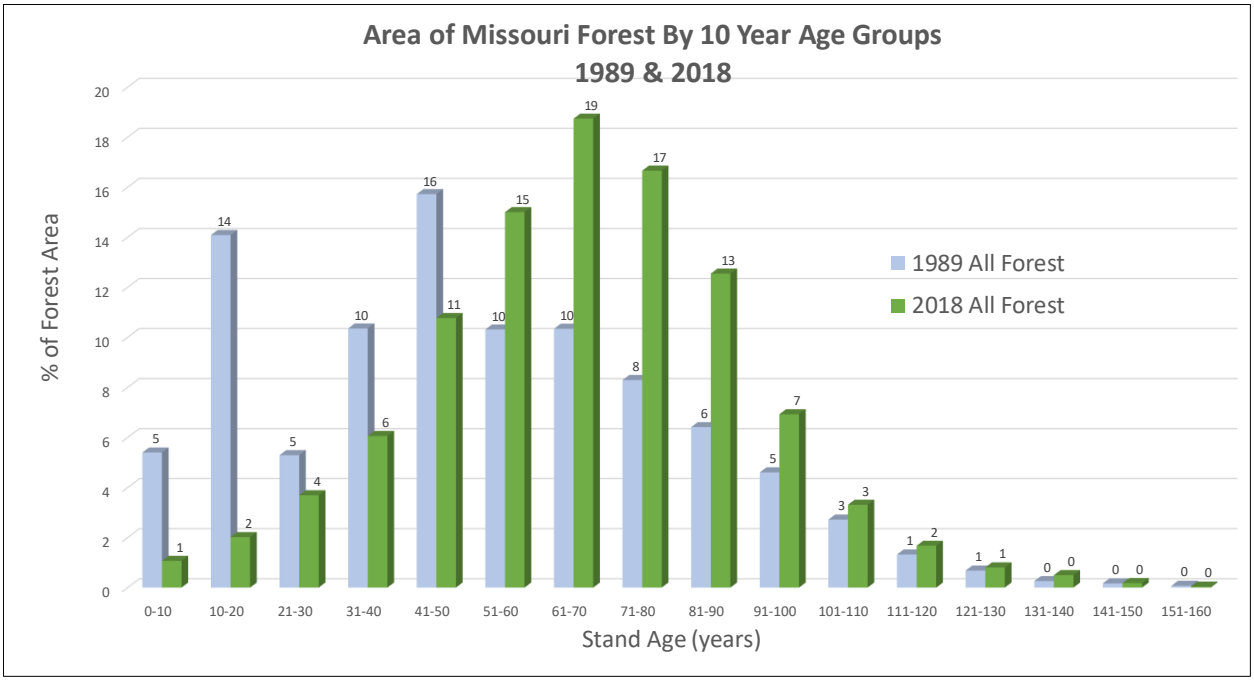


Figure G.1.1 – Forest Area by 10-Year Age Groups (%), 1989 and 2018

Figure G.1.2 shows the same pattern of early successional forest habitat changes over time. In this chart, the nonstocked and small diameter size classes represent early successional forest habitat important to numerous wildlife species. From 1945 to 2020 acres of large diameter forests increased by over 4.5 times while acres of small diameter forests have dropped by over 75 percent.

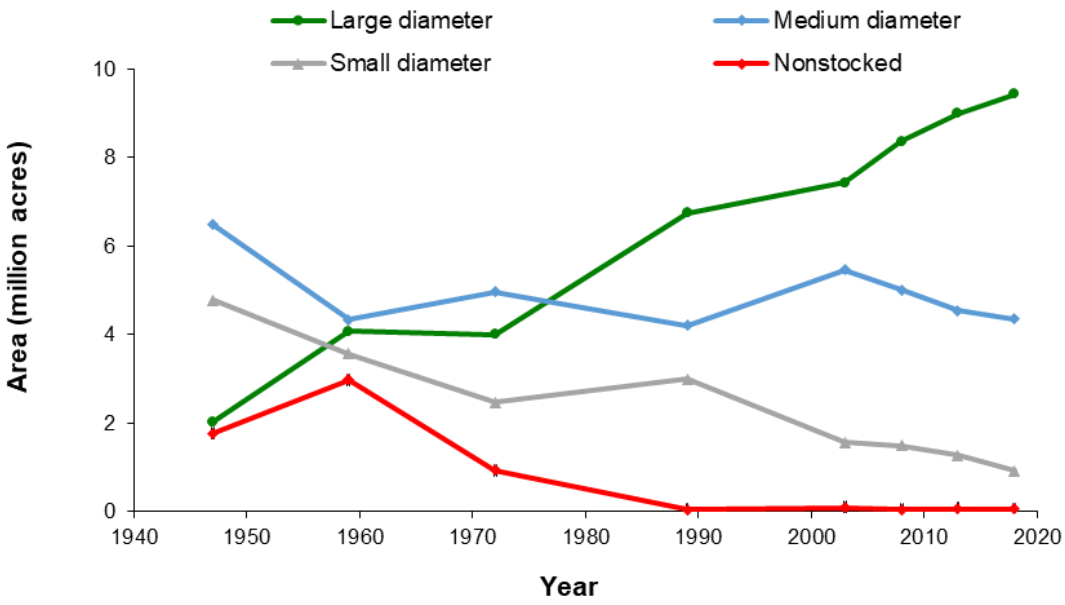


Figure G.1.2 – Timberland by Stand Size (USFS 2019)

Late successional forests are an important component of healthy forest landscapes; however, an overabundance of aging forests comes with inherent issues. The long-term sustainability effects can be subtle or drastic and can cause issues with forest health and resiliency, plant species and community diversity, wildlife populations of species dependent upon young forests, recreation, timber production sustainability, carbon sequestration, and even climate change.

Take for example the prairie warbler, a neotropical migrant songbird identified as a priority species by Partners in Flight. Prairie warble populations are in a steep decline. The prairie warbler (along with numerous other songbirds such as the field sparrow, eastern towhee, yellow-breasted chat, and the indigo bunting) are declining due to lack of early successional habitat (i.e., young forests). Numerous songbirds use regenerating forests created by either natural disturbance or forest management practices. And because most of our forests are of the same age, 60 to 100 years old, these songbirds don't have the habitat they require.

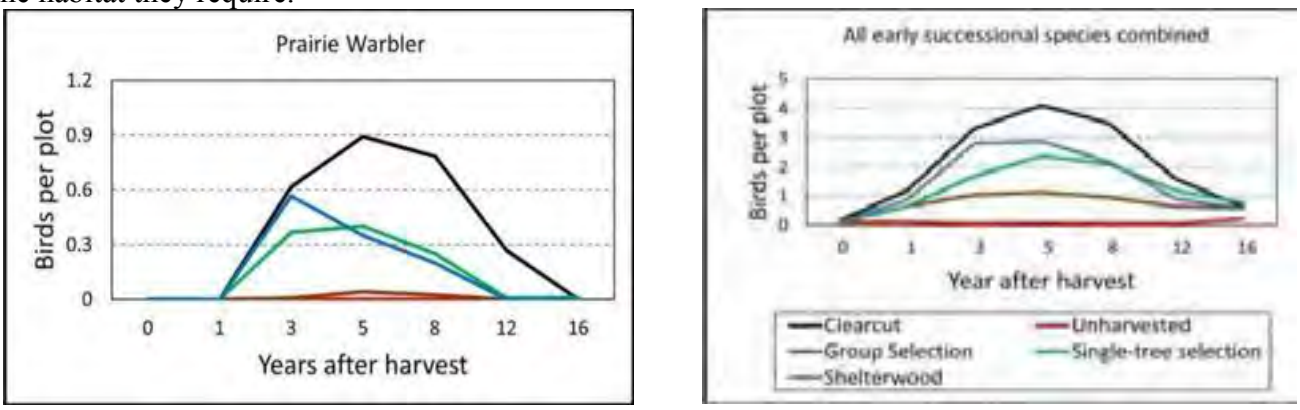


Figure G.1.3 – Prairie Warbler and All Early Successional Bird Numbers by Harvest Treatment

Sustainable management of Missouri's forests and woodlands for all of the social, economic, and environmental benefits we expect from them requires efforts be taken to ensure our forests and woodlands are diverse not only in species but also in forest/woodland tree size and age class.

G.2 Red Oak Decline and Shortleaf Pine Restoration

One of the bigger insect and disease threats currently impacting Missouri's forests and woodlands is red oak decline. Significant decline and mortality of red oak group trees (red, black, scarlet, etc.) is occurring due to a complex combination of factors such as the age of the trees, red oak borers, armillaria root rot, and drought. Missouri contains a large amount of red oak group trees, as depicted in **Figure G.2.1**. Therefore, red oak decline is expected to have a significant impact on Missouri in the coming years.

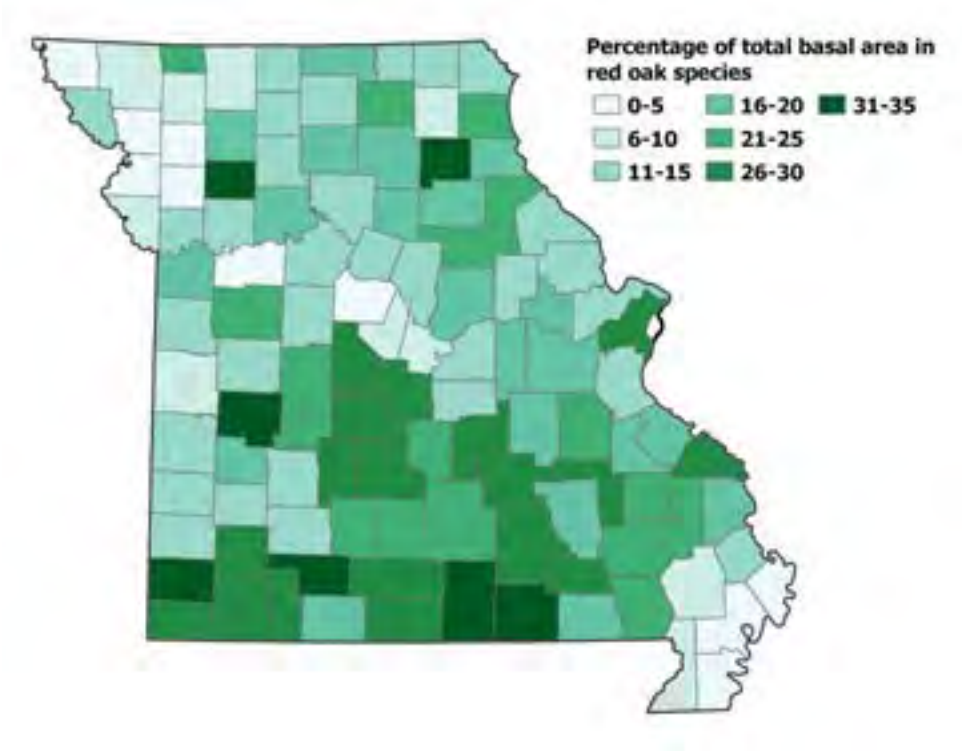


Figure G.2.1 – Percent of Total Basal Area in Red Oak Group Species on Forestland, Missouri, 2019. Includes all species in both the other red oak and select red oak species groups. (Source: USFS 2020)

Red oak decline is happening to varying degrees throughout the state, but much of this decline is of red oak group trees growing on sites better suited to shortleaf pine. Historically, Missouri contained a much larger shortleaf pine component in the Ozarks prior to being cutover, grazed, and burned repeatedly in the late 1800s/early 1900s, as depicted in **Figure G.2.2**. Of the 6.0 million acres of shortleaf pine Missouri once contained, only 1.5 million acres exist today. The oaks and hickories currently found on these sites became established because they naturally regenerated better and outcompeted what was left of the shortleaf pine in the face of significant fire and grazing pressure.

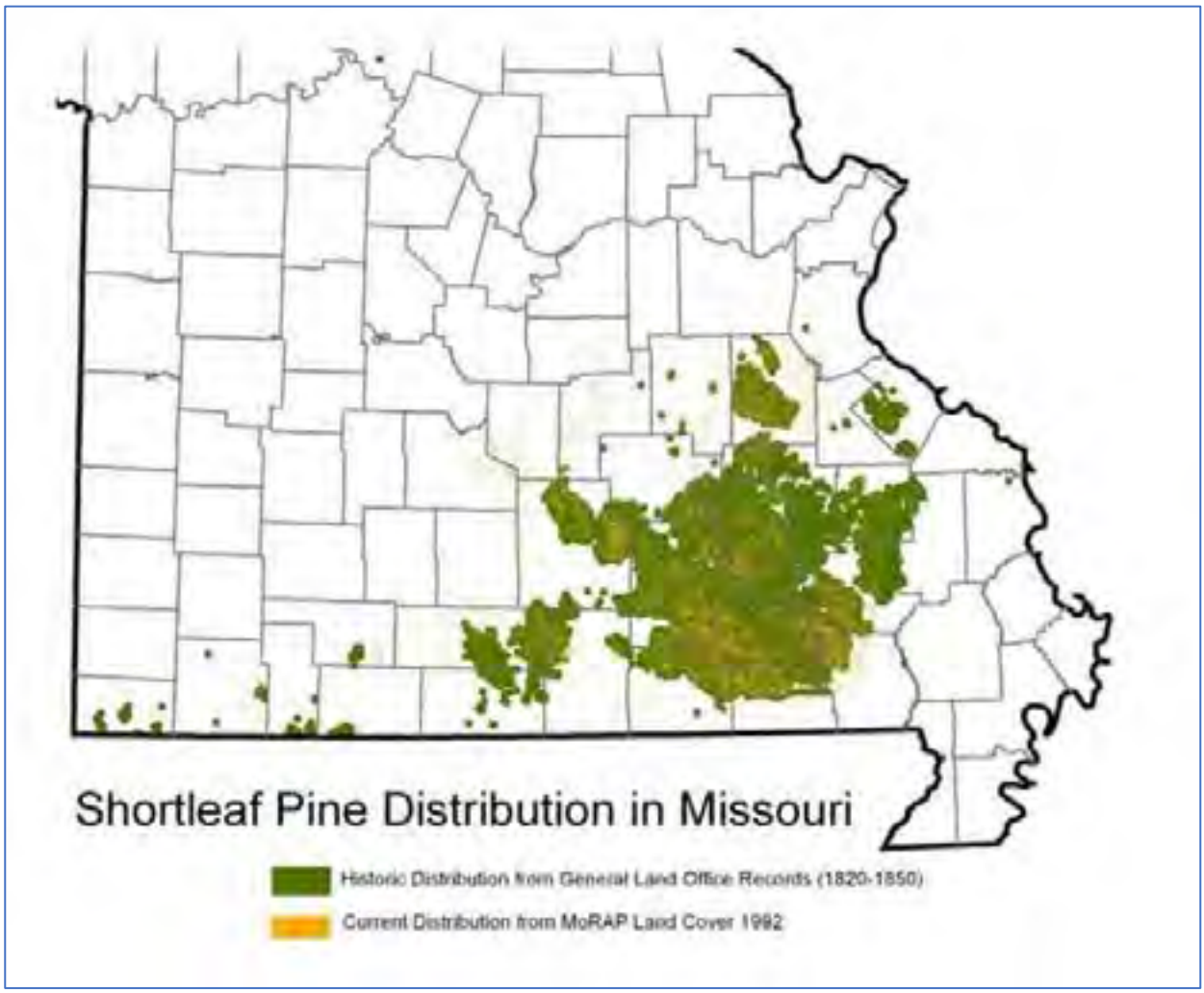


Figure G.2.2 – Current and Historic Distribution of Shortleaf Pine in Missouri. *Map generated using General Land Office Records (1820–1850) and Missouri Resource Assessment Partnership Land Cover Data – 1992*

An opportunity presents itself to restore shortleaf pine back onto some of these sites. Restoring pine on these sites is not easy. It often requires a combination of intensive management practices such as timber harvesting, tree thinning, tree planting, and site preparation (e.g., prescribed fire). However, these efforts have many rewards and could benefit wildlife species that depend on them (e.g., pine warbler, white-breasted nuthatch). Restoring shortleaf pine will also help increase tree species diversity. Therefore, if some insect or disease comes through in the future and severely impacts Missouri's oak resource (e.g., gypsy moth), our woods will still contain a lot of healthy trees. According to the USFS Climate Change Tree Atlas, while the projected future habitat suitability for many oak species is expected to remain stable or decrease, the suitability for shortleaf pine is expected to increase. Therefore, restoring shortleaf pine to the landscape could help make our woodlands more adaptable and resilient to potential changes in climate.

G.3 Increasing Presence of Shade Tolerant, Fire Intolerant Species

For thousands of years, much of Missouri's forests and woodlands evolved with frequent low-to-moderate-intensity fire disturbances. Therefore, most of our woodlands and forests contain an abundance of plant and animal species that are well adapted to or can tolerate fire. In the last 85 years, acres of Missouri's forests and woodlands burned by wildfire each year has been drastically reduced. This change has had many positive impacts, but also some unintended consequences. One of these is the significant increase of shade tolerant, fire intolerant tree species – including species like sugar maple, red maple, cedar, elm, blackgum, and ironwood.

Although these are all species native to Missouri that play an important role in Missouri's biodiversity, when left unchecked by a lack of fire these species can have significant negative impacts on forest and woodland resources. When a forest or woodland develops a significant presence of shade tolerant tree species in the understory, there is often a drastic reduction of herbaceous vegetation on the forest/woodland floor. This vegetation is important to many sensitive wildlife species and plays other important roles in the proper functioning of the forest/woodland. Without proactive measures to bring these shade tolerant species under check, it becomes impossible for shade intolerant species like oak and pine to regenerate and recruit into the future forest. Thus, over time, our woods can see drastic changes in species composition – often with negative impacts to the wildlife and forest products industry that depends on the species that have traditionally dominated our landscape.

Figures G.3.1 and **G.3.2** show trends in the number and percent increase of shade tolerant trees (including black, red, and sugar maple, musclewood, beech, hickory, blackgum, ironwood, and elm) from 1989 to 2018 by diameter class. **Figure G.3.3** shows these same trends for two specific genera – maple (including black, red, and sugar) and blackgum.

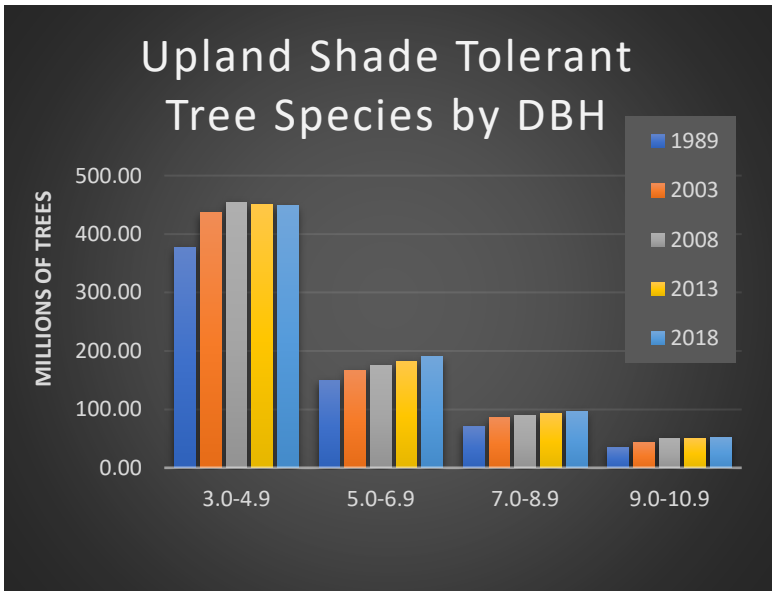


Figure G.3.1 – Number of Upland Shade Tolerant Trees by Diameter (DBH) Range

(Source: USFS FIA 2019)

Diameter range	Percentage increase
3.0–4.9	19.1
5.0–6.9	27.7
7.0–8.9	38.4
9.0–10.9	50.2

Figure G.3.2 – Percentage increase of upland shade tolerant trees by tree diameter (DBH) range (Source: USFS FIA 2019)

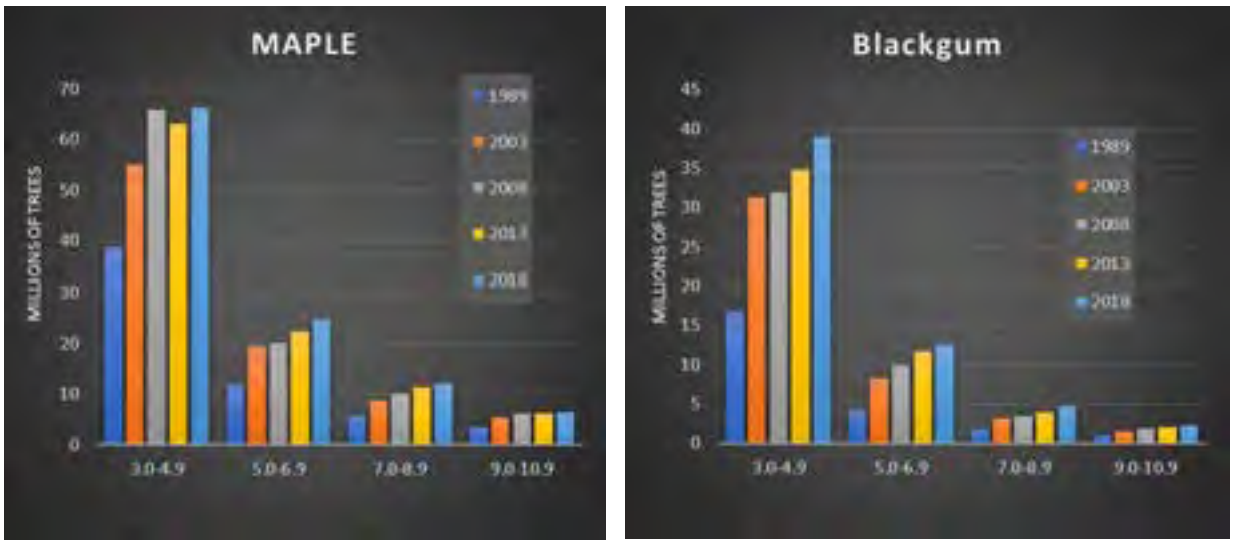


Figure G.3.3 – Number of Upland Maple and Blackgum Trees by Diameter Class, 1989–2018 (Source: USFS FIA 2019)

Ensuring the future health, diversity, and productivity of our forests and woodlands requires that these shade tolerant, fire intolerant species are properly accounted for and managed.

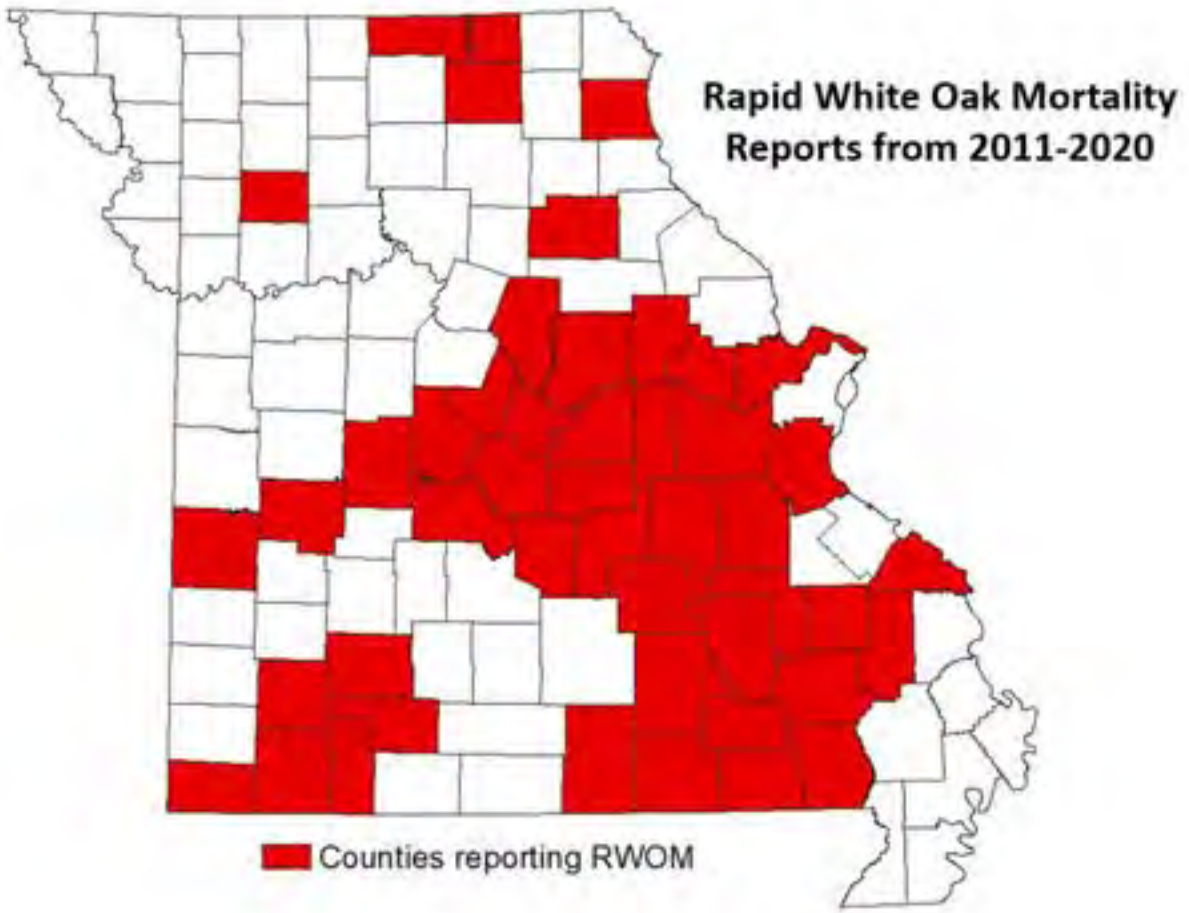
G.4 Rapid White Oak Mortality

RWOM is a relatively new and distinct pattern of white oak mortality observed in Missouri since 2011. Unlike oak decline, which typically affects mature trees in the red oak group growing on rocky upper slopes, this mortality disproportionately affects white oak and occurs on sites and in stands that would traditionally be considered favorable for continued tree growth. Mortality is most significant along drainages, and affected white oaks often die rapidly. Reports of dead white oak trees peaked in 2012 and continued through 2015, but numerous new reports of RWOM were received in 2018 and 2019.

The University of Missouri began a multi-year research investigation in 2014 led by Dr. Sharon Reed to study the factors causing RWOM and how to better predict and manage affected locations. The research team used 54 research sites on MDC and MTNF lands in east central and southeast Missouri to collect data on site and stand characteristics, tree age and growth rates, and associated insects and diseases.

The research findings suggest that RWOM is affected by soil characteristics and slope position, and that this mortality may be the result of many stressors working together over the course of several years to kill trees. Mortality tends to be concentrated on the lower half of slopes in soils that fluctuate

widely between wet and dry conditions. The pattern of alternating record rainfall followed by drought events in recent years appears to be involved in this mortality, but more research is needed to understand the role weather events play in RWOM. Investigations of associated insects and diseases resulted in the discovery of *Phytophthora cinnamomi* in several soil samples from study sites. At this time, it is unknown to what extent *P. cinnamomi* might contribute to RWOM.



G.5 Emerald Ash Borer

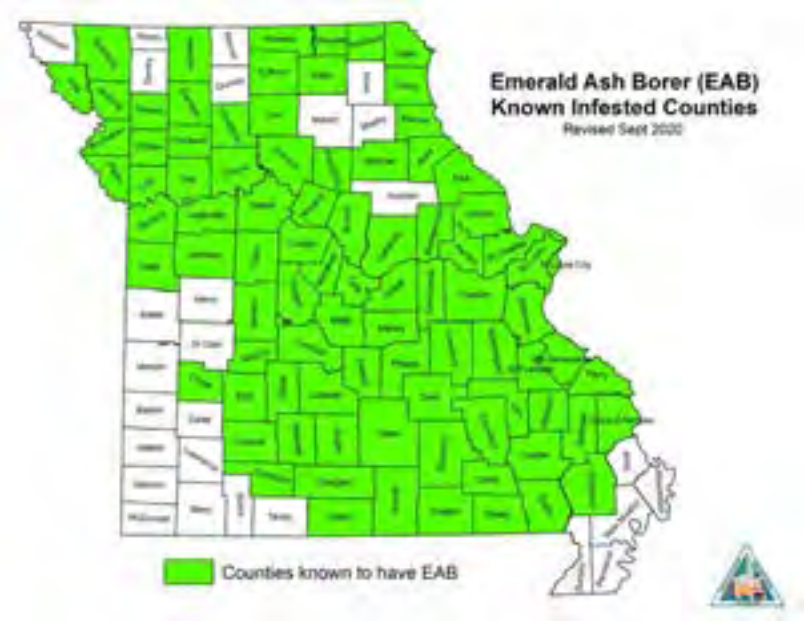
Missouri's first EAB detection occurred in 2008 within a USACE camping area on Lake Wappapello in Wayne County. The likely source of this infestation was ash (*Fraxinus* spp.) firewood brought by campers from states known to have EAB. Since that initial detection, EAB has been found in nearly two-thirds of Missouri's counties. Reports of extensive ash mortality are becoming increasingly common as EAB populations build across the state.

Ash species compose approximately 3 percent of Missouri's forest trees, with higher concentrations of ash typically observed near riparian areas. Wildlife species use these trees for food and shelter, and ash is an obligate host for several native insect species (eastern hercules beetle, Franck's sphinx, ash bark beetle, etc.). Because it was initially expected that EAB would kill all native ash species regardless of size or health, there was high concern that ash would likely be extirpated from the state. While death appears to be imminent for all large ash trees (more than 10 inches in diameter at breast height), recent observations are showing that smaller ash trees will likely be maintained on the landscape. In addition,

EAB is showing less preference for blue ash (*Fraxinus quadrangulata*) as a host, making it possible that this species will be maintained at acceptable population levels.

Unfortunately, many urban areas across the state have high numbers of ash as street and park trees. Missouri communities often replaced elms that died from Dutch elm disease with green ash because of its rapid growth and large size. Now some community forests have over 30 percent of their trees in ash species. While insecticide treatments are too cost prohibitive to use on forest trees, homeowners and municipalities are successfully treating ash trees and protecting them from EAB attack, thus maintaining many valuable urban trees – and the array of benefits they provide – for the foreseeable future.

Prior to the discovery of EAB in 2002 in the Detroit, Michigan, area, very little was known about this species, even in its native range (China, Japan, Russia, and Taiwan). EAB was considered a secondary insect pest of stressed or dying ash trees – much like Missouri's native borers that only attack stressed trees. It wasn't until EAB was introduced to a new area with host species lacking in resistance mechanisms that it was able to become an invasive forest pest. Now it is being considered one of the most destructive forest pests in North America, with the potential to kill billions of ash trees. While EAB has been a damaging addition to Missouri, the outreach message to the public regarding firewood movement will hopefully help slow the spread of the next invasive forest pest on the horizon.



G.6 Gypsy Moth

The European gypsy moth (*Lymantria dispar*) is one of the most destructive forest pests in the United States. It was introduced near Boston, Massachusetts, in 1869. Early attempts to eradicate this invader failed, and it has slowly spread over much of the northeastern United States. The gypsy moth now ranges from Maine to Wisconsin, through northern Illinois, and into Ohio and Virginia. While Missouri has no current infestations, small gypsy moth populations were found in both Dent and Taney counties in the 1990s. These populations were eradicated, delaying the spread of the gypsy moth in our state.

Nationwide, gypsy moth caterpillars defoliate over a million acres of forest per year and cost citizens an estimated $868 million in damages annually. Because gypsy moths are nonnative, they have few natural enemies in North America. Populations can reach outbreak levels in some years, severely damaging the forest and creating a terrible nuisance for humans.

Missouri's forests are highly susceptible to the gypsy moth. Thirteen of the top 20 preferred host species (mostly oaks) are common here. When combined with drought and other tree stressors, defoliation by gypsy moth could kill hundreds of thousands of trees in Missouri. Ultimately, our oak-dominated forests could change to forests with fewer oaks. Wildlife that depend on acorns, like deer, turkey, and black bear, could undergo high population losses. From an economic perspective, a decrease in oaks would mean Missouri's timber industry could lose thousands of jobs and the state would lose millions of dollars in tax revenue.

Keeping the gypsy moth out of Missouri is the best way to protect our forests. Humans can easily transport this pest to new locations. Several life stages of the gypsy moth, including eggs, caterpillars, and pupae, can hitchhike on firewood, outdoor equipment, and vehicles. Outreach campaigns encourage Missouri residents traveling to gypsy moth–infested areas of the United States to inspect vehicles and outdoor equipment to make sure no stowaways are on board before returning to the state. People moving to Missouri from states in the gypsy moth quarantine zone are required by federal law to inspect all outdoor items and remove any gypsy moth life stages.

MDC partners annually with the Missouri Department of Agriculture, the USDA, the Missouri National Guard, and the U.S. Army to place several thousand gypsy moth traps across the state. Traps are bright orange triangular cardboard boxes that contain a pheromone lure to attract male gypsy moths. Partnering agencies typically catch less than 10 moths each summer, indicating no reproducing populations of gypsy moth are currently known in Missouri.

Gypsy moth was originally projected to be established in Missouri by 2015. Fortunately, through efforts made by the USFS's Slow the Spread program, arrival of the gypsy moth to our state has been delayed—likely by decades. Current models suggest gypsy moth could arrive in Missouri by 2030 if the Slow the Spread program was eliminated. However, models also show that the gypsy moth may never reach Missouri if this valuable federal program remains funded for the foreseeable future.

G.7 Chestnut Blight and Ozark Chinquapin Restoration

The Ozark chinquapin (*Castanea pumila var. ozarkensis*), a once well-known and important nut-producing tree indigenous to the Ozarks, was decimated by chestnut blight in the mid-20th century. The fungus causing chestnut blight, *Cryphonectria parasitica*, was first introduced to North America in 1904 on infected nursery stock. The blight fungus spread throughout the native range of American chestnut and arrived in the Ozarks in the 1950s. Much like the American chestnut, Ozark chinquapin was reduced to small

bushes or heavily suppressed trees resulting from cycles of stem blight and re-sprout. Surviving stems rarely persist long enough to produce seed before being killed back by blight. The Ozark chinquapin is now a SOCC in Missouri.

In recent years, interest has grown in blight resistance research and restoration of the imperiled Ozark chinquapin. The nonprofit Ozark Chinquapin Foundation has become known in the region for their blight resistance breeding, tree planting, and outreach programs, which have helped to raise awareness of this tree and its plight. In 2018, a new and promising Ozark chinquapin research program began at the University of Missouri Center for Agroforestry through the Tree Improvement Program Cooperative Agreement funded by MDC. This research program recognizes that the conservation and use of diverse germplasm is crucial not only to the development of blight tolerant Ozark chinquapin trees but also to the long-term goal of health and restoration of this species. Germplasm collection and analysis is currently underway as the first step toward developing a breeding program.

Existing genetic research suggests that Ozark chinquapin has high genetic diversity compared to other members of Castanea in North America. Though Ozark chinquapin continues to persist on the landscape in its blighted form, it is still unfamiliar to many people, scattered in distribution, and quietly fading from its natural range. Actions taken through the Tree Improvement Program to collect and conserve genetic diversity are crucial if there is hope of blight resistance and restoration of Ozark chinquapin.

Appendix H: Species of Greatest Conservation Need

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Aruncus dioicus*	Goat's beard	–	–	X	Cliff/Talus	
Plant	*Asplenium bradleyi*	Bradley's spleenwort	–	SU	–	Cliff/Talus	–
Plant	*Asplenium montanum*	Mountain spleenwort	–	SH	–	Cliff/Talus	–
Plant	*Asplenium pinnatifidum*	Lobed spleenwort	–	SU	–	Cliff/Talus	–
Plant	*Asplenium trichomanes ssp. trichomanes*	Maidenhair spleenwort	–	SU	–	Cliff/Talus	–
Plant	*Calamagrostis porteri ssp. insperata*	Oferhollow reed grass	–	S3	–	Cliff/Talus	Forest
Plant	*Calypogeia sullivantii*	A leafy liverwort	–	S1	–	Cliff/Talus	–
Plant	*Carex eburnea*	Cedar sedge	–	–	X	Cliff/Talus	
Plant	*Corydalis aurea ssp. aurea*	Golden corydalis	–	SU	–	Cliff/Talus	–
Plant	*Fragaria vesca*	Woodland strawberry	–	S1	–	Cliff/Talus	–
Plant	*Helianthemum canadense*	A rockrose	–	SU	–	Cliff/Talus	Forest
Plant	*Jungermannia leiantha*	A liverwort	–	S1	–	Cliff/Talus	–
Plant	*Juniperus ashei*	Ashe's juniper	–	–	X	Cliff/Talus	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Kurzia pauciflora*	A liverwort	–	S1	–	Cliff/Talus	–
Plant	*Kurzia sylvatica*	A liverwort	–	S1	–	Cliff/Talus	–
Plant	*Marsupella sullivantii*	A liverwort	–	S2	–	Cliff/Talus	–
Plant	*Metzgeria furcata*	A liverwort	–	S2	–	Cliff/Talus	Glade
Plant	*Mitchella repens*	Partridgeberry	–	–	X	Cliff/Talus	
Plant	*Nardia lescurii*	A liverwort	–	S1	–	Cliff/Talus	Forest (Bottomland forest)
Plant	*Odontoschisma denudatus*	A liverwort	–	S1	–	Cliff/Talus	–
Plant	*Pellaea glabella* var. *missouriensis*	Missouri cliffbrake	–	S1S2	–	Cliff/Talus	–
Plant	*Polypodium virginianum*	Common polypody	–	–	X	Cliff/Talus	–
Plant	*Saxifraga pensylvanica* var. *forbesii*	Forbe's saxifrage	–	–	X	Cliff/Talus	–
Plant	*Trautvetteria caroliniensis*	False bugbane	–	S2	–	Cliff/Talus	–
Plant	*Viola pallens*	Smooth white violet	–	S2	–	Cliff/Talus	Forest
Plant	*Woodsia obtuse* ssp. *occidentalis*	Blunt-lobed woodsia	–	S1	–	Cliff/Talus	Glade
Plant	*Zigadenus elegans glaucus*	White camas	–	S2	–	Cliff/Talus	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Carex decomposita*	Epiphytic sedge	–	S3	X	Caves/Karst (Sinkhole)	Wetland (Swamp)
Plant	*Carex straminea*	Straw sedge	–	S1	–	Caves/Karst (Sinkhole)	–
Plant	*Gratiola viscidula*	Hedge hyssop	–	S1	–	Caves/Karst (Sinkhole)	–
Plant	*Isoetes engelmannii var. engelmannii*	Engelmann's quillwort	–	S1	X	Caves/Karst (Sinkhole)	–
Plant	*Rhynchospora macrostachya var. macrostachya*	Horned rush	–	S1	–	Caves/Karst (Sinkhole)	Grassland/Prairie
Plant	*Schoenoplectiella hallii*	Hall's bulrush	–	S2	–	Caves/Karst (Sinkhole)	Grassland/Prairie (Wet prairie)
Plant	*Schoenoplectus etuberculatus*	Canby's bulrush	–	SH	–	Caves/Karst (Sinkhole)	–
Plant	*Schoenoplectus subterminalis*	Swaying bulrush	–	S1	–	Caves/Karst (Sinkhole)	Rivers/Streams
Plant	*Dryopteris celsa*	Log fern	–	S1	–	Caves/Karst (Springs)	Forest
Plant	*Dryopteris cristata*	Crested shield fern	–	S1	–	Caves/Karst (Springs)	Forest (Bottomland Forest)
Plant	*Dryopteris goldiana*	Goldie fern	–	S2	–	Caves/Karst (Springs)	Forest
Plant	*Hydrocotyle verticillata*	Whorled water pennywort	–	S1	–	Caves/Karst (Springs)	Rivers/Streams
Plant	*Lemna trisulca*	Forked duckweed	–	S2	–	Caves/Karst (Springs)	Wetland (Marsh)
Plant	*Carex cumberlandensis*	Cumberland sedge	–	S1	–	Forest	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Carex prasina*	Drooping sedge	–	S1	–	Forest	–
Plant	*Carex reznicekii*	Tony's sedge	–	S2	–	Forest	–
Plant	*Carex sprengelii*	Long–beaked sedge	–	S2	–	Forest	–
Plant	*Carex willdenowii*	Willdenow's sedge	–	S1	–	Forest	–
Plant	*Diarrhena americana*	American beak grass	–	S1	–	Forest	Wetland
Plant	*Dryopteris carthusiana*	Spinulose shield fern	–	S2	–	Forest	Wetland (Swamp)
Plant	*Epifagus virginiana*	Beech drops	–	S2	–	Forest	–
Plant	*Hypericum ascyron ssp. pyramidatum*	Great St. John's wort	–	S1	–	Forest	–
Plant	*Hypericum lobocarpum*	Bushy St. John's wort	–	S1	–	Forest	Wetland (Fen)
Plant	*Isotria verticillata*	Large whorled pogonia	–	S1S2	–	Forest	–
Plant	*Lilium philadelphicum var. andinum*	Prairie lily	–	S1	–	Forest	–
Plant	*Obolaria virginica*	Pennywort	–	S2	–	Forest	-
Plant	*Patis racemosa*	Black-seeded rice grass	–	S1	–	Forest	–
Plant	*Phlox amplifolia*	Broadleaf phlox	–	S3	–	Forest	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Symphoricarpos occidentalis*	Wolfberry	–	S1	–	Forest	Grassland
Plant	*Tipularia discolor*	Crane-fly orchid	–	S3	–	Forest	Savanna
Plant	*Trillium nivale*	Snow trillium	–	S3	–	Forest	–
Plant	*Aconitum uncinatum*	Southern monkshood	–	S1	–	Forest (Bluff)	–
Plant	*Aralia nudicaulis*	Wild sarsaparilla	–	S2	–	Cliff/Talus	Forest
Plant	*Bartonia virginica*	Yellow screwstem	–	S1	–	Cliff/Talus	Forest
Plant	*Berberis canadensis*	American barberry	–	S1	–	Cliff/Talus	Glade
Plant	*Campanula rotundifolia*	Harebell	–	S1	–	Cliff/Talus	Forest
Plant	*Carex woodii*	Pretty sedge	–	S1	–	Forest (Bluff)	-
Plant	*Cheilanthes alabamensis*	Alabama lip-fern	–	S1	–	Cliff/Talus	Forest
Plant	*Cheilanthes tomentosa*	Wooly lip fern	–	S1	–	Cliff/Talus	Forest
Plant	*Cissus trifoliata*	Marine vine	–	S2	–	Cliff/Talus	Glade
Plant	*Clematis versicolor*	Small leather flower	–	–	X	Cliff/Talus	Glade
Plant	*Cypripedium reginae*	Showy lady's slipper	–	S2S3	–	Forest (Bluff)	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Cystopteris tenuis*	Fragile fern	–	S1	–	Cliff/Talus	Forest
Plant	*Dennstaedtia punctilobula*	Hay-scented fern	–	S2	X	Cliff/Talus	Forest
Plant	*Dryopteris intermedia*	Intermediate shield fern	–	S1	–	Cliff/Talus	Forest
Plant	*Eurybia furcata*	Forked aster	–	S2	–	Forest (Bluff)	Rivers/Streams
Plant	*Eurybia macrophylla*	Big-leaved aster	–	S2	–	Forest (Bluff)	–
Plant	*Galium boreale*	Northern bedstraw	–	S2	–	Cliff/Talus	Forest
Plant	*Gentianella quinquefolia ssp. occidentalis*	Stiff gentian	–	–	X	Forest (Bluff)	–
Plant	*Heuchera parviflora var. parviflora*	Small-flowered alum root	–	S1	–	Cliff/Talus	Forest
Plant	*Heuchera parviflora var. puberula*	Small-flowered alum root	–	–	X	Cliff/Talus	Forest
Plant	*Huperzia porophila*	Fir clubmoss	–	S2	X	Cliff/Talus	Forest
Plant	*Lycopodium dendroideum*	Round-branched clubmoss	–	S1	–	Cliff/Talus	Forest
Plant	*Lycopodium tristachyum*	Ground cedar	–	S1	–	Cliff/Talus	Forest
Plant	*Paronychia virginica*	Broom whitlow-wort	–	S1	–	Cliff/Talus	Glade
Plant	*Philadelphus pubescens var. verrucosus*	Hoary mock orange	–	S1	–	Cliff/Talus	Forest

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Primula fassettii*	Amethyst shooting star	–	S2	–	Cliff/Talus	Forest
Plant	*Primula frenchii*	French's shooting star	–	S1	–	Cliff/Talus	Forest
Plant	*Sambucus pubens*	Red-berried elder	–	S1	–	Forest (Bluff)	–
Plant	*Sapindus saponaria var. drummondii*	Soapberry	–	S2	–	Forest (Bluff)	–
Plant	*Sullivantia sullivantii*	Sullivantia	–	S2	X	Cliff/Talus	Forest
Plant	*Viburnum bracteatum*	Ozark arrowwood	–	S1S2	–	Cliff/Talus	Forest
Plant	*Carex atherodes*	Slough sedge	–	SH	–	Forest (Bottomland Forest)	Wetland (Wet prairie)
Plant	*Carex gracillima*	Graceful sedge	–	S1	–	Forest (Bottomland Forest)	–
Plant	*Carex reniformis*	Kidney-fruited sedge	–	S1	X	Forest (Bottomland Forest)	–
Plant	*Carex socialis*	Cespitose sedge	–	S2	X	Forest (Bottomland Forest)	Wetland (Swamp)
Plant	*Chelone obliqua*	Rose turtlehead	–	S2	X	Forest (Bottomland Forest)	Wetland
Plant	*Clematis viorna*	Vase vine	–	S1	–	Forest (Bottomland Forest)	Glade
Plant	*Crataegus marshallii*	Parsley hawthorn	–	S1	X	Forest (Bottomland Forest)	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Dirca decipiens*	Leatherwood	–	SU	–	Forest (Bottomland Forest)	–
Plant	*Helianthus decapetalus*	Pale sunflower	–	SU	–	Forest (Bottomland Forest)	–
Plant	*Lindera melissifolia*	Pondberry	E, SE	S1	–	Forest (Bottomland Forest)	Wetland (marsh)
Plant	*Monarda clinopodia*	Basil bee balm	–	S1	–	Forest (Bottomland Forest)	–
Plant	*Phacelia covillei*	Coville's phacelia	–	S1	–	Forest (Bottomland Forest)	–
Plant	*Platanthera flava var. flava*	Pale green orchid	–	S2	X	Forest (Bottomland Forest)	–
Plant	*Platanthera flava var. herbiola*	Tubercled orchid	–	S2	X	Forest (Bottomland Forest)	–
Plant	*Pycnanthemum muticum*	Short-toothed mountain mint	–	S2	–	Forest (Bottomland Forest)	Wetland (Swamp)
Plant	*Quercus nigra*	Water oak	–	S2	–	Forest (Bottomland Forest)	–
Plant	*Quercus texana*	Nuttall's oak	–	S2	–	Forest (Bottomland Forest)	–
Plant	*Ulmus crassifolia*	Cedar elm	–	S1	–	Forest (Bottomland Forest)	Wetland
Plant	*Viola affinis*	Sand violet	–	S1	–	Forest (Bottomland Forest)	Wetland (Swamp)

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Agastache scrophulariifolia*	Purple giant hyssop	–	S1	–	Forest/Woodland	–
Plant	*Castanea pumila var. ozarkensis*	Ozark chinquapin	–	S2	–	Forest/Woodland	–
Plant	*Crataegus spathulata*	Littlehip hawthorn	–	S1	–	Forest/Woodland	–
Plant	*Delphinium exaltatum*	Tall larkspur	–	S2	–	Forest/Woodland	–
Plant	*Tradescantia ozarkana*	Ozark spiderwort	–	S2	–	Forest/Woodland	–
Plant	*Viburnum dentatum*	Southern arrowwood	–	S1	–	Forest/Woodland	–
Plant	*Amsonia ciliata var. filifolia*	Ciliate blue star	–	S2S3	–	Glade	Rivers/Streams
Plant	*Callirhoe bushii*	Bush's poppy mallow	–	S2	–	Glade	Woodland
Plant	*Carex crawei*	Crawe's sedge	–	–	X	Glade	–
Plant	*Carex microdonta*	Little tooth sedge	–	S1	–	Glade	Grassland/Prairie
Plant	*Clematis fremontii*	Fremont's leather flower	–	S3	X	Glade	–
Plant	*Dalea gattingeri*	Gattinger's prairie clover	–	S1	X	Glade	–
Plant	*Delphinium treleasei*	Trelease's larkspur	–	–	X	Glade	–
Plant	*Echinacea paradoxa*	Yellow coneflower	–	–	X	Glade	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Eriogonum longifolium var. longifolium*	Umbrella plant	–	S2	X	Glade	Forest (Bluff)
Plant	*Geocarpon minimum*	Geocarpon	T, SE	S2	X	Glade	–
Plant	*Marshallia caespitosa var. signata*	Narrow-leaved Barbara's buttons	–	S1	–	Glade	–
Plant	*Minuartia michauxii*	Stiff sandwort	–	–	X	Glade	Forest (Bluff)
Plant	*Nemastylis geminiflora*	Celestial lily	–	S2	X	Glade	Grassland/Prairie
Plant	*Oenothera triloba*	Stemless evening primrose	–	S2	–	Glade	Grassland/Prairie
Plant	*Penstemon cobaea*	A beard-tongue	–	S1	X	Glade	Grassland/Prairie
Plant	*Physaria filiformis*	Missouri bladderpod	T, SE	S3	X	Glade	–
Plant	*Rhynchospora harveyi*	Harvey's beak rush	–	S1	–	Glade	Grassland/Prairie
Plant	*Scutellaria bushii*	Bush's skullcap	–	–	X	Glade	–
Plant	*Solidago gattingeri*	Gattinger's goldenrod	–	–	X	Glade	–
Plant	*Thelesperma filifolium*	Thelesperma	–	S2	–	Glade	Grassland/Prairie
Plant	*Valerianella ozarkana*	Ozark corn salad	–	S2	–	Glade	Savanna
Plant	*Yucca arkansana*	Soft soapweed	–	S2	–	Glade	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Zigadenus nuttallii*	Death camas	–	S1	–	Glade	–
Plant	*Agalinis aspera*	Rough false foxglove	–	–	X	Grassland/Prairie	Glade
Plant	*Agalinis auriculata*	Eared false foxglove	–	S3	X	Grassland/Prairie	–
Plant	*Agalinis heterophylla*	Prairie false foxglove	–	S1	–	Grassland/Prairie	Savanna
Plant	*Agalinis viridis*	Green false foxglove	–	S1	–	Grassland/Prairie	–
Plant	*Agrimonia gryposepala*	Tall agrimony	–	–	X	Grassland/Prairie	Savanna
Plant	*Anemone cylindrica*	Thimbleweed	–	S2	–	Grassland/Prairie	–
Plant	*Aristida desmantha*	Curly three-awn	–	S2	–	Grassland/Prairie	–
Plant	*Asclepias meadii*	Mead's milkweed	T, SE	S2	X	Grassland/Prairie	Glade
Plant	*Bouteloua hirsuta*	Hairy grama	–	–	X	Grassland/Prairie	–
Plant	*Buchnera americana*	Blue hearts	–	–	X	Grassland/Prairie	–
Plant	*Callirhoe triangulata*	Clustered poppy mallow	–	–	X	Grassland/Prairie	–
Plant	*Calopogon oklahomensis*	Prairie grass pink	–	S2	X	Grassland/Prairie	–
Plant	*Camassia angusta*	Prairie hyacinth	–	–	X	Grassland/Prairie	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Carex buxbaumii*	Brown bog sedge	–	S2	–	Grassland/Prairie	Wetland (Fen)
Plant	*Carex conoidea*	Field sedge	SE	S1	–	Grassland/Prairie	–
Plant	*Carex lacustris*	Lake bank sedge	–	S2	–	Grassland/Prairie	Wetland (marsh)
Plant	*Carex sartwellii*	Sartwell's sedge	–	S1	–	Grassland/Prairie	–
Plant	*Castilleja sessiliflora*	Downy yellow painted cup	–	S2	X	Grassland/Prairie	–
Plant	*Cirsium undulatum*	Wavy leaved thistle	–	S1	–	Grassland/Prairie	–
Plant	*Coelorachis cylindrica*	Joint grass	–	S1	–	Grassland/Prairie	–
Plant	*Corydalis micrantha ssp. australis*	Hale's corydalis	–	S2	–	Grassland/Prairie	Savanna
Plant	*Croton michauxii*	Narrowleaf rushfoil	–	S1	–	Grassland/Prairie	Savanna
Plant	*Cyperus hystricinus*	Bristly flatsedge	–	S2	–	Grassland/Prairie	Forest
Plant	*Cyperus retrofractus*	Teasel-like cyperus	–	S1	–	Grassland/Prairie	Forest
Plant	*Cypripedium candidum*	White lady's slipper	–	S1	–	Grassland/Prairie	Glade
Plant	*Dalea enneandra*	Nine-anthered prairie clover	–	S2	X	Grassland/Prairie	–
Plant	*Desmodium strictum*	Sand tick trefoil	–	S2	–	Grassland/Prairie	Savanna

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Eleocharis wolfii*	Wolf's spike rush	–	–	X	Grassland/Prairie	Wetland
Plant	*Gentiana andrewsii var. andrewsii*	Closed gentian	–	S1	–	Grassland/Prairie	–
Plant	*Gentiana puberulenta*	Downy gentian	–	–	X	Grassland/Prairie	Glade
Plant	*Juncus validus*	Round-head rush	–	S1	–	Grassland/Prairie	Wetland
Plant	*Lygodesmia juncea*	Skeleton plant	–	S3	X	Grassland/Prairie	–
Plant	*Marshallia caespitosa var. caespitosa*	Barbara's buttons	–	S3	X	Grassland/Prairie	Glade
Plant	*Minuartia muscorum*	Pitcher's sandwort	–	S1	–	Grassland/Prairie	Savanna
Plant	*Oenothera clelandii*	Evening primrose	–	S2	–	Grassland/Prairie	–
Plant	*Oenothera perennis*	Small sundrops	–	S1	–	Grassland/Prairie	Wetland (Fen)
Plant	*Oenothera suffrutescens*	Scarlet gaura	–	S1	–	Grassland/Prairie	–
Plant	*Oxytropis lambertii*	Loco weed	–	–	X	Grassland/Prairie	–
Plant	*Pediomelum argophyllum*	Silvery scurfy pea	–	S2	X	Grassland/Prairie	–
Plant	*Quercus prinoides*	Dwarf chinquapin oak	–	S3	–	Grassland/Prairie	Savanna
Plant	*Rhynchosia difformis*	Double-formed snoutbean	–	S1	–	Grassland/Prairie	Glade

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Sida elliottii*	Elliott's sida	–	S1	–	Grassland/Prairie	–
Plant	*Silene regia*	Royal catchfly	–	–	X	Grassland/Prairie	–
Plant	*Sisyrinchium atlanticum*	Eastern blue-eyed grass	–	S2	–	Grassland/Prairie	Wetland (Fen)
Plant	*Trifolium carolinianum*	Carolina clover	–	S1	–	Grassland/Prairie	Glade
Plant	*Yucca glauca*	Soapweed	–	S2	–	Grassland/Prairie	–
Plant	*Agalinis purpurea*	Purple false foxglove	–	S2	–	Grassland/Prairie (Wet prairie)	Wetland
Plant	*Melanthium virginicum*	Bunch flower	–	–	X	Grassland/Prairie (Wet prairie)	–
Plant	*Platanthera leucophaea*	Eastern prairie fringed orchid	T, SE	S1	–	Grassland/Prairie (Wet prairie)	–
Plant	*Platanthera praeclara*	Western prairie fringed orchid	T, SE	S1	–	Grassland/Prairie (Wet prairie)	–
Plant	*Sagittaria ambigua*	Kansas arrowhead	–	S1	–	Grassland/Prairie (Wet prairie)	Wetland (Pond)
Plant	*Liatris scariosa var. nieuwlandii*	Blazing star	–	S2	–	Grassland/Savanna	Glade
Plant	*Juncus debilis*	Weak rush	–	S1	–	Rivers/Streams	Wetland
Plant	*Desmodium viridiflorum*	Velvetleaf tick trefoil	–	S1	–	Savanna	Forest
Plant	*Elymus churchii*	Church's wild rye	–	S1	–	Savanna	Woodland

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Sabatia brachiata*	Narrow-leaved marsh pink	–	S1	–	Savanna	–
Plant	*Trichostema setaceum*	Bristly blue curls	–	S1	–	Savanna	Woodland
Plant	*Alopecurus aequalis*	Tufted foxtail	–	S2	–	Wetland	–
Plant	*Amorpha nitens*	Shining false indigo	–	S1	–	Wetland	–
Plant	*Boltonia decurrens*	Decurrent false aster	T, SE	S1	X	Wetland	–
Plant	*Carex comosa*	Bristly sedge	–	S2	–	Wetland	Forest (Bottomland forest)
Plant	*Carex molestiformis*	A sedge	–	S2	–	Wetland	Forest
Plant	*Cynosciadium digitatum*	Finger dog-shade	–	S2	X	Wetland	Forest (Bottomland forest)
Plant	*Eleocharis atropurpurea*	Purple spike rush	–	S1	–	Wetland	–
Plant	*Eleocharis lanceolata*	Lance-like spike rush	–	S2	–	Wetland	Grassland/Prairie
Plant	*Euonymus americanus*	Strawberry bush	–	S2	–	Wetland	Forest
Plant	*Helenium virginicum*	Virginia sneezeweed	T, SE	S3	–	Wetland	Caves/Karst (Sinkhole)
Plant	*Hydrolea ovata*	Blue waterleaf	–	S2	–	Wetland	Grassland/Prairie
Plant	*Hypericum adpressum*	Creeping St. John's wort	–	S1	–	Wetland	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Leitneria pilosa spp. ozarkana*	Corkwood	–	S2	X	Wetland	–
Plant	*Lipocarpha drummondii*	A lipocarpha	–	S1	–	Wetland	Grassland/Prairie
Plant	*Ludwigia leptocarpa*	Hairy primrose willow	–	S2	–	Wetland	–
Plant	*Mecardonia acuminata*	Bracted water hyssop	–	S1	–	Wetland	Grassland/Prairie (Wet prairie)
Plant	*Ptilimnium capillaceum*	Mock bishop's weed	–	–	X	Wetland	–
Plant	*Rorippa aquatica*	Lake cress	–	S2	–	Wetland	–
Plant	*Schoenoplectiella saximontana*	Rocky mountain bulrush	–	S1	–	Wetland	–
Plant	*Scirpus pallidus*	Cloaked bulrush	–	S2	–	Wetland	–
Plant	*Spiraea tomentosa*	Steeple bush	–	S1	–	Wetland	–
Plant	*Triadenum tubulosum*	Marsh St. John's wort	–	S1	–	Wetland	–
Plant	*Utricularia minor*	Lesser bladderwort	–	S1	–	Wetland	–
Plant	*Viburnum recognitum*	Northern arrowwood	–	S1	–	Wetland	Forest
Plant	*Berula erecta var. incisa*	Cut-leaved water-parsnip	–	S1	–	Wetland (Fen)	–
Plant	*Calopogon tuberosus*	Grass pink	–	S2	X	Wetland (Fen)	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Caltha palustris*	Marsh marigold	–	S1	–	Wetland (Fen)	–
Plant	*Campanula aparinoides*	Marsh bellflower	–	S1	–	Wetland (Fen)	–
Plant	*Carex atlantica ssp atlantica*	A sedge	–	S1	–	Wetland (Fen)	–
Plant	*Carex bromoides ssp bromoides*	A sedge	–	S2	–	Wetland (Fen)	Forest (Bottomland forest)
Plant	*Carex sterilis*	Dioecious sedge	–	S2	–	Wetland (Fen)	–
Plant	*Carex trichocarpa*	Hairy-fruited sedge	–	S1	X	Wetland (Fen)	Grassland/Prairie
Plant	*Liparis loeselii*	Green twayblade	–	S2	X	Wetland (Fen)	Forest (Bottomland forest)
Plant	*Ludwigia microcarpa*	Small-fruited false loosestrife	–	S2	–	Wetland (Fen)	–
Plant	*Lysimachia terrestris*	Swamp candles	–	S1	–	Wetland (Fen)	–
Plant	*Menyanthes trifoliata*	Buckbean	–	S1	–	Wetland (Fen)	Cave/Karst (Sinkhole)
Plant	*Oligoneuron riddellii*	Riddell's goldenrod	–	–	X	Wetland (Fen)	–
Plant	*Parnassia grandifolia*	Grass-of-Parnassus	–	–	X	Wetland (Fen)	–
Plant	*Pedicularis lanceolata*	Swamp lousewort	–	–	X	Wetland (Fen)	–
Plant	*Platanthera ciliaris*	Orange fringed orchid	–	S1	–	Wetland (Fen)	Cave/Karst (Sinkhole)

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Platanthera clavellata*	Small green fringed orchid	–	S2	–	Wetland (Fen)	Cave/Karst (Sinkhole)
Plant	*Pogonia ophioglossoides*	Snakemouth orchid	–	S1	–	Wetland (Fen)	–
Plant	*Ribes americanum*	Wild black current	–	S1	–	Wetland (Fen)	–
Plant	*Solidago patula*	Swamp goldenrod	–	–	X	Wetland (Fen)	–
Plant	*Utricularia subulata*	Hair bladderwort	–	S1	–	Wetland (Fen)	–
Plant	*Woodwardia areolata*	Netted chain fern	–	S2	–	Wetland (Fen)	–
Plant	*Epilobium leptophyllum*	Fen willow herb	–	S1	–	Wetland (Fen, marsh)	–
Plant	*Mitreola petiolata*	Miterwort	–	S1	–	Wetland (Fen, Swamp)	–
Plant	*Scutellaria galericulata*	Marsh skullcap	–	S1	–	Wetland (Marsh, fen)	–
Plant	*Decodon verticillatus*	Swamp loosestrife	–	S1	–	Wetland (Pond)	–
Plant	*Schoenoplectiella purshiana*	Weakstalk bulrush	–	S2	–	Wetland (Pond)	–
Plant	*Wolffiella gladiata*	Mud midget	–	S1	–	Wetland (Pond)	–
Plant	*Xyris jupicai*	Tall yellow-eyed grass	–	S1	–	Wetland (Pond)	–
Plant	*Carex abscondita*	Thicket sedge	–	S1	–	Wetland (Swamp)	Forest (Bottomland forest)

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Plant	*Carex gigantea*	Large sedge	–	S1S2	–	Wetland (Swamp)	Forest (Bottomland forest)
Plant	*Hottonia inflata*	Water violet	–	S2	X	Wetland (Swamp)	Cave/Karst (Sinkhole)
Plant	*Limnobium spongia ssp. spongia*	American frogbit	–	S2	–	Wetland (Swamp)	–
Plant	*Lysimachia thyrsiflora*	Tufted loosestrife	–	S1	–	Wetland (Swamp)	Grassland/Prairie (Wet prairie)
Plant	*Nyssa aquatica*	Water tupelo	–	–	X	Wetland (Swamp)	–
Plant	*Thalia dealbata*	Water canna	–	S2	–	Wetland (Swamp, pond)	–
Plant	*Listera australis*	Southern twayblade	–	S1	–	Woodland	–
Plant	*Trifolium stoloniferum*	Running buffalo clover	E, SE	S1	–	Woodland	Savanna
Plant	*Trillium pusillum var. ozarkanum*	Ozark wake robin	–	S2	–	Woodland	–
Flatworms	*Macrocotyla glandulosa*	Pink planarian	–	S1	–	Caves/Karst	–
Flatworms	*Macrocotyla lewisi*	Lewis' cave planarian	–	S1	–	Caves/Karst (Springs)	–
Flatworms	*Sphalloplana evaginata*	Perryville cave planarian	–	S1	–	Caves/Karst (Springs)	–
Flatworms	*Sphalloplana hubrichti*	Hubricht's cave planarian	–	S1	–	Caves/Karst (Springs)	–
Mollusks	*Amnicola stygius*	Stygian amnicola	–	S1	–	Caves/Karst	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Mollusks	*Antrobia culveri*	Tumbling Creek cave snail	E, SE	S1	X	Caves/Karst	
Mollusks	*Fontigens antroecetes*	Missouri cave snail	–	S2	–	Caves/Karst	–
Mollusks	*Fontigens proserpina*	Proserpine cave snail	–	S1	–	Caves/Karst	–
Mollusks	*Vertigo oscariana*	Capital vertigo	–	S1	–	Forest	–
Mollusks	*Alasmidonta marginata*	Elktoe	–	S2	–	Rivers/Streams	–
Mollusks	*Alasmidonta viridis*	Slippershell mussel	SE	S1	–	Rivers/Streams	–
Mollusks	*Utterbackiana suborbiculata*	Flat floater	–	S2	–	Rivers/Streams	Wetland (Pond)
Mollusks	*Anodontoides ferussacianus*	Cylindrical papershell	–	S1	–	Rivers/Streams	–
Mollusks	*Campeloma crassulum*	Ponderous campeloma	–	SU	–	Rivers/Streams	–
Mollusks	*Margaritifera monodonta*	Spectaclecase	E, SE	S3	–	Rivers/Streams	–
Mollusks	*Cyprogenia aberti*	Western fanshell	–	S2	–	Rivers/Streams	–
Mollusks	*Elliptio crassidens*	Elephantear	SE	S1	–	Rivers/Streams	–
Mollusks	*Epioblasma curtisii*	Curtis pearlymussel	E, SE	S1	–	Rivers/Streams	–
Mollusks	*Epioblasma triquetra*	Snuffbox	E, SE	S1	–	Rivers/Streams	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Mollusks	*Reginaia ebenus*	Ebonyshell	SE	S1	–	Rivers/Streams	
Mollusks	*Lampsilis abrupta*	Pink mucket	E, SE	S2	–	Rivers/Streams	–
Mollusks	*Lampsilis higginsii*	Higgins eye	E, SE	S1	–	Rivers/Streams	–
Mollusks	*Lampsilis rafinesqueana*	Neosho mucket	E, SE	S2	–	Rivers/Streams	–
Mollusks	*Villosa lienosa*	Little spectaclecase	–	S3	–	Rivers/Streams	–
Mollusks	*Leptodea leptodon*	Scaleshell	E, SE	S1	–	Rivers/Streams	–
Mollusks	*Leptoxis arkansensis*	Arkansas mudalia	–	S1	–	Rivers/Streams	–
Mollusks	*Ligumia recta*	Black sandshell	–	S2	–	Rivers/Streams	–
Mollusks	*Micromenetus sampsoni*	Sampson sprite	–	S2	–	Rivers/Streams	–
Mollusks	*Obovaria arkansasensis*	Southern hickorynut	–	S1	–	Rivers/Streams	–
Mollusks	*Plethobasus cyphyus*	Sheepnose	E, SE	S2	–	Rivers/Streams	–
Mollusks	*Potamilus capax*	Fat pocketbook	E, SE	S1	–	Rivers/Streams	Wetland (Pond)
Mollusks	*Ptychobranchus occidentalis*	Ouachita kidneyshell	–	S3	–	Rivers/Streams	–
Mollusks	*Theliderma cylindrica*	Rabbitsfoot	T, SE	S1	–	Rivers/Streams	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Mollusks	*Quadrula fragosa*	Winged mapleleaf	E, SE	S1	–	Rivers/Streams	
Mollusks	*Simpsonaias ambigua*	Salamander mussel	SE	S1	–	Rivers/Streams	–
Mollusks	*Somatogyrus rosewateri*	Elk pebblesnail	–	S1	–	Rivers/Streams	–
Mollusks	*Stagnicola elodes*	Marsh pondsnail	–	S2	–	Rivers/Streams	–
Mollusks	*Toxolasma lividum*	Purple lilliput	–	S1	–	Rivers/Streams	–
Mollusks	*Hendersonia occulta*	Cherrystone snail	–	S3	–	Cliff/Talus	–
Arachnids	*Apochthonius mysterius*	Mystery cave pseudoscorpion	–	S1	–	Caves/Karst	–
Arachnids	*Apochthonius typhlus*	Stone County cave pseudoscorpion	–	S1	–	Caves/Karst	–
Arachnids	*Mundochthonius Caves/Karstrnicolus*	Cavernicolous pseudoscorpion	–	SU	–	Caves/Karst	–
Arachnids	*Phanetta subterranea*	Subterranean cave spider	–	S1	–	Caves/Karst	–
Arachnids	*Porrhomma canernicola*	Cavernicolous porrhomma spider	–	S2	–	Caves/Karst	–
Arachnids	*Aphonopelma hentzi*	Missouri tarantula	–	–	X	Glade	–
Arachnids	*Centruroides vittatus*	Striped bark scorpion	–	–	X	Glade	–
Crustaceans	*Bactrurus hubrichti*	Sword-tail cave amphipod	–	S1	–	Caves/Karst	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Crustaceans	*Bactrurus pseudodomucronatus*	False sword-tail cave amphipod	–	S2	–	Caves/Karst	
Crustaceans	*Brackenridgia ashleyi*	Ashley's isopod	–	S2	–	Caves/Karst	–
Crustaceans	*Caecidotea dimorpha*	An isopod	–	S1S3	–	Caves/Karst	–
Crustaceans	*Caecidotea fustis*	Fustis cave isopod	–	S2	–	Caves/Karst	–
Crustaceans	*Caecidotea salemensis*	Salem cave isopod	–	S2	–	Caves/Karst	–
Crustaceans	*Caecidotea serrata*	Serrated cave isopod	–	S1	–	Caves/Karst	–
Crustaceans	*Caecidotea stiladactyla*	Slender-fingered cave isopod	–	S1	–	Caves/Karst	–
Crustaceans	*Caecidotea stygia*	Stygian cave isopod	–	S1	–	Caves/Karst	–
Crustaceans	*Cambarus aculabrum*	Benton County cave crayfish	E, SE	–	–	Caves/Karst	–
Crustaceans	*Cambarus setosus*	Bristly cave crayfish	–	S3	–	Caves/Karst	–
Crustaceans	*Diacyclops yeatmani*	Yeatman's groundwater copepod	–	S1S3	–	Caves/Karst	–
Crustaceans	*Orconectes stygocaneyi*	Caney mountain cave crayfish	–	S1	–	Caves/Karst	–
Crustaceans	*Stygobromus barri*	Barr's groundwater amphipod	–	S1S3	–	Caves/Karst	–
Crustaceans	*Stygobromus clantoni*	Clanton's groundwater amphipod	–	S1S3	–	Caves/Karst	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Crustaceans	*Stygobromus onondagaensis*	Onondaga Cave amphipod	–	S3	–	Caves/Karst	
Crustaceans	*Stygobromus subtilis*	Subtle groundwater amphipod	–	S1S3	–	Caves/Karst	–
Crustaceans	*Allocrangonyx hubrichti*	Hubricht's long-tailed amphipod	–	S3	–	Caves/Karst (Springs)	–
Crustaceans	*Faxonius meeki meeki*	Meek's crayfish	–	S1	–	Rivers/Streams	Springs
Crustaceans	*Cambarus maculatus*	Freckled crayfish	–	S3	–	Rivers/Streams	–
Crustaceans	*Faxonella clypeata*	Shield crayfish	–	S2S3	–	Rivers/Streams	Wetland
Crustaceans	*Macrobrachium ohione*	Ohio shrimp	–	S1	–	Rivers/Streams	–
Crustaceans	*Faxonius medius*	Saddleback crayfish	–	S3?	–	Rivers/Streams	–
Crustaceans	*Faxonius roberti*	Spring River crayfish	–	SH	–	Rivers/Streams	–
Crustaceans	*Faxonius eupunctus*	Coldwater crayfish	SE	S1	–	Rivers/Streams	–
Crustaceans	*Faxonius harrisonii*	Belted crayfish	–	S3	–	Rivers/Streams	–
Crustaceans	*Faxonius marchandi*	Mammoth Spring crayfish	–	S1S2	–	Rivers/Streams	Wetland
Crustaceans	*Faxonius peruncus*	Big Creek crayfish	–	S2	–	Rivers/Streams	–
Crustaceans	*Faxonius quadruncus*	St. Francis River crayfish	–	S2	–	Rivers/Streams	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Crustaceans	*Faxonius williamsi*	Williams' crayfish	–	S2	–	Rivers/Streams	
Crustaceans	*Lacunicambarus ludovicianus*	Painted devil crayfish	–	SU	–	Rivers/Stream Floodplain	Wetland
Crustaceans	*Lacunicambarus polychromatus*	Paintedhand mudbug	–	S1/S2	–	Rivers/Stream Floodplain	Wetland
Crustaceans	*Faxonius wagneri*	Eleven Point River crayfish	–	S1	–	Rivers/Streams	–
Crustaceans	*Creaserinus fodiens*	Digger crayfish	–	S2S3	–	Wetland	Rivers/Streams
Crustaceans	*Faxonius lancifer*	Shrimp crayfish	–	S1S2	–	Wetland (Pond)	Rivers/Streams
Crustaceans	*Triops longicaudatus*	Longtail tadpole shrimp	–	SU	–	Wetland (Pond)	–
Millipedes	*Causeyella dendropus*	Causeyella Cave millipede	–	S2	–	Caves/Karst	–
Millipedes	*Chaetaspis aleyorum*	Aleys' Cave millipede	–	S1	–	Caves/Karst	–
Millipedes	*Zosteractis interminata*	Zosteractis Cave millipede	–	SU	–	Caves/Karst	–
Insects	*Andrena (Scrapteropsis) rubi*	A solitary bee	–	S1	?	Woodland	Prairie/Grassland
Insects	*Anthophora (Melea) bomboides*	Bumblebee-like digger bee	–	S1	?	Prairie/Grassland	Woodland
Insects	*Anthophorula (Anthophorisca) pygmaea*	A bee	–	S1	?	Prairie/Grassland	Savanna
Insects	*Atryonopsis hianna*	Dusted skipper	–	S2S4	?	Prairie/Grassland	?

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Insects	*Atyrone arogos*	Arogos skipper	–	S2?	?	Prairie/Grassland	?
Insects	*Autocthon cellus*	Golden banded skipper	–	SU	?	Woodland	Forest
Insects	*Bombus (Pyrobombus) vagans*	Half-black bumblebee	–	SU	?	Forest	Woodland
Insects	*Bombus (Thoracobombus) fervidus*	Yellow bumblebee	–	S1	?	Prairie/Grassland	?
Insects	*Bombus (Thoracobombus) pensylvanicus*	American bumblebee	–	S3	?	Prairie/Grassland	Developed: Agriculture
Insects	*Bombus faternus*	Southern plains bumblebee	–	S4		Prairie/Grassland	
Insects	*Coelioxys (Boreocoelioxys) porterae*	Porter's cuckoo leafcutter bee	–	S1	?	Prairie/Grassland	?
Insects	*Coelioxys (Boreocoelioxys) rufitarsis*	Red-legged cuckoo leafcutter bee	–	S1	?	Prairie/Grassland	Woodland
Insects	*Coelioxys (Syncoelioxys) texana*	A leafcutter bee	–	S1	?	Prairie/Grassland	Savanna
Insects	*Colletes aestivalis*	A cellophane bee	–	S1/S2	?	Woodland	Prairie/Grassland
Insects	*Danaus plexippus*	Monarch butterfly	–	–	x	Prairie/Grassland	Glade, Wetland, Developed: Agri.
Insects	*Diadasia afflicta*	A solitary bee	–	S1	?	Prairie/Grassland	Glade
Insects	*Eucera (Synhalonia) fulvohirta*	A long-horned bee	–	S1	?	Prairie/Grassland	Developed: Agriculture
Insects	*Hesperapis carinata*	A melittid bee	–	S1	?	Prairie/Grassland	?

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Insects	*Hesperia ottoe*	Ottoe skipper	–	S1	?	Grassland	?
Insects	*Hoplitis (Robertsonella) micheneri*	A bee	–	S1	?	Prairie/Grassland (Wet prairie)	Wetland
Insects	*Lasioglossum (Dialictus) heterognathum*	Wide-mouthed sweat bee	–	S1	?	Prairie/Grassland (Wet prairie)	Wetland
Insects	*Lasioglossum (Evalaeus) fedorense*	A sweat bee	–	S1	?	Prairie/Grassland	Developed: Agriculture
Insects	*Lasioglossum (Lasioglossum) paraforbesii*	Bald-spot sweat bee	–	S1	?	Prairie/Grassland	Wetland
Insects	*Lasioglossum (Sphecodogastra) oenotherae*	Evening primrose sweat bee	–	S1	?	Prairie/Grassland	Glade
Insects	*Lasioglossum (Dialictus) testaceum*	Pale-marked sweat bee	–	S1	?	Prairie/Grassland	Wetland
Insects	*Lithurguis (Lithurgopsis) gibbosus*	A woodborer bee	–	S1	?	Prairie/Grassland	Glade
Insects	*Macropis steironematis*	An oil-collecting bee	–	S1	?	Prairie/Grassland	Woodland
Insects	*Megachile (Megachile) relativa*	Relative leafcutter bee	–	S1	?	Prairie/Grassland	Wetland
Insects	*Megachile (Xanthosarus) ingenua*	A leafcutter bee	–	S1	?	Prairie/Grassland	Glade
Insects	*Megachile (Xanthosarus) mucida*	A leafcutter bee	–	S1	?	Prairie/Grassland	Savanna
Insects	*Nomada asteris*	A cuckoo bee	–	S1	?	Prairie/Grassland	Savanna
Insects	*Nomada besseyi*	Bessy's cuckoo nomad bee	–	S1	?	Woodland	Savanna

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Insects	*Nomada fervida*	A cuckoo bee	–	S1	?	Prairie/Grassland	Wetland
Insects	*Nomada placida*	Placid cuckoo nomad bee	–	S1	?	Prairie/Grassland	?
Insects	*Nomada sclestus*	A cuckoo bee	–	S1	?	Prairie/Grassland	?
Insects	*Osmia (Diceratosmia) subfasciata*	A mason bee	–	S1	?	Prairie/Grassland	Woodland
Insects	*Osmia (Helicosmia) texana*	Texas mason bee	–	S1	?	Prairie/Grassland	Woodland
Insects	*Osmia (Melanosmia) illinoensis*	A mason bee	–	S1	?	Grassland	Glade
Insects	*Osmia (Melanosmia) inspergens*	Shiny-faced mason bee	–	S1	?	Prairie/Grassland	Developed: Agriculture
Insects	*Osmia (Melanosmia) sandhouseae*	A mason bee	–	S1	?	Woodland	?
Insects	*Osmia (Melanosmia) simillima*	Similar mason bee	–	S1	?	Woodland	?
Insects	*Panurginus potentillae*	A miner bee	–	S1	?	Prairie/Grassland	Woodland
Insects	*Papilio joanae*	Ozark woodland swallowtail	–	SU	?	Forest	Woodland
Insects	*Problema byssus*	Byssus skipper	–	S3	?	Grassland/Prairie (Wet Prairie)	Woodland
Insects	*Polistes annularis*	A paper wasp	–	–	X	Cliff/Talus	–
Insects	*Svastra (Epimelissodes) compta*	A longhorned beetle	–	S1	?	Prairie/Grassland	?

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Insects	*Svastra (Epimelissodes) texana*	A longhorned bee	–	S1	?	Woodland	?
Insects	*Tetraloniella albata*	An anthophorid bee	–	S1	?	Prairie/Grassland	?
Insects	*Tetraloniella paenalbata*	An anthophorid bee	–	S1	?	Prairie/Grassland	?
Insects	*Tetraloniella spissa*	An anthophorid bee	–	S1	?	Prairie/Grassland	?
Insects	*Neoconocephalus exiliscanorus*	Slightly musical conehead katydid	–	S3	–	Wetland	–
Insects	*Pentacora signoreti*	A shore bug	–	S1	–	Wetland	–
Insects	*Argia alberta*	Paiute dancer	–	S1	–	Wetland (Emergent Marsh)	–
Insects	*Nehalennia irene*	Sedge sprite	–	S1	–	Wetland (Emergent Marsh)	–
Insects	*Paroxya hoosieri*	Hoosier grasshopper	–	S1	–	Wetland (Emergent Marsh)	–
Insects	*Amphiagrion saucium*	Eastern red damsel	–	S2	–	Wetland (Fen)	–
Insects	*Nehalennia gracilis*	Sphagnum sprite	–	S1	X	Wetland (Fen)	–
Insects	*Somatochlora hineana*	Hine's emerald	E, SE	S2	X	Wetland (Fen)	–
Insects	*Neoconocephalus lyristes*	Bog conehead katydid	–	S1	–	Wetland (Fen, Emergent Marsh)	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Insects	*Calephelis muticum*	Swamp metalmark	–	S3	X	Wetland (Fen, swamp)	
Insects	*Euphyes dukesi dukesi*	Duke's skipper	–	S1	–	Wetland (Forested swamp)	–
Insects	*Inscudderia taxodii*	Bald cypress katydid	–	S1	X	Wetland (Forested Swamp)	Forest (Bottomland forest)
Insects	*Tettigidea armata*	Spined grouse locust	–	S2S3	–	Wetland (Forested Swamp)	–
Insects	*Arigomphus maxwelli*	Bayou clubtail	–	SU	–	Wetland (Swamp, marsh)	–
Insects	*Amblyscirtes linda*	Linda's roadside skipper	–	S2S3	–	Woodland	Rivers/Streams
Insects	*Calephelis borealis*	Northern metalmark	–	S1	–	Woodland	–
Insects	*Formica creightoni*	Creighton's slavemaking ant	–	S3	–	Woodland	–
Insects	*Polyergus longicornis*	Longhorned shining amazon ant	–	S1	–	Woodland	–
Insects	*Satyrodes appalachia leeuwi*	Appalachian eyed brown	–	S1	–	Woodland	Wetland (Swamp)
Insects	*Maccaffertium bednariki*	A heptageniid mayfly		S3		Rivers/Streams	
Insects	*Lasia pururata*	Purple small-headed fly		SU	–	Glade	
Insects	*Phrixocnemis truculentus*	Truculent camel cricket		SU	–	Glade	
Insects	*Amblytropidia mysteca*	A glade grasshopper		SU	X	Glade	

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Insects	*Pardalophora saussurei*	A glade grasshopper		SU	X	Glade	
Insects	*Acroneuria ozarkensis*	Ozark stonefly		S2	–	Cave/Karst	
Insects	*Agapetus artesus*	Artesian agapetus caddisfly		S3	–	Caves/Karst	
Insects	*Catocala marmorata*	Marbled underwing moth		S3	–	Caves/Karst	
Insects	*Glyphopsyche missouri*	Missouri glyphopsyche caddisfly		S1	–	Caves/Karst	
Insects	*Oncopodura hoffi*	Hoff's Cave springtail		S1S3	–	Caves/Karst	
Insects	*Pseudosinella espana*	Espana Cave springtail		S3	–	Caves/Karst	
Insects	*Sinella avita*	Avita Cave springtail		SU	–	Caves/Karst	
Insects	*Sinella barri*	Barr's Cave springtail		SU	–	Caves/Karst	
Insects	*Tomocerus missus*	Missus Cave springtail		SU	–	Caves/Karst	
Insects	*Xenotrechus condei*	Northern xenotrechus cave beetle		S1	–	Caves/Karst	
Insects	*Xenotrechus denticollis*	Southern xenotrechus cave beetle		S1	–	Caves/Karst	
Insects	*Gomphus fraternus*	Midland clubtail		SU	–	Rivers/Streams	
Insects	*Gomphus ventricosus*	Skillet clubtail		SU	–	Rivers/Streams	

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Insects	*Hydroperla fugitans*	Austin springfly		S3	–	Rivers/Streams	
Insects	*Neotridactylus apicialis*	Larger pygmy mole grasshopper		SU	–	Rivers/Streams	
Insects	*Ochrotrichia contorta*	Contorted ochrotrichian micro caddisfly		SU	–	Rivers/Streams	
Insects	*Serratella frisoni*	Frison's seratellan mayfly		S2	–	Rivers/Streams	
Insects	*Somatochlora provocans*	Treetop emerald		S1	–	Rivers/Streams	
Insects	*Stylurus notatus*	Elusive clubtail		S2S3	–	Rivers/Streams	
Insects	*Somatochlora ozarkensis*	Ozark emerald		SU	–	Rivers/Streams	
Fish	*Troglichthys rosae*	Ozark cavefish	T, SE	S2	–	Caves/Karst	–
Fish	*Cottus specus*	Grotto sculpin	E	S1	–	Caves/Karst	–
Fish	*Typhlichthys eigenmanni*	Southern cavefish	–	S2S3	–	Caves/Karst	–
Fish	*Forbesichthys agassizii*	Spring cavefish	SE	S1	–	Caves/Karst (Springs)	–
Fish	*Carpiodes velifer*	Highfin carpsucker	–	S2	–	Rivers/Streams	–
Fish	*Cyprinella camura*	Bluntface shiner	–	S2S3	–	Rivers/Streams	–
Fish	*Cyprinella galactura*	Whitetail shiner	–	–	X	Rivers/Streams	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Fish	*Cyprinella whipplei*	Steelcolor shiner	–	–	X	Rivers/Streams	–
Fish	*Erimystax harryi*	Ozark chub	–	–	X	Rivers/Streams	–
Fish	*Erimystax x-punctatus*	Gravel chub	–	–	X	Rivers/Streams	–
Fish	*Etheostoma cragini*	Arkansas darter	–	S3S4	–	Rivers/Streams	Ozark
Fish	*Etheostoma euzonum erizonum*	Current saddled darter	–	S3	–	Rivers/Streams	–
Fish	*Etheostoma euzonum euzonum*	Arkansas saddled darter	–	S2	–	Rivers/Streams	–
Fish	*Etheostoma whipplei*	Redfin darter	SE	S1	–	Rivers/Streams	Ozark
Fish	*Ichthyomyzon fossor*	Northern brook lamprey	–	–	X	Rivers/Streams	–
Fish	*Ichthyomyzon gagei*	Southern brook lamprey	–	S2S3	–	Rivers/Streams	–
Fish	*Lethenteron appendix*	American brook lamprey	–	S2	–	Rivers/Streams	–
Fish	*Luxilus cardinalis*	Cardinal shiner	–	–	X	Rivers/Streams	–
Fish	*Luxilus pilsbryi*	Duskystripe shiner	–	–	X	Rivers/Streams	–
Fish	*Luxilus zonatus*	Bleeding shiner	–	–	X	Rivers/Streams	–
Fish	*Moxostoma anisurum*	Silver redhorse	–	–	X	Rivers/Streams	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Fish	*Moxostoma carinatum*	River redhorse	–	–	X	Rivers/Streams	–
Fish	*Notropis greenei*	Wedgespot shiner	–	–	X	Rivers/Streams	–
Fish	*Notropis ozarcanus*	Ozark shiner	–	S2	–	Rivers/Streams	–
Fish	*Noturus eleutherus*	Mountain madtom	SE	S1S2	–	Rivers/Streams	–
Fish	*Noturus flavater*	Checkered madtom	–	S3S4	X	Rivers/Streams	–
Fish	*Noturus placidus*	Neosho madtom	T, SE	S1	–	Rivers/Streams	–
Fish	*Percina copelandi*	Channel darter	–	S3	–	Rivers/Streams	–
Fish	*Percina maculata*	Blackside darter	–	–	X	Rivers/Streams	Mississippi Lowland
Fish	*Percina nasuta*	Longnose darter	SE	S1	–	Rivers/Streams	–
Fish	*Percina uranidea*	Stargazing darter	–	S2	–	Rivers/Streams	–
Fish	*Percopsis omiscomaycus*	Trout-perch	–	S1	–	Rivers/Streams	–
Fish	*Pimephales tenellus parviceps*	Eastern slim minnow	–	S2S3	–	Rivers/Streams	–
Fish	*Pimephales tenellus tenellus*	Western slim minnow	–	S3	–	Rivers/Streams	Ozark
Fish	*Acipenser fulvescens*	Lake sturgeon	SE	S1	X	Rivers/Streams (Big River)	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Fish	*Alosa alabamae*	Alabama shad	–	S2	X	Rivers/Streams (Big River)	
Fish	*Alosa chrysochloris*	Skipjack herring	–	–	X	Rivers/Streams (Big River)	–
Fish	*Ammocrypta clara*	Western sand darter	–	S2S3	X	Rivers/Streams (Big River)	–
Fish	*Anguilla rostrata*	American eel	–	–	X	Rivers/Streams (Big River)	–
Fish	*Atractosteus spatula*	Alligator gar	–	S1	X	Rivers/Streams (Big River)	–
Fish	*Cycleptus elongatus*	Blue sucker	–	–	X	Rivers/Streams (Big River)	–
Fish	*Hiodon tergisus*	Mooneye	–	–	X	Rivers/Streams (Big River)	–
Fish	*Hybognathus argyritis*	Western silvery minnow	–	S2	X	Rivers/Streams (Big River)	–
Fish	*Hybognathus nuchalis*	Mississippi silvery minnow	–	S3S4	X	Rivers/Streams (Big River)	–
Fish	*Hybognathus placitus*	Plains minnow	–	S2	X	Rivers/Streams (Big River)	–
Fish	*Macrhybopsis gelida*	Sturgeon chub	–	S3	X	Rivers/Streams (Big River)	–
Fish	*Macrhybopsis meeki*	Sicklefin chub	–	–	X	Rivers/Streams (Big River)	–
Fish	*Macrhybopsis storeriana*	Silver chub	–	–	X	Rivers/Streams (Big River)	–
Fish	*Notropis shumardi*	Silverband shiner	–	–	X	Rivers/Streams (Big River)	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Fish	*Percina shumardi*	River darter	–	S3	X	Rivers/Streams (Big River)	Mississippi Lowland
Fish	*Platygobio gracilis*	Flathead chub	SE	S1	X	Rivers/Streams (Big River)	Prairie
Fish	*Polyodon spathula*	Paddlefish	–	–	X	Rivers/Streams (Big River)	–
Fish	*Scaphirhynchus albus*	Pallid sturgeon	E, SE	S1	X	Rivers/Streams (Big River)	–
Fish	*Scaphirhynchus platorynchus*	Shovelnose sturgeon	T	–	X	Rivers/Streams (Big River)	–
Fish	*Etheostoma microperca*	Least darter	–	S2	–	Rivers/Streams (Grassland/Prairie)	Ozark
Fish	*Fundulus kansae*	Northern plains killifish	–	S2	–	Rivers/Streams (Grassland/Prairie)	–
Fish	*Fundulus sciadicus*	Plains topminnow	–	S3	X	Rivers/Streams (Grassland/Prairie)	Ozark
Fish	*Hybognathus hankinsoni*	Brassy minnow	–	–	X	Rivers/Streams (Grassland/Prairie)	–
Fish	*Luxilus cornutus*	Common shiner	–	–	X	Rivers/Streams (Grassland/Prairie)	Ozark
Fish	*Notropis heterolepis*	Blacknose shiner	–	S2	-	Rivers/Streams (Grassland/Prairie)	Ozark
Fish	*Notropis topeka*	Topeka shiner	E, SE	S1	–	Rivers/Streams (Grassland/Prairie)	–
Fish	*Ameiurus nebulosus*	Brown bullhead	–	S3	–	Rivers/Streams (Mississippi Lowland)	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Fish	*Ammocrypta vivax*	Scaly sand darter	–	S3	X	Rivers/Streams (Mississippi Lowland)	–
Fish	*Centrarchus macropterus*	Flier	–	S3	X	Rivers/Streams (Mississippi Lowland)	–
Fish	*Crystallaria asprella*	Crystal darter	SE	S1	X	Rivers/Streams (Mississippi Lowland)	Ozark / Forest
Fish	*Elassoma zonatum*	Banded pygmy sunfish	–	–	X	Rivers/Streams (Mississippi Lowland)	–
Fish	*Erimyzon sucetta*	Lake chubsucker	–	S2	–	Rivers/Streams (Mississippi Lowland)	Ozark
Fish	*Etheostoma fusiforme*	Swamp darter	SE	S1	–	Rivers/Streams (Mississippi Lowland)	–
Fish	*Etheostoma histrio*	Harlequin darter	SE	S2	X	Rivers/Streams (Mississippi Lowland)	–
Fish	*Etheostoma parvipinne*	Goldstripe darter	SE	S1	–	Rivers/Streams (Mississippi Lowland)	–
Fish	*Fundulus chrysotus*	Golden topminnow	–	S1	–	Rivers/Streams (Mississippi Lowland)	–
Fish	*Fundulus dispar*	Starhead topminnow	–	S2	X	Rivers/Streams (Mississippi Lowland)	–
Fish	*Hybognathus hayi*	Cypress minnow	SE	S1	X	Rivers/Streams (Mississippi Lowland)	Wetland (Pond)
Fish	*Lepomis marginatus*	Dollar sunfish	–	S2	–	Rivers/Streams (Mississippi Lowland)	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Fish	*Lepomis symmetricus*	Bantam sunfish	–	S2	–	Rivers/Streams (Mississippi Lowland)	–
Fish	*Lythrurus fumeus*	Ribbon shiner	–	–	X	Rivers/Streams (Mississippi Lowland)	–
Fish	*Notropis chalybaeus*	Ironcolor shiner	–	S1	X	Rivers/Streams (Mississippi Lowland)	–
Fish	*Notropis maculatus*	Taillight shiner	SE	S1	X	Rivers/Streams (Mississippi Lowland)	–
Fish	*Notropis sabinae*	Sabine shiner	SE	S1	–	Rivers/Streams (Mississippi Lowland)	–
Fish	*Notropis texanus*	Weed shiner	–	S3	X	Rivers/Streams (Mississippi Lowland)	–
Fish	*Etheostoma nianguae*	Niangua darter	T, SE	S2	–	Rivers/Streams (Ozark)	–
Fish	*Lampetra aepyptera*	Least brook lamprey	–	–	X	Rivers/Streams (Ozark)	–
Fish	*Percina cymatotaenia*	Bluestripe darter	–	S2	–	Rivers/Streams (Ozark)	–
Fish	*Notropis buchanani*	Ghost shiner	–	S2	X	Wetland	Big River
Fish	*Umbra limi*	Central mudminnow	SE	S1	–	Wetland	Big River
Amphibians	*Eurycea lucifuga*	Cave salamander	–	–	X	Caves/Karst	Forest, Cliff/Talus
Amphibians	*Eurycea spelaea*	Grotto salamander	–	S2/S3	X	Caves/Karst	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Amphibians	*Ambystoma annulatum*	Ringed salamander	–	S3	X	Forest	Wetland
Amphibians	*Eurycea longicauda longicauda*	Long-tailed salamander	–	–	X	Forest	–
Amphibians	*Eurycea longicauda melanopleura*	Dark-sided salamander	–	–	X	Forest	–
Amphibians	*Hemidactylium scutatum*	Four-toed salamander	–	S4	X	Forest	Wetland, Talus
Amphibians	*Lithobates sylvaticus*	Wood frog	–	S3	X	Forest	Wetland
Amphibians	*Plethodon albagula*	Western slimy salamander	–	–	X	Forest	Caves/Karst
Amphibians	*Plethodon angusticlavius*	Ozark zigzag salamander	–	–	X	Forest	Cliff/Talus
Amphibians	*Plethodon serratus*	Southern red-backed salamander	–	–	X	Forest	Cliff/Talus
Amphibians	*Lithobates palustris*	Pickerel frog	–	–	X	Forest	Wetland, Cliff/Talus
Amphibians	*Ambystoma talpoideum*	Mole salamander	–	S2	X	Forest (Bottomland Forest)	Wetland
Amphibians	*Ambystoma texanum*	Small-mouthed salamander	–	–	X	Grassland/Prairie	Forest (Bottomland forest)
Amphibians	*Ambystoma tigrinum*	Eastern tiger salamander	–	S3	X	Grassland/Prairie	Savanna
Amphibians	*Gastrophryne olivacea*	Western narrow-mouthed toad	–	–	X	Grassland/Prairie	–
Amphibians	*Lithobates areolatus circulosus*	Northern crawfish frog	–	S3	X	Grassland/Prairie	Wetland

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Amphibians	*Pseudacris illinoensis*	Illinois chorus frog	–	S2	–	Grassland/Prairie (Sand prairie)	Wetland
Amphibians	*Scaphiopus holbrookii*	Eastern spadefoot	–	S2	–	Grassland/Prairie (Sand prairie)	Wetland
Amphibians	*Anaxyrus fowleri*	Fowler's toad	–	–	X	Rivers/Streams	–
Amphibians	*Cryptobranchus alleganiensis alleganiensis*	Eastern hellbender	SE	S1	X	Rivers/Streams	–
Amphibians	*Cryptobranchus alleganiensis bishopi*	Ozark hellbender	E, SE	S1	X	Rivers/Streams	–
Amphibians	*Eurycea tynerensis*	Oklahoma salamander	–	–	X	Rivers/Streams	–
Amphibians	*Acris blanchardi*	Blanchard's cricket frog	–	–	X	Wetland	–
Amphibians	*Amphiuma tridactylum*	Three-toed amphiuma	–	S2	X	Wetland	Rivers/Streams
Amphibians	*Anaxyrus cognatus*	Great plains toad	–	S3	–	Wetland	Big river
Amphibians	*Hyla cinerea*	Green treefrog	–	–	x	Wetland	–
Amphibians	*Lithobates blairi*	Plains leopard frog	–	–	x	Wetland	Grassland/Prairie
Amphibians	*Lithobates sphenocephalus*	Southern leopard frog	–	–	x	Wetland	–
Amphibians	*Spea bombifrons*	Plains spadefoot	–	–	X	Wetland	Big river
Reptiles	*Scinella lateralis*	Little brown skink	–	–	X	Forest	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Reptiles	*Storeria occiptomaculata occipitomaculata*	Northern red-bellied snake	–	–	X	Forest	–
Reptiles	*Crotalus horridus*	Timber rattlesnake	–	–	X	Forest/Woodland	Cliff/Talus
Reptiles	*Crotaphytus collaris*	Eastern collared lizard	–	S4	X	Glade	–
Reptiles	*Pantherophis emoryi*	Great plains ratsnake	–	–	X	Glade	Forest
Reptiles	*Plestiodon anthracinus pluvialis*	Southern coal skink	–	–	X	Glade	Woodland
Reptiles	*Masticophis flagellum flagellum*	Eastern coachwhip	–	–	X	Glade	Woodland
Reptiles	*Sistrurus miliarius streckeri*	Western pygmy rattlesnake	–	–	X	Glade	Woodland
Reptiles	*Sonora semiannulata semiannulata*	Variable groundsnake	–	–	X	Glade	–
Reptiles	*Tantilla gracilis*	Flat-headed snake	–	–	X	Glade	–
Reptiles	*Ophisaurus attenuatus attenuatus*	Western slender glass lizard	–	–	X	Grassland/Prairie	–
Reptiles	*Pantherophis ramspotti*	Western foxsnake	–	S1	X	Grassland/Prairie	Wetland
Reptiles	*Pantherophis vulpinus*	Eastern foxsnake	–	S1	X	Grassland/Prairie	Wetland
Reptiles	*Pituophis catenifer sayi*	Bullsnake	–	SU	X	Grassland/Prairie	Savanna
Reptiles	*Plestiodon obsoletus*	Great plains skink	–	S2	X	Grassland/Prairie	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Reptiles	*Plestiodon septentrionalis obtusirostris*	Southern prairie skink	–	S3	X	Grassland/Prairie	–
Reptiles	*Plestiodon septentrionalis septentrionalis*	Northern prairie skink	–	S3	X	Grassland/Prairie	–
Reptiles	*Terrapene ornata ornata*	Plains box turtle	–	–	X	Grassland/Prairie	Savanna
Reptiles	*Thamnophis radix*	Plains gartersnake	–	–	X	Grassland/Prairie	Wetland
Reptiles	*Tropidoclonion lineatum*	Lined snake	–	–	X	Grassland/Prairie	–
Reptiles	*Heterodon gloydi*	Dusty hog-nosed snake	–	S1	–	Grassland/Prairie (Sand prairie)	–
Reptiles	*Clonophis kirtlandii*	Kirtland's snake	–	S1	–	Grassland/Prairie (Wet prairie)	–
Reptiles	*Sistrurus tergeminus tergeminus*	Prairie massasauga	SE	S1	–	Grassland/Prairie (Wet prairie)	–
Reptiles	*Apalone mutica mutica*	Midland smooth softshell turtle	–	–	X	Rivers/Streams	–
Reptiles	*Macrochelys temminckii*	Alligator snapping turtle	–	S2	X	Rivers/Streams	Wetland
Reptiles	*Cemophora coccinea copei*	Northern scarlet snake	–	S2S3	–	Savanna	Woodland
Reptiles	*Chrysemys dorsalis*	Southern painted turtle	–	–	X	Wetland	Forest (Bottomland forest)
Reptiles	*Deirochelys reticularia miaria*	Western chicken turtle	SE	S1	X	Wetland	Forest (Bottomland forest)
Reptiles	*Emydoidea blandingii*	Blanding's turtle	SE	S1	X	Wetland	Grassland/Prairie

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Reptiles	*Farancia abacura reinwardtii*	Western mudsnake	–	S2	X	Wetland	Forest (Bottomland forest)
Reptiles	*Kinosternon flavescens*	Yellow mud turtle	SE	S1	–	Wetland	Grassland/Prairie
Reptiles	*Regina grahamii*	Graham's crawfish snake	–	–	X	Wetland	Grassland/Prairie (Wet prairie)
Reptiles	*Sceloporus consobrinus*	Prairie lizard	–	–	X	Woodland	Glade, Cliff/Talus
Reptiles	*Terrapene carolina triunguis*	Three-toed box turtle	–	–	X	Woodland	–
Reptiles	*Agkistrodon piscivorous leucostoma*	Western cottonmouth	–	–	X	River/Stream	Wetland/Cliff/Talus
Reptiles	*Nerodia sipedon*	Northern water snake	–	–	X	River/Stream	Wetland/Cliff/Talus
Reptiles	*Plestiodon fasciatus*	Five-lined skink	–	–	X	Woodland	Cliff/Talus
Reptiles	*Opheodrys aestivus*	Rough green snake	–	–	X	Forest	Cliff/Talus
Birds	*Accipiter striatus*	Sharp-shinned hawk	–	S2	–	Forest	–
Birds	*Chaetura pelagica*	Chimney swift	–	–	X	Forest	Woodland
Birds	*Coccyzus americanus*	Yellow-billed cuckoo	–	–	X	Forest	–
Birds	*Cyanocitta cristata*	Blue jay	–	–	X	Forest	Anywhere with trees
Birds	*Dendroica dominica*	Yellow-throated warbler	–	–	X	Forest	Wetland (Swamp)

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Birds	*Empidonax virescens*	Acadian flycatcher	–	–	X	Forest	Wetland (Swamp)
Birds	*Helmitheros vermivorus*	Worm-eating warbler	–	–	X	Forest	–
Birds	*Hylocichla mustelina*	Wood thrush	–	–	X	Forest	–
Birds	*Protonotaria citrea*	Prothonotary warbler	–	–	X	Forest	–
Birds	*Seiurus motacilla*	Louisiana waterthrush	–	–	X	Forest	–
Birds	*Setophaga cerulea*	Cerulean warbler	–	S2S3	X	Forest	Forest (Riparian forest)
Birds	*Limnothlypis swainsonii*	Swainson's warbler	SE	S2	X	Forest (Bottomland Forest)	–
Birds	*Geothlypis formosa*	Kentucky warbler	–	–	X	Forest/Woodland	–
Birds	*Geococcyx californianus*	Greater roadrunner	–	S3	X	Glade	–
Birds	*Icteria virens*	Yellow-breasted chat	–	–	X	Glade	Savanna
Birds	*Passerina ciris*	Painted bunting	–	S3	X	Glade	–
Birds	*Peucaea aestivalis*	Bachman's sparrow	SE	S1	X	Glade	–
Birds	*Ammodramus henslowii*	Henslow's sparrow	–	–	X	Grassland/Prairie	–
Birds	*Ammodramus savannarum*	Grasshopper sparrow	–	–	X	Grassland/Prairie	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Birds	*Asio flammeus*	Short-eared owl	–	S2	X	Grassland/Prairie	–
Birds	*Bartramia langicauda*	Upland sandpiper	–	–	X	Grassland/Prairie	–
Birds	*Circus hudsonius*	Northern harrier	SE	S2	X	Grassland/Prairie	Wetland (Marsh)
Birds	*Colinus virginianus*	Northern bobwhite	–	–	X	Grassland/Prairie	Woodland
Birds	*Dolichonyx oryzivorus*	Bobolink	–	–	X	Grassland/Prairie	–
Birds	*Lanius ludovicianus*	Loggerhead shrike	–	S2	X	Grassland/Prairie	–
Birds	*Spiza americana*	Dickcissel	–	–	X	Grassland/Prairie	–
Birds	*Sturnella magna*	Eastern meadowlark	–	–	X	Grassland/Prairie	–
Birds	*Tympanuchus cupido*	Greater prairie-chicken	SE	S1	X	Grassland/Prairie	–
Birds	*Tyto alba*	Barn owl	–	S3	–	Grassland/Prairie	–
Birds	*Tyrannus tyrannus*	Eastern kingbird	–	–	X	Grassland/Prairie	–
Birds	*Haliaeetus leucocephalus*	Bald eagle	–	S3	X	Rivers/Streams (Big River)	Wetlands
Birds	*Vireo bellii*	Bell's vireo	–	–	X	Rivers/Streams (Grassland/Prairie)	–
Birds	*Dendroica discolor*	Prairie warbler	–	–	X	Savanna	Glade

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Birds	*Spizella pusilla*	Field sparrow	–	–	X	Savanna	Glade
Birds	*Toxostoma rufum*	Brown thrasher	–	–	X	Savanna	Glade
Birds	*Vermivora pinus*	Blue-winged warbler	–	–	X	Savanna	–
Birds	*Icterus spurius*	Orchard oriole	–	–	X	Savanna	Woodland
Birds	*Ardea alba*	Great egret	–	S3	–	Wetland	Forest (Bottomland forest)
Birds	*Botaurus lentiginosus*	American bittern	SE	S1	X	Wetland	–
Birds	*Cistothorus palustris*	Marsh wren	–	S3	–	Wetland	–
Birds	*Coturnicops noveboracensis*	Yellow rail	–	–	X	Wetland	–
Birds	*Butorides virescens*	Green heron	–	–	X	Wetland	–
Birds	*Egretta caerulea*	Little blue heron	–	S3	–	Wetland	–
Birds	*Egretta thula*	Snowy egret	SE	S1	–	Wetland	–
Birds	*Euphagus carolinus*	Rusty blackbird	–	–	X	Wetland	–
Birds	*Falco peregrinus*	Peregrine falcon	SE	S1	–	Cliff/Talus/Urban	–
Birds	*Gallinula galeata*	Common gallinule	–	S2	–	Wetland	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Birds	*Ixobrychus exilis*	Least bittern	–	S3	X	Wetland	–
Birds	*Nycticorax nycticorax*	Black-crowned night-heron	–	S3	X	Wetland	–
Birds	*Porzana carolina*	Sora	–	S2	X	Wetland	–
Birds	*Rallus elegans*	King rail	SE	S1	X	Wetland	–
Birds	*Rallus limicola*	Virginia rail	–	S2	X	Wetland	–
Birds	*Sterna antillarum athalassos*	Interior least tern	E, SE	S1	–	Wetland	–
Birds	*Caprimulgus carolinensis*	Chuck-will's-widow	–	–	X	Woodland	Glade
Birds	*Caprimulgus vociferus*	Eastern whip-poor-will	–	–	X	Woodland	Forest
Birds	*Contopus virens*	Eastern wood-pewee	–	–	X	Woodland	Forest
Birds	*Melanerpes erythrocephalus*	Red-headed woodpecker	–	–	X	Woodland	–
Birds	*Piranga rubra*	Summer tanager	–	–	X	Woodland	Glade
Birds	*Pipilo erythrophthalmus*	Eastern towhee	–	–	X	Woodland	–
Birds	*Quiscalus quiscula*	Common grackle	–	–	X	Woodland	Savanna
Birds	*Thryomanes bewickii*	Bewick's wren	–	–	X	Woodland	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Birds	*Cathartes aura*	Turkey vulture	–	–	X	Cliff/Talus	–
Birds	*Hirundo rustica*	Barn swallow	–	–	X	Cliff/Talus	–
Birds	*Petrochelidon pyrrhonota*	Cliff swallow	–	–	X	Cliff/Talus	–
Birds	*Sayornis phoebe*	Eastern phoebe	–	–	X	Cliff/Talus	–
Birds	*Stelgidopteryx serripennis*	Northern rough-winged swallow	–	–	X	Cliff/Talus	–
Birds	*Antigone canadensis*	Sandhill crane		S1	–	Wetland	
Mammals	*Neotoma floridana*	Eastern woodrat	–	–	X	Glade	Cliff/Talus
Mammals	*Corynorhinus rafinesquii*	Rafinesque's big-eared bat	–	S1	–	Caves/Karst	–
Mammals	*Myotis grisescens*	Gray bat	E, SE	S3	X	Caves/Karst	–
Mammals	*Myotis leibii*	Eastern small-footed myotis	–	S2	–	Glade	–
Mammals	*Lasionycteris noctivagans*	Silver-haired bat	–	S3	–	Forest	–
Mammals	*Spilogale putorius interrupta*	Plains spotted skunk	SE	S1	–	Forest	–
Mammals	*Myotis austroriparius*	Southeastern bat	–	S1	–	Wetland (Forested Swamp)	Caves/Karst
Mammals	*Ochrotomys nuttalli*	Golden mouse	–	S3	X	Forest (Bottomland Forest)	–

Taxa	Scientific Name	Common Name	Federal Status	State Rank	Characteristic Species	Primary Habitat	Secondary Habitat
Mammals	*Myotis septentrionalis*	Northern myotis (N. long eared bat)	T, SE	S1	–	Forest/Woodland	Caves/Karst
Mammals	*Lasiurus cinereus*	Hoary bat	–	S3	–	Forest/Woodland	–
Mammals	*Perimyotis subflavus*	Tri-colored bat	–	S2	–	Forest/Woodland	Caves/Karst
Mammals	*Myotis lucifugus*	Little brown myotis	–	S2	–	Forest/Woodland	Caves/Karst
Mammals	*Ursus americanus*	Black bear	–	–	X	Forest/Woodland	–
Mammals	*Lepus californicus*	Black-tailed jackrabbit	SE	–	–	Grassland/Prairie	–
Mammals	*Mustela frenata*	Long-tailed weasel	–	S3	–	Grassland/Prairie	Woodland
Mammals	*Mustela nivalis*	Least weasel	–	S3	–	Grassland/Prairie	–
Mammals	*Perognathus flavescens*	Plains pocket mouse	–	S1	X	Grassland/Prairie	–
Mammals	*Poliocitellus franklinii*	Franklin's ground squirrel	–	S2S3	X	Grassland/Prairie	–
Mammals	*Taxidea taxus*	American badger	–	S3	X	Grassland/Prairie	–
Mammals	*Oryzomys palustris*	Marsh rice rat	–	SU	X	Wetland	–
Mammals	*Peromyscus gossypinus*	Cotton mouse	–	S2	X	Wetland	Forest
Mammals	*Sylvilagus aquaticus*	Swamp rabbit	–	S2	X	Wetland	–
Mammals	*Myotis sodalis*	Indiana myotis	E, SE	S1	X	Woodland	Caves/Karst

Appendix I: Natural Community Health Index Example

Assessing and Monitoring the Ecological Integrity of Terrestrial Natural Communities – Natural Community Health Indices

Table I.1 – Current List of Available CHI Models (Crosswalked to the Terrestrial Natural Community Classification for Missouri)

Community Health Index	Nelson (2010) Community Type(s)
Glaciated plains woodland	Dry and dry-mesic loess/glacial till woodlands
Ozark woodland	Dry and dry-mesic limestone/dolomite, chert, sandstone, and igneous woodlands
Glaciated plains savanna	Dry-mesic loess/glacial till savanna
Loess hill prairie	Dry loess/glacial till prairie
Upland prairie glaciated	Dry-mesic and mesic loess/glacial till prairies
Upland prairie unglaciated	Dry-mesic limestone/dolomite prairie, dry-mesic chert prairie, dry-mesic sandstone/shale prairie
Hardpan (claypan) prairie glaciated	Hardpan prairie
Hardpan (claypan) prairie unglaciated	Hardpan prairie
Dolomite glade	Dolomite glade
Dolomite glade (White River Hills ecological subsection)	Dolomite glade
Igneous glade	Igneous glade
Limestone glade	Limestone glade
Sandstone glade	Sandstone glade

Table I.2 – List of Community Health Indices Needing Future Development (Crosswalked to the Terrestrial Natural Community Classification for Missouri).*

Community Health Index	Nelson (2010) Community Type(s)
Upland forest – Ozarks	Dry-mesic and mesic limestone/dolomite and sandstone forest, dry-mesic chert forest, and dry-mesic igneous forest
Upland forest – Glaciated Plains	Dry-mesic and mesic loess/glacial till forest
Sand Forests	Dry-mesic and mesic sand forests
Fire-adapted sand communities	Dry and dry-mesic sand woodlands, sand savanna and sand prairie
Ozark flatwoods	Upland flatwoods
Ozark bottomland forest	Dry-mesic and mesic bottomland forest
Ozark riparian forest	Riverfront forest
Mississippi lowlands upper bottomland forest	Mesic and wet-mesic bottomland forest
Mississippi lowlands lower bottomland forest	Wet bottomland forest and swamp
Mississippi lowlands riparian forest	Riverfront forest
Prairie plains upper bottomland forest	Mesic and wet-mesic bottomland forest
Prairie plains lower bottomland forest	Wet bottomland forest
Prairie plains riparian forest	Riverfront forest
Savanna – Ozark and Osage plains	Limestone/dolomite, chert and sandstone/shale savannas
Bottomland prairie – glaciated plains	Prairie swale, wet-mesic and wet bottomland prairies
Bottomland prairie – Osage plains	Prairie swale, wet-mesic and wet bottomland prairies
Prairie plains marsh	Marsh
Mississippi lowlands marsh	Marsh
Prairie plains shrub swamp	Shrub swamp
Mississippi lowlands shrub swamp	Shrub swamp
Ozark fen	Ozark fen

*Bottomland woodlands/flatwoods, cliff/talus communities, stream edge communities, sinkhole pond wetlands, certain groundwater seepage communities, and springs will be addressed later.

CHI Model for Dolomite Glade

Site Name:
Sampling Date:
Evaluator(s):

Directions

First, identify the boundaries of the community unit in ArcGIS. Use ArcGIS and site knowledge to fill in the answers to the metrics in Section I. Second, proceed to a walk-through of the community unit and answer all of the components of Sections I to IV of the assessment. Record how many personnel hours are spent surveying the unit. In general, two to four hours per 80 acres is a reasonable target for survey effort depending on site conditions. NOTE that for animal records, species recorded within the past five years on an area are acceptable to count in the index. Third, compute the value for the index as detailed below.

Section I – Landscape Context (accounts for 15 percent of the total possible score)

(Ia) Percentage of surrounding landscape (one-mile radius from the edge of the community boundaries) in native vegetation

%	Points
0–25	0.5
26–50	1
51–75	3
76+	4

Score: _____

(Ib) Size of the glade community

Acres	Points
< 3	1.87
3–5	3.75
6–10	5.63
10+	7.5

Score: _____

(Ic) Distance to associated community types (e.g., woodland)

Miles	Points
>1	0.75
0.6–1	1.5
0.25–0.5	2.25
<0.25	3

Score: _____

(Id) Presence of seep zones, ephemeral wetlands, and/or ephemeral streams embedded within the glade community
Yes = 0.5
No = 0
Score: _____

Overall Section I Landscape Context Score (sum of metric scores above): _____

Section II – Vegetation Characteristics (accounts for 75% of the total possible score)

Woody Vegetation

(IIa) Percentage eastern redcedar canopy cover

%	Points
0–10	6
11–25	3
26–50	1
>50	0

Score: _____

(IIb) Percentage canopy cover of native deciduous trees (e.g., chinkapin oak, gum bumelia, etc.)

%	Points
0–5	1
6–15	1.5
16–25	1
26–50	0.25
>50	0

Score: _____

(IIc) Percentage cover of native shrubs (e.g., dwarf hackberry, aromatic sumac, etc.)

%	Points
0–5	1
6–15	1.5
16–25	1
26–50	0.25
>50	0

Score: _____

(IId) Old-age character oak trees (post and chinkapin oaks) are present and the majority of them healthy and not suppressed.
Yes = 1
No = 0

Score: ____

Herbaceous Vegetation

(IIe) Percentage native warm-season grass cover

%	Points
0–25	1
26–50	5
51–75	5
76+	3

Score: _____

(IIf) Percentage Native forb cover

%	Points
0–25	1
26–50	5
51–75	5
76+	4

Score: _____

(IIg) Number of readily identifiable characteristic matrix plant species present. Point values are assigned for each species you see, up to the 40 possible on the list.

Coefficient*	Scientific Name	Common Name
5	*Andropogon gerardii*	Big bluestem
5	*Asclepias tuberosa*	Butterfly weed
5	*Asclepias viridis*	Green-flowered milkweed
6	*Astragalus canadensis*	Canadian milk vetch
6	*Astragalus distortus*	Bent milk vetch
6	*Berchemia scandens*	Supple Jack
5	*Berlandiera texana*	Green eyes
6	*Brickellia eupatorioides*	False boneset
6	*Camassia scilloides*	Wild hyacinth
6	*Carex meadii*	Mead's sedge
6	*Castilleja coccinea*	Indian paintbrush
6	*Celtis pumila*	Dwarf hackberry
5	*Coreopsis lanceolata*	Sand coreopsis

Coefficient*	Scientific Name	Common Name
5	*Draba cuneifolia*	Wedgeleaf draba
5	*Eleocharis compressa*	Flat-stemmed spike rush
5	*Glandularia canadensis*	Rose vervain
4	*Hedeoma pulegioides*	American pennyroyal
5	*Houstonia nigricans*	Narrow-leaved bluets
5	*Hypericum sphaerocarpum*	Round-fruited St. John's
5	*Hypoxis hirsuta*	Yellow star grass
6	*Liatris aspera*	Rough blazing star
6	*Lithospermum canescens*	Hoary puccoon
5	*Matelea decipiens*	Climbing milkweed
4	*Nothoscordum bivalve*	False garlic
4	*Onosmodium molle*	Marbleseed
4	*Opuntia humifusa*	Eastern prickly pear
6	*Parthenium integrifolium*	Wild quinine
6	*Phlox pilosa*	Prairie phlox
5	*Pycnanthemum pilosum*	Hairy mountain mint
6	*Rudbeckia missouriensis*	Missouri black-eyed Susan
5	*Schizachyrium scoparium*	Little bluestem
4	*Scutellaria parvula*	Small skullcap
4	*Silphium integrifolium*	Rosinweed
5	*Silphium terebinthinaceum*	Prairie dock
5	*Sisyrinchium campestre*	Prairie blue-eyed grass
6	*Solidago radula*	Rough goldenrod
4	*Sorghastrum nutans*	Indian grass
6	*Sporobolus heterolepis*	Prairie dropseed
6	*Symphyotrichum oblongifolium*	Aromatic aster
5	*Viola pedata*	Bird's foot violet

* Coefficient of conservatism, an index value of 0–10, indicating the ecological value of a plant species (Matthews et al. 2015). Missouri coefficients developed by Ladd and Thomas (2015).

Each species recorded is worth 0.175 points.

Total number of characteristic matrix species recorded: _____ x 0.175 = Score

Score: _____

(IIh) Relative abundance of characteristic matrix plant species present. What is the visually estimated abundance (relative to the total herbaceous cover, not the whole glade area) of all characteristic plant species noted taken as a whole?

Abundance Ranking	Points
Abundant or very frequently observed (>50%) of the area)	6.5
Frequently or commonly observed (31—50%)	5
Occasional or infrequently observed (11—30%)	3
Rare or very few individuals observed (≤ 10%)	2
Characteristic matrix species not present	0

Score: _____

(IIi) Number of readily identifiable conservative plant species present. Point values are assigned for each species you see, up to the 40 possible on the list.

Coefficient	Scientific Name	Common Name
8	*Allium cernuum*	Nodding Wild Onion
8	*Amorpha canescens*	Lead Plant
9	*Asclepias stenophylla*	Glade Milkweed
7	*Asclepias viridiflora*	Short Green Milkweed
7	*Astragalus crassicarpus*	Ground Plum
7	*Baptisia bracteata*	Cream Wild Indigo
7	*Bouteloua curtipendula*	Side-Oats Grama
10	*Buchnera americana*	Blue Hearts
10	*Carex crawei*	Crawe's Sedge
7	*Cheilanthes lanosa*	Hairy Lip-Fern
7	*Clinopodium arkansanum*	Low Calamint
7	*Coreopsis palmata*	Prairie Coreopsis
8	*Dalea candida*	White Prairie Clover
8	*Dalea purpurea*	Purple Prairie Clover
7	*Delphinium carolinianum*	Carolina Larkspur
7	*Echinacea pallida*	Pale Purple Coneflower
9	*Echinacea paradoxa*	Yellow Coneflower
7	*Echinacea simulata*	Glade Purple Coneflower
8	*Evolvulus nuttallianus*	Shaggy Evolvulus
7	*Fimbristylis puberula*	Glade Fimbry
9	*Gentiana puberulenta*	Downy Gentian
8	*Heliotropium tenellum*	Glade Heliotrope
7	*Leavenworthia uniflora*	Michaux's Leavenworthia
7	*Liatris cylindracea*	Cylindrical Blazing Star
7	*Manfreda virginica*	American Aloe
7	*Minuartia patula*	Slender Sandwort
7	*Oenothera macrocarpa*	Missouri Primrose

Coefficient	Scientific Name	Common Name
7	*Ophioglossum engelmannii*	Glade Adder's Tongue
9	*Parthenium hispidum*	Hairy Feverfew
8	*Pediomelum tenuiflorum*	Scurfy Pea
7	*Pellaea atropurpurea*	Purple Cliff Brake
7	*Primula meadia*	Shooting Star
10	*Scutellaria bushii*	Bush's Skullcap
7	*Scutellaria elliptica*	Hairy Skullcap
10	*Solidago gattingeri*	Gattinger's Goldenrod
7	*Solidago speciosa*	Showy Goldenrod
7	*Spiranthes magnicamporum*	Dune Ladies' Tresses
7	*Symphyotrichum laeve*	Smooth Blue Aster
7	*Symphyotrichum oolentangiense*	Azure Aster
9	*Symphyotrichum sericeum*	Silky Aster

Each species recorded is worth 0.525 points.

Total number of conservative species recorded: _____ x 0.525 = Score

Score: _____

(IIj) Relative abundance of conservative plant species present. What is the visually estimated abundance (relative to the total herbaceous cover, not the whole glade area) of all conservative plant species noted taken as a whole?

Abundance Ranking	Points
Abundant or very frequently observed (>50 % of the area)	20.5
Frequently or commonly observed (31–50%)	16
Occasional or infrequently observed (11–30%)	11
Rare or very few individuals observed (≤ 10%)	5
Conservative species not present	0

Score: _____

Overall Section II Vegetation Characteristics Score (sum of metric scores above):_____

Section III – Animal Species Factors (accounts for 10% of the total possible score)

Note that for animal species, presence of a species on the site recorded within the last five years based on other surveys or inventories is acceptable to count in this index.

(IIIa) Herptile species

List below the herptile species you observe:

Based on how many herptile species you observe, assign the point value as follows:

# Species	Points
1	0.75
2	1.5
3	2.25
4+	3

Score: _____

For each of the herptile species below that you observe, add 0.077 points up to a total of 1 point (round to 1):

Eastern Coachwhip
Eastern Collared Lizard
Eastern Narrow-mouthed Toad
Flat-headed Snake
Great Plains Ratsnake
Prairie Lizard
Prairie Racerunner
Red Milksnake
Rough Earthsnake
Southern Coal Skink
Variable Groundsnake
Western Pygmy Rattlesnake
Western Smooth Earthsnake

Each species recorded is worth 0.077 points

Total number of characteristic herptile species recorded: _____ x 0.077 = Score

Score: _____

(IIIb) Presence of tarantulas (*Aphonopelma hentzi*), scorpions (*Centruroides vittatus*):

0.5 points for each. Score: _____

(IIIc) Presence of bird species (see list below, 15 total) heard or seen during breeding season safe dates and times:

Blue-gray Gnatcatcher
Blue-winged Warbler
Chipping Sparrow
Eastern Bluebird
Eastern Towhee
Field Sparrow
Indigo Bunting
Northern Bobwhite
Painted Bunting
Prairie Warbler
Roadrunner
Summer Tanager
White-eyed Vireo
Yellow-breasted Chat
Yellow-billed Cuckoo

# Bird Species	Points
0	0
1–3	1
4–6	3
7–10	4
11+	5

Score:_____

Overall Section III Animal Species Score (sum of metric scores above):_____

Section IV – Disturbance Factors (negative points)

(IVa) Percentage cover of aggressive exotic plant species (e.g., sericea lespedeza):

%	Points
0	0
1–2	–0.25
3–10	–1
11–15	–3
16–25	–5
26–50	–8
>51	–10

Score: _____

(IVb) Evidence of recent feral hog use:
Yes = –1
No = 0

Score: _____

(IVc) Evidence of recent illegal herptile collecting, root digging, or off-road vehicles (flipped/broken rocks etc.)
Yes = –1
No = 0

Score: _____

Overall Section IV Disturbance Factors Score: _____

*CHI score based on summing Sections I–IV: (0–100 range):*_____

Time spent surveying (hours, minutes):

Approximate number of acres surveyed:

Literature Cited

Aighewi, I., A. Ishaque, and O. Nosakhare. 2014. Geospatial evaluation for ecological watershed management II: changes in land use—land cover influence on ecosystems services. *Journal of Geographic Information System* 6(03):246.

Alexander, J.S., R.B. Jacobson, and D.L. Rus. 2013. Sediment transport and deposition in the lower Missouri River during the 2011 flood. USGS Professional Paper 1798-F.

Alexander, R.B., E.W. Boyer, R.A. Smith, G.E. Schwarz, and R.B. Moore. 2007a. The role of headwater streams in downstream water quality. *JAWRA* 43(1):41–59.

Alexander, R.B., R.A. Smith, G.E. Schwarz, E.W. Boyer, J.V. Nolan, and J.W. Brakebill. 2007b. Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin.

Alford, A., R. Kaminski, S. Grado, L. Abramo, J. Avery, and W. Schilling. 2013. Crayfish harvesting: alternative opportunities for landowners practicing moist-soil wetland management. North American Duck Symposium, Memphis, TN.

Altieri, M.A., and P. Rosset. 1996. Agroecology and the conversion of large-scale conventional systems to sustainable management. *International Journal of Environmental Studies* 50(3–4):165–185.

Amon, J.P., C.A. Thompson, Q.J. Carpenter, and J. Miner. 2002. Temperate zone fens of the glaciated Midwestern USA. *Wetlands* 22(2):301–317.

Arduser, M. 2016. Report on bees collected at Jerry Smith Park and Rocky Point (Swope Park), Kansas City, Missouri, April–October 2016. Submitted to Burroughs Audubon Society and Bridging the Gap/Kansas City Wildlands.

Asbjornsen, H., V. Hernandez-Santana, M. Liebman, J. Bayala, J. Chen, M. Helmers, C.K. Ong, and L.A. Schulte. 2014. Targeting perennial vegetation in agricultural landscapes for enhancing ecosystem services. *Renewable Agriculture and Food Systems* 29(2):101–125.

Baker, C., J.R. Thompson, and M. Simpson. 2009. Hydrological dynamics I: surface waters, flood and sediment dynamics. *The Wetlands Handbook* 2:120–168.

Ballinas, M., and V. Barradas. 2016. The urban tree as a tool to mitigate the urban heat island in Mexico City: a simple phenomological model. *Journal of Environmental Quality* 45:157–166.

Banasiak, A., L. Bilmes, and J. Loomis. 2015 (February). Carbon sequestration in the U.S. national parks: a value beyond visitation." Discussion paper 2015-66. Cambridge, MA: Harvard Project on Climate Agreements.

Barbier, E.B., and B.S. Enchelmeyer. 2014. Valuing the storm surge protection service of US Gulf Coast wetlands. *Journal of Environmental Economics and Policy* 3(2):167–185.

Barford, C.C., S.C. Wofsy, M.L. Goulden, J.W. Munger, E.H. Pyle, S.P. Urbanski, L. Hutyra, S.R. Saleska, D. Fitzjarrald, and K. Moore. 2001. Factors controlling long- and short-term sequestration of atmospheric CO2 in a mid-latitude forest. *Science* 294:1688–1691. DOI: 10.1126/science.1062962/.

Barksdale, W.F., C.J. Anderson, and L. Kalin. 2014. The influence of watershed runoff on the hydrology, forest floor litter and soil carbon of headwater wetlands. *Ecohydrology* 7(2):803–814.

Basch, C.E. 2011. Executive summary: healthier students are better learners. *Journal of School Health* 81:591–592.

Beattie, A.J., W. Barthlott, E. Elisabetsky, R. Farrel, C. Kheng, I. Prance, J. Rosenthal, D. Simpson, R. Leakey, M. Wolfson, and K. Kate. 2005. New products and industries from biodiversity. Pp. 273–295 in Ecosystems and human well-being, R. Hassan, R. Scholes and N. Ash (eds).

Bell, A., and J.E. Dyment. 2008. Grounds for health: the intersection of green school grounds and health-promoting schools. *Environ. Educ. Res*. 14:77–90.

Bellassen, V., and S. Luyssaert. 2014. Carbon sequestration: managing forests in uncertain times. *Nature* 506:153–155. DOI: 10.1038/506153a/.

Bennitt, R., and W.O. Nagel. 1937. A survey of the resident game and furbearers of Missouri. *University of Missouri Studies* 12(2).

Birkland, T.A., R.J. Burby, D. Conrad, H. Cortner, and W.K. Michener. 2003. River ecology and flood hazard mitigation. *Natural Hazards Review* 4(1):46–54.

Blevins, D.W., D. Wilkison, and S. Niesen. 2014. Pre- and post-impoundment nitrogen in the lower Missouri River. *Hydrological Processes* 28:2535–2549.

Bonan, G.B. 2008. Forests and climate change: forcings, feedbacks, and the climate benefits of forests. *Science* 320:1444–1449. DOI: 10.1126/science.1155121/.

Bonnot, T.W., D.T. Jones-Farrand, F.R. Thompson III, J.J. Millspaugh, J.A. Fitzgerald, N. Muenks, P. Hanberry, E. Stroh, L. Heggemann, and A. Fowler. 2019. Developing a decision-support process for landscape conservation design. Gen. Tech. Rep. NRS-190. Newtown Square, PA: USFS, Northern Research Station. DOI: 10.2737/NRS-GTR-190/.

Booy, G., R.J.J. Hendricks, M.J.M. Smulders, J.M. Van Groenendael, and B. Vosman. 2000. Genetic diversity and the survival of populations. *Plant Biology* 2(4):379–395.

Bouchard, M., D. Butman, T. Hawbaker, Z. Li, J. Liu, S-G. Liu, C. McDonald, et al. 2011. Baseline and projected future carbon storage and greenhouse-gas fluxes in the Great Plains region of the United States. No. 1787. US Geological Survey.

Bowden, W.B. 1987. The biogeochemistry of nitrogen in freshwater wetlands. *Biogeochemistry* 4:313–348.

Bowler, D.E., R. Mant, H. Orr, et al. 2012. What are the effects of wooded riparian zones on stream temperature? *Environ Evid* 1:3.

Boyles, J.G., P.M. Cryan, G.F. McCracken, and T.H. Kunz. 2011. Economic importance of bats in agriculture. *Science* 332(6025):41–42.

Brandt, L., H. He, L. Iverson, F.R. Thompson III, P. Butler, S. Handler, M. Janowiak, P.D. Shannon, C. Swanston, M. Albrecht, R. Blume-Weaver, P. Deizman, J. DePuy, W.D. Dijak, G. Dinkel, S. Fei, D.T. Jones-Farrand, M. Leahy, S. Matthews, P. Nelson, B. Oberle, J. Perez, M. Peters, A. Prasad, J.E. Schneiderman, J. Shuey, A.B. Smith, C. Studyvin, J.M. Tirpak, J.W. Walk, W.J. Wang, L. Watts, D. Weigel, and S. Westin. 2014. Central Hardwoods ecosystem vulnerability assessment and synthesis: a report from the Central Hardwoods Climate Change Response Framework project**.** Gen. Tech. Rep. NRS-124. Newtown Square, PA: USFS, Northern Research Station.

Brauman, K.A., G.C. Daily, T.K.E. Duarte, and H.A. Mooney. 2007. The nature and value of ecosystem services: an overview highlighting hydrologic services. *Annu. Rev. Environ. Resour.* 32:67–98.

Bridgham, S.D., J.P. Megonigal, J.K. Keller, N.B. Bliss, and C. Trettin. 2006. The carbon balance of North American wetlands. *Wetlands* 26(4):889–916.

Bridging the Gap. 2020 (February 21). Benefits of trees. Heartland Tree Alliance. **bridgingthegap.org/heartland-tree-alliance/benefits**.

Brody, S.D., W.E. Highfield, and R. Blessing. 2015. An analysis of the effects of land use and land cover on flood losses along the Gulf of Mexico coast from 1999 to 2009. *JAWRA* 51(6):1556–1567.

Brody, S.D., W.E. Highfield, R. Blessing, T. Makino, and C.C. Shepard. 2017. Evaluating the effects of open space configurations in reducing flood damage along the Gulf of Mexico coast. *Landscape and Urban Planning* 167:225–231.

Brody, S.D., S. Zahran, P. Maghelal, H. Grover, and W.E. Highfield. 2007. The rising costs of floods: examining the impact of planning and development decisions on property damage in Florida. *Journal of the American Planning Association* 73(3):330–345.

Brower, L.P, G. Castilleja, A. Peralta, J. Lopez-Garcia, L. Bojorquez-Tapia, S. Diaz, D. Melgarejo, and M. Missrie. 2002. Quantitative changes in forest quality in a principal overwintering area of the monarch butterfly in Mexico, 1971–1999. *Conservation Biology* 16(2):346–359.

Broz, B., D. Pfost, and A. Thompson. 2020 (February 18). Controlling runoff and erosion at urban construction sites. University of Missouri Extension. **extension2.missouri.edu/g1509**.

Bruenderman, S. 1999. Missouri's freshwater mussels. *Missouri Conservationist* 60:8.

Buehler, D.A., P.B. Hamel, and T. Boves. 2020. Cerulean warbler (Setophaga cerulea), version 1.0. In Birds of the world, A.F. Poole (ed). Cornell Lab of Ornithology, Ithaca, NY. DOI: 10.2173/bow.cerwar.01/.

Burnett, R. 2018. Conservation planning tools for Missouri communities: a reference manual. Conservation Commission of the State of Missouri, MDC, Jefferson City, MO. **mdc.mo.gov/sites/default/files/downloads/Conservation%20Planning.pdf**.

Butler, B.J., J.H. Hewes, B.J. Dickinson, K. Andrejczyk, S.M. Butler, and M. Markowski-Lindsay. 2016. USDA Forest Service national woodland owner survey: national, regional, and state statistics for family forest and woodland ownerships with 10+ acres, 2011–2013 Res. Bull. NRS-99. Newtown Square, PA: USFS, Northern Research Station.

Calderone, N.W. 2012. Insect pollinated crops, insect pollinators and US agriculture: trend analysis of aggregate data for the period 1992–2009. *PLoS ONE* 7(5):e37235. DOI: 10.1371/journal.pone.0037235/.

Callicott, J.B., 2004. Explicit and implicit values in the ESA. In The Endangered Species Act at thirty: retrospect and prospects, Davies, Goble, Heal, and Scott (eds). Washington, DC: Island Press.

Calvete, J.J., L. Sanz, Y. Angulo, B. Lomonte, and J.M. Gutiérrez. 2009. Venoms, venomics, antivenomics. *FEBS Letters* 583(11):1736–1743.

Camilo, G.R., P.A. Muñiz, M.S. Arduser, and E.M. Spevak. 2017. A checklist of the bees (Hymenoptera: Apoidea) of St. Louis, Missouri, USA. *Journal of the Kansas Entomological Society* 90(3):175–188.

Carvalho, P.C.F., I. Anghinoni, A. Moraes, E.D. Souza, R.M. Sulc, C.R. Lang, J.P.C. Flores, M.L.T. Lopes, J.L.S. Silva, O. Conte, C.L. Wesp, R. Levien, R.S. Fontaneli, and C. Bayer. 2010. Managing grazing animals to achieve nutrient cycling and soil improvement in no-till integrated systems. *Nutr. Cycling Agroecosyst*. 88:259–273.

Caudill, J., and E. Carver. 2019. Banking on nature 2017: the economic contributions of national wildlife refuge recreational visitation to local communities. Falls Church, VA: USFWS.

Centers for Disease Control and Prevention. Nutrition, Physical Activity, Obesity – Data, Trends and Maps by State. **nccd.cdc.gov/dnpao_dtm/rdPage.aspx?rdReport=DNPAO_DTM.ExploreByLocation&rdRequestForwarding=Form**.

Chamberlain, J.L., 2018. Assessment of nontimber forest products in the United States under changing conditions. USFS.

Chan, L., O. Hillel, T. Elmqvist, P. Werner, N. Holman, A. Mader, and E. Calcaterra. 2014. User's manual on the Singapore Index on cities' biodiversity (also known as the City Biodiversity Index). Singapore: National Parks Board.

Changnon, S.A., R.A. Pielke Jr, D. Changnon, R.T. Sylves, and R. Pulwarty. 2000. Human factors explain the increased losses from weather and climate extremes. *Bulletin of the American Meteorological Society* 81(3):437–442.

Chawla, L. 2015. Benefits of nature contact for children. *J. Plan. Lit.* 30:433–452.

Chung, M.G., T. Dietz, and J. Liu. 2018. Global relationships between biodiversity and nature-based tourism in protected areas. *Ecosystem Services* 34:11–23.

Colla, S.R., E. Willis, and L. Packer. 2009. Can green roofs provide habitat for urban bees (Hymenoptera: Apidae)? *Cities and the Environment* 2(1):4.

Commoner, B., 2020. The closing circle: nature, man, and technology. Courier Dover Publications.

Compton, J.E., J.A. Harrison, R.L. Dennis, T.L. Greaver, B.H. Hill, S.J. Jordan, H. Walker, and H.V. Campbell. 2011. Ecosystem services altered by human changes in the nitrogen cycle: a new perspective for US decision making. *Ecology Letters* 14(8):804–815.

Conservation Commission of the State of Missouri. 1944. Annual report. MDC, Jefferson City, MO.

Cooke, S.J., W.M. Twardek, R.J. Lennox, A.J. Zolderdo, S.D. Bower, L.F. Gutowsky, A.J. Danylchuk, R. Arlinghaus, and D. Beard. 2018. The nexus of fun and nutrition: recreational fishing is also about food. *Fish and Fisheries* 19(2):201–224.

Corrales, J., G. Melodie Naja, R.G. Rivero, F. Miralles-Wilhelm, and M.G. Bhat. 2013. Water quality trading programs toward solving environmental pollution problems. *Irrigation and Drainage* 62(S2).

Covino, T. 2017. Hydrologic connectivity as a framework for understanding biogeochemical flux through watersheds and along fluvial networks. *Geomorphology* 277:133–144.

Creutzburg, M.K., R.M. Scheller, M.S. Lucash, S.D. LeDuc, and M.G. Johnson. 2017. Forest management scenarios in a changing climate: trade-offs between carbon, timber, and old forest. *Ecological Applications* 27(2): 503-518. DOI: 10.1002/eap.1460/.

Dadvand, P., M.J. Nieuwenhuijsen, M. Esnaola, J. Forns, X. Basagaña, M. Alvarez-Pedrerol, I. Rivas, M. Lopez-Vicente, M.D.C. Pascual, J. Su, M. Jerrett, X. Querol, and J. Sunyer. 2015. Green spaces and cognitive development in primary schoolchildren. *Proceedings of the National Academy of Sciences* 112:26, 7937–7942.

Daily, G.C. (ed.). 1997. Nature's Services: Societal Dependence on Natural Ecosystems.Washington, DC: Island Press.

Daily, G.C., S. Alexander, P.R. Ehrlich, L. Goulder, J. Lubchenco, P.A. Matson, H.A. Mooney, S. Postel, S.H. Schneider, D. Tilman, and G.M. Woodwell. 1997. Ecosystem services: benefits supplied to human societies by natural ecosystems. *Issues in Ecology* 2: 1–17.

D'Amato, A. W., J. B. Bradford, S. Fraver, and B. J. Palik. 2011. Forest management for mitigation and adaptation to climate change: insights from long-term silviculture experiments. *Forest Ecology and Management* 262(5): 803-816. DOI: 10.1016/j.foreco.2011.05.014/.

Dasgupta, S., W. Wurts, and R. Durborow. 2007. Can catfish aquaculture be profitable in farm ponds? Southern Agricultural Economics Association Annual Meetings, Mobile, Alabama, February 4–7.

David, M.B., and L.E. Gentry. 2000. Anthropogenic inputs of nitrogen and phosphorus and riverine export for Illinois, USA. *Journal of Environmental Quality* 29(2):494–508.

David, M.B., G.F. McIsaac, T.V. Royer, R.G. Darmody, and L.E. Gentry. 2001. Estimated historical and current nitrogen balances for Illinois. *Scientific World* 1(S2):597–604.

Deci, E.L., R.J. Vallerand, L.G. Pelletier, and R.M. Ryan. 2011. Motivation and education: the self-determination perspective. *Educ. Psychol*. 26:325–346.

Dewitz, J., 2019, National Land Cover Database (NLCD) 2016 Products: U.S. Geological Survey data release, https://doi.org/10.5066/P96HHBIE.

Domke, G.M., B.F. Walters, D.J. Nowak, J.E. Smith, S.M. Ogle, J.W. Coulston, and T.C. Wirth. 2020. Greenhouse gas emissions and removals from forest land, woodlands, and urban trees in the United States, 1990–2018. Resource Update FS-227. Madison, WI: USFS, Northern Research Station. DOI: 10.2737/FS-RU-227/.

Dorioz, J.M., D. Wang, J. Poulenard, and D. Trévisan. 2006. The effect of grass buffer strips on phosphorus dynamics: a critical review and synthesis as a basis for application in agricultural landscapes in France. *Agriculture Ecosystems & Environment* 117:4–21.

Dosskey, M.G. 2001. Toward quantifying water pollution abatement in response to installing buffers on crop land. *Environmental Management* 28(5):577–598.

Dunfee, M., A. Forstchen, E. Haubold, M. Humpert, J. Newmark, J. Sumners, and C. Smith. 2019. Fish and wildlife relevancy roadmap: enhanced conservation through broader engagement. Vol. 1.0. Washington, DC: AFWA and the Wildlife Management Institute.

Dupas, R., G. Gruau, S. Gu, G. Humbert, A. Jaffrezic, and C. Gascuel-Odoux. 2015. Groundwater control of biogeochemical processes causing phosphorus release from riparian wetlands. *Water Research* 84:307–314.

Ehrenfeld J.G. 2000. Evaluating wetlands within an urban context. *Ecological Engineering* 15:253–265.

Ehrenfeld, J.G., and J.P. Schneider. 1993. Responses of forested wetland vegetation to perturbations of water chemistry and hydrology. *Wetlands* 13:122–129.

Elliott, W.R. 2007. A guide to Missouri's cave life. MDC, Jefferson City, MO.

Ensign, S.H., and M.W. Doyle. 2006. Nutrient spiraling in streams and river networks. *Journal of Geophysical Research* 111.

ENVIRON International Corporation. 2014. The 2011 economic impacts of fishing, hunting, and wildlife viewing in Missouri. Prepared for MDC, Jefferson City, MO.

Ernst, J., and D. Stanek. 2006. The prairie science class: a model for re-visioning environmental education within the national wildlife refuge system. *Hum. Dimens. Wildl.* 11:255–265.

Euliss, N.H. Jr, R.A. Gleason, A. Olness, R.L. McDougal, H.R. Murkin, R.D. Robarts, R.A. Bourbonniere, and B.G. Warner. 2006. North American prairie wetlands are important nonforested land-based carbon storage sites. *Science of the Total Environment* 361:179– 188.

Faber-Langendoen, D., J. Lemly, W. Nichols, J. Rocchio, K. Walz, and R. Smyth. 2019. Development and evaluation of NatureServe's multi-metric ecological integrity assessment method for wetland ecosystems. *Ecological Indicators* 104:764–775.

Faber-Langendoen, D., W. Nichols, J. Rocchio, K. Walz, and J. Lemly. 2016. An introduction to NatureServe's ecological integrity assessment method. NatureServe, Arlington, VA.

Faber Taylor, A., and F.E. Kuo. 2009. Children with attention deficits concentrate better after walk in the park. *Journal of Attention Disorders* 12:402–409.

Faber Taylor, A., F. Kuo, and W. Sullivan. 2002. Views of nature and self-discipline: evidence from inner city children. *J. Environ. Psychol.* 22:49–63.

Fägerstam, E., and J. Blom. 2012. Learning biology and mathematics outdoors: effects and attitudes in a Swedish high school context. *J. Adventure Educ. Outdoor Leadersh*. 13:56–75.

Farnham, M., and N. Mutrie. 2003. Research section: the potential benefits of outdoor development for children with special needs. *Br. J. Special Educ.* 24:31–38.

Federal Register: The Daily Journal of the United States. 2014 (December 31). 79 Fed. Reg. 250. Web.

Fennessy, S., and C. Craft. 2011. Agricultural conservation practices increase wetland ecosystem services in the glaciated interior plains. *Ecological Applications* 21(1):S49–S64.

Fenstermacher, D.E., M.C. Rabenhorst, M.W. Lang, G.W. McCarty, and B.A. Needelman. 2016. Carbon in natural, cultivated, and restored depressional wetlands in the mid-atlantic coastal plain. *Journal of Environmental Quality* 45(2):743–750.

Fisher-Vanden, K., and S. Olmstead. 2013. Moving pollution trading from air to water: potential, problems, and prognosis. *Journal of Economic Perspectives* 27(1):147–172.

Flockhart, D.T.T., Fitz-gerald, B., Brower, L.P. *et al.* 2017. Migration distance as a selective episode for wing morphology in a migratory insect. *Movement Ecology* 5**,** 7. doi.org/10.1186/s40462-017-0098-9

Flores-Martinez, J.J., A. Martínez-Pacheco, E. Rendón-Salinas, J. Rickards, S. Sarkar, and V. Sánchez-Cordero. 2019. Recent forest cover loss in the core zones of the monarch butterfly biosphere reserve in Mexico. *Frontiers in Environmental Science* 7:167.

Floyd, Myron, D. Ross-Winslow, E. Thompson, N. Sexton, A. Diestsh, and K. Conlon. 2016 (March 18). Barriers and strategies to connecting urban audiences to wildlife and nature: results from a multi-method research project. NC State Extension. **content.ces.ncsu.edu/barriers-and-strategies-to-connecting-urban-audiences-to-wildlife-and-nature** or **content.ces.ncsu.edu/show_ep3_pdf/1587579799/23136**.

Foley, J.A., R. DeFries, G.P. Asner, C. Barford, G. Bonan, S.R. Carpenter, F.S. Chapin, M.T. Coe, G.C. Daily, H.K. Gibbs, and J.H. Helkowski. 2005. Global consequences of land use. *Science* 309(5734):570–574.

Fort Collins, Colorado, City of. Undated. Nature in the city. Citizen Science Biodiversity Project. **fcgov.com/natureinthecity/volunteer-biodiversity-project.php**.

Foster, D., F. Swanson, J. Aber, I. Burke, N. Brokaw, D. Tilman, and A. Knapp. 2003. The importance of land-use legacies to ecology and conservation. *BioScience* 53(1):77–88.

Foster, S. 1997. Medicinal plant development in the United States. Pp.26–41 in Special forest products: biodiversity meets the marketplace. GTRWO-63. Washington, DC: USFS.

Frankson, R., K.E. Kunkel, S. Champion, and B.C. Stewart. 2017. NOAA national centers for environmental information, state climate summaries: Missouri.

Freeman, A.M., III. 1993. The measurement of environmental and resource values: theory and methods. Washington, DC: Resources for the Future.

Furey, N.M., and P.A. Racey. 2016. Conservation ecology of cave bats. Pp. 463–502 in Bats in the Anthropocene: conservation of bats in a changing world, C.C. Voigt and T. Kingston (eds). Springer Publishing.

Galat, D.L., L.H. Fredrickson, D.D. Humburg, K.J. Bataille, J.R. Bodie, J. Dohrenwend, G.T. Gelwicks, J.E. Havel, D.L. Helmers, J.B. Hooker, and J.R. Jones. 1998. Flooding to restore connectivity of regulated, large-river wetlands: natural and controlled flooding as complementary processes along the lower Missouri River. *BioScience* 48(9):721–733.

Gardiner, M., D. Landis, C. Gratton, C. DiFionzo, M. O'Neal, J. Chacon, M. Wayo, N. Schmidt, E. Mueller, and G. Heimpel. 2009. Landscape diversity enhances biological control of an introduced crop pest in the north-central USA. *Ecological Applications* 19(1):143–154.

Garnett, M.H., P. Ineson, and A.C. Stevenson. 2000. Effects of burning and grazing on carbon sequestration in a Pennine blanket bog, UK. *Holocene* 10(6):729–736.

Gebre, T., and B. Gebremedhin. 2019. The mutual benefits of promoting rural-urban interdependence through linked ecosystem services. *Global Ecology and Conservation.*

George, S.E., D.L. Cremeens, L.S. Hart, and D.E. Buck. 2016. Missouri Ozark fens: soils, geomorphology, hydrogeoloic-ecological settings and vegetation communities. In draft.

Goff, T. 2018. Forests of Missouri, 2017 resource update FS-146. Newtown Square, PA: USFS, Northern Research Station.

Goff, T.C. 2020 (February 11). Missouri 2018 forest inventory estimate tables. Forest inventory and analysis: Missouri forest inventory. **www.nrs.fs.fed.us/fia/data-tools/state-reports/MO/default.asp.**

Goguen, A.D., S.J. Riley, J.F. Organ, and B.A. Rudolph. 2018. Wild-harvested venison yields and sharing by Michigan deer hunters. *Human Dimensions of Wildlife* 23(3):197–212.

Goodwell, A.E., Z. Zhu, D. Dutta, J.A. Greenberg, P. Kumar, M.H. Garcia, B.L. Rhoads, R.R. Holmes, G. Parker, D.P. Berretta, and R.B. Jacobson. 2014. Assessment of floodplain vulnerability during extreme Mississippi River flood 2011. *Environmental Science & Technology* 48(5):2619–2625.

Goulder, L.H., and D. Kennedy. 1997. Valuing ecosystem services: philosophical bases and empirical methods (pp. 23-47). Washington, DC: Island Press.

Grannis, J.C. 1992. Students' stress, distress, and achievement in an urban intermediate school. *J. Early Adolesc*. 12:4–27.

Gregory, J.M., C.D. Jones, P. Cadule, and P. Friedlingstein. 2009. Quantifying carbon cycle feedbacks. *Journal of Climate* 22:5232-5250. DOI: 10.1175/2009JCLI2949.1/.

Guida, R.J., J.W. Remo, and S. Secchi. 2016. Tradeoffs of strategically reconnecting rivers to their floodplains: the case of the lower Illinois River (USA). *Science of the Total Environment* 572:43–55.

Gurnell, A.M. 1998. The hydrogeomorphological effects of beaver dam-building activity. *Progress in Physical Geography* 22(2):167–189.

Guyette, R., D. Dey, and M. Dey. 1999 (March 10). An Ozark fire history. *Missouri Conservationist*.

Harmon, M.E., and B. Marks. 2002. Effects of silvicultural practices on carbon stores in Douglas-fir—western hemlock forests in the Pacific Northwest, USA: results from a simulation model. *Canadian Journal of Forest Research* 32(5): 863-877. DOI: 10.1139/x01-216/.

Harrison, M.D., A.J. Miller, P.M. Groffman, P.M. Mayer, and S.S. Kaushal. 2014. Hydrologic controls on nitrogen and phosphorous dynamics in relict oxbow wetlands adjacent to an urban restored stream. *JAWRA* 50(6):1365–1382.

Hathway, E.A., and S. Sharples. 2012. The interaction of rivers and urban form in mitigating the urban heat island effect: A UK case study. *Building and Environment* 58:14–22.

Havens, K.E. 2008. Cyanobacteria blooms: effects on aquatic ecosystems. Pp. 733–747 in Cyanobacterial harmful algal blooms: state of the science and research needs. Springer, NY.

Hayes, D.J., D.P. Turner, G. Stinson, A.D. MCGuire, Y. Wei, T.O. West, L.S. Heath, B. de Jong, B.G. McConkey, R.A. Birdsey, W.A. Kurz, A.R. Jacobson, D.N. Huntzinger, Y. Pan, W.M. Post, and R.B. Cook. 2012. Reconciling estimates of the contemporary North American carbon balance among terrestrial biosphere models, atmospheric inversions, and a new approach for estimating net ecosystem exchange from inventory-based data. *Global Change Biology* 18:1282–1299. DOI: 10.1111/j.1365-2486.2011.02627.x/.

Heimann, D.C. 2009. Comparison of hydrologic and water-quality characteristics of two native tallgrass prairie streams with agricultural streams in Missouri and Kansas. U.S. Geological Survey Scientific Investigations Report 2009-5213.

Heimann, D.C. 2016. Generalized sediment budgets of the Lower Missouri River, 1968–2014. No. 2016-5097. USGS.

The Heinz Center. 2013. Pollinators and the State Wildlife Action Plans: voluntary guidance for state wildlife agencies. Washington, DC.

Hendrickson, M.K., and S.H. Massengale. 2017. Local food systems in rural North America: findings from Missouri and Nebraska. Online Proceedings. P.222 in XXVII European Society for Rural Sociology Congress, the Institute of Sociology, Jagiellonian University in Krakow, Poland, July 24–27.

Hodgson, S.M., L. Maltby, A. Paetzold, and D. Phillips. 2007. Getting a measure of nature: cultures and values in an ecosystem services approach. *Interdisciplinary Science Reviews* 32(3):249–262.

Hoegh-Guldber, O., D. Jacob, M. Taylor, M. Bindi, S. Brown, I. Camilloni, A. Diedhiou, R. Djalante, K.L. Engelbrecht, J. Guiot, Y. Hijioka, S. Mehrotra, A. Payne, S.I. Seneviratne, A. Thomas, R. Warren, and G. Zhou. 2018. Impacts of 1.5°C global warming on natural and human systems. In global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development and efforts to eradicate poverty. In Press.

Homer, C.G., J.A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N.D. Herold, J.D. Wickham, and K. Megown. 2015. Completion of the 2011 National Land Cover Database for the conterminous

United States: representing a decade of land cover change information. *Photogrammetric Engineering and Remote Sensing* 81:345–354.

Hopfensperger, K.N., K. Schwarz, and E.R. Kirtman. 2014. Effects of seasonal variation and land cover on riparian denitrification along a mid-sized river. *Journal of Freshwater Ecology* 29:4, 457–473.

Houghton, R.A., 1999. The annual net flux of carbon to the atmosphere from changes in land use 1850–1990. *Tellus B* 51(2):298–313.

Hua, G., M.W. Salo, C.G. Schmit, and C.H. Hay. 2016. Nitrate and phosphate removal from agricultural subsurface drainage using laboratory woodchip bioreactors and recycled steel byproduct filters. *Water Research* 102:180–189.

Hungate, B.A., E.B. Barbier, A.W. Ando, S.P. Marks, P.B. Reich, N. Van Gestel, D. Tilman, J.M.H. Knops, D.U. Hooper, B.J. Butterfield, and B.J. Cardinale. 2017. The economic value of grassland species for carbon storage. *Science Advances* 3(4):e1601880.

Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES).

Jacobson, R.B., and A.T. Primm. 1997. Historical land-use changes and potential effects on stream disturbance in the Ozark Plateaus, Missouri. Pp.1–85 in US Geological Survey water-supply paper.

Jaganmohan, M., S. Knapp, C.M. Buchmann, and N. Schwarz. 2016. The bigger, the better? The influence of urban green space design on cooling effects for residential areas. *Journal of Environmental Quality* 45:134–145.

Janowiak, M, W.J. Connelly, K. Dante-Wood, G.M. Domke, C. Giardina, Z. Kayler, K. Marcinkowski, T. Ontl, C. Rodriguez-Franco, C. Swanston, C.W. Woodall, and M. Buford. 2017. Considering forest and grassland carbon in land management. USDA Forest Service General Technical Report WO-95.

Jenkins, W.A., B.C. Murray, R.A. Kramer, and S.P. Faulkner. 2010. Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley. *Ecological Economics* 69(5):1051–1061.

Jenny, H. 1941. Factors of soil formation. New York.

Jeon, E.Y., B.H. Hwang, Y.J. Yang, B.J. Kim, B.H. Choi, G.Y. Jung, and H.J. Cha. 2015. Rapidly light-activated surgical protein glue inspired by mussel adhesion and insect structural crosslinking. *Biomaterials* 67:11–19.

Jessop, J. 2014. Tradeoffs among ecosystem services in restored wetlands. Master's thesis, University of Illinois at Urbana–Champaign.

Jessop, J., G. Spyreas, G.E. Pociask, T.J. Benson, M.P. Ward, A.D. Kent, and J.W. Matthews. 2015. Tradeoffs among ecosystem services in restored wetlands. *Biological Conservation* 191:341–348.

Johnson, K.A., O.E. Wing, P.D. Bates, J. Fargione, T. Kroeger, W.D. Larson, C.C. Sampson, and A.M. Smith. 2020. A benefit–cost analysis of floodplain land acquisition for US flood damage reduction. *Nature Sustainability* 3(1):56–62.

Johnson, L.C., and J.R. Matchett. 2001. Fire and grazing regulate belowground processes in tallgrass prairie. *Ecology* 82: 3377–3389.

Johnson, P.S., S.R. Shifley, and R. Rogers. 2009. The ecology and silviculture of oaks. 2nd ed. Wallingford, UK: CABI Publishing, CAB International. DOI: 10.1079/9781845934743.0000/.

Juan, A., A. Gori, and A. Sebastian. 2020. Comparing floodplain evolution in channelized and unchannelized urban watersheds in Houston, Texas. *Journal of Flood Risk Management*, e12604.

Kaplan, S. 1995. The restorative benefits of nature: toward an integrative framework. *J. of Enviro. Psych*. 15:169–182.

Katz, J.V.E., C. Jeffres, J.L. Conrad, T.R. Sommer, J. Martinez, S. Brumbaugh, et al. 2017. Floodplain farm fields provide novel rearing habitat for Chinook salmon. *PLoS ONE* 12(6):e0177409.

Kemp, W.M., R.R. Twilley, J.C. Stevenson, W.R. Boynton, and J.C. Means. 1983. The decline of submerged vascular plants in upper Chesapeake Bay: summary of results concerning possible causes. *Marine Technology Society Journal* 17(2):78–89.

Kim, S.Y. and P.M. Geary. 2001. The impact of biomass harvesting on phosphorus uptake by wetland plants. *Water Science and Technology* 44(11–12):61–67.

Kindscher, K., and L.L. Tieszen. 1998. Floristic and soil organic matter changes after five and thirty-five years of native tallgrass prairie restoration. *Restoration Ecology* 6:181–196.

King, A.W., R.J. Andres, K.J. Davis, M. Hafer, D.J. Hayes, D.N. Huntzinger, B. de Jong, W.A. Kurz, A.D. McGuire, R. Vargas, Y. Wei, T.O. West, and C.W. Woodall. 2015. North America's net terrestrial CO2 exchange with the atmosphere, 1990–2009. *Biogeosciences* 12:399-414. DOI: 10.5194/bg-12-399-2015/.

Kirschenmann, Frederick. 2002 (May 3). A revolution in agriculture. Paper presented in Cold Spring, New York, as part of the Glynwood Center's agriculture initiative conference Connecting Communities, Farmers and Food.

Kirschenmann, F.L. 2010. Cultivating an ecological conscious: essays from a farmer philosopher. Edited by Constance L. Falk.

Klein, A.M., B.E. Vaissiere, J.H. Cane, I. Steffan-Dewenter, S.A. Cunningham, C. Kremen, and T. Tscharntke. 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society of London Series B 274:303–313.

Kleinman, P.J.A., A.N. Sharpley, R.W. McDowell, D.N. Flaten, A.R. Buda, L. Tao, L. Bergstrom, and Q. Zhu. 2011. Managing agricultural phosphorus for water quality protection: principles for progress. *Plant Soil* 349(1−2):169−182.

Knight, K.W., R.C. Schultz, C.M. Mabry, and T.M. Isenhart. 2010. Ability of remnant riparian forests, with and without grass filters, to buffer concentrated surface runoff. *JAWRA* 46(2):311–322.

Knowlton, M.F., C. Cuvellier, and J.R. Jones. 2002. Initial performance of a high capacity surface-flow treatment wetland. *Wetlands* 22(3):522–527.

Knowlton, M.F., and J.R. Jones. 2003. Fecal bacteria, nutrients, chlorophyll, and dissolved oxygen in a constructed habitat wetland receiving treated municipal effluent and river water. *Lake and Reservoir Management* 19(2):171–183.

Kolka, R., S.D. Bridgham, and C. Ping. 2015. Soils of peatlands: histosols and gelisols. Chapter, in Wetland soils: genesis, hydrology, landscapes, and classification, M.J. Vepraskas and C.B. Craft (eds). 2nd ed. CRC Press.

Kolok, A. 2016. Modern poisons: A brief introduction to contemporary toxicology. Ch. 8. Washington, DC: Island Press.

Kreibich, H., P. Bubeck, M. Van Vliet, and H. De Moel. 2015. A review of damage-reducing measures to manage fluvial flood risks in a changing climate. *Mitigation and Adaptation Strategies for Global Change* 20(6):967–989.

Krosby, M., D.M. Theobald, R. Norheim, and B.H. McRae. 2018. Identifying riparianclimate corridors to informclimate adaptation planning. *PLoS ONE* 13(11).

Krutilla, J.V. 1967. Conservation reconsidered. *American Economic Review* 57(4):777–786.

Kuo, F.E. 2015. How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Front. Psychol*. 6:1093.

Kuo, M., M. Barnes, and C. Jordan. 2019. Do experiences with nature promote learning? Converging evidence of a cause-and-effect relationship. *Front. Psychol.* 19.

Kuo, M., M.H.E.M. Browning, and M.L. Penner. 2018. Do lessons in nature boost subsequent classroom engagement? Refueling students in flight. *Front Psychol*. 8:2253.

Kweon, B.S., C.D. Ellis, J. Lee, and K. Jacobs. 2017. The link between school environments and student academic performance. *Urban Forestry & Urban Greening* 23:35–43.

Lacis, A.A., G.A. Schmidt, D. Rind, and R.A. Ruedy. 2010. Atmospheric CO2: principal control knob governing Earth's temperature. *Science* 330: 356–359. DOI: 10.1126/science.1190653/.

Ladd, D., and J.R. Thomas. 2015. Ecological checklist of the Missouri flora for floristic quality assessment. *Phytoneuron* 12:1–274.

Lal, R., J.A. Delgado, P.M. Groffman, N. Millar, C. Dell, and A. Rotz. 2011. Management to mitigate and adapt to climate change. *Journal of Soil and Water Conservation* 66:276– 285.

Lavelle, P., R. Dugdale, and R. Scholes. 2005. Millennium ecosystem assessment, ecosystems and human well-being: current state and trends. *Nutrient Cycling* 1(12):331–353.

Lawton, K. 2017 (March 13). Economics of Soil Loss. *FarmProgress.* **farmprogress.com/soil-health/economics-soil-loss**.

Leahy, M. 2011. Discover Missouri Natural Areas. MDC, Jefferson City, MO.

Leopold, Luna B. (ed). 1993. *Round River*. From the Journals of Aldo Leopold. 2nd ed. Oxford University Press.

Leppink, E.W., B.L. Odlaug, K. Lust, G. Christenson, and J.E. Grant. 2016. The young and the stressed: stress, impulse control, and health in college students. *J. Nerv. Ment. Dis*. 204:931–938.

Leung, W.T.V., T.Y.T. Tam, W-C. Pan, C-D. Wu, S-C. C. Lung, and J. D. Spengler. 2019. How is environmental greenness related to student' academic performance in English and mathematics? *Landscape and Urban Planning* 181:118–124.

Lewis, H.T. 1973. Patterns of Indian burning in California: ecology and ethnohistory. Ramona, CA: Ballena Press.

Li, D., and W.C. Sullivan. 2016. Impacts of views to school landscapes on recovery from stress and mental fatigue. *Landscape and Urban Planning* 148:149–158.

Liehr, S.K., A.R. Rubin, and B. Tonning. 2004. Natural treatment and onsite processes. *Water Environment Research* 76(6):1191–1237.

Lin, C.H., R.N. Lerch, H.E. Garrett, and M.F. George. 2004. Incorporating forage grasses in riparian buffers for bioremediation of atrazine, isoxaflutole and nitrate in Missouri. *Agroforestry Systems* 63:91–99.

Lopez-Llompart, P., and G.M. Kondolf. 2016. Encroachments in floodways of the Mississippi River and tributaries project. *Natural Hazards* 81(1):513–542.

Losey, J.E., and M. Vaughan. 2006. The economic value of ecological services provided by insects. *Bioscience* 56(4):311–323.

Lowenstein, D.M., K.C. Matteson, I. Xiao, A.M. Silva, and E.S. Minor. 2014. Humans, bees, and pollination services in the city: the case of Chicago, IL (USA). *Biodiversity and Conservation* 23(11):2857–2874.

Lurie-Luke, E. 2014. Product and technology innovation: what can biomimicry inspire? *Biotechnology Advances* 32(8):1494–1505.

Lynch, A.J., B.J.E. Myers, C. Chu, L.A. Eby, J.A. Falke, R.P. Kovach, T.J. Krabbenhoft, T.J. Kwak, J. Lyons, C.P. Paukert, and J.E. Whitney. 2016. Climate change effects on North American inland fish populations and assemblages. *Fisheries* 41:346–361.

Maas, B., Y. Clough, and T. Tscharntke. 2013. Bats and birds increase crop yield in tropical agroforestry landscapes. *Ecology Letters* 16(12):1480–1487.

Maavara, T., R. Lauerwald, P. Regnier, and P. Van Cappellen. 2017. Global perturbation of organic carbon cycling by river damming. *Nature Communications* 8:15347.

Mack, E.A., and S. Wrase. 2017. A burgeoning crisis? A nationwide assessment of the geography of water affordability in the United States. *PLOS ONE* 12:e0169488.

MacLeod, A., S. Wratten, N. Sotherton, and M. Thomas. 2004. "Beetle banks" as refuges for beneficial arthropods in farmland: long-term changes in predator communities and habitat. *Agricultural and Forest Entomology* 6:147–154.

Mallakpour, Iman. The tale of flooding over the central United States. 2016. PhD thesis, University of Iowa.

Maltby, E., and M.C. Acreman. 2011. Ecosystem services of wetlands: pathfinder for a new paradigm. *Hydrological Sciences Journal* 56(8):1341–1359.

Matsuoka, R.H. 2010. Student performance and high school landscapes: Examining the links. *Landscape and Urban Planning* 97:273–282.

Matthews, S., L. Iverson, A. Prasad, and M. Peters. 2014. Climate change bird atlas. Delaware, OH: Northern Research Station, USFS.

Matthews, J.W., G. Spyreas, and C.M. Long. 2015. A null model test of floristic quality assessment: are plant species coefficients of conservatism valid? *Ecological Indicators* 52:1–7.

Mattingly, K.Z., and D.J. Leopold. 2018. Habitat indicators of a federally listed glacial relict plant species restricted to cliffs in the northern United States. *Natural Areas Journal* 38:54–67.

McAllister, L.S., B.E. Peniston, S.G. Leibowitz, B. Abbruzzese, and J.B. Hyman. 2000. A synoptic assessment for prioritizing wetland restoration efforts to optimize flood attenuation. *Wetlands* 20(1):70.

McCauley, L.A., M.J. Anteau, M.P. van der Burg, and M.T. Wiltermuth. 2015. Land use and wetland drainage affect water levels and dynamics of remaining wetlands. *Ecosphere* 6(6):1–22.

McClain, W.R., and R.P. Romaire. 2004. Crawfish culture: a Louisiana aquaculture success story. *World Aquaculture* 35(4):31–35.

McMillan, S.K., and G.B. Noe. 2017. Increasing floodplain connectivity through urban stream restoration increases nutrient and sediment retention. *Ecological Engineering* 108:284–295.

McMurray, S.E., J.A. Fairman, A. Roberts, B. Simmons, and M.C. Barnhart. 2012. A guide to Missouri's freshwater mussels. MDC, Jefferson City, MO.

Merry, K., J. Siry, P. Bettinger, and J. M. Bowker. 2013. Efficient assessments of urban tree planting potential within or near the southern Piedmont region of the United States. *Computers, Environment and Urban Systems* 39:39–47. DOI: 10.1016/j.compenvurbsys.2013.01.00/.

Metropolitan Sewer District. 2012 (May). MSD landscape guide for stormwater best management practice design. **stlmsd.com/sites/default/files/engineering/442680.pdf**.

Meyer, J.L., L.A. Kaplan, D. Newbold, D.L. Strayer, C.J. Woltemade, J.B. Zedler, R. Beilfus, Q. Carpenter, R. Semlitsch, M.C. Watzin, and P.H. Zedler. 2003. Where rivers are born. American Rivers and The Sierra Club.

Midwest Association of Fish and Wildlife Agencies. 2018. Mid-America Monarch Conservation Strategy, 2018-2038, Version 1.0.

Miller, Stuart. Soil health as a foundation of conservation planning and management. A presentation at the Missouri Natural Resources Conference, February 4, 2015. Tan Tara Resort, Camdenton, MO.

Missouri Bird Conservation Plan Technical Team. 2019. Missouri bird conservation plan: technical section. MDC, Jefferson City, MO. **short.mdc.mo.gov/ZAF**.

Missouri Department of Conservation. 1994. Missouri Ozark Forest Ecosystem Project. MDC, Jefferson City, MO.

Missouri Department of Conservation. 2005. Missouri Forest Legacy Program assessment of need. MDC, Jefferson City, MO.

Missouri Department of Conservation. 2009. Watershed and Stream Management Guidelines. MDC, Jefferson City, MO.

Missouri Department of Conservation. 2014. Missouri Forest Management Guidelines. MDC, Jefferson City, MO.

Missouri Department of Conservation. 2015. Wetland Planning Initiative. MDC, Jefferson City, MO.

Missouri Department of Conservation. 2020 (February 13). About us. **mdc.mo.gov/about-us**.

Missouri Department of Health and Senior Services. 2020 (September 30). Heart disease. **health.mo.gov/living/healthcondiseases/chronic/heartdisease**.

Missouri Department of Natural Resources. 2019 (June 14). Archeaological surveys and reports. **dnr.mo.gov/shpo/archaeology.htm**.

Missouri Department of Natural Resources. 2020 (February 12). About the Missouri state park system. **mostateparks.com/page/55047/about-missouri-state-park-system**.

Missouri Invasive Plant Task Force. 2020 (February 21). Missouri Invasive Plant Task Force invasive plant assessment. **moinvasives.org/about/goals**.

Missouri Office of Administration. Division of Budget and Planning. 2020 (September 25). Population trends. **oa.mo.gov/budget-planning/demographic-information/population-projections/population-trends**.

Missouri Regional Arthritis Centers. 2020 (September 30). Learn about arthritis. **moarthritis.org/learn-about-arthritis**.

Missouri Statewide Comprehensive Outdoor Recreation Plan (SCORP) 2018–2022, Produced by Missouri State Parks, a division of Missouri Department of Natural Resources. https://mostateparks.com/sites/mostateparks/files/2018-2022%20Show%20Me%20the%20Great%20Outdoors_SCORP_Final.pdf.

Mitsch, W.J., J.W. Day, J.W. Gilliam, P.M. Groffman, D.L. Hey, G.W. Randall, and N.M. Wang. 2001. Reducing nitrogen loading to the Gulf of Mexico from the Mississippi River Basin: strategies to counter a persistent ecological problem. *Bioscience* 51:373–388.

Mitsch, W.J., and J.G. Gosselink. 2000. The value of wetlands: importance of scale and landscape setting. *Ecological Economics* 35:25–33.

Molnar, J.L., and I. Kubiszewski. 2012. Managing natural wealth: research and implementation of ecosystem services in the United States and Canada. *Ecosystem Services* 2:45–55.

Montgomery, D.R. 2017. Growing a revolution: bringing our soil back to life. WW Norton.

Montgomery, D.R., and A. Biklé. 2015. The hidden half of nature: the microbial roots of life and health. WW Norton.

Moore, M., S.P. Romano, and T. Cook. 2010. Synthesis of Upper Mississippi River System submersed and emergent aquatic vegetation: past, present, and future. *Hydrobiologia* 640(1):103–114.

Morley, Terry R., A.S. Reeve, and A.J.K. Calhoun. 2011. The role of headwater wetlands in altering streamflow and chemistry in a Maine, USA catchment. *JAWRA* 47(2):337–349.

Morris, J.T. 1991. Effects of nitrogen loading on wetland ecosystems with particular reference to atmospheric deposition. *Annual Review of Ecology, Evolution, and Systematics* 22:257–279.

Mudge, K., and S. Gabriel. 2014. Farming the woods: an integrated permaculture approach to growing food and medicinals in temperate forests. Chelsea Green Publishing.

Multi-Hazard Mitigation Council. 2019. Natural hazard mitigation saves: 2019 report. Principal investigator K. Porter; co-principal investigators N. Dash, C. Huyck, J. Santos, C. Scawthorn; investigators M. Eguchi, R. Eguchi, S. Ghosh., M. Isteita, K. Mickey, T. Rashed, A. Reeder, P. Schneider, and J. Yuan; directors, MMC; investigator intern, A. Cohen-Porter. Washington, DC, National Institute of Building Sciences. **nibs.org**.

Munoz, S.E., L. Giosan, M.D. Therrell, J.W. Remo, Z. Shen, R.M. Sullivan, C. Wiman, M. O'Donnell, and J.P. Donnelly. 2018. Climatic control of Mississippi River flood hazard amplified by river engineering. *Nature* 556(7699):95.

Nadeau, T-L., and M.C. Rains. 2007. Hydrological connectivity between headwater streams and downstream waters: how science can inform policy. *JAWRA* 3(1):118–133.

Narayan, S., M.W. Beck, P. Wilson, C.J. Thomas, A. Guerrero, C.C. Shepard, B.G. Reguero, G. Franco, J.C. Ingram, and D. Trespalacios. 2017. The value of coastal wetlands for flood damage reduction in the northeastern USA. *Scientific Reports* 7(1):9463.

National Center for Education Statistics. 2017. Children and youth with disabilities, pp. 1–5.

National Conservation Easement Database. 2020 (January 30). **conservationeasement.us**.

National Oceanic and Atmospheric Administration. Panel on Contingent Valuation. 1993. Natural resource damage assessment under the Oil Pollution Act of 1990. *Federal Register* 58(10):4601–4614.

National Park Service. 2020a (February 12). About us. **nps.gov/aboutus/index.htm**.

National Park Service. 2020b (February 12). Ozark National Scenic Riverways. **nps.gov/ozar/more-than-just-the-rivers.htm**.

National Research Council. 2005. Valuing ecosystem services: toward better environmental decision-making. Washington, DC: The National Academies Press.

National Research Council. 2007. Status of pollinators in North America. Washington, DC: The National Academies Press.

National Research Council. 2013. Urban forestry: toward an ecosystem services research agenda – a workshop summary. Washington, DC: The National Academies Press. DOI: 10.17226/18370.

The Nature Conservancy. 2014. Meramec River conservation action plan. St. Louis, MO: TNC, Missouri Chapter.

NatureServe. 2015. Why biodiversity matters: in the grip of global extinction. **natureserve.org/news-events/stories/why-biodiversity-matters-grip-global-extinction**.

Nelson, F.A., Diamond, D.D., C.D. True, P. Hanberry, L.F. Elliott, and M. Sunde. 2019. Missouri bottomland functional assessment: past and present. Final Report to EPA.

Nelson, P.W. 2010. The terrestrial natural communities of Missouri. Missouri Natural Areas Committee, Jefferson City, MO.

Nelson, P.W. 2018. Missouri Natural Glades Map. msdis.missouri.edu/data.

Nelson, P.W., J.A. Fitzgerald, K. Larson, R. McCoy, A. Schotz, J. Taft, T. Witsell, and B. Yahn. 2013. Central Hardwoods Joint Venture glade conservation assessment for the interior highlands and interior low plateaus of the central hardwoods region. Central Hardwoods Joint Venture. **chjv.org/ projects.html**.

Newman, D.J., and G.M. Cragg. 2016. Natural products as sources of new drugs from 1981 to 2014. *Journal of Natural Products* 79(3):629–661.

Nickerson, M.A., A.L. Pitt, J.J. Tavano, K.A. Hecht, and J.C. Mitchell. 2017. Forest removal and the cascade of effects corresponding with an Ozark hellbender population decline. *Bulletin of the Florida Museum of Natural History* 54(10):147–164.

Nigh, T., and W. Schroeder. 2002. Atlas of Missouri ecoregions. MDC, Jefferson City, MO.

Noe, G.B., and C.R. Hupp. 2009. Retention of riverine sediment and nutrient loads by coastal plain floodplains. *Ecosystems* 12:728–746.

Nowak, D.J., et al. 2010. Sustaining America's urban trees and forests: a Forests on the Edge report. Gen. Tech. Rep. NRS-62. Newtown Square, PA: USFS, Northern Research Station.

Oberhauser, K., R. Wiederholt, J. Diffendorfer, D. Semmens, L. Ries, W. Thogmartin, L. Lopez-Hoffman, and B. Semmens. 2016. A trans-national monarch butterfly population model and implications for regional conservation priorities: regional monarch conservation priorities. *Ecological Entomology* 42. DOI:10.1111/een.12351.

Oesch, R.D. 1984. Missouri naiades: a guide to the mussels of Missouri. M. McIntosh and L. Rutledge (eds). MDC, Jefferson City, MO.

O'Hare, N.K. 2019. Guest editor's introduction to special issue on wild foods. *Southeastern Geographer* 59(1):6–13.

OneSTL. 2017 (October 11). Biodiversity. **onestl.org/get-involved/regional-working-groups/biodiversity**.

Opperman, J.J., A. Warner, E. Girvetz, D. Harrison, and T. Fry. 2011. Integrated floodplain-reservior management as an ecosystem-based adaption strategy to climate change. AWRA Spring Specialty Conference. Baltimore MD.

Osborne, L.L., and D.A. Kovacic. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. *Freshwater Biology* 29:243–258.

Oswalt, S.N., W.B. Smith, P.D. Miles, and S.A. Pugh. 2014. Forest resources of the United States, 2012: a technical document supporting the Forest Service update for the 2010 RPA assessment. General Technical Report WO-91. Washington, DC: USFS.

Outdoor Foundation. 2020 (January 29). 2019 outdoor participation report. **outdoorindustry.org/resource/2019-outdoor-participation-report**.

Outdoor Industry Association. 2020 (September 30). Outdoor recreation and economic impact in Missouri. **outdoorindustry.org/wp-content/uploads/2017/07/OIA_RecEcoState_MO.pdf**.

Pacala, S., R. Birdsey, S. Bridgham, R. Conant, K. Davis, B. Hales, R.A. Houghton, J.C. Jenkins, M. Johnston, G. Marland, and K. Paustian. 2007. The North American carbon budget past and present. Chapter 3 in The first state of the carbon cycle report, North American budget and implication for the global carbon cycle, U.S Climate Change Science Program, Sythesis and Assessment Product 2.2.

Palmer, B. 1991. Missouri forests, their history, values and management. MDC, Jefferson City, MO.

Palmer, Bruce. 2000 (September). Back from the ashes. *Missouri Conservationist Magazine*. MDC, Jefferson City, MO.

Palta, M.M., J.G. Ehrenfeld, D. Giménez, P.M. Groffman, and V. Subroy. 2016. Soil texture and water retention as spatial predictors of denitrification in urban wetlands. *Soil Biology and Biochemistry* 101:237–250.

Panno, S.V., K.C. Hackley, W.R. Kelly, and H.H. Hwang. 2006. Isotopic evidence of nitrate sources and denitrification in the Mississippi River, Illinois. *Journal of Environmental Quality* 35:495–504.

Panzer, R., K. Gnaedinger, and G. Derkovitz. 2010. The prevalence and status of conservative prairie and sand savanna insects in the Chicago wilderness region. *Natural Areas Journal* 30(1):73–81.

Park, B.J., Y. Tsunetsugu, T. Kasetani, T. Kagawa, and Y. Miyazaki. 2010. The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. *Environ. Health. Prev. Med.* 15:18–26.

Perez-Garcia, J., B. Lippke, J. Comnick, and C. Manriquez. 2005. An assessment of carbon pools, storage, and wood products market substitution using life-cycle analysis results. *Wood and Fiber Science* 37:140–148.

Pflieger, W.L. 1996. The crayfishes of Missouri. MDC, Jefferson City, MO.

Pflieger, W.L. 1997. The fishes of Missouri. MDC, Jefferson City, MO.

Pielke, R.A. Jr, and M.W. Downton. 2000. Precipitation and damaging floods: trends in the United States, 1932–97. *Journal of Climate* 13(20):3625–3637.

Polvi, L.E., and J.M. Sarneel. 2018. Ecosystem engineers in rivers: an introduction to how and where organisms create positive biogeomorphic feedbacks. *Wiley Interdisciplinary Reviews: Water* 5(2):e1271.

Power, A.G. 2010. Ecosystem services and agriculture: tradeoffs and synergies. *Philosophical Transactions of the Royal Society B: Biological Sciences* 365(1554):2959–2971.

Prasad, A., L. Iverson, M. Peters, and S. Matthews. 2014. Climate change tree atlas. Delaware, OH: Northern Research Station, USFS.

Puig-Montserrat, X., I. Torre, A. López-Baucells, E. Guerrieri, M.M. Monti, R. Ràfols-García, X. Ferrer, D. Gisbert, and C. Flaquer. 2015. Pest control service provided by bats in Mediterranean rice paddies: linking agroecosystems structure to ecological functions. *Mammalian Biology* 80(3):237–245.

Puttock, A., H.A. Graham, A.M. Cunliffe, M. Elliott, and R.E. Brazier. 2017. Eurasian beaver activity increases water storage, attenuates flow and mitigates diffuse pollution from intensively managed grasslands. *Science of the Total Environment* 576:430–443.

Radeloff, V., M.H. Mockrin, and D. Helmers. 2020 (February 7). Mapping change in the Wildland Urban Interface (WUI), 1990–2010: state summary statistics, June 2018. University of Wisconsin – SILVIS Lab **silvis.forest.wisc.edu/GeoData/WUI_cp12/WUI_change_1990_2010_State_Stats_Report.pdf**.

Ratnadass, A., P. Fernandes, J. Avelino, and R. Habib. 2012. Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review. *Agronomy for Sustainable Development* 32(1):273–303.

Ray, J.H., N.H. Lopinot, E.R. Hajic, and R.D. Mandel. 1998. The Big Eddy site: a multicomponent Paleoindian site on the Ozark border, southwest Missouri. *Plains Anthropologist* 43(163):73–81.

Rehm, E.A., P. Olivas, J. Stroud, and K.J. Feeley. 2015. Losing your edge: climate change and the conservation value of range-edge populations. *Ecology and Evolution* 5 (19): 4315–4326.

Remo, J.W., R.J. Guida, and S. Secchi. 2017. Screening the suitability of levee protected areas for strategic floodplain reconnection along the LaGrange segment of the Illinois River, USA. *River Research and Applications* 33(6):863–878.

Remo, J.W., J. Ryherd, C.M. Ruffner, and M.D. Therrell. 2018. Temporal and spatial patterns of sedimentation within the batture lands of the middle Mississippi River, USA. *Geomorphology* 308:129–141.

Riccucci, M., and B. Lanza. 2014. Bats and insect pest control: a review. *Vespertilio* 17:161–169.

Rikoon, S., J. Hermsen, E. Bjornstrom, S. Wilhelm Stanis, B. Leap, J. Lucht, and R. Bacon. 2014. *Your ideas count! Report of results of the 2013 conservation opinion survey for the Missouri Department of Conservation.* Columbia: University of Missouri–Columbia.

Robbins, C.S. 2000. Comparative analysis of management regimes and medicinal plant trade monitoring mechanisms for American ginseng and goldenseal. *Conservation Biology* 14(5):1422–1434.

Robbins, J. 2020. Ecopsychology: how immersion in nature benefits your health. Yale School of Forestry and Environmental Studies. **e360.yale.edu/features/ecopsychology-how-immersion-in-nature-benefits-your-health**.

Robertson, G.P., K.L. Gross, S.K. Hamilton, D.A. Landis, T.M. Schmidt, S.S. Snapp, and S.M. Swinton. 2007. Farming for ecosystem services: an ecological approach to production agriculture. *BioScience* 20:1–12.

Rosell, F., O. Bozser, P. Collen, and H. Parker. 2005. Ecological impact of beavers Castor fiber and Castor canadensis and their ability to modify ecosystems. *Mammal Review* 35(3–4):248–276.

Rosenberg, K.V., A.M. Dokter, P.J. Blancher, J.R. Sauer, A.C. Smith, P.A. Smith, J.C. Stanton, A. Panjabi, L. Helft, M. Parr, and P.P. Marra. 2019. Decline of the North American avifauna. *Science* 366(6461):120–124.

Ruhe, R.V. 1969. Quaternary landscapes in Iowa. Ames: Iowa State University Press.

Sagoff, M. 1994. Should preferences count? *Land Economics* 70(2):127–144.

Salassi, M.E., M.A. Deliberto, and E.P. Webster. 2008. Evaluating the economic impact of crawfish production on the rice enterprise in a rice/crawfish crop rotation system. Louisiana State University AgCenter, Staff Report, 4.

Schaper, J. 2007. Blue jewels in the Ozarks: a beginner's guide to Missouri springs. **missourisprings.com**.

Scharlemann, J.P., E.V. Tanner, R. Hiederer, and V. Kapos. 2014. Global soil carbon: understanding and managing the largest terrestrial carbon pool. *Carbon Management* 5(1):81–91.

Schmidt, N., M. O'Neal, and P. Dixon. 2008. Aphidophagous predators in Iowa soybean: a community comparison across multiple years and sampling methods. *Annals of the Entomological Society of America* 101(2):341–335.

Schroeder, W.A. 1981. Presettlement prairie of Missouri. Natural History Series no. 2. MDC, Jefferson City, MO.

Schulte, L.A., J. Niemi, M.J. Helmers, M. Liebman, J.G. Arbuckle, D.E. James, R.K. Kolka, M.E. O'Neal, M.D. Tomer, J.C. Tyndall, H. Asbjornsen, P. Drobney, J. Neal, G. Van Ryswyk, and C. Witte. 2017. Prairie strips improve biodiversity and the delivery of multiple ecosystem services from corn–soybean croplands. *Proceedings of the National Academy of Sciences* 114(42):11247–11252.

Semmens, B., D. Semmens, W. Thogmartin, R. Wiederholt, L. López-Hoffman, J. Diffendorfer, J. Pleasants, K. Oberhauser, and O. Taylor. 2016. Quasi-extinction risk and population targets for the eastern, migratory population of monarch butterflies (Danaus plexippus). *Sci. Rep.* 6:23265. DOI: 10.1038/srep23265/.

Shadie, C.E., P. Lopez-Llompart, M. Samet, T. Strole, and G.M. Kondolf. 2018. Managing floods in large river basins in the USA: the Mississippi River. Pp. 11–41 in Managing flood risk. Palgrave Macmillan, Cham.

Sharpley, A.N., P.J.A. Kleinman, R.W. McDowell, M. Gitau, and R.B. Bryant. 2002. Modeling phosphorus transport in agricultural watersheds: processes and possibilities. *J. Soil Water Conserv.* 57(6):425−439.

Shifley, S. 2007. Fairly sustainable forestry: seven key concepts for defining local sustainability in a global ecosystem. P. 306 in Integrated restoration of forested ecosystems to achieve multi resource benefits: proceedings of the 2007 national silvicultural workshop. Gen. Tech. Rep. PNW-GTR-733. Portland, OR: USFS, Pacific Northwest Research Station.

Shu, L.H., K. Ueda, I. Chiu, and H. Cheong. 2011. Biologically inspired design. *CIRP Annals* 60(2):673–693.

Simonson, R.W. 1959. Outline of a generalized theory of soil genesis. *Soil Science Society of America Journal* 23(2):152–156.

Skinner, E.A., and U. Chi. 2012. The Learning-Gardens Educational Assessment Group. Intrinsic motivation and engagement as "active ingredients" in garden-based education: examining models and measures derived from self-determination theory. *J. Environ. Educ.*

Sluis, W., and J. Tandarich. 2004. Siltation and hydrologic regime determine species composition in herbaceous floodplain communities. *Plant Ecology* 173(1):115–124.

Smith, J.B., T.D. Tuberville, and J.C. Beasley. 2018. Hunting and game consumption patterns of hunters in South Carolina. *Journal of Fish and Wildlife Management* 9(1):321–329.

Smith, W.B., P.D. Miles, C.H. Perry, and S.A. Pugh. 2009. Forest resources of the United States, 2007. Gen. Tech. Rep. WO-78. Washington, DC: USFS.

Sommer, Ted. 2001. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. *Fisheries* 26(8):6–16.

Spencer, J.S. Jr., and B.L. Essex. 1976. Timber in Missouri, 1972. Resource Bulletin NC-30. St. Paul, MN: USFS, North Central Forest Experiment Station.

Statista. 2020 (January 9). Population of the St. Louis metro area in the United States from 2010 to 2018. **www.statista.com/statistics/815285/st-louis-metro-area-population**.

Stedman, R.C., L.R. Larson, K.G. Tidball, M. Tidball, and P.D. Curtis. 2017. Hunting and the local food movement: insights from central New York State. *Wildlife Society Bulletin* 41(4):720–728.

Steyermark, J.A., G.A. Yatskievych, and Missouri Botanical Garden. 1999. Steyermark's Flora of Missouri. Vol. 1. Jefferson City, MO: MDC in cooperation with Missouri Botanical Garden Press.

Steyermark, J.A., G.A. Yatskievych, and Missouri Botanical Garden. 2006. Steyermark's Flora of Missouri. Vol. 2. Jefferson City, MO: MDC in cooperation with Missouri Botanical Garden Press.

Steyermark, J.A., G.A. Yatskievych, and Missouri Botanical Garden. 2013. Steyermark's Flora of Missouri. Vol. 3. Jefferson City, MO: MDC in cooperation with Missouri Botanical Garden Press.

Struecker, B.P., and J.R. Milanovich. 2017. Predicted suitable habitat declines for Midwestern United States amphibians under future climate change and land-use change. *Herpetological Conservation and Biology* 12: 635–654.

Sun, R., A. Chen, L. Chen, and Y. Lü. 2012. Cooling effects of wetlands in an urban region: the case of Beijing. *Ecological Indicators* 20:57–64.

Sutton-Grier, A.E., M.A. Kenney, and C.J. Richardson. 2010. Examining the relationship between ecosystem structure and function using structural equation modelling: a case study examining denitrification potential in restored wetland soils. *Ecological Modelling* 221(5):761–768.

Svadlenak-Gomez, K. 2010 (October). Biodiversity-friendly aquaculture on the Veta la Palma Estate. Spain. EcoagricultureFood (Commercial Fishing and Aquaculture).

Swift, M.J., A.M. Izac, and M. Van Noordwijk. 2004. Biodiversity and ecosystem services in agricultural landscapes—are we asking the right questions? *Agriculture, Ecosystems & Environment* 104(1):113–134.

Taylor, A.R., J.R. Wang, and W.A. Kurz. 2008. Effects of harvesting intensity on carbon stocks in Eastern Canadian red spruce (Picea rubens) forests: an exploratory analysis using the CBMCFS3 simulation model. *Forest Ecology and Management* 255(10):3632–3641. DOI: 10.1016/j.foreco.2008.02.052/.

Teixeira, R., W. Frey, and R. Griffin. 2105 (February). States of change – the demographic evolution of the American electorate, 1974–2060. American Enterprise Institute – Brookings Institution – Center for American Progress. **cdn.americanprogress.org/wp-content/uploads/2015/02/SOC-report1SUMMARY.pdf**.

Tidball, K.G., M.M. Tidball, and P. Curtis. 2013. Extending the locavore movement to wild fish and game: questions and implications. *Natural Sciences Education* 42(1):185–189.

Tidball, K.G., M. Tidball, L.R. Larson, P. Curtis, L. Poindexter, and R.C. Stedman. 2014. Locavore preferences for wild fish and game: implications for wildlife recreation in New York State. Human Dimensions Research Unit Series Publication 14-06. Ithaca, NY.

Tonietto, R., J. Fant, J. Ascher, K. Ellis, and D. Larkin. 2011. A comparison of bee communities of Chicago green roofs, parks and prairies. *Landscape and Urban Planning* 103(1):102–108.

Treiman, T. 2015. Missourians and their community trees: results from an MDC Survey. *MDC Science Notes* 8(7).

Treiman, T. 2017a. (Economic) life without Missouri's forests. MDC, Jefferson City, MO.

Treiman, T. 2017b. Who's shooting? A user survey of MDC's unstaffed ranges. *Science Notes* 12(1). MDC, Jefferson City, MO.

Treiman, T., and S. Ipock. 2017. Did you see the elk? Visitor survey results from MDC's elk tour loops. *Science Notes* 12 no. MDC. 2 pp.

Treiman, T., and M. Morris. 2018. Missouri's 2018 timber product output report. MDC, Jefferson City, MO.

Treiman, T.B., S.L. Sheriff, R.B. Renken, and J. Loomis. 2014. The economic value of Missouri River recreation: estimates from the Missouri River public use assessment. *River Research and Applications* 30(5):639–649.

Trozzo, K., J. Munsell, K. Niewolny, and J.L. Chamberlain. 2019. Forest food and medicine in contemporary Appalachia. *Southeastern Geographer* 59(1):52–76.

Turner, R.E., and N.N. Rabalais. 1991. Changes in Mississippi River water quality this century. *BioScience* 41:140–147.

Turner, R.E., and N.N. Rabalais. 2003. Linking landscape and water quality in the Mississippi River Basin for 200 years. *Bioscience* 53(6):563–572.

Turner, R.K. 1999. The place of economic values in environmental valuation. Pp.17–41 in Valuing environmental preferences: theory and practice of the contingent valuation method in the US, EU, and developing countries, Bateman, I., and K.G. Willis (eds). London: Oxford University Press.

Tyrväinen, L., A. Ojala, K. Korpela, T. Lanke, Y. Tsunetsuga, and T. Kagawa. 2014. The influence of urban green environments on stress relief measures: a field experiment. *J. of Enviro Psych*. 38:1–9.

U.S. Army Corps of Engineers. Civil Works Division. 2020 (February 12). **usace.army.mil/Missions/Civil-Works**.

U.S. Census Bureau. 2018. Quick facts: Missouri. **census.gov/quickfacts/mo**.

U.S. Census Bureau. 2020 (January 17). Quick facts Missouri. **census.gov/quickfacts/mo**.

U.S. Congress. 2004. Individuals with Disabilities Education Act of 2004. 108th Congress, Washington, DC.

U.S. Department of Agriculture – Forest Service. 2017. Forest Legacy Program implementation guidelines. Washington, DC: USFS.

U.S. Department of Agriculture – Forest Service. 2018. Urban nature for human health and well-being: a research summary for communicating the health benefits of urban trees and green space. FS-1096. Washington, DC.

U.S. Department of Agriculture – Forest Service. 2019a. Forest inventory and analysis data, 2018. Washington, DC: USFS.

U.S. Department of Agriculture – Forest Service. 2019b (October). National forests to faucets 2.0. Washington, DC: USFS.

U.S. Department of Agriculture – Forest Service. 2020a (January 24). 2018 update. National insect and disease risk and hazard mapping. **fs.fed.us/foresthealth/applied-sciences/mapping-reporting/national-risk-maps.shtml**.

U.S. Department of Agriculture – Forest Service. 2020b (February 12). Home. **fs.usda.gov/main/mtnf/home**.

U.S. Department of Agriculture – Forest Service. 2020c (February 13). About the agency. **fs.usda.gov/about-agency**.

U.S. Department of Agriculture – Forest Service. Forest Inventory and Analysis Database. 2014. **apps.fs.fed.us/fiadb-downloads/datamart.html** (current data as of July 21, 2014).

U.S. Department of Agriculture – Forest Service. Forest Inventory and Analysis Program. 2019 (Wed Jul 24 13:53:49 GMT). Forest Inventory EVALIDator web-application Version 1.8.0.00. St. Paul, MN: USFS, Northern Research Station. [Available only on internet: apps.fs.usda.gov/Evalidator/evalidator.jsp]

U.S. Department of Agriculture – Forest Service. Forest Inventory and Analysis Program. 2020 (Fri Feb 21 14:45:34 GMT). Forest Inventory EVALIDator web-application Version 1.8.0.01. St. Paul, MN: USFS, Northern Research Station. [Available only on internet: **apps.fs.usda.gov/Evalidator/evalidator.jsp**]

U.S. Department of Agriculture – Natural Resources Conservation Service. 2018 (October 31). 2015 national resources inventory. **nrcs.usda.gov/Internet/NRCS_RCA/reports/nri_eros_mo.html**.

U.S. Department of Agriculture – Natural Resources Conservation Service, Soil Survey Staff. 2020 (January 24). Web soil survey. **websoilsurvey.sc.egov.usda.gov**.

U.S. Department of Army. Army Environmental Command. 2020 (February 14). Mission and vision. **aec.army.mil/index.php/about-aec/mission-vision**.

U.S. Department of the Interior. Fish and Wildlife Service. 2020a (February 12). About us. National Wildlife Refuge System. **fws.gov/refuges/about**.

U.S. Department of the Interior. Fish and Wildlife Service. 2020b (February 21). Fact sheet, natural history, ecology and recovery. Midwest Region – bald and golden eagles. **fws.gov/midwest/eagle/Nhistory/biologue.html**.

U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2018. 2016 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

U.S. Environmental Protection Agency. 2017. Integrated climate and land-use scenarios (ICLUS version 2.1) for the Fourth National Climate Assessment. **epa,gov/iclus**.

U.S. Environmental Protection Agency. 2020. Greenhouse gas equivalency calculator. **epa.gov/energy/greenhouse-gas-equivalencies-calculator**. Accessed April 22, 2020.

U.S. Global Change Research Program. 2018. Impacts, risks, and adaptation in the United States: fourth national climate assessment. Vol. 2, D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds). Washington, DC: USGCRP.

U.S. Geological Survey. National Minerals Information Center. 2016 (November). 2012–2013 mineral yearbook – Missouri. **s3-us-west-2.amazonaws.com/prd-wret/assets/palladium/production/mineral-pubs/state/2012_13/myb2-2012_13-mo.pdf**.

U.S. Geological Survey. National Minerals Information Center. 2019 (March). 2015 minerals yearbook. **prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb1-2015-stati.pdf**.

University of Wisconsin–Madison SILVIS Lab. 2020 (February 7). *Wildland Urban Interface (WUI) Change 1990–2010.* University of Wisconsin–Madison SILVIS Lab: **silvis.forest.wisc.edu/GeoData/WUI_cp12/maps/gifs/white/Missouri_WUI_cp12_white_2010.gif**.

van den Berg, A.E., and C.G. van den Berg. 2011. A comparison of children with ADHD in a natural and built setting. *Child: Care, Health, and Development* 37:430–439.

van der Burg, M.P., K.E. Jenni, T.L. Nieman, J.D. Eash, and G.A. Knutsen. 2017. Understanding and finding solutions to the problem of sedimentation in the National Wildlife Refuge System. *Journal of Fish and Wildlife Management* 8(2):648–660.

Van Meter, K.J., N.B. Basu, and P. Van Cappellen. 2017. Two centuries of nitrogen dynamics: legacy sources and sinks in the Mississippi and Susquehanna River Basins. *Global Biogeochemical Cycles* 31(1): 2–23.

Varble, S., and S. Secchi. 2013. Human consumption as an invasive species management strategy: a preliminary assessment of the marketing potential of invasive Asian carp in the US. *Appetite* 65:58–67.

Vitousek, P.M., H.A. Mooney, J. Lubchenco, and J.M. Melillo. 1997. Human domination of Earth's ecosystems. *Science* 277(5325):494–499.

Wassenaar, L. I., and K. A. Hobson. 1998. Natal origins of migratory monarch butterflies at wintering colonies in Mexico: new isotopic evidence. *Proceedings of the National Academy of Sciences* 95:15436–15439.

Webb, J.R., I.R. Santos, B. Robson, B. Macdonald, L. Jeffrey, and D.T. Maher. 2017. Constraining the annual groundwater contribution to the water balance of an agricultural floodplain using radon: the importance of floods. *Water Resources Research* 53(1):544–562.

Weller, D.E., T.E. Jordan, and D.L. Correll. 1998. Heuristic models for material discharge from landscapes with riparian buffers. *Ecological Applications* 8(4):1156–1169.

Wenny, D.G., T.L. Devault, M.D. Johnson, D. Kelly, C.H. Sekercioglu, D.F. Tomback, and C.J. Whelan. 2011. The need to quantify ecosystem services provided by birds. *The auk* 128(1):1–14.

Westhoff, J.T., and C.P. Paukert. 2014. Climate change simulations predict altered biotic response in a thermally heterogeneous stream system. *PloS one* 9(10):e111438.

Westhoff, J.T., C. Paukert, S. Ettinger-Dietzel, H. Dodd, and M. Siepker. 2016. Behavioural thermoregulation and bioenergetics of riverine smallmouth bass associated with ambient cold-period thermal refuge. *Ecology of Freshwater Fish* 25(1):72–85.

Wezel, A., M. Casagrande, F. Celette, J.F. Vian, A. Ferrer, and J. Peigné. 2014. Agroecological practices for sustainable agriculture. A review. *Agronomy for Sustainable Development* 34(1):1–20.

Whelan, C.J., D.G. Wenny, and R.J. Marquis. 2008. Ecosystem services provided by birds. *Annals of the New York Academy of Sciences* 1134(1):25–60.

Whitaker, J.O. Jr. 1995. Food of the big brown bat Eptesicus fuscus from maternity colonies in Indiana and Illinois. *American Midland Naturalist* 134(2):346–360.

White, M.P., I. Alcock, J. Grellier, et al. 2019. Spending at least 120 minutes a week in nature is associated with good health and wellbeing. *Sci Rep 9, 7730 (2019).* https://doi.org/10.1038/s41598-019-44097-3.

The White House, Office of the Press Secretary. 2014 (June 20). Presidential memorandum – creating a federal strategy to promote the health of honey bees and other pollinators. Press release. **obamawhitehouse.archives.gov/the-press-office/2014/06/20/presidential-memorandum-creating-federal-strategy-promote-health-honey-b**.

Wiens, V., H. Hyngaˈs, and T. Poˈlkki. 2016. The meaning of seasonal changes, nature, and animals for adolescent girls' wellbeing in northern Finland: a qualitative descriptive study. *Int. J. Qual. Stud. Health Well-Being* 11:30160.

Wilcox, K.R. J.M. Blair, and A.K. Knapp. 2016. Stability of grassland soil C and N pools despite 25 years of an extreme climatic and disturbance regime. *Journal of Geophysical Research: Biogeosciences* 121:1934–1945.

Wilson, A.T. 1978. Pioneer agriculture explosion and CO_2 levels in the atmosphere. *Nature* 273:40–41.

Wing, O., K. Johnson, J. Fargione, P. Bates, C. Sampson, and A. Smith. 2018 (April). The economic benefit of avoided floodplain development in the conterminous United States. Vol. 20 p. 4904 in EGU General Assembly Conference Abstracts.

Winsemius, H.C., J.C. Aerts, L.P. Van Beek, M.F. Bierkens, A. Bouwman, B. Jongman, J.C. Kwadijk, W. Ligtvoet, P.L. Lucas, D.P. Van Vuuren, and P.J. Ward. 2016. Global drivers of future river flood risk. *Nature Climate Change* 6(4):381.

Wise, Steve. 2008. Green infrastructure rising. *Planning* 74(8):14–19.

Woodall, Christopher W., J.W. Coulston, G.M. Domke, B.F. Walters, D.N. Wear, J.E. Smith, H-E. Andersen, B.J. Clough, W.B. Cohen, D.M. Griffith, S.C. Hagen, I.S. Hanou, M.C. Nichols, C.H. Perry, M.B. Russell, J.A. Westfall, and B.T. Wilson. 2015. The U.S. forest carbon accounting framework: stocks and stock change, 1990–2016. Gen. Tech. Rep. NRS-154. Newtown Square, PA: USFS, Northern Research Station.

Woodwell, G.M., J.E. Hobbie, R.A. Houghton, J.M. Melillo, B. Moore, B.J. Peterson, and G.R. Shaver. 1983. Global deforestation: contribution to atmospheric carbon dioxide. *Science* 222(4628):1081–1086.

World Health Organization. 2017. Preventing disease through healthy environments: A global assessment of the burden of disease from environmental risks.

Wormstead, S., and R. Neuenfeldt. 2018. *Guide for State Forest Action Plans*. Durham, NH: USFS Northeast-Midwest State Foresters Alliance.

Wu, C.D., E. McNeely, J.G. Cedeno-Laurent, W.C. Pan, G. Adamkiewicz, F. Dominici, S.C. Lung, H. Su, J.D. Spengler. 2014. Linking student performance in Massachusetts elementary schools with the greenness of school surroundings using remote sensing. *PLoS One* 9. Article e108548.

Wurts, W. A. 2000. Sustainable aquaculture in the twenty-first century. *Reviews in Fisheries Science* 8(2):141–150.

Wurts, W.A. 2004. Small-scale and home-use channel catfish farming in Kentucky. *World Aquaculture* 35(3): 8–9.

Wurts, W.A. 2007. Low input shrimp farming in Kentucky, Macrobrachium rosenbergii. *World Aquaculture* 38(4): 44–49.

Wurts, W.A., S.D. Mims, and R.J. Onders. 2010. Paddlefish Polyodon spathula polyculture with freshwater shrimp Macrobrachium rosenbergii. *World Aquaculture* 41(2):30–31.

Xiao, Y., J. Wan, and G.J. Hewings. 2013. Flooding and the Midwest economy: assessing the Midwest floods of 1993 and 2008. *GeoJournal* 78(2):245–258.

Yang, Y., Y. Luo, and A. C. Finzi. 2011. Carbon and nitrogen dynamics during forest stand development: a global synthesis. *New Phytologist* 190(4):977–989. DOI: 10.1111/j.1469-8137.2011.03645.x/.

Yang, Y., and D. Tilman. 2020. Soil and root carbon storage is key to climate benefits of bioenergy crops. *Biofuel Research Journal* 26:1143–1148.

Yu, Z., C. Lu, P. Cao, and H. Tian. 2018. Long-term terrestrial carbon dynamics in the Midwestern United States during 1850–2015: roles of land use and cover change and agricultural management. *Global Change Biology* 24(6):2673–2690.